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TESIS DOCTORAL

INTERNET OF THINGS. SOLUCIONES PERVASIVAS BASADAS EN GEOLOCALIZACIÓN Y NEAR FIELD COMMUNICATION: EDUCACIÓN, TURISMO, MARKETING Y PUBLICIDAD

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INTERNET OF THINGS. SOLUCIONES PERVASIVAS BASADAS EN GEOLOCALIZACIÓN Y NEAR FIELD COMMUNICATION: EDUCACIÓN, TURISMO, MARKETING Y PUBLICIDAD

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Trabajo presentado para optar al grado de Doctor en Ingeniería Informática

TÍTULO DE LA TESIS: **INTERNET OF THINGS. SOLUCIONES PERVASIVAS BASADAS EN GEOLOCALIZACIÓN Y NEAR FIELD COMMUNICATIONS: EDUCACIÓN, TURISMO, MARKETING Y PUBLICIDAD**

DOCTORANDO/A: **FRANCISCO MANUEL BORREGO JARABA**

INFORME RAZONADO DEL/DE LOS DIRECTOR/ES DE LA TESIS

(Se hará mención a la evolución y desarrollo de la tesis, así como a trabajos y publicaciones derivados de la misma).

Los resultados obtenidos en la investigación llevada a cabo en esta Tesis Doctoral, han supuesto un avance en el estudio y solución de algunos de los problemas existentes en el desarrollo del "Internet de las Cosas", considerando como marco tecnológico de aplicación el uso de la tecnología conocida como "Comunicación de Campo Cercano (NFC)".

Esta investigación ha demostrado como la tecnología NFC puede revolucionar ámbitos como el turismo, la educación o el marketing y publicidad. Los resultados obtenidos, demuestran además, como el uso de esta tecnología permitirá el futuro desarrollo de las denominadas "Smart Cities", ciudades donde se ofrezcan a todas las personas multitud de servicios a los que se podrá acceder a través de interacciones con los objetos del mundo real.

La formación investigadora en el periodo 2008-2015 de D. Francisco Manuel Borrego Jaraba ha estado marcada por un gran esfuerzo, finalizando el Trabajo de Investigación del "Máster universitario en Soft Computing y Sistemas Inteligentes" de la Universidad de Granada en 2011. Ese mismo curso se matricula de la tutela académica en el programa de doctorado "Ingeniería y Tecnología" de la Universidad de Córdoba, desarrollando su trabajo en el grupo de investigación "Ingeniería del Software, Conocimiento y Bases de Datos (TIC110)".

Los resultados de su investigación han sido refrendados por prestigiosas publicaciones en las Actas de Congresos de carácter internacional, y en revistas especializadas, con alto índice de impacto, que se encuentran tabuladas por el Journal Citation Report en los primeros cuartiles en áreas de investigación relacionadas con el tema de la tesis que se presenta.

Teniendo en cuenta la formación adquirida, el trabajo investigador realizado, los resultados obtenidos y los que en un futuro se deriven, así como la profesionalidad, extensión y estilo de la Memoria de Tesis Doctoral, el director de este trabajo autoriza su presentación.

Córdoba, 01 de Abril de 2015

Firma del/de los director/es

Fdo.: Gonzalo Cerruela García

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Me enfrento una vez más a esta página en blanco, quizás la más compleja, donde tengo que dar mil gracias a todos aquellos que de una forma u otra han contribuido a que este documento que da paso a mi título de Doctor sea un hecho.

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A mi madre, siempre estarás presente en mi vida. Cuídame allí donde estés.

A todos, ¡gracias!

ÍNDICE DE CONTENIDOS

Glosario

AAL	Ambient Assisted Living
AmI	Ambient Intelligence
ECMA	European Computer Manufacturers' Association
EDGE	Enhanced Data Rates for GSM Evolution
EML	Lenguaje de Modelado Educativo
ETSI	European Telecommunications Standards Institute
GPRS	General Packet Radio Service
IEC	International Electrotechnical Commission
IoT	Internet of Things
ISO	International Organization for Standardization
ISO 14443	ISO standard governing proximity smartcards
ISTAG	Information Society Technologies Advisory Group
MIFARE	Tecnología de tarjetas inteligentes sin contacto
NDEF	NFC Data Exchange Format
NFC	Near Field Communication
RFID	Radio Frequency Identification
RTD	Record Type Definition
TIC	Tecnologías de la Información y de las Comunicaciones
UMTS	Universal Mobile Telecommunications System
UoT	University of Things

PARTE I

1 | Introducción

1 INTRODUCCIÓN

En la actualidad, muchos sistemas de información basan una parte importante de su funcionalidad en el intercambio de datos y servicios, implicando de forma directa o indirecta a diferentes tipos de objetos físicos. A medida que la tecnología avanza, aumenta la variedad de objetos físicos que, de alguna manera, pasan a formar parte de algunos tipos de sistemas de información. Los nuevos avances tecnológicos no sólo influyen en los propios objetos físicos, también lo hacen en las posibilidades de interacción y colaboración de estos con otros objetos físicos y aplicaciones informáticas.

Internet nació conectando personas a través de máquinas. Ahora una parte importante de su red conecta máquinas, que hablan entre ellas, para cumplir una tarea sin necesitar al hombre. El siguiente paso es la llamada Internet de las cosas (*Internet of Things*), IoT en adelante.

El concepto de Internet de las cosas se atribuye originalmente al Auto-ID Center, fundado en 1999 y basado en el Instituto Tecnológico de Massachusetts (MIT). La idea es muy sencilla: parte de que cualquier "cosa", es decir objeto convenientemente etiquetado, pueda ser capaz de comunicarse con otros objetos y personas a través de Internet, redes privadas u otros protocolos [1,2]. Los objetos que formarían parte de la red pueden ser de lo más variado, desde maquinaria industrial, electrodomésticos, vehículos, a productos del supermercado. Dependiendo del tipo de objeto contendrán pequeños chips, sensores o mini computadores [3].

Las posibilidades que ofrece el IoT para facilitar la vida de las personas y automatizar muchas de las tareas que realizamos actualmente son enormes. Por ejemplo, es posible que el frigorífico envíe un mensaje al teléfono si se acaba la leche, monitorizar a pacientes clínicos vía Internet y una multitud de aplicaciones prácticas que, en la actualidad, empiezan a ver la luz y que, en breve, impactarán de lleno en nuestra vida cotidiana.

Aunque la idea fundamental es simple, su aplicación resulta difícil. Con el paso de los años, la comunicación entre objetos ha evolucionado, se han sumado nuevas técnicas y mejorado las ya existentes, que comprenden desde etiquetar objetos a través de tags RFID (*Radio Frequency IDentification*) a añadir microprocesadores para dotarlos de más inteligencia y capacidad de reacción. No se trata sólo de conseguir que los objetos hablen, sino de que interactúen entre si y dotarlos de inteligencia.

El concepto de IoT entró en foco de atención mundial en 2005 cuando la *International Telecommunications Union* publicó el primer informe sobre el tema[1]. El informe adopta un enfoque global y sugería que, en un futuro, IoT conectaría objetos repartidos por todo el mundo, tanto de una forma sensorial como inteligente, a través de la combinación de los avances tecnológicos en la identificación de objetos, redes de sensores, sistemas integrados y la nanotecnología [4].

El IoT tiene como meta que prácticamente todas las “cosas” que hay en este mundo físico puedan convertirse en objetos conectados a Internet u otras redes [4]. Uno podría preguntarse si realmente todas las cosas necesitan disponer de un mini computador que las mantenga conectadas al actual Internet, la respuesta es no. Por ejemplo, un bien de consumo como un yogurt se podría considerar integrado en Internet de las cosas cuando se encuentra etiquetado con una etiqueta RFID que permita a otros dispositivos obtener información acerca del estado del producto, composición, ciclo de vida, etc. [5].

Existen otro tipo de objetos que poseen una elevada capacidad de comunicación con su entorno o con otras aplicaciones. Este tipo de objetos sí suelen contar con un mini computador y una conexión a la red. Ejemplos de estos objetos son las redes de sensores a las que se puede acceder desde cualquier lugar del mundo.

Derivado del concepto del IoT, donde los objetos cotidianos están etiquetados por pequeños tags para que puedan ser identificados y manejados

[1] The Internet of Things", ITU, November 2005

por un ordenador en un mundo virtual donde sean manejados por las personas en un mundo real, nos encontramos con el significado del término Inteligencia Ambiental (*Ambient Intelligence*), AmI en adelante, [6-7] que describe un entorno donde las personas estén rodeadas por interfaces intuitivas e inteligentes embebidas en objetos cotidianos y que a su vez estas interfaces se comuniquen unas con otras creando un entorno electrónico que reconocerá y responderá a la presencia de individuos que estén inmersos. Esta comunicación es invisible para el individuo [8]. A través de una interacción natural, el usuario puede acceder a un conjunto de servicios proporcionados por los objetos de los que está rodeado, definiendo un escenario de interacción. Esos servicios están adaptados en función del contexto y de las preferencias del usuario, por lo que podrían ayudarnos en las actividades cotidianas. La característica central de los escenarios es que las personas están a la vanguardia de la Sociedad de la Información. Esta visión de personas beneficiándose de servicios y aplicaciones soportadas por nuevas tecnologías e interfaces inteligentes fue esencial para el grupo *Information Society Technologies Advisory Group* (ISTAG) con respecto a la noción de Ambiente Inteligente [9].

Algunas características de AmI de acuerdo con el ISTAG son: a) facilidad de contacto humano, b) proporcionar ayuda para crear conocimiento y habilidades para el trabajo, c) inspirar confianza y seguridad, d) ser controlable por cualquier usuario.

AmI representa una visión de futuro donde los entornos inteligentes y los sistemas reaccionan de forma activa y adaptable a la presencia de individuos y objetos con el fin de proporcionar servicios a estos individuos en dichos entornos inteligentes. Los objetivos de este paradigma son desarrollar entornos capaces de interaccionar con los individuos de forma autónoma para facilitarles actividades cotidianas. Olaru et al. [10] ven un entorno inteligente como un gran número de dispositivos interconectados que suministran las necesidades de los individuos.

Bajo el término AmI se engloban todas aquellas técnicas que permiten disfrutar de las ventajas que ofrecen las TICs sin que el entorno se convierta en un factor limitante. AmI involucra varias áreas dentro del campo de la computación, como son computación ubicua o pervasiva, sistemas inteligentes y conciencia del contexto [11].

El paradigma de la computación ubicua [12] permite el desarrollo de entornos activos y móviles, permitiendo el acceso a una enorme cantidad de información y a su tratamiento, independientemente de la ubicación de los usuarios, gracias al uso de elementos computacionales intercomunicados por redes inalámbricas, radio, GSM, etc. Aquellos elementos embebidos en muebles, objetos, carteles, máquinas, libros, etc. Una de las tecnologías que nos permiten el acceso a la información digital disponible en los objetos físicos en el mundo real es la tecnología RFID.

Enrico Rukzio en [13] presenta un primer análisis y clasificación de las interacciones físicas con los dispositivos móviles, describiendo algunas de las experiencias, las guías y métodos para facilitar el uso de las interacciones físicas, así como algunas aplicaciones, y también muestra un análisis en términos de privacidad. En este artículo se presenta un conjunto de paradigmas sobre la base de tres tipos de interacciones: pointing, scanning and touching. Touching significa tocar el tag físico con el lector para seleccionarlo y es la fórmula elegida para desarrollar el IoT. Relacionado con este último paradigma (*Touching Paradigm*), ha aparecido la tecnología Near Field Communication (NFC) [14]. NFC es una evolución de RFID. NFC generará una nueva revolución tecnológica en los próximos años: la revolución sin contacto, lo que permite ofrecer servicios ubicuos a los usuarios con necesidad de información en diferentes momentos y lugares, el apoyo a lo que se ha llamado como Internet de los objetos.

Uno de los principales entornos con servicios ubicuos son las U-cities o ciudades ubicuas donde todo está interconectado y donde la información está disponible ad-hoc y no hay límite de comunicación entre personas y ordenadores. En Europa, la ciudad de Oulu [15] es líder en el uso de NFC para construir ciudades ubicuas.

Las iniciativas y prototipos que se están llevando a cabo, la revolución "sin contacto" y el IoT guiados por la tecnología NFC, van a incluir no solo aplicaciones para identificación, pago o ticketing, sino cualquier tipo de servicios en cualquier entorno, en nuestro caso el entorno educativo, el marketing, el turismo y la publicidad.

La presente memoria resume el esfuerzo realizado en el estudio de los principales avances hasta la actualidad y expone los logros conseguidos en el desarrollo de nuevos modelos de interacción basados en la tecnología NFC, principalmente, y en otras tecnologías móviles presentando modelos de ambientes inteligentes en distintos escenarios de interacción como son el turismo, la educación, el marketing y la publicidad. El objetivo principal es presentar las bondades de la innovadora tecnología NFC y su inclusión en el IoT.

El documento se ha divido en dos partes, la primera abarca el capítulo I que además de la presente introducción incluye las hipótesis y objetivos de la tesis; el capítulo II describe los fundamentos teóricos y conceptos básicos implicados en este trabajo.

La segunda parte (capítulos III, IV, V y VI) incluye copia exacta de las cuatro publicaciones resultado de la investigación realizada, definiendo la estructura de la memoria como "compendio de publicaciones" según el artículo 20 de la normativa de doctorado de la Universidad de Córdoba. Finalmente, se hace una síntesis de las principales aportaciones de esta tesis, así como un resumen de las líneas de trabajo futuro que se inician a partir de los resultados obtenidos en la misma.

1.1 Hipótesis y objetivos de la Tesis

A partir de la visión de Weiser [16] de un mundo totalmente conectado a través de ordenadores invisibles asociados a cualquier objeto del entorno, la computación ubicua es una línea de investigación y desarrollo de gran importancia. Tecnologías no invasivas como NFC permiten asociar a cualquier objeto del mundo real con capacidad de interacción y ofrecer información y servicios a través de la "nube" a los usuarios en cualquier lugar y en todo momento (IoT).

1.1.1 Hipótesis de partida

La tecnología NFC está considerada como el disparador de la nueva fase de desarrollo de la sociedad de la información, Internet del Futuro y, la a menudo denominada como el IoT. NFC permitirá en un futuro no muy lejano el desarrollo de los "idealmente" concebidos hace unas décadas ambientes inteligentes (AmI), permitiendo que el usuario interaccione con cualquier objeto de su entorno y que le proporcione servicios e información. Las aplicaciones de esta tecnología son innumerables: pago, ticketing, AAL (*Ambient Assisted Living*), turismo, identificación, seguridad, marketing y fidelización, enseñanza, sanitarias, redes sociales, etc., son algunos de los múltiples ejemplos que pueden proponerse.

La finalidad de la investigación es llevar a cabo estudios, proponer modelos y desarrollar herramientas para el fortalecimiento y avance de la tecnología NFC, proponiendo un marco de conocimiento para el diseño, modelado y desarrollo de escenarios inteligentes con los que el usuario interacciona de forma personalizada y desarrollando un conjunto de productos que, soportando los modelos propuestos, permiten la construcción de estos escenarios, su despliegue, la localización y aprovisionamiento de los servicios ofrecidos por los objetos.

La hipótesis de partida establece que: "el uso de la tecnología NFC se considera ideal para el desarrollo de aplicaciones dentro del ámbito del IoT con el objetivo final de facilitar actividades cotidianas para las personas y mejora de modelos de negocio existentes actualmente".

Esta hipótesis se fundamenta en:

- El uso de los dispositivos móviles (Smartphone, tablets, etc) ha crecido notablemente en los últimos años y su tendencia es que su presencia en nuestras vidas sea casi imprescindible. Por tanto, se considera necesaria la proliferación de soluciones para estos dispositivos que faciliten tareas y actividades cotidianas.
- La combinación de soluciones móviles con el uso de la tecnología NFC, en particular, y las tecnologías móviles emergentes, en

general, permitirá definir ambientes inteligentes donde los usuarios podrán interaccionar con personas y objetos de su entorno.

- La interacción del usuario con su entorno a través de la tecnología NFC (*Touching Paradigm*) permitirá interacciones personalizadas para cada usuario de forma que los servicios estén adaptados a las necesidades del usuario que realiza la interacción.
- Todo lo anterior sumado a las ventajas en términos de seguridad, a la facilidad de uso, al funcionamiento intuitivo y a la estandarización de dicha tecnología, hace que NFC se convierta en una tecnología clave y fundamental para desarrollar soluciones dentro del ámbito del IoT.

1.1.2 Objetivos

El objetivo general que se plantea en esta investigación es avanzar en el estudio y aportar soluciones a algunos de los problemas existentes en el desarrollo del IoT, considerando como marco tecnológico para su aplicación el uso de la tecnología NFC.

Para realizar el estudio de NFC en el desarrollo de soluciones móviles ubicuas dentro del marco del IoT, se han seleccionado un conjunto de áreas de aplicación donde el empleo de NFC mejore procesos, actividades y tareas cotidianas. Dichas áreas, nos permitirán concluir que haciendo uso de NFC podremos crear ambientes inteligentes que permitan interacciones persona-objeto mejorando los procesos y tareas actuales dentro del IoT. Las áreas de aplicación seleccionadas son: *Turismo, Educación, Marketing y Publicidad*.

Para dar solución a este objetivo general, se definen los siguientes objetivos específicos:

Objetivo 1: Modelar y desarrollar un sistema ubicuo para la navegación en áreas urbanas y para localización de puntos de interés haciendo uso de la tecnología NFC.

El área de desarrollo de aplicaciones ubicuas se ha visto incrementado notablemente en la última década gracias al desarrollo de nuevas tecnologías de comunicación y móviles. Estas aplicaciones cubren un gran rango de problemas, sectores, escenarios y entornos que permiten la construcción de entornos inteligentes que soportan interacciones con las personas.

El turismo es un sector económico muy importante para muchas ciudades y países y, por tanto, se convierte en un área muy interesante para la propuesta y desarrollo de soluciones ubicuas. El objetivo principal de este tipo de aplicaciones es facilitar a los usuarios el acceso a cualquier información turística de interés.

Con el objetivo de facilitar a los usuarios el acceso a información turística, es recomendable plantear una propuesta de sistema generalizado cuyo principal cometido sea ayudar a estos usuarios a "navegar" en un entorno urbano y localización de puntos de interés turístico. Todo ello sumado a los beneficios que nos aporta el uso de la tecnología NFC, se propondrá una solución que, haciendo uso de dicha tecnología, nos permita interaccionar con objetos físicos del entorno urbano que nos ofrecerán información y nos ayudarán a navegar por dicho entorno. Se dará respuesta a cuestiones como, *¿qué es esto?, ¿dónde estoy?, ¿dónde está? o ¿qué hay a mi alrededor?*, de forma rápida e intuitiva.

Objetivo 2: Modelar y desarrollar un sistema generalizado para el entorno educativo que facilite el acceso a información bibliográfica implicada en el proceso de aprendizaje de los estudiantes.

Debido a las nuevas directivas del Espacio Europeo de Educación Superior (EEES), un nuevo modelo de enseñanza debe ser implantado en las universidades europeas. La implantación de este modelo requiere de la aplicación de nuevas metodologías y técnicas docentes, así como del uso de tecnologías informáticas que faciliten una formación personalizada y ubicua, de forma que el alumno pueda desarrollar sus habilidades y aptitudes a través de un proceso de formación presencia y virtual.

Por tanto, se va a implementar una propuesta de solución que abarque el estudio del uso de la tecnología NFC para la construcción de un sistema personalizado de ayuda al estudiante universitario en el acceso, consulta y estudio de fuentes bibliográficas necesarias para su formación profesional. El estudio independiente del alumno universitario y la consulta de fuentes bibliográficas es una carencia en el sistema actual y, sin embargo, de vital importancia en el nuevo modelo de formación.

Bajo esta metodología se propondrá la arquitectura de un sistema ubicuo basado en el Web-services y el uso de la tecnología NFC de forma que con "sólo tocar" una fuente bibliográfica, el alumno pueda recibir en su terminal móvil información personalizada de los "elementos de información esenciales" que esa fuente le puede aportar en su formación académica y profesional.

Objetivo 3: Modelar y desarrollar una solución tecnológica aplicada a modelos de marketing.

En los últimos años, nos encontramos con un gran incremento del uso de la computación ubicua y móvil para el desarrollo de nuevos modelos de marketing. Entre los más utilizados por las empresas se encuentra el modelo de negocio de "oferta del día" consistente en ofrecer una oferta a los consumidores con un tiempo de vida muy corto. El principal inconveniente que se encuentran las empresas con este modelo es gestionarlo y obtener un feedback que mejore su negocio y obtenga un mejor retorno de la inversión (ROI).

Actualmente existen muchas empresas que ofrecen sistemas de ofertas y tarjetas de fidelización basados en cupones descuento, pero la mayoría emplean el tradicional vale en formato papel, aunque poco a poco van eliminando este formato orientándolo al uso de nuevas tecnologías y dispositivos móviles.

A pesar de esta evolución, son muchos los aspectos que no están cubiertos a día de hoy con las soluciones existentes: problemas de seguridad en la obtención y canje de ofertas; tipo de vales descuento que manejan; la infraestructura necesaria para la gestión de este tipo de modelo de marketing; la gestión virtual de tarjetas de fidelización, entre otros.

Por ello, se va a proponer una solución que permite mejorar este tipo de soluciones y cierre la brecha de problemas existentes. La solución que se va a plantear consistirá en un ecosistema encargado de difundir, distribuir, aprovisionar, validar y gestionar tarjetas de fidelización y cupones electrónicos usando tecnologías móviles. Además, la solución que se va a plantear tendrá que garantizar la seguridad e integrará tecnologías tales como códigos QR y NFC.

La aplicación de la tecnología NFC en los modelos de marketing ofrecerá varias ventajas sobre los sistemas existentes.

Objetivo 4: Modelar y desarrollar una solución, abierta a las diferentes tecnologías móviles, que permita dar servicio de publicidad no intrusivo y personalizado en cualquier momento y lugar y que permita gestionar un elevadísimo número de localizaciones en las que la publicidad pueda difundirse.

Si revisamos el mercado de la publicidad en todos sus aspectos, el número de anuncios a nivel nacional es del orden de decenas de millones de anuncios “vivos” cuyo contenido tiene una vida media inferior a una semana. Por ello, se va a proponer una solución que gestione un gran número de anuncios que podrán estar en múltiples ubicaciones al mismo tiempo, con un contenido que puede cambiar en tiempo real.

Además, la publicidad debe estar al alcance del receptor en cualquier momento y lugar, adaptada a las necesidades el emisor y a las preferencias del receptor. Esto va a implicar el manejo un elevadísimo número de localizaciones donde ubicar contenido publicitario.

La publicidad pierde su valor si no llega al receptor en el tiempo y lugar adecuado. Para ello es necesario que la solución pueda dar servicios a: a) un elevado volumen de información publicitaria y, b) un elevadísimo número de potenciales receptores de esta información.

Si la publicidad es intrusiva, agresiva, desproporcionada en la información que transmite y en la incidencia sobre el receptor, el efecto que se obtiene es el opuesto al deseado. Por lo tanto, nos encontramos con el desafío de que nuestra propuesta debe adaptarse a las preferencias de emisores y receptores de información.

Por último, la solución que se proponga deberá utilizar la tecnología NFC para permitir utilizar dicha solución con cualquier otro sistema de publicidad novedoso que incorpore tecnología RFID permitiendo interacciones *contactless* con los mismos.

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2 | Fundamentos Teóricos y Antededentes

2 FUNDAMENTOS TEÓRICOS Y ANTECEDENTES

En los últimos años estamos presenciando un aumento exponencial del uso de dispositivos móviles en nuestras tareas del día a día. Multitud de aplicaciones existen en el mercado con el claro objetivo de ayudar a los usuarios en sus tareas cotidianas.

Es por ello que es evidente que poco a poco la tecnología es más accesible para los usuarios pero aún estamos lejos de conseguir que la tecnología se adapte a las necesidades del usuario y no sea el propio usuario el que tenga que adaptarse a ella para obtener el máximo beneficio que aporta. Para alcanzar esta meta, el usuario necesita un entorno inteligente en el que los computadores sean diseminados en el entorno con capacidad de comunicación y ayuden al usuario en sus actividades cotidianas. Además, el usuario podrá interaccionar con estos computadores de forma natural e intuitiva a través de aplicaciones sensibles al contexto.

Tenemos que remontarnos al año 1991 cuando el visionario Mark Weiser [1] propuso esta nueva visión de computación denominada *Computación Ubicua* o *Ubiquitous Computing* y que a la postre ha sido integrada en un paradigma más general denominado *Inteligencia Ambiental* o *Ambient Intelligence* [2]. Transcurridos más de 20 años desde la propuesta de Weiser, se han presentado un gran número de paradigmas que reflejan el avance en esta área.

2.1 Computación Ubicua

El futuro de Internet parece como un mundo totalmente conectado a través de ordenadores ocultos vinculados a objetos desde libros, coches, o cualquier objeto.

Según Weiser [3], la computación ubicua consiste en diseminar las computadoras en el entorno físico de forma que estén integradas en los objetos cotidianos de forma invisible para el usuario. En esta nueva generación de la computación, cada individuo está continuamente interactuando con cientos de ordenadores interconectados que están embebidos en objetos de la vida cotidiana.

La proliferación de dispositivos pequeños y móviles como los teléfonos móviles ofrecen el primer paso hacia el desarrollo de aplicaciones ubicuas.

De acuerdo con Weiser, las dos características más importantes de la computación ubicua son: la ubicuidad propiamente dicha y la transparencia; entendiendo por ubicuidad el hecho de que el procesamiento de sistema está integrado en el entorno de forma que sea accesible por el usuario en cualquier momento y lugar (*anywhere and anytime*); y por transparencia que la interacción del usuario con los computadores integrados en el entorno se realice de forma natural.

Para alcanzar estos objetivos, Weiser estableció tres líneas de actuación:

- Existencia de dispositivos móviles.
- Integración del entorno físico.
- Interacción natural usuario-sistema.

El avance de la computación ubicua garantiza la descentralización de los sistemas dando lugar al desarrollo de los denominados sistemas ubicuos. Gran parte de los sistemas ubicuos desarrollados caen dentro del área de aplicaciones sensibles al contexto y entornos activos. Otras áreas donde ha calado la computación ubicua son: asistencia a la tercera edad, modelado de usuario, seguridad y privacidad, etc.

2.2 La Inteligencia Ambiental

La Inteligencia Ambiental o *Ambient Intelligence* (AmI) propone la creación de entornos o ambientes inteligentes que se adapten a las necesidades, gustos e intereses de la gente que vive en ellos, ayudando a llevar a cabo sus tareas diarias mediante la integración de la informática en el entorno de la persona, de forma que los ordenadores no se perciban como objetos diferenciados [4]. Bajo el término Inteligencia Ambiental se engloban todas aquellas técnicas que permiten disfrutar de las ventajas que ofrecen las TICs sin que el entorno se convierta en un factor limitante. AmI involucra varias áreas dentro del campo de la computación como son computación ubicua o pervasiva, sistemas inteligentes y conciencia del contexto [5].

Los ambientes inteligentes (AmI) representan una nueva generación de entornos computacionales centrados en el usuario que tienen como propósito encontrar nuevas formas de obtener una mayor integración de las tecnologías de la información en dispositivos y actividades de la vida cotidiana. AmI [6-7] consiste en la creación de entornos inteligentes [8] donde los usuarios interactúan de forma natural e intuitiva con el entorno obteniendo recursos y servicios que facilitan al usuario la realización de actividades del día a día. En dichos entornos inteligentes, el usuario se encuentra rodeado de recursos ubicuos que están embebidos en objetos [9].

A través de una interacción natural, el usuario tiene acceso a un conjunto de servicios que definen un escenario de interacción. Estos servicios están adaptados al entorno y a las preferencias del usuario.

En esta visión, el modelo de interacción del usuario, la visualización de la información, el acceso personalizado y el contexto juegan un papel muy importante y ha sido tratado por distintos autores [10-11] que han propuesto diversos modelos y paradigmas.

Según Aarts et al. [4] las principales características que debe tener un sistema de Inteligencia Ambiental son:

- **Discreción:** los dispositivos deben ser invisibles para los usuarios.
- **Personalización:** deben reaccionar en función del usuario y de su entorno.
- **Adaptabilidad:** deben modificar el entorno en función de la información y del usuario.
- **Pro-actividad:** deben aportar gran cantidad de procesos al entorno.

Tal y como se recoge en [12], la Inteligencia Ambiental, en su aspecto tecnológico, pretende ser invisible, embebida, presente en todo momento que sea necesaria, operativa con interacciones naturales y adaptadas a usuarios y contexto. Por ello, Aarts [4] define la Inteligencia Ambiental como la sinergia de tres atributos:

- **Ubicuidad:** donde el entorno está enmarcado por múltiples sistemas embebidos e interconectados.
- **Transparencia:** la tecnología es invisible y está integrada en el entorno del usuario.
- **Inteligencia:** el entorno es capaz de reconocer a los usuarios, adaptarse y aprender de su comportamiento.

2.3 Contexto y Context-Aware

Dey et al. [13] proponen una definición general de *contexto* como: "*cualquier información que caracteriza el estado de una entidad entendiendo por entidad cualquier persona, lugar u objeto que se considera relevante para la interacción entre un usuario y una aplicación, incluyendo al propio usuario y a la aplicación*".

La definición de contexto implica la definición de todos los actores involucrados en la aplicación. La profundidad y características de esta definición dependen de la naturaleza de los actores y de las tareas que estos actores realizan en el sistema. Se han propuesto diversas definiciones formales de contexto y mostrando la complejidad de esta actividad cuando se trata de aplicaciones sensibles al contexto (*Context-Aware*) [14].

Dey también propone la definición de context-aware, donde: "*Una aplicación sensible al contexto es aquella que emplea el contexto para ofrecer al usuario información y/o servicios relevantes, donde la relevancia va a depender de la tarea del usuario*".

En el trabajo de Dey et al., también proponen una clasificación de las aplicaciones sensibles al contexto atendiendo a las siguientes características:

- *Presentación de la información.* Son aquellas aplicaciones que muestran información personalizada según el contexto del usuario.
- *Ejecución automática* de un servicio dependiendo del contexto.
- *Etiquetado del contexto.* Estas aplicaciones etiquetan el contexto recopilado para que posteriormente el usuario pueda consultar los cambios que se han producido.

Por otra parte, Shilit et al. [15] establecen cuatro categorías de aplicaciones sensibles al contexto que surgen de aplicar dos criterios ortogonales. El primero divide las aplicaciones según si la tarea que realizan provee algún tipo de información o si permite enviar comandos. El segundo criterio establece si la tarea precisa de la intervención del usuario (manual) o no (automática). Estas cuatro categorías se resumen de la siguiente forma:

- *Selección próxima.* Aplicaciones con una interfaz capaz de resaltar aquellos objetos o recursos que se encuentran más próximos al usuario.
- *Reconfiguración automática contextual.* Aplicaciones que usan la información contextual para cambiar la configuración de los componentes del sistema.
- *Comandos contextuales.* Aplicaciones en las que la activación de un comando produce resultados en función del contexto.
- *Acciones disparadas por contexto.* Aplicaciones que realizan diferentes acciones en función de los eventos producidos por cambios en el contexto.

La clasificación anterior la resumen Chen y Kotz [16] como:

- *Aplicaciones sensibles al contexto activas.* Aplicaciones que de forma automática se adaptan a los cambios en el contexto.
- *Aplicaciones sensibles al contexto pasivas.* Aplicaciones que reaccionan a los cambios en el contexto por petición del usuario.

El aspecto más crítico de los sistemas sensibles al contexto es la localización (*location-aware*). Los sistemas sensibles a la localización o location-aware obtienen información de la localización actual del usuario para proporcionar información y servicios [17]. Los entornos sensibles a la localización ofrecen un alto grado de precisión en cuanto a la obtención automática y real de la localización del usuario. Tanto los avances en tecnología como en comunicaciones inalámbricas permiten el desarrollo de sistemas de localización nunca antes posibles.

2.4 La Tecnología NFC – Near Field Communication

Cada vez más se tiende a darle nuevos usos a dispositivos ya existentes para solucionar o hacer más fáciles situaciones de distintos ámbitos de la vida cotidiana. Este es el caso de los teléfonos móviles.

Fue en el año 2002 cuando Philips y Sony decidieron ponerse de acuerdo para investigar juntos con el fin de conseguir un protocolo compatible con sus tecnologías propietarias “contactless” (sin contacto físico) existentes en el mercado: Mifare, del primero; y FeliCa, del segundo. Como evolución de ambas, surge ahora la tecnología NFC (Near Field Communication o Comunicación de campo corto) [18].

NFC es una tecnología que evolucionó a partir de las tecnologías existentes de identificación e interconexión. Utiliza la tecnología *Radio Frequency IDentification* o *Identificación por Radiofrecuencia (*RFID) [19] para el intercambio de información entre dispositivos. Principalmente destinada para su uso en dispositivos móviles (aunque no exclusivamente).

Simplifica enormemente el proceso de interconexión entre dispositivos a través de una comunicación inalámbrica. Elimina la necesidad del proceso de configuración requerido por otras tecnologías (como por ejemplo, Bluetooth o WIFI), y lo reduce a un simple “toque” del dispositivo móvil al lector. Conforme a los estándares ISO, ECMA y ETSI, permite la interoperabilidad entre otros dispositivos y tecnologías.

2.4.1 Características principales de NFC

NFC es una tecnología intuitiva, que permite al consumidor conectado interactuar con su entorno, y cuyo estándar ISO/IEC se aprobó el 8 de Diciembre de 2003. Sus principales características son:

- Trabaja mediante inducción magnética, en la banda RF no regulada de 13,56 MHz.
- La distancia de trabajo es entre 0 y 20 cm. Los dispositivos NFC se comunican solo si están prácticamente "tocándose" uno al otro (sobre 10 cms), pero las aplicaciones requieren gran cantidad de seguridad, por lo que con frecuencia operan dentro del rango de los 4 cms.
- Permite una velocidad de transmisión de 106, 212 o 424 Kbps.

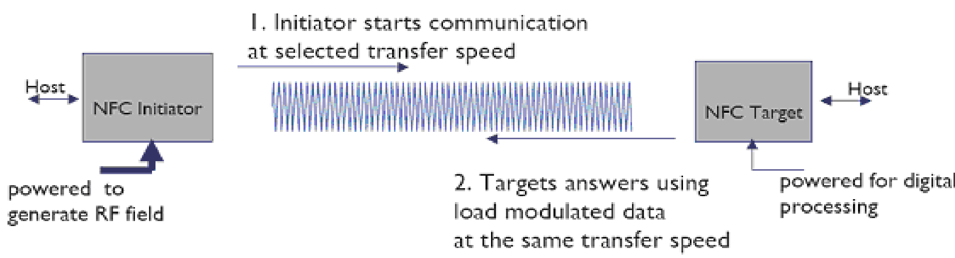


Figure 1. Esquema de comunicación pasiva

- Modo pasivo de comunicación, el iniciador genera una portadora y el destinatario responde modulando el campo existente. El equipo receptor por medio del acoplamiento inductivo, absorbe la energía para poder comunicarse e intercambiar datos con el dispositivo activo. La *Figura 1* refleja el esquema de una comunicación pasiva, el iniciador de la comunicación es el encargado de generar el campo electromagnético. El dispositivo pasivo no necesita alimentación propia y sólo puede ser leído o escrito. Es el caso de las tarjetas Mifare por ejemplo. El modo de comunicación pasivo es muy importante para dispositivos por el ahorro de energía, como puedan los teléfonos móviles y PDAs, donde se hace necesario priorizar el uso de la energía.

- Modo activo de comunicación, tanto emisor como receptor generan su propio campo electromagnético, que utilizarán para transmitir sus datos y comunicarse. Los dos elementos necesitan energía para funcionar (véase la *Figura 2*), son capaces de leer y escribir datos e incluso establecer una comunicación peer-to-peer entre ellos.
- NFC puede usarse para configurar e iniciar otras conexiones inalámbricas como Bluetooth o Wi-Fi, lo que permite la utilización conjunta de múltiples tecnologías de comunicación: telefonía móvil y tecnología RFID, etc.

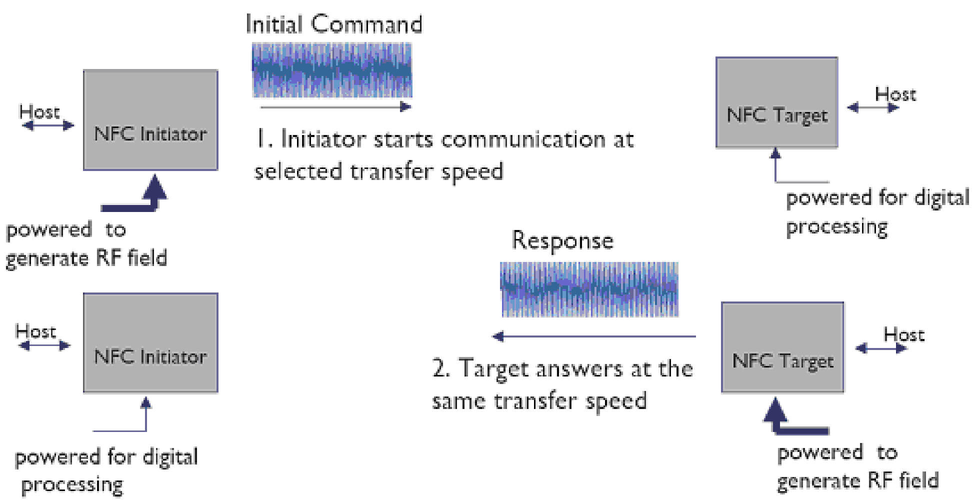


Figure 2. Esquema de comunicación activa

Su principal función es permitir a dos equipos comunicarse entre sí únicamente si están prácticamente tocándose uno a otro. Se trata por tanto de una tecnología para conexiones inalámbricas de muy corto alcance en ambos sentidos y se basa en una tecnología de radiofrecuencia de corto alcance que permite a un dispositivo leer pequeñas cantidades de datos de otros dispositivos o etiquetas cuando se aproxima el uno al otro.

NFC es una tecnología especialmente apropiada para el desarrollo de Ambientes Inteligentes (AmI). Su uso en unidades / dispositivos como los teléfonos móviles (o PDAs), su interacción con otras tecnologías inalámbricas (WiFi, Bluetooth, etc.) y de comunicaciones (GPRS, UMTS, EDGE, etc.), su uso fácil e intuitivo que no requiere instalación/configuración por parte del usuario, etc., posibilita el desarrollo de soluciones computacionales, generalizadas y ubicuas.

Su funcionamiento no resulta muy difícil de explicar. Parte de una solución inalámbrica de radiofrecuencia (RFID) que está compuesta por un lector y una etiqueta. Cuando se enciende el primero, emite una señal de radio de corto alcance que activa un microchip en la etiqueta, lo que permite la lectura de una pequeña cantidad de datos que pueden ser almacenados en él.

El pequeño radio de acción de esta tecnología es, además, una gran ventaja por dos motivos:

1. El primero es que resulta idóneo para atender servicios que impliquen una necesaria privacidad, como una operación de pago.
2. El segundo es que, al estar tan cerca ambos dispositivos, se evitan los errores en la comunicación y se asegura una mayor eficacia en la transmisión de datos.

Visto su funcionamiento, no resulta extraño imaginar las ventajas que ofrece en distintos ámbitos cotidianos. De hecho, proporciona un modo de acceso a los servicios muy familiar e intuitivo para todo tipo de usuarios. Y es que todo el mundo entiende la frase: "*Si quieres un servicio, tócalo*". Evidentemente, no requiere ninguna configuración previa, basta con acercar el dispositivo a la fuente emisora. Incluso, aun cuando está en funcionamiento, no necesita consumir batería para establecer la conexión y realizar el intercambio de datos.

Existen tres formas de utilizar NFC:

1. *Emulación de tarjetas:* El dispositivo NFC se comporta como una contactless card y puede ser utilizado para el manejo de sistemas de

pagos basados en diferentes métodos como MIFARE, Visa payWave, MasterCard PayPass o American Express ExpressPay.

2. *Modo Reader:* Esta forma es una de las más comunes y utilizadas hoy en día; en donde el dispositivo NFC se encuentra en modo activo y lee un tag RFID pasivo; como lo es por ejemplo la lectura y almacenamiento de una dirección web, datos de una locación o cupones publicitarios.
3. *Modalidad P2P:* Dos dispositivos NFC se comunican entre sí para el intercambio de información.

Los inconvenientes tecnológicos iniciales del uso de esta tecnología debidos a la disponibilidad de dispositivos NFC han sido superados, puesto que: a) fabricantes están poniendo en el mercado estos dispositivos y su expansión está prevista próximamente, b) fabricantes y operadoras están desarrollando dispositivos y SIMs soportando el protocolo SWP-1 que permitirá el uso de las SIMs como elemento seguro, c) nuevos dispositivos como micro-SD-NFC, twinlinks y Myztro (bluetooth-NFC), etc., están disponible y permiten que cualquier dispositivo móvil integre NFC, d) las experiencias piloto han demostrado la gran aceptación de los usuarios con la tecnología, lo que ofrece un nuevo campo de negocio.

2.4.2 NFC-Forum y Estandarización

En 2004, Philips, Nokia y Sony fundaron el NFC-Forum [20], una asociación industrial sin ánimo de lucro, para promover esta tecnología. Sus proponentes quisieron que NFC fuera compatible con otras formas de tecnologías contactless, como la ISO 14443A, implementada en los productos MIFARE de Philips y PicoPass de Inside Contactless; y la ISO 14443B, el estándar más popular usado con la tecnología FeliCa de Sony. Al igual que NFC ambas operan en los rangos de frecuencia de 13.56 MHz.

En junio de 2006, el NFC Forum introdujo la arquitectura estandarizada de la tecnología, las especificaciones iniciales y los formatos de tags para dispositivos compatibles con NFC. Estos incluyen NDEF (*Data*

Exchange Format), y tres especificaciones iniciales para RTD (*Record Type Definition*) para posters inteligentes, texto, y aplicaciones de lectura de recursos de internet.

Con el fin de promover NFC a nivel mundial, Sony y Philips enviaron las especificaciones preliminares a la organización ECMA International, responsable de la estandarización de sistemas de información y de comunicación. Luego de desarrollar unas especificaciones técnicas abiertas, el protocolo NFCIP-1 fue aprobado bajo ECMA-340, y subsecuentemente enviado por ECMA International a ISO/IEC. Esta especificación fue aprobada bajo la ISO/IEC IS 18092. Más tarde fue aprobada por ETSI bajo el estándar ETSI TS 102 190.

Actualmente la colaboración técnica y de negocios relacionada con NFC se realiza bajo los acuerdos del NFC Forum. Sus miembros principales son: Google, NXP (Philips), Sony, Nokia, HP, Texas Instruments, NEC, Samsung, Motorola, MasterCard, Visa, Panasonic, Microsoft, Gemalto, Vodafone, NTT DoCoMo, Siemens, entre otros. En otras palabras, todos los jugadores principales del mercado de las comunicaciones móviles y electrodomésticos.

A continuación se van a nombrar y describir brevemente cuales son los principales participantes en el proceso de estandarización de esta tecnología.

2.4.2.1 ISO, ECMA y ETSI

Estos estándares especifican los esquemas de modulación, codificación, velocidades de transferencia y formato de marco de la interfaz RF (radio-frecuencia) de los dispositivos NFC.

Definen también esquemas de inicialización y condiciones requeridas para control de colisiones de datos durante la inicialización, tanto para modos pasivos como modos activos de NFC, y protocolos de transporte, incluyendo protocolos de activación y métodos de intercambio de datos. NFC se encuentra estandarizado bajo:

- ISO/IEC 18092/ECMA-340/ETSI TS 102 190: Near Field Communication Interface and Protocol-1(NFCIP-1).
- ISO/IEC 21481/ECMA-352/ETSI TS 102 312: Near Field Communication Interface and Protocol-2 (NFCIP-2).

NFC también incorpora una variedad de estándares preexistentes, lo que habilita a esta tecnología para ser compatible con otras infraestructuras tecnológicas, y otro tipo de dispositivos de lectura:

- ISO 15693: Vicinity Cards.
- HISOH 14443: Proximity Cards.

Otro de los estándares definidos por ISO es el estándar ISO 7816 que es el estándar de comunicación que define la organización, seguridad y comandos para el intercambio de información en smartcards.

2.4.2.2 Estándares NFC-Forum

Estas especificaciones son:

- Formato de intercambio de datos NFC (NDEF)
- Definición de tipo de registros NFC (RTD)
- Descripción del tipo de registro de servicio URI NFC (Identificador Uniforme de recursos).
- Descripción del registro NFC de tipo texto.
- Descripción del registro NFC de tipo Smart Poster.
- Descripción del registro NFC de tipo firma: se usa para verificar la integridad y autentificar el contenido de los registros.
- Descripción del registro NFC de tipo Genérico, que proporciona el mecanismo para requerir una acción específica de un dispositivo NFC desde otro dispositivo, tag o tarjeta a través de comunicación NFC.
- Especificación del manejo de conexiones (*Connection Handover*) a través de NFC. El objeto de esta especificación es proporcionar un mecanismo para establecer una comunicación alternativa entre dos dispositivos NFC, de forma que se aproveche la ventaja de NFC

para iniciar y ejecutar protocolos definidos por el usuario entre dispositivos NFC.

- La especificación NFC Digital Protocol hace referencia al protocolo digital en la comunicación entre dos dispositivos NFC, suministrando una especificación de la implementación por encima de los estándares de ISO/IEC 18092 y ISO/IEC 14443. Armoniza las tecnologías ya integradas, especifica las opciones de implementación y limita la interpretación de los estándar, es decir, en esencia muestra a los desarrolladores como deben usar los estándares NFC, ISO/IEC 14443 y JIS X6319-4 juntos para asegurar una interoperabilidad global entre diferentes dispositivos NFC y entre dispositivos NFC y las estructura contactless ya existente. Más concretamente esta especificación cubre la interfaz digital y el protocolo de transmisión half-duplex de los dispositivos NFC cuando cumples los 4 roles de iniciador de la comunicación, Lector / Escritor o cuando actúa en modo pasivo emulando una tarjeta contacless.
- La especificación NFC Logical Link Control Protocol (LLCP) define una nueva capa y protocolo para soportar las comunicaciones peer-to-peer entre dos dispositivos NFC. Esto es esencial para cualquier aplicación NFC que implique una comunicación bidireccional. Esta especificación define dos tipos de servicios, los orientados a la conexión y los no orientados a la conexión, organizados en tres clases: servicios sólo orientados a la conexión, servicios sólo no orientados a la conexión y servicios orientados y no orientados a la conexión. LLCP es un protocolo compacto, basado en el estándar IEEE 802.2, diseñado para soportar tanto pequeñas aplicaciones con unos limitados requerimientos de transferencia de datos, como transferencia de grandes archivos o protocolos de red como OBEX y TCP/IP, que a su vez proporcionan un entorno para estos servicios y aplicaciones mucho más robusto. Por lo tanto NFC LLCP proporciona una sólida base para las comunicaciones P2P mejorando la

funcionalidad básica ofrecida por ISO/IEC 18092, pero sin afectar en la interoperabilidad de las aplicaciones o chips NFC actuales.

- La especificación NFC Activity Technical Especification define una capa complementaria para el protocolo NFC Digital Protocol

Responsables de NFC Forum también anunciaron los cuatro formatos de etiqueta iniciales basados en las normas ISO 14443 tipo A y 14443 tipo B. (ISO 14443 es una norma internacional para las tarjetas inteligentes sin contacto que operan a 13,56 MHz en estrecha proximidad con la antena de un lector) y con ISO 18092. Estas especificaciones de etiquetas son:

- NFC Forum Type 1 Tag, que hace referencia a las tarjetas Innovision Topaz
- NFC Forum Type 2 Tag, que hace referencia a las tarjetas NXP MIFARE ultralight y NXP MIFARE Ultralight C
- NFC Forum Type 3 Tag, que hace referencia a las tarjetas Sony FeliCa
- NFC Forum Type 4 Tag, que hace referencia a las tarjetas NXP DESfire y NXP SmartMX with JCOP u otros productos contacless compatibles.

La mayoría de los principales fabricantes de dispositivos móviles soportan las especificaciones desarrolladas por el NFC-Forum. Sus productos son compatibles con millones de tarjetas contactless que ya están en uso en todo el mundo.

2.4.3 Estado actual de la tecnología NFC

Las aplicaciones de la tecnología NFC son innumerables. Un aspecto importante que favorece el desarrollo de entornos inteligentes empleando tecnología NFC es debido a la evolución de los dispositivos móviles y el número de terminales en el mundo [21]. El incremento en el número de teléfonos ha resultado ser exponencial desde aproximadamente mil millones en el año 2001 hasta casi cinco mil millones en el año 2016. Se han desarrollado nuevas aplicaciones basadas en NFC aplicadas a una gran variedad de servicios [22]. Además de aplicaciones sobre pago y seguridad [23-26], NFC ha proporcionado aplicabilidad en transporte [27-30], publicidad y promoción turística [31-34], ambient assisted living (AAL) [35-38], cuidado de ancianos [39-42], compras [43-44], autentificación [45-48], y otras aplicaciones orientadas a la ciencias y otras áreas de negocio [49-50].

La Comunidad Europea ha constituido el consorcio StoLPaN [51] soportado por el programa IST, cuyo objetivo es el estudio de las aplicaciones potenciales de la tecnología NFC. En este consorcio participan empresas como: Motorola, NXP, Auto-ID-Lab St. Gallen, Banca Popolare di Vicenza, Bull, Baker&McKenzie, Consorzio Triveneto S.P.A., Consult Hyperion, Deloitte, Fornax, Libri, Safepay Systems, Sun Microsystems, T-Systems, la Universidad de Budapest, etc.

El proyecto pretende definir las Reglas de Negocio y las Especificaciones Técnicas requeridas para el éxito comercial de aplicaciones comerciales y aplicaciones seguras que generarán estándares para su adopción en aplicaciones de pago y ticketing. Los objetivos principales de esta iniciativa europea son:

- El uso de terminales móviles para diferentes servicios NFC.
- Conseguir que el uso de NFC sea más económico, productivo y conveniente que los medios electrónicos y manuales actuales.
- Migrar las aplicaciones con tecnología sin contactos actuales a NFC utilizando la infraestructura y servicios actuales.
- Desarrollar un apropiado conjunto de experiencias de compras suportadas por servicios NFC.
- Dirigir estudios de negocio, legales, de seguridad, de pago, etc., con el fin de elaborar el entorno operativo necesario para estos nuevos servicios y contribuir a la estandarización y presentar los resultados a la industria, organizaciones públicas y privadas.

Otro proyecto Europeo (Eureka) financiado por el programa ITEA (Tecnología de la Información para el Avance Europeo) y encabezado por el

Centro de Investigación Técnica de Finlandia (VTT) tiene como objetivo investigar el uso de la tecnología de comunicación de campo cercano (NFC) en la vida cotidiana.

El proyecto SmartTouch [52] trata sobre objetos denominados “inteligentes” que están dotados de un lector móvil, incorporados a un teléfono móvil, por ejemplo. De este modo el usuario puede acceder a información o realizar pagos. Dicho proyecto SmartTouch se basa en la tecnología de identificación por radiofrecuencia (RFID) y también en la interfaz y el protocolo de conectividad inalámbrica de corto alcance para NFC. Esta tecnología es similar al estándar de Bluetooth tan extendido, si bien las etiquetas inteligentes de NFC tienen un alcance de tan sólo diez centímetros. NFC es capaz de proporcionar algo más de información que una simple tarjeta de identificación; contiene información y también algo de potencia de procesamiento. La tecnología de Bluetooth es más rápida, pero la tecnología de campo cercano tiene ventajas evidentes si uno piensa en la capacidad de pagos, abono de diversas entradas y billetes y el contacto entre aparatos próximos entre sí.

Uno de los principales proyectos españoles de investigación que están generando importantes resultados es el proyecto mIO! [53]. El objetivo del proyecto mIO! es hacer realidad las tecnologías que permitan prestar servicios ubicuos en un entorno inteligente y adaptado a cada individuo y a su contexto, usando el terminal móvil como base de interacción tanto con servicios proporcionados por empresas, como con microservicios creados y prestados por los propios usuarios en movilidad. Se trata de un proyecto CENIT liderado por Telefónica I+D, y en el que Treelogic colaborará con los Centros de investigación asturianos European Centre for Soft Computing y la Fundación CTIC, junto con más de 20 entidades de toda España. El proyecto mIO! tiene como objetivos: a) proporcionar una nueva generación de servicios en movilidad, con el móvil como punto de interacción, consumo, generar y proveer de servicio, gracias a las futuras tecnologías de terminal y entorno móvil, b) incorporar un nuevo concepto de acceso a dichos servicios: priorizar la experiencia de usuario, aprovechando los nuevos interfaces de acceso, c) explotar las capacidades del entorno y gestionar el contexto (aquí y ahora) dentro del universo de inteligencia ambiental del futuro, d) generación de servicios relevantes, personales e instantáneos en movilidad en el entorno inteligente de la ciudad y las empresas. Las actividades principales en las que se estructura este proyecto son las siguientes: a) Inteligencia Ambiental y Gestión del Contexto, b) Tecnologías de Interfaces de Acceso, c) Entorno Tecnológico Integral para el Usuario en Movilidad, d) Entornos Tecnológicos de Servicios, e) Nuevas Tecnologías en Infraestructura Inteligente, f) Tecnologías de Comunicación y Conectividad, g) Escenarios y Validación Tecnológica.

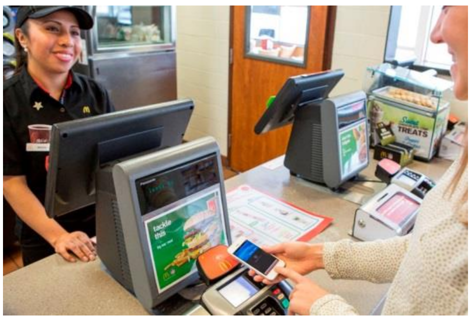
En España, las ciudades que lideran el uso de NFC son Madrid con iniciativas como la creación por parte de Telefónica de un “Distrito NFC” a las afueras de Madrid [54]; y Barcelona que se ha convertido en un verdadero laboratorio de pruebas NFC [55], con aplicaciones como pago en el transporte, tiendas, taxis y con el uso de NFC como llave en habitaciones de hoteles durante la celebración del Mobile World Congress en 2013.

2.4.4 Experiencias reales con NFC

Todo el trabajo conjunto de desarrollo por parte de numerosas empresas de la tecnología NFC, tanto para la estandarización como para lograr un sistema seguro, va a posibilitar su desarrollo y su aplicación a ámbitos concretos de la vida cotidiana.

De las posibles aplicaciones, la que quizás más hondo pueda calar en los consumidores es el de pago (ver *Figura 3a*). Gracias a la incorporación de NFC en los móviles, los usuarios podrán realizar transacciones económicas tan sólo acercando el dispositivo al terminal de cobro, sin tener que teclear nada en el móvil. Además, los teléfonos incorporarán una serie de características de seguridad para proteger los datos financieros y garantizar la seguridad de las comunicaciones. Ahora bien, ésta no es su única aplicación real.

Aparte de esta posibilidad, hay otras también interesantes, como el intercambio de datos entre usuarios, la tarjeta de visita electrónica o el ticketing (ver *Figura 3b*). Esto, sin duda, empieza a ser muy valorado por las compañías de marketing, interesadas en este método por su capacidad para desarrollar campañas personales de fidelización a sus clientes.



(a) (b)

Figura 3. Ejemplos de experiencias con NFC

Otra aplicación interesante es para las compañías de transporte urbano (ver *Figura 3c*). También destacar un uso más común que hoy en día ya es una realidad y es haciendo interacciones con los objetos denominados Smart Poster (ver *Figura 4d*) que almacenan información de todo tipo como puede ser información turística, horarios de transportes públicos, trailers de películas en cartelera, etc.

En Japón, la operadora NTT DoCoMo [56] ha puesto en marcha el servicio "DCMX mini", que permite a sus clientes comprar productos o servicios simplemente pasando su teléfono móvil especialmente equipado por lectores. La transacción se añade a la factura mensual del usuario.

La compañía O2, filial de Telefónica España, en conjunción con Vodafone y T-Mobile (los socios tecnológicos son Atron, Giesecke & Devrient y NXP), se han involucrado en un proyecto en Berlín sobre ticketing para transporte público (tranvía, autobús, tren). El proyecto, llamado Touch & Travel [57], es simple, los pasajeros solamente tiene que tocar un lector NFC con su dispositivo móvil al comenzar y al finalizar su trayecto. Con ello, la tarifa se calcula automáticamente se realizar el cargo a su cuenta bancaria. Este estudio es importante ya que las pruebas realizadas previamente con NFC en el transporte público se han limitado a los ambientes de tarifa plana o billetes de un solo viaje.

Dentro de nuestro país han sido diversos los proyectos orientados en el uso de NFC en los últimos años, especialmente en lo referente a pago móvil y transporte. En Sitges España [58] se ha llevado a cabo una prueba de la tecnología NFC para realizar compras usando de teléfonos móviles. El proyecto ha sido gestionado por el Ayuntamiento en colaboración con la empresa nacional de telecomunicaciones, Telefónica, además de Visa y un banco (La Caixa). Se han anunciado planes para realizar este estudio en Barcelona.

Ciudades como Valencia o Málaga ya han hecho real la experiencia del uso de NFC en el transporte. Valencia se convirtió en julio de 2014 en la primera ciudad española en la que funciona la nueva Móbilis NFC, una sencilla aplicación que se emplea para acceder al transporte público donde el usuario sólo debe acercar su Smartphone NFC a las validadoras de entrada en los autobuses, metro, tranvía y bicicletas de préstamo. Este servicio fue posible gracias a la colaboración de la Generalitat de Valencia, la operadora Orange, la empresa Transermobile y los operadores de transporte de Valencia. La operadora Orange también trabajó en los proyectos piloto de

Málaga entre 2008 y 2012 de la mano de la Empresa Malagueña de Transportes (EMT). La EMT fue pionera en el uso de nuevas tecnologías.

Ahora bien, a pesar de todas estas experiencias reales, todavía queda mucho camino por recorrer, porque la tecnología NFC es poco conocida entre los usuarios. Habrá que esperar, por tanto, para que esta tecnología acabe por extenderse como ya ha sucedido con Bluetooth.

2.5 NFC – Áreas de Aplicación

Cuando NFC se lanzó, parecía lleno de promesas, con un número ilimitado de usos posibles: una brillante forma de simplificar las tareas de la vida cotidiana y que consumen mucho tiempo llevarlas a cabo, permitiendo a la gente anunciar su presencia, pagar sus cuentas o conectar dispositivos unos a otros. Los ensayos en todo el mundo han sido recibidos con entusiasmo por parte de los consumidores que les encanta la idea de poder hacer la vida más simple mediante la búsqueda de nuevos usos para sus teléfonos móviles.

Coskun et al. [59] realizaron un estudio de las áreas de aplicación de la tecnología NFC. En este estudio destacaron las siguientes áreas:

- Ámbito sanitario.
- Intercambio de información.
- Pago móvil, fidelización y ticketing.
- Ocio y entretenimiento.
- Redes sociales y localización.
- Educación.
- Gestión de ventas al por menor.

En esta tesis doctoral, se hace hincapié en las cuatro áreas en las que se ha estudiado el empleo de la tecnología NFC. Estas áreas son: turismo, entorno educativo, marketing y publicidad.

2.5.1 NFC – Entorno turístico

El turismo es una actividad económica importante en muchos países representando en España aproximadamente el 10% del Producto Interior Bruto (PIB). La industria turística tiene características específicas que explican su importancia en el desarrollo económico y su inclinación hacia el uso de nuevas tecnologías como puede ser un sistema software para la gestión de reservas o el marketing turística. Este sector económico ha sido pionero en el desarrollo de aplicaciones y servicios turísticos [60].

El turismo es una especial área de aplicación de nuevas tecnologías móviles y en especial de la tecnología NFC para el desarrollo de entornos inteligentes dando lugar al desarrollo de multitud de aplicaciones y propuestas. Este tipo de aplicaciones están orientadas a dos tipos de escenarios [61-63]: (a) en entornos *indoor* como guías para museos y (b) en entornos *outdoor* como navegación a través de ciudades.

Son muchos los autores que han presentado propuestas y modelos aplicados al sector turístico haciendo uso de nuevas tecnologías como RFID o NFC. En [64-65] se muestra la importancia del sector turístico introduciendo servicios que este tipo de aplicaciones deberían incluir.

Reilly et al. [66] estudiaron las ventajas de usar mapas en formato papel aumentados con etiquetas RFID. De esta forma, el usuario interaccionaba en este mapa haciendo uso de su PDA. El usuario selecciona un punto de interés, aumentado con una etiqueta RFID, y obtenía información adicional de este punto de interés.

El proyecto KAMO [67] tiene como principal objetivo proporcionar información sobre rutas y líneas de autobús a los usuarios. Además de esta aplicación, ofrece un servicio de pago en el transporte a través de móvil. En este sistema, el usuario dispone de paneles informativos en las paradas de autobús con los que interacciona haciendo uso de su dispositivo NFC. Mediante esta interacción, el usuario obtiene información sobre los horarios del transporte público y sus paradas.

Hardy and Rukzio [68] hacen uso de teléfonos móviles con tecnología NFC y grandes pantallas situadas en lugares públicos. La idea es usar el teléfono móvil para escribir y señalizar objetos sobre la pantalla y mostrarlos paralelamente en el dispositivo móvil.

Kenteris et al. [69] han desarrollado un sistema de guía turístico multiplataforma que adopta el modelo "Web-to-mobile" en webs turísticas. Este sistema permite transferir a los usuarios móviles el contenido turístico de la web pero teniendo en cuenta las preferencias del usuario. Por otro lado, Martin et al. [70] han desarrollado un servicio móvil georreferenciado que envía a los turistas información teniendo en cuenta su contexto. Finalmente, Biuk-Aghai et al. [71] presentan un sistema de recomendación turística que puede servir para obtener itinerarios de viajes.

2.5.2 NFC – Entorno universitario

En el entorno educativo ha surgido en los últimos años la idea de la *Universidad de las Cosas* (UoT) (*University of Things*) basado en la aplicación del concepto de IoT en el entorno universitario [72]. La idea básica de este paradigma es acercar la universidad tanto a estudiantes y trabajadores como a la sociedad en general, ofreciendo servicios disponibles en cualquier momento y lugar.

Actualmente, las personas tienen que buscar y adaptarse a estos servicios, mientras que este paradigma plantea el uso de servicios que se adaptan al contexto donde el usuario los solicita obteniendo como resultado un entorno activo donde las computadores interaccionan con el usuario de forma inteligente y no intrusiva.

En una universidad pervasiva, todos los elementos del entorno son potencialmente objetos inteligentes gracias a que están etiquetados con tags.

La universidad es una entidad que necesita aplicaciones ubicuas que ayuden al estudiante a mejorar su rendimiento académico a través de juegos ubicuos para motivarlos, ayudar a localizar material en la biblioteca, a través de gestión de tutorías, etc., además de sistemas de pago y ticketing seguros para transporte, máquinas expendedoras o reprografía así como sistemas de navegación y localización tanto dentro como fuera del campus universitario.

Las universidades ofrecen una amplia variedad de servicios a los usuarios como pueden ser servicios administrativos, control del cumplimiento académico, información de acceso e identificación, etc. A su vez ofrecen servicios para el personal docente tales como gestión de tutorías, información de exámenes, horarios, clases, enseñanza virtual, etc. Por último, servicios orientados a los estudiantes como guías docentes, transporte público, deportes, tiendas, etc.

Sin embargo, en muchos casos el acceso a estos servicios es una tarea difícil. Es por ello que con este objetivo de acercar a la comunidad universitaria estos servicios se han planteado en los últimos años nuevos modelos de enseñanza y gestión en las universidades europeas [73]. El objetivo no es otro que mejorar la calidad de las universidades ofreciendo formas alternativas de acceso a los servicios disponibles.

Centrándonos en el avance de la sociedad del conocimiento y en la promoción e importancia del uso de nuevas tecnologías, la tecnología NFC se convierte en la más apropiada para implementar la universidad del futuro. Es por ello que multitud de autores han propuesto el uso de la computación ubicua y los paradigmas de "touch" [74] que trabajan con NFC para la creación de ambientes inteligentes en el entorno universitario.

Nava et al. [75] presentan el estudio de nuevas interfaces para mejorar procesos y ayudar a los estudiantes en el desarrollo de sus actividades diarias. Ellos proponen utilizar tecnologías como RFID y NFC para facilitar las explicaciones en clase. López de Ipiña [76] propone posibles soluciones basadas en RFID, NFC y Bluetooth en el entorno universitario. González et al. [77] presentan alternativas del uso de NFC en entornos de enseñanza. Otros autores como Zender et al. [78] proponen nuevas arquitecturas y modelos de comunicación para obtener un entorno universitario pervasivo.

En la Universidad de Córdoba, y siguiendo las directrices del Espacio Europeo de Educación Superior [79], el grupo de investigación Ingeniería del Software, Conocimiento y Bases de Datos (TIC-110) han implementado varios sistemas aplicados al entorno universitario haciendo uso de la tecnología NFC:

- Smart Posters en entornos universitarios, ofreciendo información y servicios a la comunidad universitaria [80-81].
- Control de cumplimiento académico [82].
- Juegos pervasivos para motivar a los estudiantes [83].
- Navegación en campus universitarios.

2.5.3 NFC – Marketing

Debido a la crisis económica que azota con dureza muchos países, multitud de empresas están adoptando la idea de *oferta del día* en sus modelos de negocio, algunas de ellas con gran éxito. El objetivo principal que se pretende conseguir con este modelo es atraer y fidelizar a los consumidores a través de cupones descuento y tarjetas de regalo usando una distribución tradicional, principalmente en formato físico.

Las técnicas de marketing y fidelización están cambiando guiadas principalmente por el creciente uso de smartphones, extendiéndose por tanto el concepto de m-cupones o cupones móviles.

Debido a ello, son muchos los autores que presentan paradigmas y modelos orientados a este tipo de marketing. Chen et al. [84] proponen un esquema de m-cupones que utilizan dispositivos móviles para distribuir cupones de descuento a través de las redes sociales permitiendo el intercambio de cupones. En este esquema, las empresas seleccionan su público objetivo para enviarles los cupones siendo este público objetivo el encargado de compartirlos.

Dominikus y Aigner [85] proponen una nueva forma de cupones llamada mCoupons que pueden ser descargados a través de posters o periódicos equipados con dispositivos NFC pasivos (etiquetas), a su dispositivo móvil para canjearlos. Estos autores, además, han descrito dos protocolos de seguridad para estos mCoupons.

Will et al. [86] describen un modelo que pretende explotar el uso de las redes sociales para campañas de marketing con el objetivo final de apoyar a los minoristas en la mejora de la comunicación con el cliente.

Además de estas propuestas, hoy en día existen multitud de aplicaciones y portales webs disponibles para la adquisición de cupones descuento. Este es el caso del famoso portal Groupon [87] que ofrece ofertas con una duración determinada, generalmente de un día (oferta del día). El usuario adquiere y paga la oferta y obtiene un cupón para canjearlo, ya sea a través de cupones en papel o cupones electrónicos dotados con códigos QR [88]. Otras aplicaciones como LetsBonus [89] o Groupalia [90] usan también estos códigos QR para el canjeo de cupones.

Sin embargo, la aplicación Coupies [91] usa tecnología NFC para el canjeo de cupones. El usuario solo tiene que acercar su dispositivo móvil, equipado con NFC, a un punto de canjeo. Estos puntos de canjeo son pegatinas situadas en los establecimientos. Estas pegatinas están equipadas tanto con códigos QR como con tecnología NFC.

Aunque algunos sistemas como los que se han descrito están orientados a la eliminación de los cupones en papel, al uso de dispositivos móviles y nuevas tecnologías, existen desafíos por resolver en términos de seguridad, distribución de cupones o tarjetas de fidelización.

2.5.4 NFC – Publicidad

Hoy en día, la mayoría de los usuarios que consumen publicidad lo hacen a través de los medios tradicionales existentes como televisión, radio, prensa escrita, folletos, etc. El éxito de los anuncios y el valor que tienen para los usuarios viene determinado por el tipo de anuncio, el contenido del mismo y el lugar en el que reciben el impacto del anuncio (en términos de localización y tiempo) [92].

Los anuncios móviles son un mecanismo eficiente debido a que llega al usuario aquello que le interesa de una forma personal a sus dispositivos móviles. Cuando se combina con información basada en la localización del usuario, la efectividad del impacto del anuncio aumenta considerablemente. Muchas empresas estiman el potencial del mercado de los anuncios móviles en billones de dólares por año. Por ello, existe la necesidad de diseñar y evaluar herramientas para estudiar la publicidad móvil y su difusión [93].

Omntrakul et al. [94] presentan un desarrollo reciente de un sistema de publicidad (llamado AdTouch) basado en códigos QR. Su trabajo ofrece un conjunto de servicios para anunciantes y publicistas con el fin de que sitúen sus códigos QR en publicidad en diferentes medios. El usuario final, captura la información de estos códigos QR con su dispositivo móvil Android.

Aalto et al. [95] introducen un novedoso sistema llamado B-MAD (Publicidad móvil con Bluetooth). Este sistema, con permiso previo del usuario, ofrece anuncios basados en la localización del usuario a través de Bluetooth y notificaciones Push. El inconveniente de este sistema es que no ha sido diseñado correctamente en términos de privacidad y seguridad. Los datos que se envían al servidor a través del Bluetooth no están encriptados. A esto se suma que para que haya transferencia entre los dispositivos debe de existir un emparejamiento previo entre los mismos.

Haddadi et al. [96] introducen MobiAd, un escalable, personalizado y privado sistema de publicidad basado en localización para plataformas móviles. Los autores presentan un prototipo inicial para publicidad personalizada, localizada y dirigida para Smart Phones. Utilizando la información del dispositivo móvil, MobiAd ofrece al usuario anuncios locales preservando su privacidad.

La publicidad móvil que tiene en cuenta la localización implica enviar información a los usuarios en determinadas localizaciones usando las preferencias del usuario de forma que no se convierta en publicidad intrusiva. La efectividad de este tipo de publicidad es alta especialmente si los anuncios se dirigen a los usuarios en el momento adecuado. Esta efectividad podría mejorarse usando contextos derivados de múltiples conjuntos de información.

Las ideas básicas que esconden los sistemas que son conscientes del contexto, son crear herramientas pro-activas e inteligentes de forma que se minimizan los esfuerzos e interacciones del usuario, creando sistemas con alto nivel de inteligencia, añadiendo reglas de decisión efectivas y adaptables e incrementando el nivel de personalización para los usuarios [93].

2.6 Lenguajes de Modelado Educativo

Los Lenguajes de Modelado Educativo, *Educational Modeling Languages* (EMLs), son lenguajes computacionales con el objetivo de permitir el modelado de unidades didácticas de acuerdo a distintas aproximaciones pedagógicas. La idea principal tras un EML es que un docente puede crear un modelo (es decir, una descripción o representación idealizada de la realidad) de una unidad didáctica y que dicho modelo pueda ser interpretado de forma computacional por un sistema que facilita o apoya su realización con las TICs.

La aparición de los EMLs en el dominio de los sistemas de educación soportados por las TICs ha sido relativamente reciente. Estos lenguajes ofrecen una visión novedosa y original con respeto a otras soluciones existentes en el dominio, planteando en muchos aspectos un cambio importante en la concepción y el desarrollo de sistemas.

En la enseñanza apoyada por la tecnología, y que globalmente se denomina por el término en inglés e-learning, se ha producido una gran revolución con la nueva forma de crear contenidos que suponen los objetos de aprendizaje (OA, en inglés *learning objects*). Aunque los objetos de aprendizaje tienen múltiples definiciones una de las más aceptadas es la utilizada en el estándar LOM (*Learning Object Metadata*) [97] donde se definen como “cualquier entidad que puede ser usada, reutilizada o referenciada durante un proceso de aprendizaje apoyado por la tecnología”. La principal ventaja es que permite crear cursos mediante combinación de contenidos previamente existentes es decir potencia la reusabilidad y la interoperabilidad. No obstante, y a pesar de las ventajas que aportan los OA en e-learning, existe también un amplio consenso entre los educadores de que la creación y presentación de materiales educativos de gran calidad no es suficiente para obtener una experiencia educativa plena y satisfactoria. Es igualmente importante la planificación de las otras actividades (tutorías, exámenes, lectura de libros, etc.) que el estudiante debe llevar a cabo para conseguir los objetivos educativos propuestos por el profesor.

De este análisis surge el concepto de Lenguaje de Modelado Educativo (EML) (del inglés *Educational Modeling Language*) como nueva piedra angular del e-learning.

La generalización del término EML en e-learning proviene del trabajo desarrollado en la Universidad Abierta de los Países Bajos (OUNL) durante finales de los años 90. El grupo de investigación liderado por el Profesor Rob Koper analizó los sistemas de gestión de la enseñanza (LMSs de su término en inglés Learning Management Systems) que existían y que eran los más utilizados en aquella época, intentando identificar los problemas y defectos de dichos sistemas de e-learning. En particular se identificó como principal problema la falta de aplicación de la teoría instruccional y del aprendizaje dentro de los mismos. Como resultado desarrolló y puso en práctica una propuesta basada en la definición de un Lenguaje específico de dominio llamado Educational Modelling Language (OUNL-EML) (para evitar ambigüedades se denominará a este lenguaje OUNL-EML a lo largo de este capítulo, en lugar de simplemente EML).

En un estudio realizado por el CEN/ISSS WS/LT Learning Technology Workshop acerca de los Lenguajes de Modelado Educativo se definió el concepto de EML como: Modelo de información semántico y su vinculación, que describen el contenido y el proceso dentro de una “Unidad de Aprendizaje” desde una perspectiva pedagógica y con el objetivo de dar soporte a la reutilización y la interoperabilidad [98].

2.6.1 Clasificación de los principales EMLs

A partir de las diferentes iniciativas desarrolladas en base a los principios de los Lenguajes de Modelado Educativo previamente mencionados y a los EMLs descritos en [98], es posible crear una clasificación para los mismos:

- Lenguajes Específicos. En esta categoría se encuentran los lenguajes que, aún sin cumplir estrictamente todas las características de un EML, permiten a los diseñadores describir las etapas del proceso de aprendizaje utilizando una metodología específica. En particular, dentro de esta categoría podemos destacar aquellos lenguajes aplicados a la metodología de enseñanza basada en la resolución de problemas mediante el planteamiento de preguntas y a la recolección de soluciones y respuestas. Algunos ejemplos de lenguajes específicos son:
  - Tutorial Markup Language (TML) [99] es una extensión de HTML para crear preguntas.
  - IMS Question and Test Interoperability (IMS-QTI) es una propuesta llevada a cabo por el consorcio internacional IMS para crear bancos de preguntas y de evaluaciones [100].
- Lenguajes de estructuración de contenidos. Esta categoría está formada por aquellos lenguajes que permiten a los diseñadores organizar los recursos educativos en una secuencia, siempre teniendo en cuenta las necesidades del estudiante y la interacción con el propio contenido, a fin de mejorar la experiencia educativa. Algunos ejemplos son:
  - ARIADNE Course Description Format (A-CDF) es un EML que permite la creación de cursos en línea [101]. Un curso en A-CDF consiste en documentos XML que serán utilizados conjuntamente con una herramienta LMS que será la que finalmente generará los cursos.

  - IMS Simple Sequencing (IMS-SS) define métodos para poder representar el comportamiento dentro de una experiencia educativa, de manera que un LMS pueda secuenciar actividades discretas de forma consistente [102]. Utiliza el concepto de actividad de aprendizaje (learning activity) como unidad de aprendizaje.
  - ADL Sharable Content Object Reference Model (SCORM) representa un modelo de coordinación que tiene el objetivo de proporcionar una colección de prácticas estandarizadas susceptibles de ser ampliamente aceptadas y ampliamente implementadas en entornos de e-learning [103]. De hecho, el modelo SCORM puede ser considerado como un "perfil de aplicación" (en inglés application profile) de estas prácticas ya que se apoya en otras especificaciones más generales como, por ejemplo, las proporcionadas por IMS, pero además concreta algunos aspectos que no están fijados en dichas especificaciones. La iniciativa SCORM pone en práctica diferentes desarrollos tecnológicos de las iniciativas propuestas por grupos como IMS, AICC, ARIADNE y IEEE-LTSC, todos ellos agrupados en un único modelo de referencia para especificar una implementación consistente que pueda ser utilizada por toda la comunidad de e-learning.

- Lenguajes de Actividad. En esta categoría se encuentran los lenguajes que están enfocados principalmente a la organización de actividades en general (utilizando computadoras o no) durante el proceso de aprendizaje. Algunos ejemplos son los siguientes:

  - PALO es un lenguaje de modelado desarrollado en la Universidad Nacional de Enseñanza a Distancia (UNED) [104]. PALO permite describir cursos organizados mediante módulos que contienen actividades educativas, contenido y un plan de enseñanza. Utilizando PALO el diseñador puede crear plantillas para definir tipos de escenarios de aprendizaje. Utilizando las características del lenguaje, es posible secuenciar tareas de aprendizaje y módulos. Como complemento, se pueden añadir restricciones sobre los cursos, permitiendo definir tiempos y fechas límite, así como dependencias entre módulos y tareas. Utiliza el concepto de módulo como unidad de aprendizaje.

- En OUNL-EML el concepto de "diseño de aprendizaje" (learning design) representa el concepto de UOL. Un diseño de aprendizaje es una instancia concreta de un modelo pedagógico, el cual a su vez es una instancia de un meta-modelo pedagógico. Este meta-modelo no fuerza a los usuarios de OUNL-EML [105] a utilizar un modelo pedagógico concreto, sino que les permite crear y describir sus propios modelos de manera expresiva. El meta-modelo ofrecido por OUNL-EML ha sido desarrollado a partir del análisis de los modelos existentes basados en las aproximaciones constructivistas (sociales), de comportamiento y cognitivas.
- Finalmente entre las diferentes propuestas de especificaciones, *IMS Learning Design* [106] ha emergido como el estándar de-facto para la representación de cualquier unidad de aprendizaje ya que en principio permite utilizar cualquier teoría de aprendizaje.

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PARTE II

3 | A NFC-Based Pervasive Solution for City Touristic Surfing

El contenido de este capítulo ha sido publicado en la revista *Personal and Ubiquitous Computing* con la siguiente referencia de publicación:

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Los Ambientes Inteligentes son una nueva área de investigación en computación que consiste en crear entornos inteligentes donde los usuarios puedan interactuar de forma natural e intuitiva con servicios que facilitan las tareas cotidianas de dichos servicios. Dentro de esta área, la tecnología NFC ofrece una solución simple basada en el "touching paradigm" que hace posible el intercambio de información y acceso a contenido y servicios de forma intuitiva.

En este capítulo, se presenta una solución context-aware para localización navegación en entornos urbanos. La idea propuesta es que el usuario puede diseñar sus propias rutas haciendo uso de un conjunto de objetos inteligentes (llamados Smart Posters) los cuales están aumentados por medio de tags RFID con información sobre localizaciones donde un turista podría ir. Esta información turística se presenta al usuario con diferentes imágenes y detalles. La localización y la navegación a través de los diferentes puntos del escenarios se muestra con un mapa con información en tiempo real de la ruta ofrecida al usuario para llegar a dicho punto de interés. El usuario recibe respuesta de forma intuitiva y fácil a preguntas como ¿Qué es?, ¿Dónde estoy?, ¿Dónde está? o ¿Qué hay a mi alrededor?, entre otras.

El sistema desarrollado es barato y sencillo de usar. El usuario simplemente necesita un teléfono móvil dotado con tecnología NFC para interactuar con los Smart Posters. Los resultados de la prueba del sistema son bastante favorables a partir de la evaluación de un conjunto de usuarios seleccionado al azar. Estos usuarios evaluaron muy positivamente la simplicidad de uso y la ayuda que el sistema proporciona para la navegación por la ciudad, encontrando bastante atractivo el hecho de que solo necesitan su dispositivo móvil, en contraposición con técnicas de búsqueda de puntos de interés tradicionales.

Además, el sistema podría ser empleado con otros propósitos comerciales como por ejemplo la ayuda en la navegación en grandes áreas comerciales.

3 A NFC-BASED PERVASIVE SOLUTION FOR CITY TOURISTIC SURFING

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ABSTRACT. Context-aware and pervasive computing applications have increased their number during the last decade, thanks to the development of new communication and mobile technologies. These applications cover a wide spectrum of problems, sectors, scenarios, and environments that aim to build smart environments supporting many kinds of human interactions. Tourism is an important economic sector for many cities and countries and therefore a research area where the development of ubiquitous applications is having a great interest. In this paper, we propose a solution oriented to help the user to find the location of interest points within the city and navigate through them. In this work, we propose the use of mobile phones with the near-field communication technology incorporated and Smart Posters disseminated along the city. Indoor and outdoor locations and navigation are allowed, ‘‘where is it?’’, ‘‘what is it?’’, ‘‘where am I?’’, ‘‘what is there around me?’’ and the remaining hits of locations and navigation paradigms are supported by an easy, cheap, and context-awareness system without the need of hard tasks to the user related to system installation or tailoring.

KEYWORDS *Near-field communication - Tourism - Pervasive system - City surfing - Ambient intelligence*

3.1 Introduction

The Ambient Intelligence (AmI) [1, 2] is a new investigation area that consists in the creation of living environments (called ‘‘intelligent environments’’) [3] where users interact in a natural and intuitive way with computational services which ease the completion of the user’s everyday tasks, being this for leisure, help or work assistance [4, 5]. In these environments, the user is surrounded by ubiquitous resources embedded in augmented objects (Tags environments).

In this vision of the future that AmI forecasts, the model of user interaction, information visualization, access personalization, and context sensitivity play a very important role that has been studied by different authors [6, 7], where several models and paradigms have been proposed.

Near-field communication (NFC) [8, 9] is an emerging technology that provides a natural way of interaction between the user and their environment. This characteristic makes it the preferred candidate for the development of intelligent ambients. NFC technology is a combination of the contactless radio frequency identification technology (RFID) [10] and interconnection technologies that allows short-range wireless communication among mobile devices, PCs, and intelligent objects [11].

NFC offers a simple solution based on the ‘‘touching paradigm’’ [12] that makes possible the information exchange and access to content and services in an intuitive way. Besides, it simplifies people’s interaction with the environment, resulting in the ‘‘Touch Computing’’ paradigm, where users get their mobile device close to everyday life objects, doted with visual marks and RFID Tags or other NFC devices, with the aim of triggering the intelligent services offered by those objects. Therefore, this combination of RFID and visual tagging of physical objects and NFC devices available have contributed to the development of the ‘‘Internet-of-Things’’ [12] where all the resources that surround us and their associated services are available through any connection (GPRS/UMTS, Bluetooth, etc.). A possible application area of the Ambient Intelligence and the development of pervasive systems is the tourism, which is always growing.

This kind of applications are mainly oriented to two type of scenarios [13–15]: (a) indoors, as museum guides (preinstalled maps in the unit, follow-up mechanism through sensor webs (RFID) or communications (Bluetooth) localization), (b) outdoors, as pre-installed maps in the mobile unit and/or access through WLAN/GPRS to servers that provides maps or information, based or not on the user position (GPS). An example of these applications includes navigation through real traffic, transportation services, tourism guides, and commerce.

Nowadays, different investigations are studying the use of NFC in a wide spectrum of problems, including commerce, ticketing and payment, transportation, tourism, identification and security, university [16–18], among other.

Kenteris et al. [19] studied the use of mobile phones and touristic maps of the city of Mylinene. In this system, an application (MIDlet) and the maps are downloaded to the user's mobile device from a server on demand. The advantages from using J2ME for the development of pervasive applications are demonstrated, showing their adaptability to different units, services, and users.

Reilly et al. [20] studied the advantages of using paper maps augmented with RFID Tags. The user touches with his PDA one of the marked points (augmented with a RFID Tag) and gets information from the marked point through the access to a Web page. Three application scenarios are used: (a) a map of the Montreal underground, (b) a touristic map of Nottingham city, and (c) a map of the Vancouver region roads.

In [21–23], the importance of the touristic sector worldwide is revealed, introducing the services that these applications should include as follows:

- (Semantic) interoperability and mediated architectures (where it can be distinguished between the system integration and the semantics issue, related to the problem of too much information).
- E-business frameworks supporting processes across organizations—virtual organizations.
- Mobility and embedded intelligence.
- Natural multilingual interfaces (also novel interface technologies).
- Personalization and context-based services.
- Information to knowledge transformations, data mining, and knowledge management.

KAMO project [24] has as its main objective to provide information about routes and bus lines to the user, also supporting transportation payment. In this system, informative panels placed in bus stops allow the user, using his NFC device, to obtain information about public transportation schedules for the stop where the informative panel is placed. The user gets in his device the list of busses that will get to the stop where he is located and each one's destination plus the arrival time. Besides, during the trip, and in real time, the user could receive information of the bus next stop and alarms/notifications of when the user's destination will be reached. This system allows the user, when touching the informative panel in the bus stop, to identify its destination and being informed about the best line or combination for getting to its destination. Different prototypes of similar systems have been deployed in several countries' public transportation systems [23, 25, 26].

Hardy and Rukzio's proposal [23] makes use of NFC mobile phones and big screens placed in public places in a way that the information displayed in the mobile phone could be displayed in a bigger dimension. The idea is to use the mobile phone as writing and signaling object over the screen and make use of big displays to show the information in parallel with the mobile device. One of the applications presented uses a big screen that contains Tags (in its back side). Each Tag stores a string with the position inside the display. The display shows a Google map with marks referring hotels, restaurants, or other establishments in the zone shown. The user through its NFC mobile phone could look up the marks in the map, amplify them, and create routes.

In this paper, we present a touristic context-aware solution for the localization and navigation in urban environments. The idea proposed in this work is that the user could design its own routes making use of a set of intelligent objects (Smart Posters) augmented by RFID Tags with information about localizations where the tourist could go. The touristic information is shown to the user with different shapes and details; localization and surfing (navigation through different points of the scenario) is provided through real-time maps downloaded. Answers to ‘‘what is this?’’, ‘‘where am I?’’, ‘‘where it is?’’, ‘‘what is there nearby me?’’, etc. are given to the user in an intuitive and quick way, without any previous manipulation of the mobile device by the user.

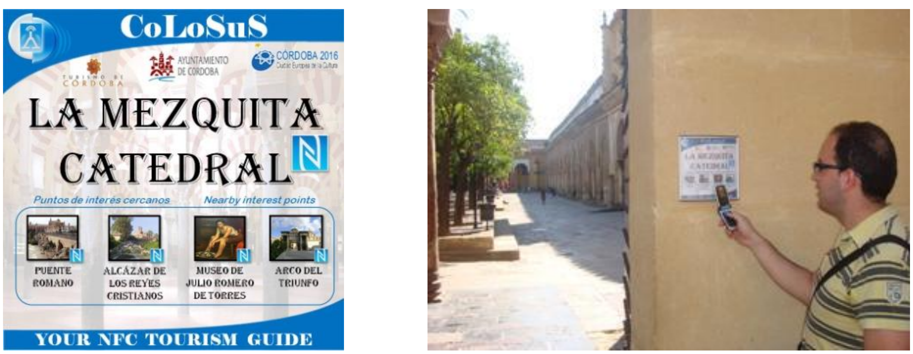


Figure 1. An example of a Touristic Smart Poster

The proponed solution, named CoLoSus (Contactless Location and Surfing System), is based on the use of Smart Posters with text and visual information corresponding to the places where they are located. The Smart Posters, similar as the one shown in Fig. 1, are formed by a set of Tags associated with each visual element of the Smart Poster, which offer the user different touristic locations, interesting to the tourist, within the urban environment.

The information stored in the Tags (using the NFCForum standard [27]), the location of the Smart Posters, the user selection, and the information stored in the system about the previous interactions of the user with the environment would allow the system to offer, through maps and text information, a swift, quick, and user-customized channel to navigate through its environment.

The following sections of this paper describe the proposed solution. In Sect. 2, the proposed solution is presented, describing the interactive model and system architecture. In Sect. 3, the structure of the Smart Posters is described, together with the information stored in each poster and the objects in it which have a Tag associated. In Sect. 4, the tool used for developing the scenarios is detailed, and finally, an example of some of the applications carried out in urban environments is given together with a discussion about the proposed solution and future works.

3.2 A navigation and location model based on NFC

Current NFC mobile devices are kept to only some models from just some commercial brands. Those models do not include several of the functionalities normally available in most of the mobile devices, such as GPS. Although it has been forecasted that by 2011 more than 50% of all the mobile phones will include NFC technology, the commercial policies about how that evolution would be carried out are not yet completely defined. So, while some manufacturers are fostering the introduction of the new NFC chip in new mobile devices, others are going for external NFC solutions. For instance, SanDisk [28] is developing SD/MiniSD cards that when introduced in any mobile device will automatically provide it with the NFC functionality; TranZFinity [29] have developed an NFC device that exchange information with the mobile device through Bluetooth.

The development model of intelligent ambients applied to urban location described in this paper is based on the use of the Touch paradigm as a swift, easy, and intuitive model for helping the user to find the location of interest points in an urban environment, having a direct impact on the tourism and location in big commercial surfaces (outdoors and indoors).

Figure 2 shows the general architecture of the proposed solution. In this solution, there are Smart Posters spread in the intelligent environment containing visual, graphic, and text information about different locations. Different objects distributed in the Smart Poster that represent different locations are augmented by Tags that keep services and information about themselves.

Figure 2. Proposed architecture

When the user ‘‘touches’’ any of the Tags (objects) located in the Smart Poster with his NFC device, a MIDlet previously downloaded in the mobile device is instantiated. This MIDlet gets the information stored in the Tag and establishes a GPRS/EDGE/UMTS communication with a service located in the server.

This service gets the information from the MIDlet corresponding to the device and the Tag and moves this information to the server that answers back the MIDlet, being the MIDlet responsible for showing the answer to the user in a proper way.

For our navigation and urban location model, the server required is a map and route generator from the information stored in the Tag. Therefore, the MIDlet will obtain that information from the Tag and will send it through GPRS/UMTS to a services server. The services server will get the information corresponding to the Tag, the NFC device, and any other supplied by the MIDlet; then it will generate the requested information and will send it back to the MIDlet, which is in charge of formatting that information in a proper way.

As observed in Fig. 3, the functional components in the interaction model are five: (a) the scenario, (b) the Tags, (c) the MIDlet, (d) the service listener, and (e) the service manager.

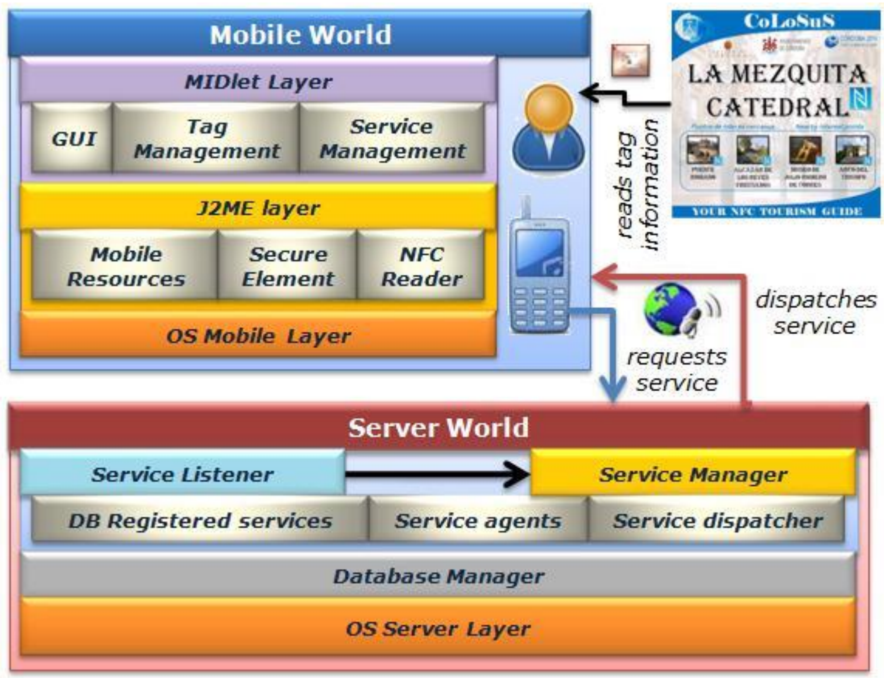


Figure 3. Surfing model components

The scenario is comprised of a set of Smart Posters with information and pictograms about the following:

- The location, place of interest where the Smart Poster is located.
- A set of locations for the points of interest suggested, which are related, within the application context, with the current location and are adequate to the user.

The Tags are Mifare 4K [30] Tags associated with each one of the pictograms in the Smart Posters. The Tags store text and graphic information related to the object and pictogram; they are associated with the service or set of services offered to the user and recognized by the MIDlet installed in the mobile device when the user gets its NFC device close to the Tag.

The MIDlet is a Java application that is executed in the NFC device and that guides the interaction between the user and the scenario. When the user ''touches'' a Tag with its NFC device, thanks to the information stored in the Tag, the MIDlet stored in the mobile device is instantiated allowing the interaction of the system with the user. This event is carried out thanks to the ''push registry'' method. Through the ''push registry'' method, the mobile phone would activate a specific MIDlet depending on the kind of information that has been read in the Tag.

When the MIDlet has not been previously installed in the NFC device, a message alerting about the need of downloading the MIDlet from the server is received. Once the MIDlet is downloaded and installed in the device, the user can configure it.

As shown in Fig. 3, once the information from the Tag is received, the MIDlet creates the interface which drives the interaction with the user. The user can visualize the information received from the Tag and choose the desired service among the ones offered by the Tag.

Services have been implemented using the NFC business platform developed by Nexperts [31]. The development and implementation of each service was not a trivial process. The procedures were implemented using C# language and compiled for obtaining the server application. Then, each service application was executed on an external tool called ''Proxy Generator'' with two purposes: (a) installing the DLL in the Windows assembly of server (install the server service) and (b) generating a proxy file in Java that handles the network traffic for the client application providing several functions that could be instantiated by the MIDlet and which goal was to establish a reliable and secure bidirectional communication between the MIDlet installed in the phone and the service dispatcher. Hence, the

MIDlet is composed by two main packages: (a) the application code developed specifically by the client and (b) the proxy object generated by the proxy generator. Once compiled and generated the final application, it must be installed in the devices. For this purpose, we have used the Nexperts Business Platform [31] because it allows the deployment of a signed MIDlet to the user's mobile phone using the OTA (Over the Air) Deployment module by WAP Push or by starting the download from a Tag.

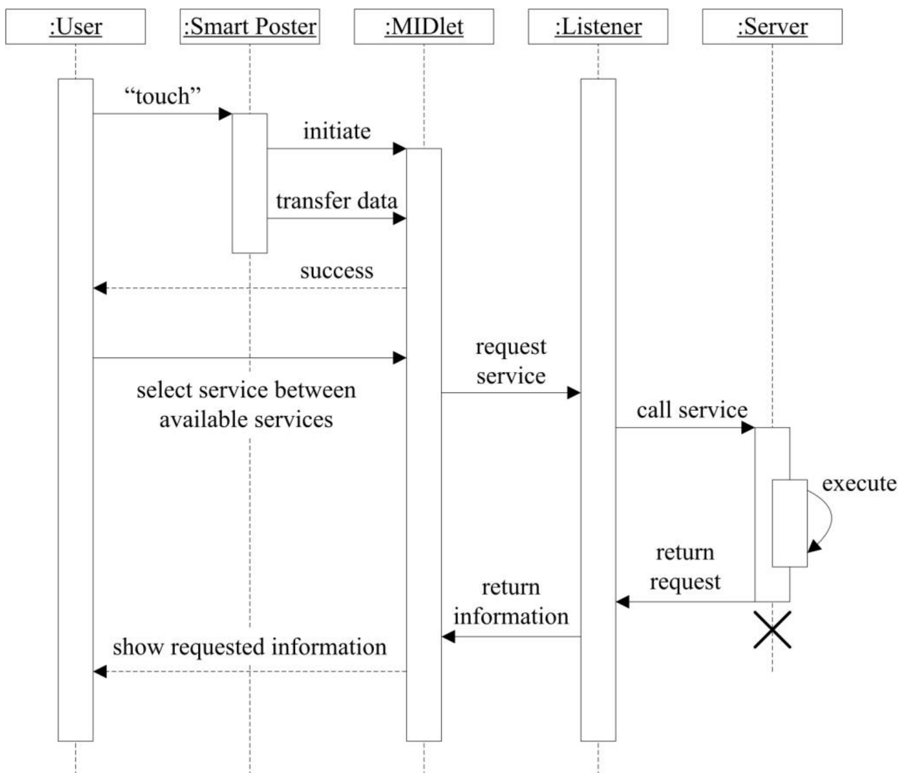


Figure 4. Sequence diagram of the system components interaction

Figure 4 shows the sequential diagram corresponding to the interaction process among the system's components. Once the service is selected, the request is sent through the communication modules of the mobile phone (GSM/GPRS/UMTS/EDGE) to the system server side. In that side, a service server that is listening would receive the request and process it.

The service listener is an agent located in the services server in charge of receiving any request from the MIDlet executed in the NFC device. The MIDlet requests could be the following: (a) information or services about an interest point and (b) a map or location route of a certain point of interest.

When the service listener receives a request, it analyzes it, checks its registry, and processes it to the Service Manager, who is responsible to execute it and sends back a response to the MIDlet, being the MIDlet the one in charge of formatting it into a proper display to the user and offer him the programmed functionality for the handling of the information received.

Both the listening service and the service server have been implemented making use of the NFC Business Platform from Nexperts. The NFC Business Platform is software created for the developing, use, and integration of business functions for NFC-based applications. Through this software, clients (mobile phones or computers) are connected to the server through GSM/GPRS which is the one that controls them and provides the proper service to each client. The mobile device transfers the information received from the Tag or generated by the MIDlet to the server, which is in charge of processing the request and answer the MIDlet. In case of a temporal connection failure, the server would keep the answer to the requested service server, being it send only when the connection is recovered.

3.3 Smart Poster's Structure

As mentioned previously, the operation scenario is an open and intelligent environment thanks to the Smart Posters spread through it where there are objects with visual information and Tags associated. Each object would represent a specific location, a touristic interest point, a company, or any other location within the application scenario.

The user will met the Smart Poster where, at first sight, he will see the name assigned to it (the place, location, interest point, etc., where it is placed) and where, through icons, pictures or any other text, and visual information in the Smart Poster, other interest points or locations within the environment are placed. Main role of those Smart Posters is to:

- Allow the user to access the available information and services in a touristic information service, related to (a) the point of interest where the Smart Poster is located and (b) any of the other points of interest or locations showed in the Smart Poster.
- Display different options to the user (any different icon/picture/object listed in the Smart Poster) in order to get information about it, led to it and, therefore, locate it from a Smart Poster placement.

So, in a Smart Poster, the existence of the following kinds of objects could be recognized, being those objects displayed in a visual and textual way: (a) a sole object (CP: current point) corresponding to the location or point of interest where the Smart Poster is located and (b) a set of objects related to the ‘‘suggestions’’ (AP: Advance Points) displayed to the user about other interest points or locations within the scenario.

Each Tag related to an object in the Smart Poster has a unique identifier (TUID), as each interest point or location (LUID) independently of the Smart Poster where it is located. One or more Smart Posters can, clearly, include the same location which would allow the user to find different location routes within the scenario depending on the location or starting point.

Besides, each Tag (a Tag is related to a unique interest point: CP or AP) stores the following information:

- A description corresponding to the name of the interest point or location.
- A brief description of the interest point related to the Tag.
- A picture (icon) corresponding with the interest point (CP/AP).

- Physical coordinates where the Smart Poster is placed.
- Physical coordinates of the interest point related to the Tag.
- A set of locations, in case they exist, or ‘‘intermediate’’ interest points in the route from the location of the Smart Poster to the suggested interest point (AP).

3.3.1 Tool for Smart Posters developing

A Java application for the development of the scenarios handled by the CoLoSuS system (contactless location and surfing system) has been developed. The tool allows the developing of Smart Posters where a non-defined number of Tags will be located; those Tags would be related to some visual objects that would display points of interest within the environment for guiding the user through the urban navigation or surfing.

Figure 5 shows a snapshot of the general interface of the application. As can be perceived, the general interface is divided into a toolbar and a menu, the project explorer zone that would allow the handling of the information about the Smart Posters previously created, the working zone where the information about the Smart Posters is displayed, and a zone for messages and alerts occurred during the application execution together with a status bar.

The menu bar shows the available options for the application. Through this bar, it is possible to create new scenarios (Smart Posters) and Tags and also to manipulate the information related to them, as well as to perform the recording of the Tags in Mifare cards for placing them afterward in the objects that display the interest points.

Besides, as shown in the upper zone of the interface, there is a quick access bar that allows the quick execution of the functionality more used by the user. The most significant zone of the interface is displayed in the explorer zone (left area) and the working area (central area), as shown in Fig. 5.

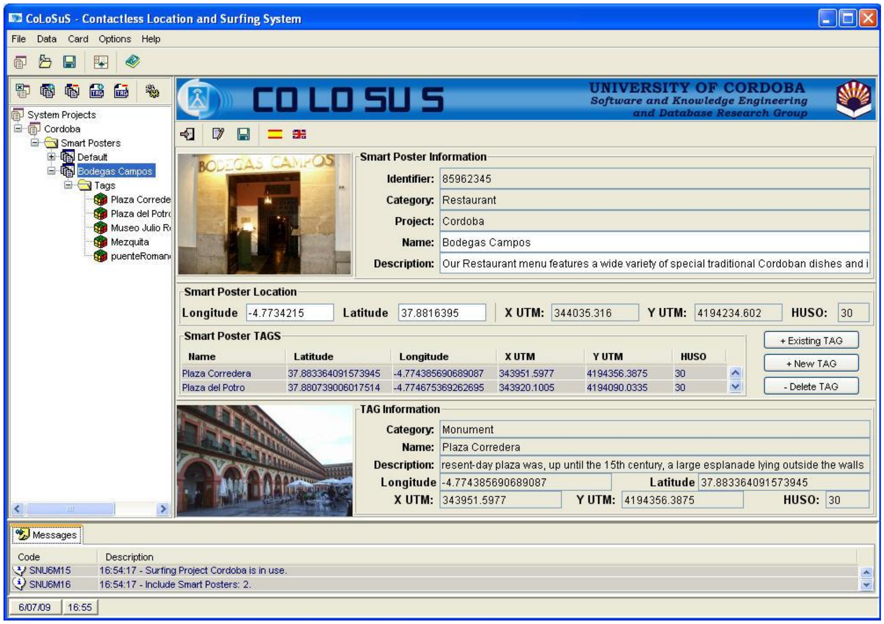


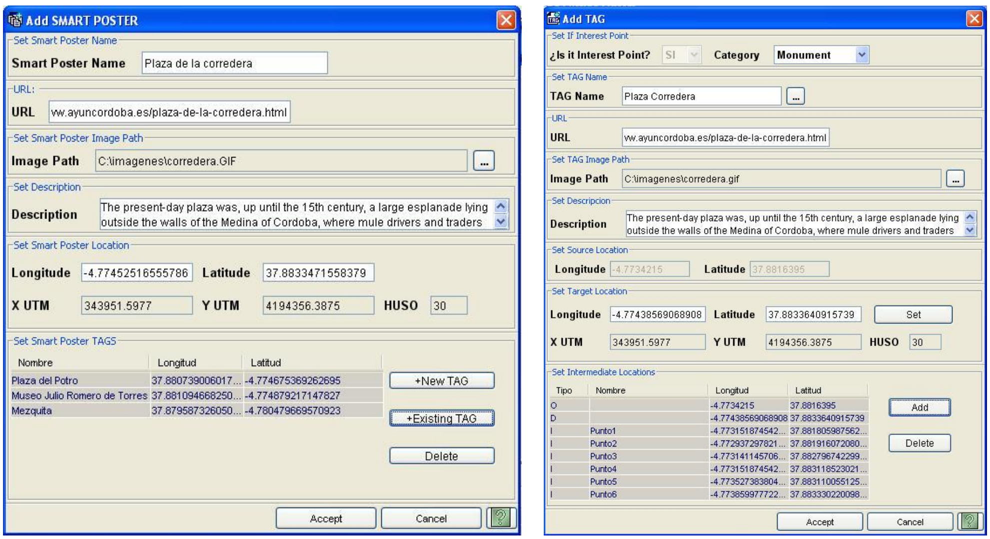
Figure 5. Snapshot of the application interface

The project explorer displays, in a hierarchic menu structure, the currently active information in the application, which it includes the set of Smart Posters and their associated Tags. The working area allows the display and edit of the information related to the Tags and Smart Posters.

All the error, information, warning, and exception messages are displayed in a frame defined for that purpose and placed at the bottom of the working area. The purpose of this frame is to show the user all the different actions that are being executed and their result during the handling process of the scenarios and projects.

The tool groups the information under the concept of scenarios or projects. Each project could be composed by a non-defined number of Smart Posters, and each one has also a non-defined number of Tags associated with it.

Once the project has been created or an existing one has been opened, the information about the project components (Smart Posters and Tags) is displayed in the hierarchic menu (See Fig. 5). The user can create or edit Smart Posters of the scenario, using the interface shown in Fig. 6a.



(a) (b)

Figure 6. Snapshot of the application interface

For each Smart Poster, the user could decide a nondefined number of Tags that will be related to the pictograms of the Smart Poster. Each Tag will store information and services corresponding to the AP (advice points) available in the Smart Poster. For performing this function, the user will fill in the information as shown in Fig. 6b, selecting it from existing APs or creating new ones. The information related to the Tags created for each Smart Poster could be displayed as a list and being accessed for edition at any time (see Fig. 6b).

The user, making use of the ‘‘Store Tags’’ function available in the main menu of the application, can, at any time, carry out the recording of the different Tags associated with the Smart Posters. This recording process could be performed for a Tag or for the set of Tags in the Smart Poster. Once recorded, the information related to the UID of the Tag associated with each Smart Poster is also stored in the database.

3.4 CoLoSuS MIDlet

The CoLoSus MIDlet is a Java application for a NFC device, in our case a mobile phone. The tool allows getting information about a point of interest through Smart Posters that contain visual objects with a NFC Tag assigned to them, which stores the information about the point of interest.

Figure 7 shows a snapshot of the application's interface. The MIDlet could be instantiated on demand by the user (Fig. 7a) or automatically (Fig. 7b) when the user ''touches'' a Tag available in the Smart Poster.

As shown in Fig. 7a, if the MIDlet is instantiated on demand, the application shows to the user all the available options: (a) Browse information, (b) Configuration, (c) Delete history, (d) Recover information, (e) Recover map, (f) Search, and g) Touch Tag.

The information (maps and text) received by the user in previous interactions with Smart Posters could be stored for future accesses and requests. This information is stored in the mobile device, being the location chosen by the user in the ''Configuration'' options (Fig. 7c). The user could at any time, manually or guided by the MIDlet, delete the historical information stored in the device.

The system allows the user, without the need of touching a Tag, to make different requests about points of interest located in his environment. During the search process (see Fig. 7d), the MIDlet allows the user to include some optional search criteria: (a) category or type of the interest point, (b) name or search criteria, and (c) distance from the current location.

Once the search criteria have been chosen, the MIDlet sends the request to the server that answers back a map and a list with the current location of the points of interest that fulfill the current search criteria.

(a) (b) (c)

(d) (e) (f)

Figure 7. Some MIDlet snapshots

As the system does not use a GPS for knowing the current location of the user when the request is performed, the position of the last Smart Poster accessed by the user would be considered as the current position, being marked in the generated map. Figure 7e, f show the resulting map and the list of interest points for the search criteria selected in Fig. 7d.

When a Tag in a Smart Poster is ‘‘touched’’ with the NFC device (Fig. 7b), the MIDlet is initiated (if it has not been previously by the user) and it guides the user through the interaction, informing about the services stored in the Tag. As shown in Fig. 7b, in the current MIDlet implementation, three options could be selected by the user: (a) a short description of the interest point, (b) Web access, and (c) map download.

(a) (b) (c)

Figure 8. Smart Poster Tags touch process

The information of the short description about the point of interest (Fig. 8a) is stored in the Tag, and there is no need to connect to the server to obtain it.

Each Tag stores a Web address that could be accessed by the user, with detailed information about the corresponding point of interest. In this case, the user accesses to a Web page with detailed information about the interest point (Fig. 8b).

Finally, the user can download a map with the location of the point of interest selected (Fig. 8c). This map shows the user's current location, the point of interest location, and the route to get to it. The locations visited previously by the user are marked, meaning this, the places where the Tag corresponding to a Smart Poster was touched. This information is temporarily stored (until the user deletes the history). Besides, different options in the MIDlet allow the user to handle the map image and store it for later requests.

3.5 Test Scenarios

The system was tested in two different scenarios pretending to demonstrate the application of the test solution. The first scenario covers a touristic area in Cordoba city and its development has tried to propose to the city majors its future use, as an initiative if Cordoba is named in 2016 Worldwide Culture City. The second scenario aims to demonstrate its commercial use for the navigation and location of companies in large commercial areas.

For the development of the Smart Posters Tags, Mifare 4k [30] and Omnikey 5120 USB [32] have been used as read/write device. The NFC devices used have been Nokia 6131 NFC [33] mobile phones.

(a) (b) (c) (d) (e)

(f) (g) (h) (i) (j)

Figure 9. Tourism in Córdoba using CoLoSuS.

3.5.1 Cordoba’s Historic Center

For the development of this scenario, a set of Smart Posters as the one shown in Fig. 1 has been built and placed in different points of interest within the selected tourism area. Each Smart Poster holds a Tag corresponding to the location where it is placed plus another set of Tags corresponding to other interest points suggested, which are marked in the

Smart Poster through a picture. Production costs for each Smart Poster are low (about 20 Euros).

The first time a user ‘‘touches’’ a Tag with his NFC device, the system detects that the MIDlet is not installed in the NFC device, and it asks the user whether he wants it to be downloaded or not. Once the user has the MIDlet installed, it can configure its execution. The user can surf among different touristic interest points within the historic center of Cordoba just touching the image of any of the suggested points of interest available in the Smart Posters. Figure 9a shows how a user located in the ‘‘Alcazar de los Reyes Cristianos’’ touches the Smart Poster in order to obtain information about the ‘‘Mezquita Catedral’’. A map with the suggested route, the intermediate points of interest between the current location and the destination, is downloaded to the mobile device (Fig. 9b).

After the monument has been visited, the user asks for information about the ‘‘Julio Romero Museum’’ touching the corresponding picture in the Smart poster located in the monument visited (Fig. 9c, d). However, the user might decide to have lunch, and using the MIDlet, it could make a search for restaurants in the area nearby (Fig. 9e); when the search is completed, a map (Fig. 9f) and text information is received in the mobile device.

Once the user has had lunch in the ‘‘Bodegas Campos’’ restaurant, the user might decide to visit ‘‘La Plaza de la Corredera’’ and touching its corresponding picture in the Smart Poster located close to the restaurant (Fig. 9g), she gets the new route for the new monument. A Smart Poster located at the restaurant would allow the user to continue with his/her personalized touristic visit to Cordoba.

3.5.2 City Business Area

Business or commercial areas of a city are normally large commercial areas located outside the city center where the companies are placed in big commercial spaces. Those commercial areas where several companies are placed use to be badly signaled, there is also a lack of information about them in city maps and the users have big difficulties to locate the companies they are searching for. The use of Smart Posters could be an opening move that favors the business in those commercial areas, helping to locate the companies and easing the flowing of users to them. The test scenario chosen has been the biggest industrial area in Córdoba city, named ‘‘Las Quemadas’’. In this scenario, different Smart Posters have been placed (see Fig. 10) where there is information about the companies located near the Smart Poster.

(a) (b)

Figure 10. Using CoLoSus in Commercial areas.

When the user ‘‘touches’’ the icon of a company (area of the Smart Poster dedicated to the company), he could get the map, a short description of the company (where there is a contact number and detailed address), or access to the Web page of the company. If the company the user looks for is not in the Smart Poster, the user can make a search about it or ‘‘touch’’ a specific icon in the Smart Poster that provides him a map with the location of the different information points (Posters) located in the area.

3.5.3 System’s Evaluation by Users

For several days, a system testing evaluation was carried out in the historical and touristic area of Cordoba city. The users were randomly chosen among the people that willingly decided to take part in the experience. As the participants did not know the NFC technology, they were provided with a brief explanation (2–3 min) of its characteristics, the capabilities of a NFC mobile, and its operation. Then, the NFC device was offered to the participants for interacting with any of the icons (services) of the Smart Poster.

Once finished the user interaction and solved all the doubts raised by the users (the most usual was whether the mobile phone owned by the user had the capabilities of the NFC device used during the experience), they had to answer a small survey related to the experience. The survey had the following eight questions that have to be evaluated between 1 (very low) and 5 (very high):

- Q1: The system is easy to user.
- Q2: I think that the deployment of this type of systems would be useful.
- Q3: I will use the system when deployed.
- Q4: The system helps me to navigate through the urban environment.
- Q5: I consider a good idea the use of my mobile device as touristic guide.
- Q6: I consider that this is a good alternative for substituting the current access model to the touristic information: maps, guides, etc.
- Q7: I am pleased with the cost that the use of the system will imply.
- Q8: Global valuation of the CoLoSus system.

Table 1 shows the results obtained, distributed by age and sex for a set of 109 users surveyed. As can be observed in the results, all the users considered the system as very easy to use (Q1) as well as useful when deployed (Q2); the users were in favor of its use as help in the urban surfing through the mobile device (Q3, Q4, Q5, Q6).

Participants gave a very favorable evaluation to the system (Q8); the lower mark given by the users was to question Q7. Although the deployment of the system is quite cheap, some participants had doubts due to the high price of the mobile data traffic of the telecom operators in Spain, being more reluctant those users in an age range where the purchasing power is lower (under 18 and over 60).

As can be observed in Table 1, the results do not show considerable deviations between sexes in the same age range, neither for participants under 60 years. Participants over 60 years (15) were those who valuated lower the experience, which can be explained by the technological handicap that could exist for some of those participants.

Tabla I. Results of users' experience with the system

	< 18		18-30		30-40		40-50		50-60		> 60		Total
	M	F	M	F	M	F	M	F	M	F	M	F	
People	5	7	12	15	7	9	11	11	8	9	5	10	109
Q1	4.8	4.3	4.7	4.3	4.7	4.4	4.3	4.6	4.4	4.7	4.6	4.2	4.5
Q2	5.0	4.7	4.7	4.6	4.6	4.7	4.6	4.5	4.4	4.6	4.0	4.2	4.6
Q3	4.2	4.1	3.9	4.0	3.9	4.0	4.3	3.8	3.9	4.2	3.8	3.4	4.0
Q4	4.8	4.4	4.4	4.5	4.4	4.4	4.9	4.4	4.5	4.2	4.4	4.2	4.5
Q5	4.8	4.6	4.5	4.7	4.7	4.7	4.4	4.6	4.6	4.6	4.0	4.4	4.6
Q6	4.6	4.7	4.5	4.6	4.4	4.4	4.7	4.3	4.5	4.6	3.8	4.0	4.4
Q7	3.2	3.7	4.1	3.8	4.1	3.8	4.0	3.7	4.0	4.3	3.4	3.5	3.8
Q8	4.8	4.3	4.4	4.2	4.4	4.2	4.4	4.4	4.3	4.8	4.2	3.9	4.4
Average	4.5	4.4	4.4	4.3	4.4	4.3	4.5	4.3	4.3	4.5	4.0	3.9	4.4

3.6 Discussion and Remarks

In this paper, we have presented a generalized system for surfing in urban areas and for location of points of interest making use of near-field communication technology. The system is cheap and easy to be set up, without needing any special device (generally, the devices could be hired in any Tourist Center Point). The user just needs a single NFC-enabled phone for interacting with the set of Smart Posters spread along the city area considered, which have cheap Tags associated with pictures of the points of interest, therefore offering the user information and personalized surfing services through maps and text information.

The system developed does not require any configuration by the user, or he is going to any Tourist Information Points or any tourist Web portal access in order to get the system downloaded. First time the user ‘‘touches’’ a Tag in a Smart Poster, the MIDlet is downloaded to the device and the user just have to choose the language for interacting with the service.

The combination of an intuitive paradigm for the interaction with the user (touching paradigm), the use of clear and simple interfaces in order to avoid screen limitations in mobile devices, and the functionality of the developed system offers the user all the requested services for the fulfillment of basic requisites of an ubiquitous system: where am I, what is this, how can I get to, where can I find something, what amenities are close to this place, etc., through text information and maps.

The results of the system testing performed have reported a quite favorable evaluation by the users. Users have assessed very positively the simplicity of its use and the help that the system provides for surfing in urban environments, finding quite attractive that they just need their mobile device, as a support or alternative to traditional techniques.

Currently, CoLoSus is an operating prototype that is being proposed for the study of its near deployment. Cities implicitly touristic as Cordoba (applicant to be European Culture Capital in 2016) and others within Spain and the world would require systems as the one described in this paper in order to provide its touristic offer with extra added value, given the social and economic impact of the tourism revenue in those kinds of cities.

Besides, CoLoSus could be deployed with other commercial purposes. Its deployment in big commercial areas, where the user has trouble with the location of the companies located there, could underpin an increase and expansion of the business in those areas.

Acknowledgments

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4 | An NFC Based Context-Aware Solution for Access to Bibliographic Sources in University Environments

El contenido de este capítulo ha sido publicado en la revista *Journal of Ambient Intelligence and Smart Environments* con la siguiente referencia de publicación:

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El Espacio Europeo de Educación Superior (EEES) es el objetivo del plan de Bolonia para crear un sistema educativo europeo más comparable, compatible y coherente. Con el objetivo de adaptar las universidades a estas nuevas directivas, es necesario desarrollar sistemas basados en el uso de nuevas tecnologías, de esta forma se proporciona a los profesores un conjunto de experiencias de aprendizaje para sus estudiantes. Ordenadores, internet y otras herramientas proporcionan grandes mejores en enseñanza y aprendizaje más allá del uso del correo electrónico o los foros.

En este capítulo se presenta una propuesta de un sistema pervasivo que facilite a los estudiantes el acceso a fuentes bibliográficas recomendadas por los profesores en sus asignaturas o cursos. La herramienta desarrollada se denomina PINAKES. Esta herramienta proporciona acceso a información sobre fuentes bibliográficas las cuales han sido aumentadas con etiquetas NFC. Los estudiantes interaccionan con estas fuentes bibliográficas haciendo uso de su teléfono móvil dotado con tecnología NFC. En esta interacción, el sistema muestra información de la fuente bibliográfica, el uso de esta fuente para sus asignaturas o cursos o comentarios de otros usuarios. Además, el usuario utilizará este sistema para conocer la localización de la fuente dentro de la biblioteca o para comunicarse con los profesores por medios de post-its virtuales.

El modelo de enseñanza establecido en el plan de Bolonia anima a los estudiantes a adquirir las habilidades necesarias para alcanzar los conocimientos. Con este objetivo se describe esta herramienta para dar soporte a los estudiantes en el acceso a información necesaria de las fuentes bilbiográficas para alcanzar los conocimientos descritos en las guías docentes de asignaturas o cursos. Además el sistema permite una relación más cercana entre profesor y alumno intercambiando información relativa a su proceso de aprendizaje.

4 An NFC Based Context-Aware Solution for Access to Bibliographic Sources in University Environments

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ABSTRACT. The advance of mobile and wireless technologies in recent years is permitting the development of new and more complex context-aware and pervasive systems. These applications cover a wide spectrum of problems, sectors, scenarios, and environments that aim to build smart environments, such as educative innovation. In this paper we present a proposal for a pervasive system providing students the access to bibliographic sources recommended by teachers on the subjects or courses on which the students are enrolled. In order to define the educational contents of a subject or course the IMS Learning Design standard has been used. Finally, we describe the use of NFC (Near Field Communication) for the development of the proposed pervasive system, showing the usefulness of the proposal and user acceptance.

KEYWORDS. *Near Field Communication, pervasive system, Ambient intelligence, IMS Learning Design, ontology.*

4.1 Introduction

The European Higher Education Area (EHEA) [11, 45] is the objective of the Bologna Declaration [7] to create more comparable, compatible and coherent systems of higher education in Europe. In order to adapt the universities to EHEA it is necessary to develop systems based on the use of new technologies, thereby helping the educators to set-up powerful learning experiences for students. Computers, Internet, and other tools offer the promise of significant improvements in teaching and learning not only using electronic mails or forums, but also for virtual teaching, sharing information, and so on.

It is evident that Universities need to make big changes in teaching-learning models and also in the quantity, quality and type of services that they offer to society. This involves the introduction of new management and organization measures, control and quality assurance of education, and modernization of the University through the full implementation of new technologies in all university areas.

As the University is a teaching entity there is a need for ubiquitous applications that help the student to improve his/her academic experience, such as ubiquitous games to motivate students, help in the library to find the material, tutorials management, attending control systems, etc. [8, 33].

The visionary idea of Weiser [49] about ubiquitous or pervasive computing is emerging thanks to the advance in mobile and wireless technologies. The ubiquitous paradigm allows the development of active and mobile environments, allowing access to a huge amount of information and its processing, independent of the users' location, thanks to the use of computational elements intercommunicated by wireless networks, radio, GSM, etc.; elements embedded in furniture, belongings, posters, machines, books, etc.

The ubiquitous computing idea has recently evolved into a more general paradigm known as Ambient Intelligence (AmI). Ambient Intelligence represents a new generation of user-centred computing environments aiming to find new ways to obtain a better integration of information technology for devices and activities in everyday life. AmI [24, 25] consists of the creation of living environments (called *intelligent environments*) [26] where users interact in a natural and intuitive way with computational services facilitating the completion of the user's everyday tasks, whether for leisure, help or work assistance [1]. In these environments, the user is surrounded by ubiquitous resources embedded in augmented objects [20].

In this vision of the future that AmI forecasts, the model of user interaction, information visualization, access personalization, and context sensitivity play a very important role that has been studied by different authors [2, 31], where several models, paradigms and applications to learning environments [29] have been stated have been proposed.

Ubiquitous or pervasive computing research is characterized primarily by a concern with potential future computational worlds [50]. This notion situates research as the initial step upon a path of technological development inspired by an explicit vision of possible future relationships between people, practices, and technologies.

An interesting technology that has emerged in recent years that seems to be an ideal possibility for the development of pervasive systems is Near Field Communication (NFC) technology [13]. NFC provides a natural interaction path between the user and its environment that makes it the ideal candidate for the development of ambient intelligence.

NFC is based on RFID (Radio Frequency Identification) [16] enabling a simple and safe two-way interaction between electronic devices, and allowing users to perform contactless transactions, access digital content and connect devices with a single "touch". In other words NFC is a mobile device with RFID technology with the capacity to function in active and passive mode. Thus, the NFC device has the ability to read/write information onto the RFID-chip and to establish peer-to-peer communication between two NFC devices.

Thus, NFC offers a simple solution based on the "touching paradigm" where users, with their NFC device, touch everyday life objects augmented with visual marks and RFID Tags, with the aim of triggering intelligent services offered by those objects [39, 44]. Nowadays, different investigations are studying the use of NFC for a wide spectrum of problems, including commerce, ticketing and payment, transport, tourism, identification and security, university, among others [19, 34, 35, 36, 42].

Therefore NFC is a useful technology in the development of the Internet of Things [17] generating not only commercial applications for identification, payment or ticketing, but any kind of service in any kind of environment or scenario.

The educative environment is one of them, giving rise in recent years to the idea of the *University of Things* (UoT) based on the application of the Internet of Things (IoT) concept to the university environment [37]. The central idea of this paradigm is to bring the university close to students and workers, as well as the whole of society in general; offering university services which may be available anytime and anywhere.

With this aim, Aittola et al., [3] describe a location-aware mobile library service which provides map-based guidance to books and collections on PDA. Solution, called "*SmartLibrary*", helps users to find books and other material from the library. This system shows the user a map to locate a source in the library. Solution can access the online resources anywhere within the library using a mobile device.

The proposal described in this paper increases the goals of this contribution, relating any kind of bibliographic sources with learning activities and contents, helping students with access to bibliographic sources and study of the main and recommend contents corresponding to the subject and knowledge necessary for their university learning.

Our goal is the monitoring of students by teachers, to give support to students in their study by promoting access to personalized bibliographic sources, guiding them to specific sources (articles, books, and any kind of recommended bibliography) that need to be accessed by students in order to acquire the required knowledge in each of the disciplines. In addition, our proposal facilitates teacher-student communication, offering pervasive methods to teachers so that they can advise students in the learning process and students can communicate with teachers to establish contact and resolve doubts.

Our work is focused on the use of existing ontological standards (Learning Technology Standards Observatory, LTSO [32]) for the proposal of an ontology for describing custom teaching guides. Specifically, we have made use of the IMS Learning Design (IMS-LD) [22] standard which offers a way to describe learning activities and their organization. The ontology contents are related to bibliographic information "*chunks*" which have been recommended by teachers in order to improve the understanding of the subjects and the development of expected skills.

Moreover, this study is focused on the use of NFC technology to build a customized system devoted to help university students to access, read and review the necessary bibliography sources for the development of their learning.

Basically, our system has an architecture based on a backend system responsible for the management of the information about teachers, students, teaching guides, etc., and a frontend system based on an NFC enabled device. The frontend system is designed to be used for students anytime and anywhere in a personalized way. Its main application area is university libraries, giving students access to the main and recommended specific contents of the bibliographic sources located in the library. In addition, the frontend system allows students to search for personalized and generalized information about bibliographic sources, subjects, content and teachers' notes and recommendations, etc., anytime and anywhere.

With this aim, we propose a pervasive solution based on Web-services and the use of NFC technology. When a student "touches" a bibliographic source, he/she receives personalized information on his/her

NFC device about the information elements that this source can contribute to his/her academic and professional training.

In order to apply and test this approach, a tool called Pinakes (*Pervasive and INtelligent system for the Awareness Elicitation for Students*) has been created. Pinakes gives access to information about bibliographic sources which has been augmented through an NFC Tag.

Figure 1. An example of the Pinakes scenarios

Pinakes works with different scenarios: a) the library building where the bibliographic sources are located; in this environment users go and, by touching a source, retrieve appropriate information, b) the teacher's office doorway or classroom or any other place where post-its related to teachers are located; students can retrieve information related to the teacher as well as ask the teacher for a meeting, for instance, and c) anywhere students can execute services related to access to subject and content information or news provided by the teachers.

Figure 1 shows the Pinakes scenario where the bibliographic sources offer the user different services within the university environment. Thus, when a student touches the Tag associated to a book, for instance, he/she can retrieve general as well as personalized information. The mobile application sends a side request to the server with information about the user and the bibliographic source. Information stored in the server about the book, main contents, advised contents and tailored information for the student is sent back and shown on the mobile screen. Later, the mobile application guides the user to access to the source, to read a specific issue or request new information or services.

Furthermore, as is shown in Fig. 1 (bottom), Tags associated to teacher's office doorways (or any other location) can be used for students to retrieve general or specific information, as well as enabling students to send communications to the teachers.

In Related work section we comment the existing solutions related with our proposal. These studies propose ontological models for representing the information of the learning process and technological solutions for the development of appropriate implementation scenarios. We describe in this section how Pinakes take the advantage of the existing ontological models, extending them for the building of a pervasive solution using mobile phones and NFC technology.

The paper has been organized as follows: in section 2, the learning design specifications and the Pinakes ontology proposed are described. In section 3, the proposed solution is presented, describing the system architecture and the interaction model between the different system components, showing in section 4 the Pinakes mobile application and in section 5 describing the validation of the system. Finally, related works is discussed in section 6 and in the Discussion section we comment the results and our future works.

4.2 Pinakes Ontology

The specifications for the learning design, known as Educational Modelling Languages (EML), are models of semantic information and aggregation describing, from a pedagogic point of view, the content as well as the educational activities [4]. These elements are organized into study units with the aims of allowing their reuse and interoperability [41].

Moreover, EMLs facilitate the description of pedagogic aspects that are related to learning objects (LO) in educational process. The main standard specifications are:

- IMS Learning Design (IMS LD) [22], drawn up by the IMS/LDWG work group, is an integration of the EML developed by the OUNL, with other existing IMS specifications for the exchange and interoperability of e-learning material. IMS LD describes the structure and educational processes based on pedagogic metamodel, using units of learning called Learning Design. A unit-of-learning may represent a course, a module or a lesson containing one or more educational objectives. IMS LD describes a method that is made up of a number of activities carried out by both learner and staff in order to achieve particular learning objectives.
- EML-OUNL [14] is a meta-vocabulary based on the diversity of concepts existing in a wide range of pedagogic techniques. EML-OUNL offers a metamodel based on the description of activities having to be carried out by student roles and teachers in certain environments. The central element is the concept of unit of study which is considered as the smallest unit satisfying one or more educational objectives. This means that a unit of study cannot be decomposed into parts without loss of its effectiveness in achieving educational goals.
- PALO [40] is a modelling language that has been developed by the UNED (National Distance Education University, Spain). PALO uses the concept of module as a unit of study describing courses

organized into modules containing learning activities (description of exercises) and contents (concepts, problems, and others). These contents and activities are structured hierarchically to establish the execution sequences.

The metadata specifications are useful to describe educational resources, and therefore to facilitate interoperability and reuse between learning software platforms, due to the fact that they represent the vocabulary describing the different aspects of the learning design process. However, the main drawback is that the meaning of the specification is usually expressed in natural language. In order to solve this problem, ontologies come in handy to describe formally and explicitly the structure and meaning of the metadata elements; that is, ontology would semantically describe the metadata concepts.

4.2.1 The proposed model

The aim of the Pinakes ontology is to capture the knowledge needed by the teacher to carry out the planning of the learning objectives and to specify the learning activities, prerequisites, methods and resources/contents that will be used on a course. Through this ontology, we can define customized teaching guides. The contents of these teaching guides are related to bibliographic information, which is recommended by the teacher to achieve the learning objectives.

This ontology is based on the IMS Global Learning Consortium specifications [23], which are rooted in the Educational Modelling Language (EML) and it incorporates all concepts contained in the conceptual model of the IMS specification level A.

The IMS LD specification is a metalanguage that describes all elements of the design of a teaching-learning process. This specification has been formally modelled through the XML-Schema language [4].

In our proposal, we make use of the IMS standard for defining *Units of Leaning*, an integral part of a learning process. A *Unit of Learning* is an integral part of any *Subject* and a set of subjects represent a *Syllabus*.

The upper node of the Pinakes ontology is the *Syllabus* concept that defines the set of subjects, practices, studies and other learning activities that determine the content of an educational program.

The classes represented with dark boxes in Fig. 2 show the new terms added to the specification. Consideration of *Student* and *Teacher* classes allows us to represent the relationship between these actors and the subjects. Thus, the services provided by the system can be customized for each student and teacher.

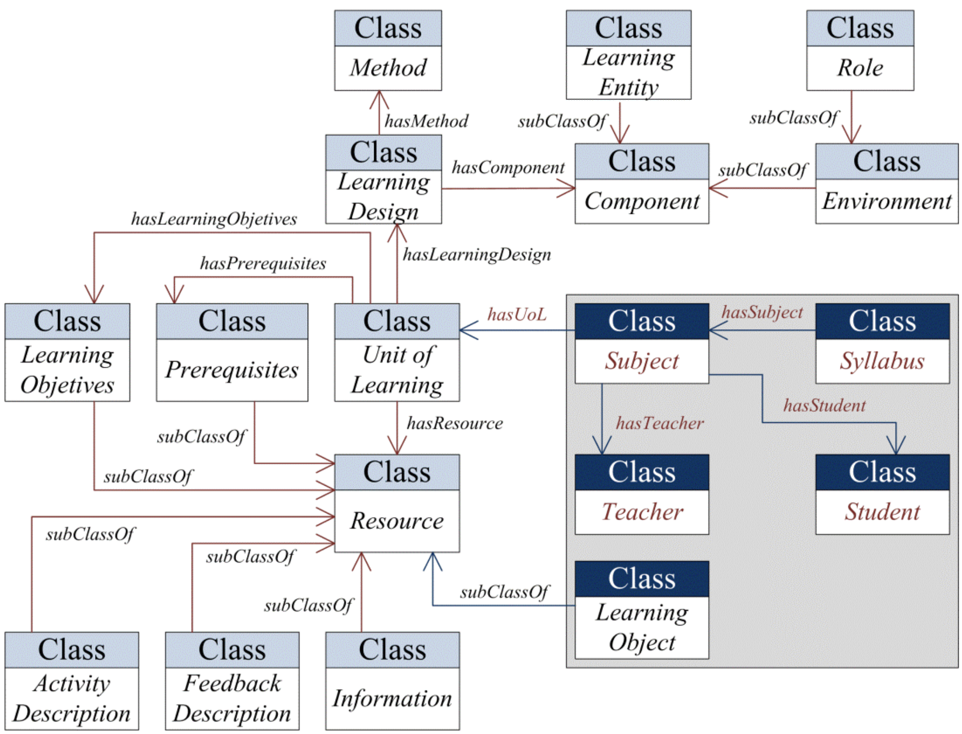


Figure 2. Upper concepts of the Pinakes ontology

We have modelled the IMS LD elements in a concept taxonomy in which relations between the concepts are explicitly represented. We have identified the most important concepts, classifying them according to the criteria for constructing taxonomy to guide the process of building the corresponding ontology. Thus, the ontology elements are organized as follows:

- *Unit of Learning* concept defines a general module of an educational process, such as a course or a lesson (Fig. 2). We have considered a unit of learning as a lesson that belongs to one subject. A unit of learning integrates the description of both the learning design and the set of resources related to it.
- *Resource* concept allows representing various entities, such as physical resources (Web pages, files, etc.), and concepts whose attribute description is domain-dependent (*Learning objectives*, *Prerequisites*, etc.).
- *Learning Design* concept is a description of a method enabling learners to attain certain learning objectives by performing, in order, some learning activities in the context of a learning environment. *Learning Design* starts with the *Learning Objectives* and *Prerequisites* definition.
- The *Learning Objectives* and *Prerequisites* define the intended outcomes when the unit of learning is carried out, and the previous knowledge needed to participate in it, respectively. The IMS specification for learning objectives and prerequisites can be basically considered as textual information or as resource.
- *Components* concept provides the "*building blocks*" of the learning design: learning entities, roles and environments. These elements are: a) *Roles* participating in the execution of activities, b) *Learning Entities* which can be activities or group of activities, and c) *Environments* describing the educational resources to be used in the activities (see Fig. 3). These concepts constitute an exhaustive and disjoint partition, because an instance of a *Component* must necessarily be an instance of one of its subclasses.

- The *Learning Entities* are the activities to be carried out, which can be *Activities* or *Activity Structures*. An *Activity* is a set of learning acts performed to achieve an objective and the sequence of all the activities will determine the "learning workflow" in a learning design. The IMS LD specification considers two different activities: *Learning Activity* as a set of acts performed by students using learning resources within an environment to achieve certain objectives, and *Support Activity* referring to activities that are not carried out to achieve a certain objective but supporting the learning activities. When activities are grouped an *Activity Structure* is defined which can also group other activity structures.

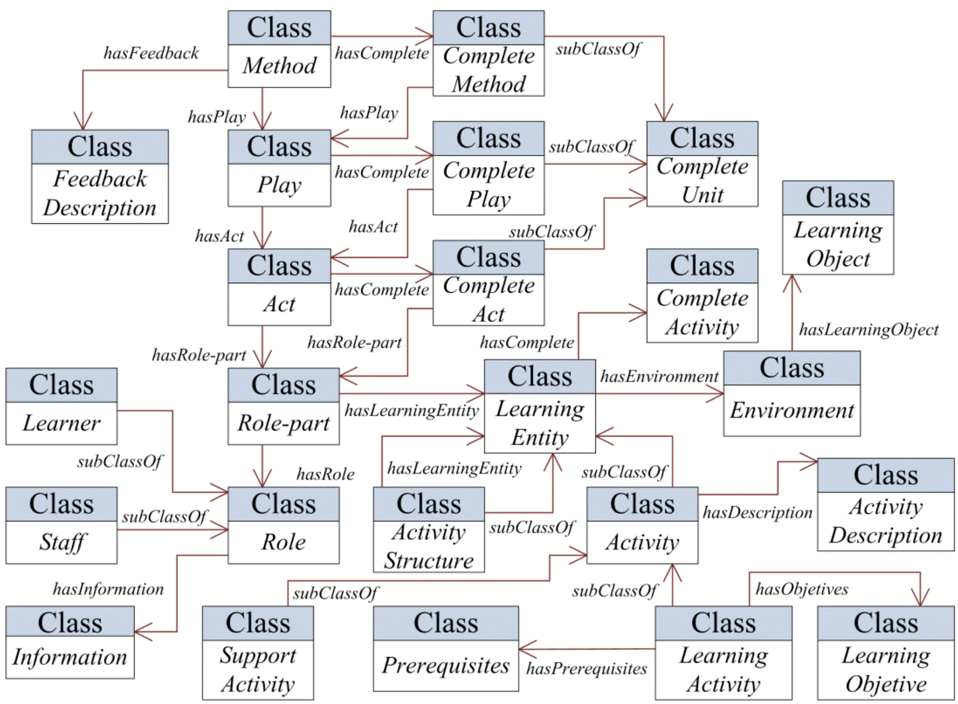


Figure 3. Concept taxonomy that describes the dynamics of learning design

- The *Role* concept specifies the participants of the learning process. According to the IMS specification there are two basic roles: *Learner* and *Staff*.
- *Activities* are carried out in an *Environment* containing resources used by the roles in the development of a learning activity. According to the standard, a *Learning Object* is a resource that is used to carry out a learning activity. For our proposal, we have considered a *Learning Object* as a bibliographic resource. This learning object is used to represent the Tags information associated with a bibliographic source. This information represents the bibliographic sources that a student should consult to complete his/her learning. The *Learning Object* concept has been modified to fit in with Pinakes requirements.
- *Learning Design* concept is also related to the *Method* concept, which describes the dynamics of the learning process (Fig. 3): a method is composed of a number of instances of the *Play* concept that may be interpreted as the runscript for the execution of the unit of learning. All the play instances have to be executed in parallel, and each one consists of *Act* instances, which may be understood as a stage of a course or module. The *Act* instances must be executed in sequence and they are composed of a number of *Role-Part* instances that will be executed concurrently. A *Role-Part* associates a *Role(s)* with a *Learning Entity* to be carried out in the context of the act.
- Every concept involved in the dynamics of the learning process (*Method*, *Play*, *Act* and *Activity*) establishes a relation with one of the subclasses of the *Complete Unit* concept indicating when an execution is finished. In the IMS LD Level A, this condition can be specified through the time limit attribute, which defines the temporal duration of the execution, or refers to an instance of the entity of which it is composed.
- The IMS LD specification defines other important elements providing detailed information about an element of the learning

design: *Information*, *Activity Description* and *Feedback Description*.

4.3 Pinakes: Pervasive System NFC-Based

The development model for intelligent ambients using NFC technology and applied to university environments described in this paper is based on the use of the "*Touch Computing*" paradigm as a swift, easy, and intuitive model for bringing the university close to students and workers, as well as society in general, offering university services to be available anytime and anywhere.

Figure 4 shows the general architecture of the proposed solution which is based on the use of three actors: a) smart objects augmented with RFID Tags disseminated in the university environment, b) users, using NFC mobile phones storing appropriate software, and c) a backend software in charge of dispatching the user requests.

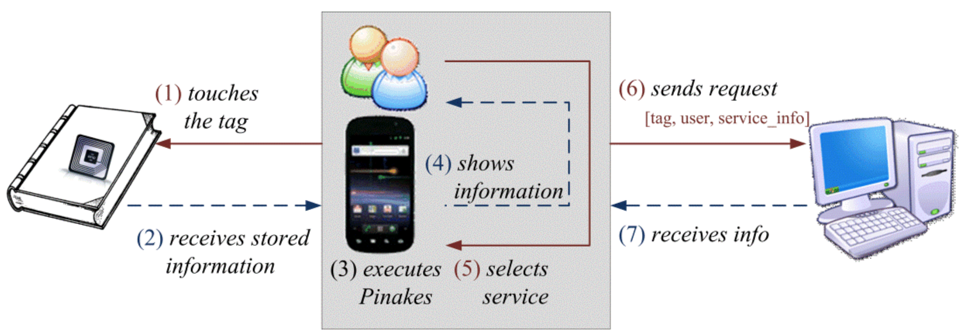


Figure 4. Interaction flow for bibliographic sources

As Fig. 4 shows, when the user "touches" any of the Tags associated to a bibliographic source with his/her NFC device (flow 1), if Pinakes mobile application is not running in the mobile phone, it is started (flow 3) and the information stored in the Tag is received (flow 2). The Tag associated to bibliographic sources stored the main information about the issue, that is, library reference, ISBN/ISSN, title, authors, etc. This information together with the unique identification of the RFID Tag is received in this step.

Pinakes mobile application shows this information to the user (flow 4); next the user decides to request some of the defined services (flow 5). Then, a GPRS/EDGE/UMTS communication is established with server side, sending information about the user identification, requested service, and Tag and bibliographic source identification (flow 6).

Finally, the request is executed on the server side, sending back the information requested to the mobile application (flow 7), and the mobile application being responsible for showing the answer to the user in a proper way.

4.3.1 System Architecture and Interaction between Pinakes Components

Pinakes involves two main components or subsystems: Pinakes mobile and Pinakes server. The mobile application allows the user to interact with real objects by means of the NFC, as well as to communicate with Pinakes server in order to request general and personalized information. Pinakes server involves two different subsystems in charge of: a) the management of the information (Web portal), and b) the dispatching of the user requests. Pinakes Web portal manages the information using the ontology described above in this paper, allowing the teachers to manage the "*chunks*" of information and to link theses chunks to subjects, students and bibliographic sources. Moreover, Pinakes server includes a set of functionalities in charge of the communication with Pinakes mobile application and to respond to the user requests by retrieving the information from the database.

Figure 5 shows the main architecture of these Pinakes subsystems. Pinakes interacts with a smart scenario augmented with RFID Tags. The Tags are Mifare 4K [38] labels associated with an object (a bibliographic source in this case). The Tags store information related to the source. This information is gathered by the mobile application allowing the user to request any of the defined services to be dispatched by the server.

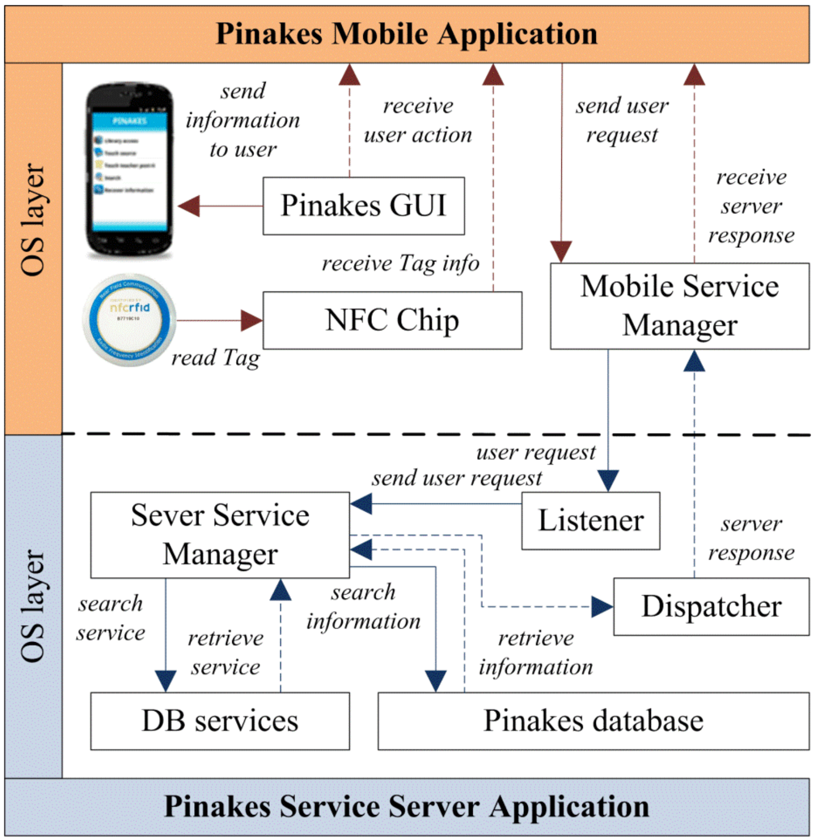


Figure 5. Interaction flow between Pinakes components

The mobile application is a Java application developed in Android OS [6] and the users must have it installed on their mobile devices in order to obtain the services offered. This application is executed in the NFC device guiding the user interaction as follows: a) read Tag information, b) shows information, c) offers a set of options to users, and d) establishes communication with the server to get user requests.

The server application is a Java application developed in J2EE platform [27]. This application is necessary for teachers to define the syllabus. The server is responsible for: (a) registering the contents of the syllabus customized; this content is recorded by the teacher who is responsible for providing the necessary bibliographic sources to complete student learning, and (b) providing the information and services requested by the user by means of the Pinakes mobile application.

As we can observe in Fig. 5, when the user "touches" a Tag associated with a bibliographic source with his/her NFC device, thanks to the information stored in the Tag, the application stored in the mobile device is automatically instantiated. This event is carried out thanks to the "intent filter" method [27]. The core components of an application are activated by *intents*. An intent is a bundle of information describing a desired action, including the data to be acted upon, the category of component that should perform the action, and other relevant instructions.

When the mobile application has not been previously installed in the NFC device, a message alerting for the need to download it from the server is received. Once the mobile application is downloaded and installed in the device, the user can configure it.

Figure 5 shows the process flow and communication between the Pinakes components. Information read from Tags by users using the NFC component of the mobile phone is managed by Pinakes mobile application showing it in an appropriate way using the GUI component. The user can visualize the information received from the Tag and to choose the desired action/service from among what is available. Preferences defined by the user using the "*Configuration option*" of the mobile application determine how the information is shown, as well as how the communication will be performed with Pinakes server side. The user request is sent to the server side using the Service manager component. This component is an agent responsible for communicating with the server side, sending the user request and receiving the information from the server.

Pinakes Server has a listener service in charge of receiving user requests. Requests are managed by the *Service Manager* component of the server that has access to the database of registered services, selecting the appropriate service to answer the user request. Then, the service is executed retrieving the necessary information from Pinakes database and using the *Dispatcher* service to send back the requested information to the mobile application.

Services have been implemented using Java language and defined using Web Service Description Language (WSDL) [23]. These services are Java applications which respond to client requests (computers or mobile phones).

Thus, as Fig. 5 shows, we propose a service model which aims to enable rapid prototyping of context-aware services in pervasive computing environments [21]. Context-aware mobile services [12, 15] are applications and services that make use of different level of contexts and adapt the way they behave according to current contexts. To construct context-aware mobile services, a common way is to specify actions that are triggered by a set of rules whenever the current context changes. These rules use user preferences.

Our context is formed by a set of objects which are augmented through RFID/NFC Tags. Depending on the Tag type (if is a Tag associated to a bibliographic source or a post-it) and depending on the available information related to the object associated with the Tag (book, journal, digitalized source, subjects, etc.) and the actors (student and teacher) related to the interaction, different services can be offered and therefore dispatched. In addition, the user preferences, the technology currently available and the environment will determine how the services are dispatched and how and when the user has access to them.

4.3.2 System Components Interaction

Figure 6 shows the UML interaction diagram corresponding to the interaction process among the system's components. When the user touches a Tag the mobile application reads the information stored in the Tag and the Tag identification (unique for each Tag). Next, the information is shown to the user, allowing the user to select the desired action.

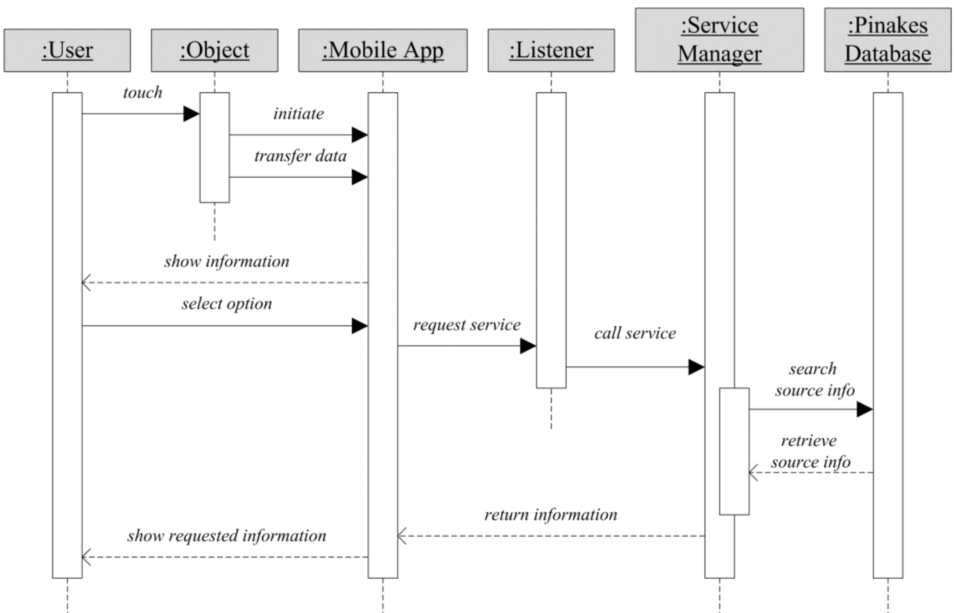


Figure 6. Sequence diagram of the user interaction with bibliographic sources

Once the service is selected, the request is sent through the communication module of the mobile phone to the server side, where a listener service would receive the request and process it.

The listener is an agent in charge of receiving any request from the mobile application. The mobile application requests are: (a) information or services about a source, (b) information about advice, reviews and uses of a certain source, (c) teacher notes, (d) library access, € search source information, (f) and others described below.

When the listener receives a request, analyzes it and transmits it to the *Service Manager*. *Service Manager* checks the request in the database of registered services, selecting the appropriate service to respond to the request. Next the service is executed retrieving the information from the Pinakes database and sending back a response to the mobile application by means of the *Dispatcher* service (see also Fig. 5).Then, the mobile application is in charge of formatting the answer properly for the user, offering the programmed functionality for the handling of the information received.

4.3.3 Augmented Objects and NFC Readers Interacting with Pinakes

As mentioned previously, the scenario is an open and intelligent environment thanks to the smart objects which are augmented with RFID Tags. Pinakes application works with different types of smart objects.

The main smart objects are the bibliographic sources. A bibliographic source represents any book, journal, magazine, manual, etc., available in a university library. These sources are tagged with Tags. These Tags store information about the source, so the user can request a set of services related to the source.

Moreover, Pinakes works with post-its. A teacher post-it is a smart object located in the teacher's office (or any other place, such as the classroom door). These objects store information about the teacher (schedules, suggested bibliography, etc.).

Students touching teacher post-it objects can retrieve updated information related to a subject that the teacher has stored for them. These objects can include other types of services the students may request.

An example is shown in Fig. 7. When a student touches the post-it corresponding to a teacher, information stored in the Tag is transferred to the mobile application. Next, the mobile application sends the server side a request for news, if any exists. In this request the mobile application sends the identification of student and the Tag.

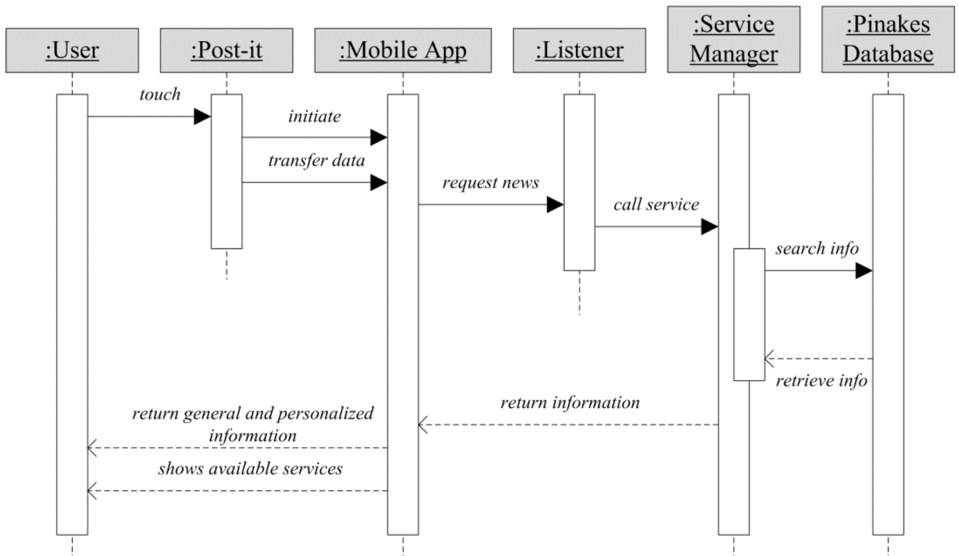


Figure 7. Sequence diagram of the system for a post-it service

The *Service Manager* on the server side receives this request and executes the corresponding service in charge of searching information in the database. Finally, the retrieved information is sent back to the mobile application, showing the user general and personalized information stored by the teacher, as well as the available services to be selected.

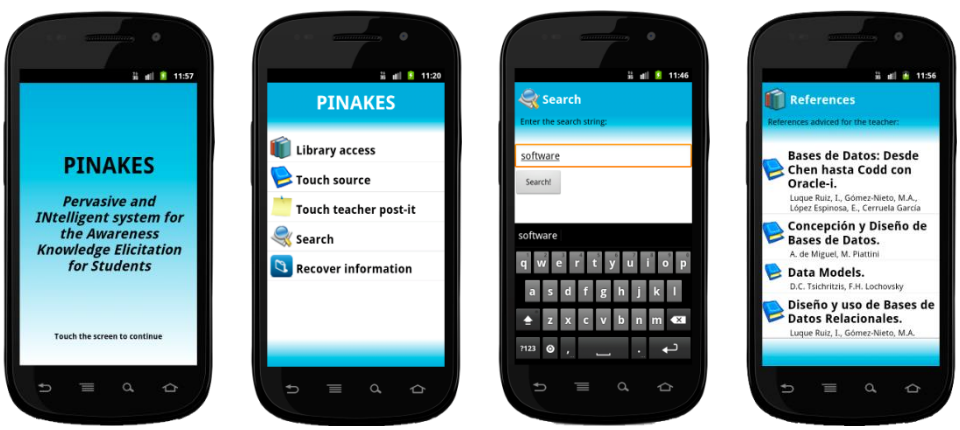
Tags associated to teacher post-its only store information related to teachers and/or subjects. This information is transferred to the server side together with student identification and it is the server who determines the response corresponding to the input data, that is, learning teacher information, teacher information for a subject and/or for a student.

In addition, we have considered the development of a fully based library scenario. Thus, Pinakes also works with NFC readers. An NFC reader is an object located in a university library. NFC readers can be used by librarians to control student access, loaning of books, etc., substituting the use of barcode readers.

4.4 Pinakes Mobile Application

Pinakes mobile application is a Java application for NFC mobile phones. The tool allows getting information about a source with an NFC Tag attached storing the information about the source and the service or set of services offered to the user.

We have developed a prototype which uses the information that has been defined through IMS-LD ontology previously described. The prototype user interface is developed on top of the Android platform and tested on Nexus-S smart phone [43].



(a) (b) (c) (d)

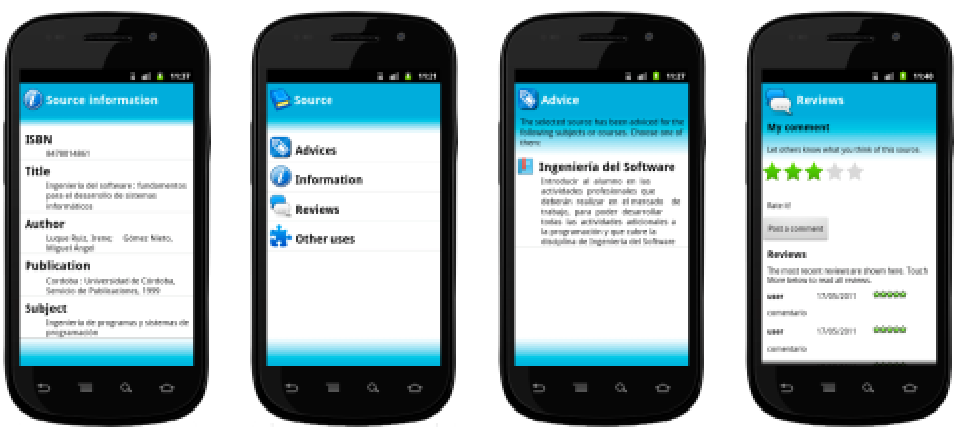
Figure 8. Some Pinakes snapshots

Figure 8 shows some snapshots of the application's interface. When the mobile application is instantiated by the user (Fig. 8a), a list of options are shown to the user (Fig. 8b), allowing interaction with all the "smart objects" considered in the systems: Tags associated with bibliographic sources, Tags associated with teacher post-it, NFC readers located in the library for access control, for instance, and general search and recover options.

The information received by the user in previous interactions may be stored for future accesses and requests. All information is stored in the mobile device, the location being chosen by the user in the "*Configuration*" options. The user can, at any time, manually or guided by the application, delete the historical information stored in the device.

Furthermore, during the search process (see Fig. 8c), the mobile application allows the user to include some search criteria. Once the search criteria have been chosen, the mobile application sends the request to the server which answers back with a list of bibliographic sources fulfil the current search criteria (see Fig. 8d).

This functionality can be performed at anytime and anywhere and it is not necessarily related to touching activity. Thus, users may perform searching for any content stored in the database: books, recommended books for a subject, recommended information content for issue and so on.



(a) (b) (c) (d)

Figure 9. Snapshots of the interaction with bibliographic sources

When a Tag in a source is "touched" with the NFC device, the main information about the source is shown on the mobile screen (Fig. 9a). This information is stored in the Tag, so no connection is necessary with the server for this action. Then, users can select between a set of options considered in the system for this kind of Tag (Fig. 9b). Thus, personalized or general advices about the source can be accessed (Fig. 9c). The advice show the subjects and learning activities corresponding to the recommended bibliographic source.

Furthermore, students can write some comments about the source, to evaluate the utility of the source and to review other evaluations performed by other users (Fig. 9d).

Moreover, teachers and students can choose bibliographic sources for other subjects different from those assigned on the courses (Fig. 10a). This functionality included in the system allows student to share the information and its utility in the learning process.

(a) (b) (c) (d)

Figure 10. Snapshots corresponding to other Pinakes functionalities

Tags located as post-it on teacher's door, office or classroom, for instance, allow students to retrieve information closely related to the teacher and the learning activity. Thus, as Fig. 10b shows as a post-it is touched, the information about the subjects related to the teacher is shown, allowing the students to ask for information about them.

News about the subject written down by the teacher in Pinakes database can also be retrieved (Fig. 10c). This news could inform the students of any matter about the teaching process; e.g., new information added to Pinakes portal, change of the class schedule, tutorial timetable, etc.

In addition, students can write notes to the teacher (Fig. 10d). This option allows the students, for instance, to request a tutorial meeting with the teacher or to ask for some information related to the learning process. When a student writes a note in a post-it, this information is not stored in the Tag associated. In this process a communication is established with the server side and the information is stored in the server database. In addition, a service is instantiated in real time, sending an email to the teacher.

4.5 Validation of the Proposal

In order to put our proposal into practice and validate the user acceptance of the approach, we have carried out a system testing evaluation at the University of Córdoba. Fifteen students participated in the experiment (5 female and 10 male). As the participants did not know the NFC technology, they were provided with a brief explanation (10-15 min) of its characteristics, the capabilities of a NFC mobile, and its operation. Then, the NFC device was offered to the participants for system evaluation.

Once the user interaction was finished, and all the doubts raised by the users were resolved (the most usual was whether the mobile phone owned by the user had the capabilities of the NFC device used during the experience), they had to answer a small questionnaire related to the experience.

Our goals for this study were several: a) study of the user acceptance and usability of NFC technology, b) user evaluation of the system, analyzing all subsystems and functionalities, c) capacity of the ontology used to adapt to the current subject curricula, d) usefulness of Pinakes to access to bibliographic sources of the university library, e) student acceptation of the system for access to recommended and usefulness contents related with subject, and f) general acceptation of this kind of application to be applied in the new learning environment.

However, for this study we only had a small number of students and this study can only be applied to the subject responsibility of the teachers involved in the research. Currently, the system is a prototype not implemented at the University of Córdoba due, in part, to political and economic reasons. In spite of that, as we describe below, excellent results were obtained in the study carried out.

In order to evaluate the user acceptance, we used an adapted IMB Post-Study questionnaire [30] which allowed us to measure user satisfaction with system usability. The survey consisted of the following questions that had to be evaluated between 1 (very low) and 5 (very high):

- *Q1*: Overall, I am satisfied with how easy it is to use the system.
- *Q2*: It was simple to use the system.
- *Q3*: I could effectively complete the tasks and scenarios using the system.
- *Q4*: I was able to complete the tasks and scenarios quickly using this system.
- *Q5*: I felt comfortable using this system.
- *Q6*: It was easy to learn to use the system.
- *Q7*: The information provided with this system was clear.
- *Q8*: The organization of information on the system screens was clear.
- *Q9*: The interface of this system was pleasant.
- *Q10*: Overall, I am satisfied with this system.

Participants were between 19 and 25 years old, twelve of the fifteen were familiar with the use of a Smartphone, and three own an Android device similar to the one used in the experiment.

4.5.1 Evaluation of the Results

We present the evaluation of the user acceptance for the functionality provided in the scenario. Questions were answered using a 5-point Likert scale (Completely Disagree, Disagree, Neutral, Agree, and Completely Agree). Table 1 shows a summarized of the obtained results.

Table 1. Results of users' experience with the system expressed in percentage. E: completely disagree, D: disagree, C: Neutral, B: Agree, A: Completely agree

Question	E	D	C	B	A
Q1	0.00	0.00	20.00	13.33	66.67
Q2	0.00	0.00	0.00	13.33	86.67
Q3	0.00	0.00	0.00	6.67	93.33
Q4	0.00	0.00	20.00	20.00	60.00
Q5	0.00	0.00	0.00	0.00	100.00
Q6	0.00	0.00	0.00	53.33	46.67
Q7	0.00	13.33	13.33	40.00	33.33
Q8	0.00	0.00	40.00	40.00	20.00
Q9	0.00	20.00	20.00	13.33	46.67
Q10	0.00	0.00	6.67	53.33	40.00

Most users (85%) were satisfied with the system and how to use it. More than 80% of the people also strongly agreed that by using the system they were able to complete the tasks and scenarios effectively and quickly.

More than 85% of users agreed or strongly agreed that the interfaces were pleasant and clearly organized and all the subjects considered that the system is simple to use and they felt comfortable using this system.

Finally, more than 90 % of users agreed or strongly agreed that they were satisfied with this system.

Although the initial results of the experiment show that by following our approach we can greatly facilitate users with access to bibliographical sources, additional experimentation would be required to analyse the user acceptance of the system over longer periods.

4.6 Related Works

Pinakes is a pervasive system aims providing students the access to bibliographic sources recommended by teachers on the subjects or courses on which the student are enrolled. Teacher recommendations are defined as knowledge chunks that students should access in order to get the necessary knowledge about a subject or course. Thus, the knowledge chunks could be any content included in a bibliographic source (a definition, a book chapter, a research paper, etc.).

The main characteristic of Pinakes is that students can access to bibliographic sources anywhere and anytime using their mobile phone and NFC technology, consulting both overall and personalized teacher recommendations. Furthermore, students can provide to other students recommendations about the quality or utility of the teacher ones.

Pinakes is based on IMS-LD standard to define the ontological model leveraging the proposals of other authors and extending them to define the Pinakes ontological model as we comment in this section.

In addition, in this section, we comment proposal where mobile phone and QR or RFID technologies have been studied for library applications, demonstrating that NFC technology provides a new and more intuitive interaction model.

Amorim et al. [5], define EUME as an educational ontology describing terms of learning design, contents and resources with the aims to support traditional learning as well as other emerging methodologies, such as collaborative learning. Our proposal extends this model including new class allowing represent the new characteristics considered by Pinakes solution.

Knight et al. [28], describe an ontology-based framework for bridging learning design and learning object content. They develop a conceptual model and create an ontology called Learning Object Context Ontology (LOCO) based on the IMS LD. Pinakes uses the learning objects considered in LOCO to represent the bibliographic sources as part of the learning design.

Gómez et al. [18], study some specifications, architectures and technologies that can be used in content adaptation processes by considering the characteristics of the context to design units of learning based on IMS LD specification. Our proposal is also based on IMS LD extending it by the consideration of new knowledge chunks and entities allowing the consideration of general and personalized contents for students.

Chu et al. [10], propose an approach for developing and employing libraries to support context-aware ubiquitous learning, describing the butterfly and ecology electronic library. Moreover, an innovative approach based on the repertory grid method is proposed to assist teachers to develop context-aware u-learning activities with learning content retrieved from electronic libraries. A practical application has been conducted on an elementary school to evaluate the performance of the innovative approach. This work is not based on providing information on bibliographic sources recommended in a university library. They provide a mechanism for building an electronic library on a specific topic to help students in their learning. We present a proposal to make use of existing resources in university libraries.

Wilson et al. [50], illustrate how library services can be adapted to the mobile environment and how the library can play a role in broader campus mobile initiatives, and Walsh [46] presents the use of QR codes at the library of the University of Huddersfield, outlining and also looking forward the potential use of alternative technologies such as RFID to deliver similar types of information. The development is focused to services such as: links to electronic resources, instructional videos, and useful websites for further information and as a way of storing information for future reference. Our contribution advance in these proposals using NFC technology (a technology more secure, easy to use and quick than QR) and incorporating in Pinakes functionalities devoted to pervasive services of the library.

Wang et al. [47], describe an adaptive u-learning system was developed in the lifelong learning context in combination with associated learning theories as well as context-aware technology. The design of the study's courseware recommendation model uses the lifelong learner characteristics, learner behavior and learning preferences to make appropriate courseware recommendations. This study shows the benefits of using mobile learning models. Also, authors show a study to add RFID technology to the learning and the benefits of using this technology. With these results, we base our work on the use of NFC technology in the learning process.

A location-aware book recommendation service that most closely resembles the work here is the example from Chen and Yang. Chen and Yang [9] describe a system for location-aware book recommendations, using a system architecture close related with the proposed in this paper, modeling the problem based learning using services in charge to recommends resources based on user data and learning objectives. It should be noted that this model was implemented in a vocational high school library in Taipei, Taiwan. In our approach, we do not define recommendations to students based on their location. We provide information to the student when he/she interacts with a bibliographic source.

4.7 Discussion and Remarks

In this paper, we have presented a pervasive and context-aware system for access to bibliographic sources. The solution based on an ontology describing the learning process permits the relationship of bibliographic sources, or part of them, with knowledge chunks involved in the activity of the learning process. The aim is to support compliance with the EHEA directives.

Users need just a single NFC-enabled phone for interacting with the set of smart objects spread throughout the university environment considered. The main smart objects are bibliographic sources which are augmented by RFID/NFC Tags or post-it related with teachers located at teacher's office doorway, for instance.

The system composed of a Web portal devoted to the management of the knowledge chunks related to the subject contents and learning activities allow teachers to relate this information to the recommended sources to be studied by students, allowing teachers to establish general and personalized activities and recommendations. Students using and mobile NFC-enabled phones can perform searching actions at anytime and anywhere, receive news from teachers, touch a bibliographic source and retrieve teacher suggestions as well as ratings and recommendations from other students, in an easy and intuitive interaction.

The set of functionalities defined by the described system are performed by a set of specialized services managed by the server subsystem. These services collect the user request and initialize the necessary service access to the database, sending back to the user the requested information.

The learning model based on the Bologna declaration encourages students to learn to acquire the skills necessary to achieve the required knowledge, which is free to access for the study of necessary bibliographical sources. For this goal, we described in this paper a useful tool to give students access to the main and necessary information from the sources related to the necessary concepts belonging to the subjects. Moreover, the system allows, in a pervasive way, a close relationship between teacher and student, exchanging information related to the learning process.

Currently, Pinakes is an operating prototype that is being proposed for the study of its near deployment. Refinement of the system based on the application test will be carried out for its improvement. We are currently working on the development of new services and new interaction models of interaction. The aim is the building of so-called smart environments and their inclusion at University, having NFC as the main interaction mode. In this way we are trying to create the *University of Things* [4].

Acknowledgments

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5 | An Ubiquitous NFC Solution for the Development of Tailored Marketing Strategies Based on Discount Vouchers and Loyalty Cards

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Debido a la crisis económica global, hoy en día son muchas las empresas que están orientando su modelo de negocio hacia nuevos modelos como "deal of the day" (oferta del día), algunos de ellos con gran éxito. Generalmente estas empresas intentan atraer y fidelizar clientes por medio de cupones descuento y tarjetas regalo, usando medidos de distribución tradicionales.

Este capítulo presenta un sistema que integra entornos inteligentes usando tecnología NFC orientados a la gestión completa de vales descuento y tarjetas de fidelización. El sistema, llamado WingBonus, se encarga de la difusión, distribución, aprovisionamiento, validación y canje de vales descuento, tarjetas de fidelización y todo tipo de cupones móviles a través de tecnologías como NFC y QR.

WingBonus es un ecosistema totalmente personalizable a proveedores, minoristas y usuarios y soporta cualquier tipo de vale descuento, incluyendo aquellos vales destinados a fidelizar clientes a través de descuentos por cada compra de un producto o servicio.

Existen varias e importantes empresas que ofrecen descuentos, sin embargo, usar y adquirir estos descuentos no siempre es fácil. El principal punto débil es la interacción del cliente con la empresa para la utilización de estos vales descuento. El uso de NFC y su aplicación en dispositivos móviles proporciona una sencilla forma de adquirir, almacenar, gestionar y usar vales descuento. Además hace el proceso rápido, seguro, eficiente y transparente. WingBonus, por tanto, es una potente herramienta de difusión que se puede utilizar en las campañas de marketing de empresas que se basen en emitir ofertas o descuentos a sus clientes u ofrecer tarjetas de fidelización.

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5 AN UBIQUITOUS NFC SOLUTION FOR THE DEVELOPMENT OF TAILORED MARKETING STRATEGIES BASED ON DISCOUNT VOUCHERS AND LOYALTY CARDS

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ABSTRACT. Because of the global economic turmoil, nowadays a lot of companies are adopting a “deal of the day” business model, some of them with great success. Generally, they try to attract and retain customers through discount coupons and gift cards, using, generally, traditional distribution media. This paper describes a framework, which integrates intelligent environments by using NFC, oriented to the full management of this kind of businesses. The system is responsible for diffusion, distribution, sourcing, validation, redemption and managing of vouchers, loyalty cards and all kind of mobile coupons using NFC, as well as QR codes. WingBonus can be fully adapted to the requirements of marketing campaigns, voucher providers, shop or retailer infrastructures and mobile devices and purchasing habits. Security of the voucher is granted by the system by synchronizing procedures using secure encriptation algorithms. The WingBonus website and mobile applications can be adapted to any requirement of the system actors.

KEYWORDS. *Near Field Communication, mobile phones, vouchers, m-coupons, marketing, loyalty cards.*

5.1 Introduction

The ambient intelligence paradigm (AmI) aims to develop environments able to interact with the user in an autonomous way in order to make life easier for people in different fields [1]. A technology that facilitates the achievement of the AmI objectives is Near Field Communication (NFC) [2]. NFC simplifies the users' interactions with the context-aware services offered in intelligent environments, also promoting a new interaction model, called "*touch paradigm*". This paradigm allows the construction of a complete information environment, where ubiquitous applications allow users to obtain any information or services from the surrounding objects, which are augmented with RFID Tags, just by touching them with a NFC device.

Another important aspect that favors the development of intelligent environments is the current and future evolution of mobile devices and the number of terminals around the world [3]. The increase in the number of phones in the world has followed an exponential curve, from about one thousand million mobile phones worldwide in 2001, to about five thousand million in 2011, which has led to the development of new applications based on NFC, applied to a wide variety of services [4].

In addition to the obvious payment and security applications [5–8], NFC has provided a wealth of applications in transport [9–12], advertising and promotion of tourism businesses [13–17], ambient assisted living (AAL) [18–21], elderly care [22–25], shopping [26,27], authentication [28–31], university of things [32,33], and oriented to a wide variety of scientific, as well as business areas [34,35].

Besides this, the current global turmoil is forcing citizens to save money and to seek cheaper prices when they purchase products and services. Thus, marketing and loyalty techniques are changing, helped by the overwhelming power of smart phones over traditional mobile phones, creating the concept of m-coupons or mobile coupons.

In the market, we can find some applications that already work with m-coupons. Chen et al. [36] propose an m-coupon sharing scheme that uses mobile devices to distribute coupons among existing social networks, increasing m-coupons exchange. In this scheme, the company first selects targeted members and then it sends a virtual coupon book and a virtual sharable coupon book to each of these targeted members. The targeted member is encouraged to forward the sharable coupons to his/her peers.

Dominikus and Aigner [37] propose a new form of coupons called mCoupons which can be downloaded from a poster or a newspaper equipped with a passive NFC device to a mobile phone. With this mobile device the user can then cash in the mCoupon at the cashier. They also have described two protocols for secure mCoupons with different security features.

Will et al. [38] describe a framework to exploit social network connections for targeted campaign delivery in order to support local retailers in enhancing customer communication. They have implemented a client application enabling end users to find relevant coupons and offers and retrieve them after completing specific tasks.

Other applications such as Groupon [39] offer deals that last about a day in most of the markets around the World. This type of offer is known as "deal of the day". The user pays first and then he/she gets the coupons to be exchanged at the indicated shop. These types of deals are exchanged through traditional paper coupons or through their mobile application using QR codes [40], that the partner shop reads using a QR reader or checking and writing down the coupons code. Other applications like LetsBonus [41] or Groupalia [42] also use QR codes for redemption of the coupons. However, Coupies application [43] uses NFC technology to redeem the coupons. The buyer only has to bring his/her NFC device to Coupies Touch Points. These Coupies Touch Points are coded stickers which are located at the points of sale. In addition, this sticker has a QR code for those users who do not have mobile devices equipped with NFC technology.

Although some existing systems are oriented to the elimination of the traditional paper voucher using new technologies and mobile devices, some challenges are as yet unsolved. Valuable aspects required to pervasive systems, such as mobile applications, are not considered, as in the following:

- Security: vouchers are managed in mobile devices as tangible coupons. Once the voucher is bought from the provider website, security can only be checked by the PoS (point of sale) system. Aspects regarding the loss of vouchers, error in the redemption process, error in the manipulation process by the user or device, fraudulent copying, etc., are not well solved yet.
- Voucher type: most of the current systems usually consider a restricted type of vouchers: discount coupons; that users must pay in advance and vouchers can be later redeemed at a specific establishment. However, the providers and shops/retailers would need a wider type of voucher, depending on the characteristics of the product or service, voucher price, the desired targets or user characteristics, etc. For instance: coupons not necessarily being paid in advance, vouchers that could include a set of redemptions (bonds), vouchers that could be a kind of prize that the user accumulates until the user has a large enough number of them to be redeemed by a product or service, etc.
- Architecture: websites are in charge of the voucher publicity, provision and payment, and the commerce infrastructure, if it exists, is in charge of the checking and exchange. Thus, current proposals are not open to the requirements of the voucher providers, where providers systems' can be involved in the process. The voucher provider is the company that provides the marketing campaign, which can be the same shop in which the coupons will be redeemed or a manufacturer that trades the product considered in the voucher.
- Loyalty cards: consideration of the loyalty cards corresponding to providers and/or commerces have not been taken into account. Although some existing applications manage loyalty cards, these applications do not integrate in a unique solution all type of vouchers and loyalty products.

- Adaptive vouchers: current systems show shortcomings in the management of user preferences in order to offer and supply vouchers. Because of the above mentioned paradigm “deal-of-the-day”, they are offering just a few vouchers each day that do not adjust to the user preferences but only to the city selected for the redeem process.
- Getting vouchers: current systems supply vouchers mainly through the website. This does not adjust to a pervasive system. Thus, the process of getting vouchers should be distributed by getting them anywhere easily with a smart phone.

This paper presents a framework aimed to solve all the aforementioned problems. The framework, called WingBonus [44], is not only an application oriented to mobile coupons management. WingBonus is an ecosystem that can be fully tailored to providers, retailers and users’ requirements. Thus vouchers publicity, sourcing and redemption can be performed by any infrastructure owned by any of the actors participating in the different processes. Besides, security of vouchers is always granted through unique secure keys, information encryption and double or triple secure validation using WingBonus, providers’ and/or retailers’ infrastructure.

WingBonus supports any type of vouchers, including the ones oriented to attract user loyalty through discounts on each purchase of a product or service. This kind of voucher is called a chit and its management is very similar to loyalty cards management that is also considered by WingBonus, thus integrating in a unique system all type of vouchers.

Moreover, the WingBonus Mobile Application is fully adapted to providers and users’ requirements. Providers’ campaigns are automatically displayed in the mobile and web applications. The system can even be personalized to providers in the same way as the systems that are owned by providers.

Finally, WingBonus integrates QR and NFC technologies, allowing the sourcing and redemption of any kind of vouchers using the available technology: smart posters, NFC readers and QR readers for retailers, environment and user devices.

The paper is organized as follows: Section 2 describes the system and environment infrastructures. Section 3 presents the architecture of the system, describing the main components and the processes between the actors, showing how the solution can be tailored for different levels of security and different characteristics of retailer infrastructure. The WingBonus website is described in Section 4 and the WingBonus mobile application in Section 5. Finally, in Section 6 we discuss the results obtained and we show the advantages of WingBonus compared to classical marketing campaigns based on paper vouchers and other existing systems where NFC technology is not considered.

5.2 Description of the system

In this paper, we propose an ecosystem called *WingBonus*. WingBonus is in charge of disseminating, distributing, sourcing, validating and managing loyalty cards and electronic vouchers using mobile technologies.

5.2.1 System Technology

WingBonus is composed of two main systems: the WingBonus website and the WingBonus mobile application. WingBonus website has been developed using as HTML5 [45] and CSS3 [46] ensuring its adaptation to the standards recommended by W3C [47]. We have followed one-page development paradigm using Javascript and Backbone.js [48] complemented by JQuery [49] and libraries such as Underscore [50] of Require.js [51]. The server side processing has been developed using PHP.

The WingBonus mobile application communicates with the server side through web services. In this proposal, we have implemented RESTful web services [52]. For service representation we have used JSON format

[53] in order to implement communications between the server and mobile applications in the synchronization process. The database engine used has been MySQL on the server and SQLite in the mobile application.

In order to provide security to the information stored on both the server and the mobile device, we have decided to encrypt the information using a symmetric cipher called Blowfish [54]. To date, no effective Blowfish analyzer has been found, maybe because more importance has been given to the decoding of larger blocks using programs such as AES [55] or Twofish [56]. Blowfish uses 64-bit blocks and a key size from 32 bits to 448 bits. Another important aspect is that Blowfish is not patented. The algorithm is publicly available and can be freely used by anyone.

The WingBonus mobile application currently runs on the Android [57] and RIM [58] operating systems. Regarding environment infrastructure WingBonus considers different types of RFID Tags [59,60], several types of NFC readers, such as the ACR 122U [61], and any QR reader, to redeem vouchers if the user or the establishment does not use NFC.

Thus, a driver and an API have been developed in Java. This API implements the communication between a mobile device and a reader at the point of sale (PoS). This communication allows: (a) redemption of vouchers, (b) distribution of vouchers, and (c) transactions with loyalty cards. Furthermore, this API enables communication processes using NFC and QR codes. This communication process is carried out as follows:

- NFC communication: the user touches the NFC reader located at the PoS with his/her mobile device equipped with NFC to redeem a voucher. At this time, the communication process is carried out. The PoS reads the information from the mobile phone and sends it to the server to verify the validity of the voucher. Then, the PoS sends the user the answer through the reader. This process is similar for distributing vouchers at the PoS and transactions with a loyalty card.
- Non-NFC communication: the user shows the QR-code of the voucher at the PoS and the communication process is carried out.

PoS reads the information through QR-reader and it sends the information to the server to verify and validate the voucher. This process is similar to transactions with a loyalty card.

5.2.2 Environment Infrastructure

Our pervasive system is open to a wide range of infrastructures in order to manage the full voucher processing chain. Different actors are considered by the systems: (a) providers, any manufacturer promoting a product or service, (b) retailers, any shop or commerce that either promotes a product and/or participates as PoS (point of sale) in any of the voucher processes, and (c) users, any user selecting and redemption of any kind of vouchers and managing loyalty cards.

All vouchers and loyalty card processes are related to these actors and their characteristics depend on the existing environment infrastructure. WingBonus permits voucher advertising and sourcing to be performed from provider and retailer infrastructure, if existing. Thus, provider and retailer websites can be used for promoting and sourcing vouchers to users as if the process is performed from the WingBonus website. In addition, vouchers can be sourced to users from NFC readers or any Smart Poster including RFID Tags or QR codes distributed by providers or retailers. The mobile application is in charge of the selection and sourcing of the voucher and sending this information to the server to be validated.

In addition, the WingBonus website manages all kind of vouchers as well as providers' and retailers campaigns. Users connect to the web portal, selecting and downloading the desired vouchers or loyalty cards. Moreover, WingBonus website validates the voucher sourcing carried out by providers, retailers and smart posters.

Moreover, in the voucher redemption and validation processes and card operations different actors are also involved depending on the actors involved in the sourcing process. Vouchers are always redeemed in the PoS using the retailer infrastructure, this process being controlled and validated by the WingBonus server. In addition, provider and retailer website may participate if they are in charge of the voucher sourcing. Depending on PoS infrastructure the validation and redemption of vouchers can be carried out using different security levels. As we describe below in the paper, the security level in the voucher management is related to characteristics of the advertising campaign, type of voucher, use or not of NFC reader in the PoS, etc.

5.3 Architecture of the System

5.3.1 Type of Vouchers

Figure 1 shows some of the main information classes considered for the representation of vouchers' information. Three different types of vouchers are managed by the systems, as follows:

- Coupons: a coupon allows the end customer to acquire a product or a service with a certain discount. Current solutions require printed coupons, or, in the best-case scenario, the need to install several apps in the mobile device. WingBonus gathers and stores all kind of coupons that the user can use when and where he/she wants, in a simple and safe way.
- Bonds: a bond is a set of coupons. The user can take advantage of a bulk purchase of coupons obtaining a notable discount because WingBonus offers capabilities for bonds management.
- Chits: If retailers and providers want to attract customers to purchase the same product or service more than once, customer loyalty and savings are encouraged. WingBonus creates the concept of "chit". A "chit" is a small reward for the purchase of a product or service. WingBonus manages user chits and it allows users to exchange them at will for new products or services or even discounts.

Offers and providers' promotional campaigns are managed through *Containers*. Containers allow providers to group some vouchers, satisfying their business policies. Moreover, containers can be classified in *Folders*, the vouchers being assigned to a specific folder. A folder is used to define specifics providers' campaigns. Thus, a provider can distribute their vouchers in different business activities and different campaigns using different provider's images, requirements, and promotional, business and marketing policies using the same user environment.

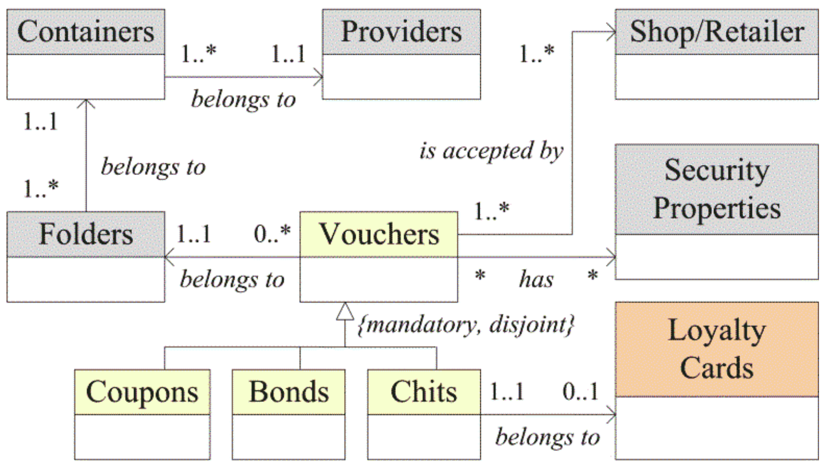

Figure 1. Class diagram corresponding to voucher information.

In addition, WingBonus functionality includes the management of electronic loyalty cards. The user can manage any number of loyalty cards in his/her mobile phone. Furthermore, a loyalty card is managed like a folder, restricted to storing only chits. When a user buys any product or service corresponding to a specific provider or retailer he/she receives economic or symbolic rewards that are accumulated in the loyalty card corresponding to the retailer or provider. Afterwards, the user can exchange those rewards wherever he/she wants for other products or services, always following the requirements of the loyalty card.

Properties defined in containers and folders allow for use of different icons, images, etc., and to define the different type and characteristics of the voucher for each of them. WingBonus manages this information to generate tailored interface in the mobile application as we will describe later.

Users can select vouchers, these vouchers being assigned unequivocally to each user to be later sourced to the mobile application. These vouchers are exchanged in retailers or shops, any point of sale (PoS), defined and accepted previously when a voucher is created. Retailers and providers can be the same actors, for example in the case of a shop offering a loyalty card to its customers.

Security of the vouchers is defined by the providers depending on the characteristics of the marketing and business campaigns of the vouchers. Voucher security is managed depending on the user activity and the voucher characteristics. Thus, voucher security is defined for:

- Voucher selection: when a user chooses a voucher in order to be downloaded afterwards in his/her mobile phone.
- Voucher sourcing: in this process the marked voucher is downloaded to the mobile phone.
- Voucher redemption: the voucher is exchanged in an accepted retailer.
- Voucher transfer: the voucher is transferred from one user to another.

For each of these functionalities the system considers security properties about:

- User identification: the user must be identified in the system. When the process is being carried out, the system will check the user granting or rejecting the request.
- Voucher properties: the properties of each voucher, defined individually for each one of these processes.

Environment/scenario: vouchers can be allocated, as will be described below, and therefore sourced from different media or infrastructures. Thus, a voucher can be sourced from smart posters, store readers, as well as WingBonus or provider websites. Besides, users' mobile phone or environment can determine the communication infrastructure (feasibility of WiFi and GPRS communication, for instance). These characteristics can be defined in the security properties of the vouchers in order to adjust the security level for each of the processes.

5.3.2 Voucher Lifecycle

Vouchers are defined at different status depending on the process performed on them by the actors participating in the system. Figure 2 shows a sequence diagram of the voucher lifecycle and the process in charge of moving a voucher from one status to another.

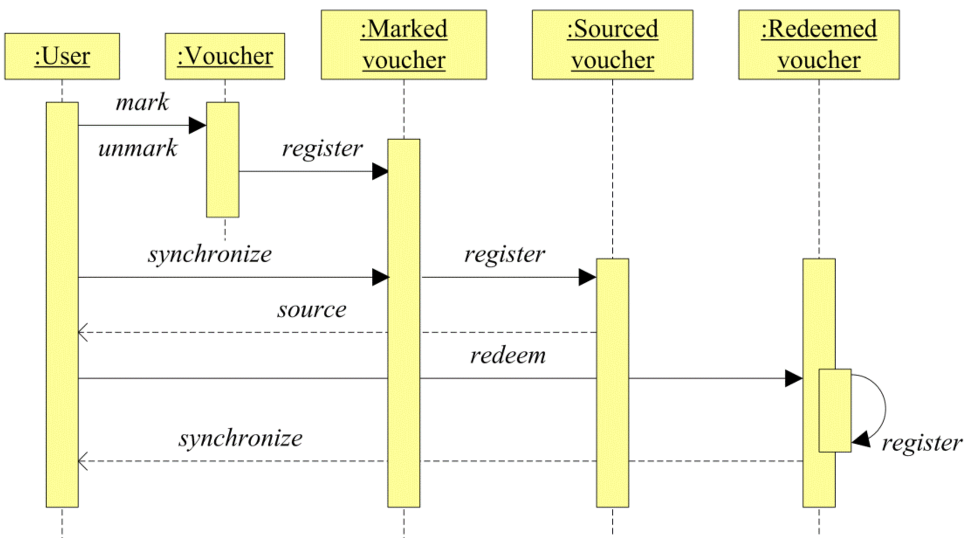

Figure 2. Sequence diagram showing the voucher lifecycle.

First of all, vouchers are defined and set at the disposal of the users for their selection. Characteristics of the vouchers such as due date, total number of sourcings, total selection number by user, number of sourcings by user and time, deadline for the exchange, etc., are set in the voucher definition.

When a user marks a voucher, it goes to the “Marked voucher” status and a unique identification is given for it, considering the user and voucher identification. Thus, users can mark any quantity of voucher at anytime and those vouchers are stored in the system, waiting to be provisioned to the user device.

The sourcing of a voucher can be performed automatically or on user demand. When a voucher is sourced to the user mobile, the voucher passes to the “Sourced voucher” status. The voucher sourcing is performed through a synchronization process in the WingBonus mobile application.

Finally, the voucher passes to the “Redeemed voucher” status when the user redeems the voucher in one of the accepted stores or locations. The synchronization during the redemption process can be carried out in several ways depending on user and shop infrastructure.

WingBonus’s database stores information about the whole voucher lifecycle. Vouchers have a unique identification in each status and all voucher statuses are related to each other. The synchronization process validates the mobile and server databases, maintaining one unique and congruent information flow over vouchers in their different status.

Depending on voucher security properties, mobile and server databases can store a different image of user vouchers. For instance, users can source a voucher with low security requirements (i.e., from a smart poster), and users can even redeem those vouchers in shops with the security level established by themselves (for instance, vouchers spread up in smart posters around a city, chits of their own shop, etc.). Even in this case, each voucher is uniquely identified in the mobile database, therefore two identical vouchers do not exist. Just when the synchronization is performed, vouchers are stored in the server database and mobile vouchers are updated in order to relate and unify both databases.

5.3.3 Actors and Infrastructure

It can be observed that the system considers three types of actors: providers of vouchers, retailers or shops and users or customers. Providers are companies having marketing or promotional vouchers or loyalty card campaigns. Retailers are the stores or shops where customers earn and redeem vouchers and can play the role of providers in some cases, and users are the customers using the application.

WingBonus is currently open to any provider infrastructure as well as shops’ business policies. Therefore, the system allows any infrastructure to be used for any of the process involved in the voucher management.

Vouchers can be selected and sourced from: (a) the WingBonus website, (b) the provider’s website, (c) shops’ readers, and (d) smart posters.

The user can select and source vouchers from the WingBonus website from a laptop or mobile application. In this case, the system has full control of the information and the process. Besides this, providers can publish vouchers on their own websites and users can select and source those vouchers with or without using the WingBonus system at that moment. The providers define how these vouchers operate through the vouchers’ security properties, taking into account the infrastructure of the PoS where the vouchers may be redeemed.

Furthermore, vouchers can be selected and sourced from shop readers, for instance when a loyalty card is used, or from any smart poster displayed anywhere. In this case, vouchers’ security is defined by the provider, it being in the low-high range depending on the provider campaign. The security level affects different voucher and infrastructure characteristics that are defined by the provider when an advertising campaign is trade. Thus, providers define how a voucher can be sourced (from WingBonus website, provider website, smart poster and/or NFC reader at the shop), how many vouchers can be sourced (total number of vouchers, total number of vouchers per day, total number of vouchers issued to each user, number of voucher per day for each user, etc.), if the voucher should be validated beforehand to be redeemed, how the vouchers should be redeemed (using a NFC reader, using a Smart Posters, both, etc.).

User infrastructure is also open. Although WingBonus is a system conceived for using NFC technology, due to the fact that currently some users do not own NFC devices, the system also allows the use of QR codes for the selection of the vouchers. The sourcing also can be performed using any communication media: Wi-Fi, GPRS, Bluetooth, MMS or connecting the phone to the computer.

Depending of the security properties of the vouchers, the redemption process also can be performed using different infrastructures. Thus, retailers can use Tags, NFC or QR readers as media control, and voucher validation can be performed by the retailers, providers and/or WingBonus in real time. In any case, as described below in this paper, full control of vouchers is managed by WingBonus during the whole life of the voucher.

5.3.4 Voucher Management

Security, infrastructure, actors and voucher's lifecycle are fully related in WingBonus in order to offer an open system. Indeed, WingBonus is not properly a system but rather a framework allowing any provider or retailer to develop their own publicity, marketing, loyalty and marketing campaigns using a fully tailored mobile application and considering any voucher characteristics and security requirements.

Management of vouchers (see Figure 3) depends on the security properties defined for each voucher type involved in an advertising campaign. Security level is defined for each of the main processes performed with the vouchers by the system and users, that is: selection, sourcing, redemption and transference among users.

The security level defined by a process determines the security of the later process in the voucher lifecycle. Security level takes into account user identification as well as the grants to perform a process by the user. Furthermore, security level determines in what step of the voucher lifecycle the system grants the voucher authentication and therefore the system stores all the information about the voucher, process and participating actors.

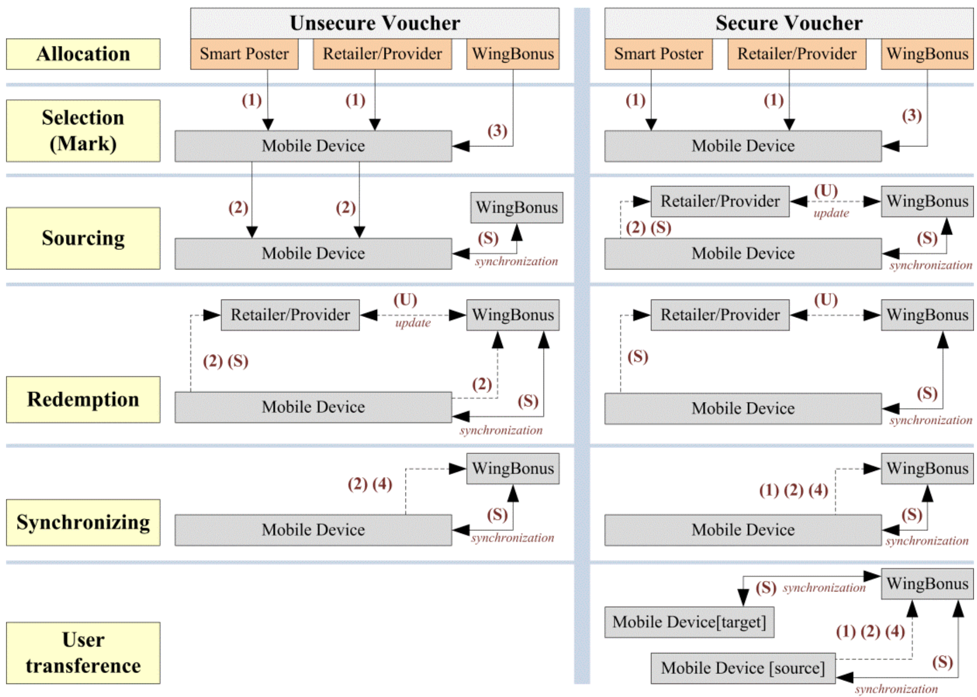

Figure 3. Flow of information between the system actors for secure and unsecure vouchers.

Figure 3 shows the different kind of flows depending on the voucher security and the actors participating in the different phases of the voucher lifecycle. Thus, flows (1) and (2) represent the information gathered by the mobile application from smart posters and retailers (or providers), respectively; (3) represents the information managed by WingBonus server that it can be marked and sourced to users, and (4) the information sent to the WingBonus server by the mobile application in order to be validated and later to process a synchronization between server and mobile applications; finally the flow of synchronization (S) is in charge of matching information between both sides, mobile and server, maintaining the consistency of the information, and the flow label as (U) represents the communication between retailers (and providers) with the server application in order to share information about any information transference between users and retailers (and providers) and users with WingBonus server.

Vouchers can be defined as unsecure for sourcing (see Figure 3). Thus, identified and unidentified users can get vouchers from any source: provider, store, smart poster (flows 1, 2). Selected and sourced vouchers from WingBonus website (flow 3) are stored in the system database as Figure 3 shows. When users access the retailer/provider website, they can select and download vouchers, in this process, provider's website sends a request to a WingBonus server service (flow U), WingBonus's system being in charge of sourcing the voucher to the user and store the information in the system database. Furthermore, the user can get vouchers from smart posters.

Smart posters can store full or partial information of the vouchers depending on the source security property (see Figure 3). If the voucher is secure for sourcing, the partial information got from the smart poster is sent to the system and the full voucher's information is sent back to the user (flow S). These vouchers cannot be sourced in the mobile device until synchronization with the system is performed; however, temporary information about the selected voucher is stored on the phone.

If the voucher is unsecure for sourcing, the mobile application generates a unique voucher identification, which is temporary until the next synchronization is performed. Stores are considered as smart posters although reading infrastructure was used.

Before the later process vouchers always have to be validated by means of a synchronization process. Hence, vouchers are not previously synchronized (flows 1 and 2) and vouchers not previously validated are sent to WingBonus server being validated (or not) and a synchronization process is performed.

Redemption process also can be performed by identified and unidentified users. In this process the user shows the voucher in the store to be exchanged for a product or service. If a high security is not defined for redemption, the user can exchange a source voucher in the allowed shop (see Figure 3). For that, information of allowed stores where the voucher can be redeemed must be stored in the mobile phone, otherwise synchronization is needed, and at this moment the voucher is validated, or not, as well as updated in the mobile phone and stored in the server by means of a new synchronization.

If any security level is defined for redemption, the voucher must be validated prior to being redeemed. In this process, validation codes are sent to the mobile application in order to generate the QR code or NFC keys corresponding to the voucher. The validation process can be performed by different means: (a) the user touches the store's NFC reader connected to the store's computer that communicates with WingBonus's website using a specific service, (b) the user reads a specific Tag (QR or NFC) with his/her mobile phone and use Wi-Fi or GPRS to communicate with the WingBonus system. Finally, the redemption of the voucher is confirmed and communicated to all the involved actors. Retailers will receive information about the vouchers managed by WingBonus at any time depending on the established business agreements.

The most secure way to redeem vouchers is through NFC. This technology is safe because the small distance range in which it operates makes it very difficult to sniff part of the communication by third parties. We assume then that special security protocols are not required; however, an algorithm that verifies consistency and integrity of vouchers has been used to improve the strength of the system.

The method is similar to the one used in certificates and digital signatures. When a user downloads a voucher, the server sends all the information of the voucher and also a digest codified as a byte array. The contents of the digest are hidden by the encryption with a symmetric key algorithm. The algorithm used is Blowfish [54], and it uses a private key that is hosted on the server. Users do not need to know the information encoded in the digest, because it is not needed to expose the key. Thus, each time the user downloads a voucher the application stores data corresponding to the voucher and an array of bytes, which encodes the encrypted digest.

When the user wants to perform voucher redemption with NFC, the mobile application transmits all the voucher data to the controller installed on the store. This requires sending the server all the received data with the purpose of verifying the authenticity of the voucher. Once the data, originally sent by the store, is in the server, it decrypts the digest and verifies that the digest corresponds exactly to the provisioned voucher data. The server also checks the identification of the user involved in the process testing if he/she is the voucher owner. If integrity is maintained and the voucher is valid, the server sends a confirmation message to the controller; otherwise it sends an error message.

When the redemption is made using QR codes, the procedure is similar because the code has enough storage capacity to store the voucher data and the encrypted digest. The redemption of vouchers with bar codes does not support this verifying method, and therefore its use is not recommended.

Finally, transference of vouchers between users can only be performed with secure vouchers and identified users. This process is always validated by WingBonus server checking the user and vouchers authenticity and the rules defined for those vouchers in the marketing campaign.

5.3.5 Synchronization Process

Synchronization is a process performed by the mobile application automatically or on user's demand. This process is in charge of several important actions (see Figure 3):

- Updating the mobile database with information corresponding to the selected voucher from the WingBonus and provider's websites, sourcing the vouchers and updating the server database.
- Sending the server partial information of vouchers gathered in the selection process from smart posters or shops. Vouchers are

updated with information, stored in the server database and sent back to the mobile device in order to update the mobile database.

- Matching information corresponding to mobile and server databases is analyzed in order to detect errors, lacks, inconsistencies or counterfeits. In this process, entries in the mobile database are sent to the server to be validated and send back to the mobile. Vouchers accidentally lost by the user are then recovered.

Sending and receiving information between the mobile and server sides has been implemented by encapsulating information in JSON objects. Unlike the usual format, web services have been used in both directions: to initiate and to finish the communication.

Synchronization process requires identification of the user. Although anonymous users can select, source and even redeem unsecure vouchers, during the synchronization, the user must be authenticated through a login process.

5.4 WingBonus Website

The WingBonus server subsystem is composed of several functional components: (a) the website responsible for the web interaction with the user and the administrators, (b) the database storing all the information involving users, vouchers, clients, establishments, etc., and (c) a set of web services that compose an API that is consumed by the mobile application and the web-client side.

The WingBonus server has been built using the one-page paradigm, using Backbone.js that supports Model-View-Controller (MVC) [62], HTML5 and CSS3 for the page makeup and JQuery for DOM manipulation. All the work concerning interactions with the final user is made on the client side once the website has been loaded, letting the server be an API and a set of services that work against the database. Like other JavaScript web applications, WingBonus uses several libraries such as Underscore, Require.js, etc.

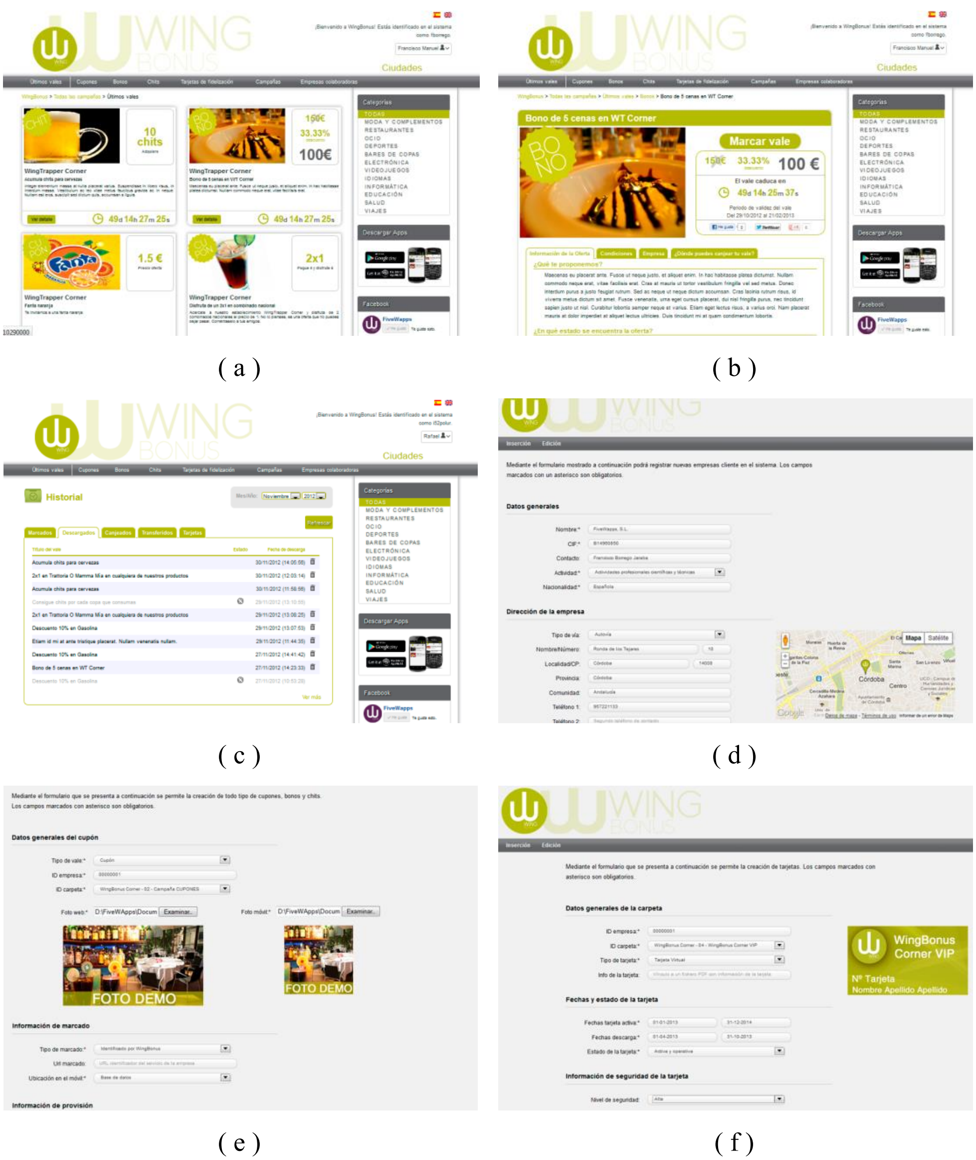

Figure 4. Some snapshots of the WingBonus website.

The WingBonus website constitutes an access platform for users and system administrators. From the main page, shown in Figure 4(a), users can access the registration form. Once registered, the user can define a set of profile options that allows WingBonus to build a personal site showing information tailored to the user.

Users can view offers classified in different items: coupons, bonds and chits. In addition, offers can be sorted by companies and marketing, simply by selecting the desired option in the upper selection bar. In addition, the voucher view can be filtered by categories selected from the right side selector.

Once a voucher has been selected, a detailed view is shown as in Figure 4(b). Then, the user can "mark" the voucher to be later provided in the next synchronization process from the mobile application.

The full user activity is stored in the database. Thus, security of marked and provisioned vouchers can be checked before the exchange process. In addition, the server system provides information about the user activity. As Figure 4(c) shows, users can view the whole history of their related vouchers.

Moreover, the WingBonus server provides a complete administration tool for the management of the information. Thus, Figure 4(d) shows the screenshot corresponding to the management of user data for retailers/providers. Figure 4(e) corresponds to the management of an advertising campaign for vouchers and Figure 4(f) to the management of loyalty cards. In addition, this administration tool involves a set of functionalities in charge of the data analysis and of generating different reports oriented to collecting information on users, vouchers, user preferences and activity, marketing, companies and so on.

As mentioned previously, neither the mobile application nor the JavaScript part of the website should access the database directly. For this purpose, we have developed an API for performing any operation needed for the database; giving in addition facilities for logging, registration and user activation, as well as voucher retrieving. Thus, the information is protected as a layer over the database, normalizing the access and allowing the adaptation of the input/output to each scenario. The API acts on the server side and has been developed using PHP and giving outputs formatted as a JSON object.

The web services provided by the API also agglomerate the operations for the synchronization. Generally, this kind of system gives an output based on a few inputs. WingBonus implements a complete system that receives all the data to be updated from the mobile application and operates over the database. Later, the services give a JSON response with the data requested by the mobile application, letting the device updated and fixing the date of the synchronization process.

5.5 WingBonus Mobile Application

The WingBonus mobile application allows checking and downloading vouchers anywhere at any time, with the purpose of carrying them in the phone and solving the problem of paper coupons or loyalty cards (forgetting them or loss). Besides this, the mobile application allows getting vouchers by means of smart posters and using it with the advantages that NFC technology provides, or QR codes in case NFC is not supported by the phone device. The mobile application has been developed for the Android 2.3 (or later) and RIM 7.1 operating systems.

The first time the user runs the application, the screen of Figure 5(a) is shown. The application distinguishes between anonymous and registered users. If the user is registered, he/she has to introduce his/her credentials on the login form. Anonymous users have limited use while authenticated users can access the whole system functionality without restrictions. Both types of users can customize the application through the preference windows (see Figure 5(b)), different options such as, the number of coupons shown, the sorting order, favorite categories and activate nearness and expiration notifications of vouchers, can be set up.

Once the user is identified (being registered or anonymous), the mobile application shows the main menu (Figure 5(c)). From this menu, users can perform any operation implemented in the WingBonus system. Thereby, users can download coupons (see Figure 5(d)), view a single coupon detail (Figure 5(e)), remove coupons, use a coupon or download a loyalty card (Figure 5(f)) among other actions.

Figure 5. Some WingBonus mobile applications snapshots.

WingBonus mobile allows storing an unlimited number of electronic vouchers. As Figure 5(g) shows, vouchers are organized in containers, identifying the different provider campaigns or companies. In addition, containers could be organized in folders. Folders identify the different business activities and different campaigns using different images and they may be assigned different requirements or characteristics depending on company politics.

By default, the application installs the WingBonus container. This container can never be deleted. Installation of any other container or folder is automatically performed during the synchronization process when a voucher belonging to the container or folder is provisioned. Loyalty cards also are stored and shown to the users in the folders (see Figure 5(f)). Both containers and folders are easily accessible from the main menu.

Mobile application permits the user to view the existing voucher offers that fits the user preferences (see Figure 5(b)). Selected and marked vouchers are temporally stored in the mobile database, until in the next secure synchronization process the vouchers are checked against the server database and provisioned to the mobile database.

Although in some synchronizations the amount of transferred information between mobile and server applications may be small (few number of vouchers), usually the synchronization process will require the exchanged of new preferences, download and upload of vouchers, etc. In any case, the time required is negligible. During this process, all user data is checked on the server, and fake or inconsistent vouchers are erased.

In addition, vouchers can also be acquired through smart posters. The storage capacity of an RFID tag is enough to store a complete electronic voucher. Two types of supplying are possible using smart posters:

- The smart poster has a tag storing a “mark record”. When the user touches the tag, the record is transferred via NFC and stored in the mobile database. Then, the record is used to download the voucher as if it had been marked directly from the Website.
- The tag stores the provisioned voucher, so the user will receive the full voucher information without a further synchronization against the server. This last type of voucher is only implemented for unsecured vouchers or in case the provider wants the broadcasting of an offer without control.

How offers are shown is completely dependent on user preferences. User can view a summary of stored vouchers with the possibility to access the detailed information, as shown in Figure 5(h).

The most important feature of WingBonus is the secure exchange of coupons using NFC (Figure 5(i)). A voucher that has been already provided and stored in the mobile phone database can be exchanged selecting the appropriate option from the detailed view of such voucher. The mobile application supports two ways to redeem vouchers:

- The SNEP Specification (NFC Simple NDEF Exchange Protocol) [63] allows an application on an NFC-enabled device to exchange NFC Data Exchange Format (NDEF) messages with another NFC Forum device when operating in NFC Forum peer-to-peer mode. The protocol makes use of the Logical Link Control Protocol (LLCP) connection-oriented transport mode to provide a reliable data exchange. Using the SNEP in order to send the information of the voucher to the NFC reader, and wait for a reply that is sent from the server to the mobile phone through the NFC reader in order to complete the P2P communication. By using this technology, users can also exchange vouchers between them. Thus, the user sends the voucher identification to another user by NFC P2P. Using this identification, the second user will download the transferred voucher. A confirmation signal is sent back by the server to both users for accepting or cancelling the process.
- Although the ideal exchange method is NFC, redemption can be performed through QR codes and traditional barcodes. WingBonus uses the ZXing [64] core, in order to generate the QR barcode that contains all the information needed to redeem the voucher (Figure 5(j)). This QR code is shown by the mobile application and read by the barcode reader. The information read is taken by the controller and sent securely to the server, which is responsible for checking the integrity. If the information is properly verified, a confirmation

message is displayed on the controller and the voucher is redeemed.

WingBonus mobile also supports traditional barcode formats like EAN13. These codes can save thirteen characters, some of which are reserved for convention, allowing a minimum storage capacity. The store can read the barcode and redeem the voucher, but the server cannot verify the integrity. This procedure is maintained to facilitate the integration of the application on the market but is strongly discouraged.

5.6 Discussion and Remarks

The combination of NFC with the growing success of mobile technology will allow, in the near future, the development of "ideally" smart environments, which were conceived decades ago. The application of NFC to marketing models of companies offers several advantages over existing systems.

There are several and important companies that provide discount and offer services, however, getting and using coupons is not always easy. The main weak point is the client's interaction with the coupon and the company or system that serves the product or service. The use of NFC and its application in mobile devices provides users with an easy way to acquire, store, manage and use vouchers. Besides, these features make the process fast, secure, efficient and transparent.

The system described in this paper has the advantage of the consideration of any type of vouchers: discount coupons, bonds and chits. In addition, loyalty cards are also considered and the card operations such as chit operations are managed. Managing marketing campaigns in containers and folders, WingBonus provides a powerful diffusion tool for companies and their marketing activities, as well as an easy way for the users to manage offers.

In addition, WingBonus can be fully tailored to different marketing strategies. Thus, each campaign and type of voucher can be adapted to a different security level, source of distribution and retailer infrastructure. This versatility allows its application for companies of different size and commercial sector.

WingBonus allows consumers to take advantage of all offers made by companies. This guarantees a huge savings on the purchase of consumer products. Vouchers and loyalty cards are carried on the mobile phone without any possibility of fraud, loss or forgetting.

For partner companies, WingBonus offers great advantages: cost reductions, elimination of paper and/or plastic supports, reaching more customers, elimination of forgeries, real time tracking, market analysis, study of trends, capability to build customer loyalty, etc. Moreover, the commerce where the vouchers are adopted benefits from the speed and safety of the process.

Currently, we are working on the improvement of the system described in this paper in order to add new features and also allow the storage of the offers in the secure element of the NFC phone. In addition, we are combining the marketing based on vouchers and loyalty cards with marketing based on gaming, thus offering new models for attracting loyal customers to companies.

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6 | A Ubiquitous and Non Intrusive System for Pervasive Advertising Using NFC and Geolocation Technologies and Air Hand Gestures

El contenido de este capítulo ha sido aceptado para publicación en la revista *Mobile Information System* con la siguiente referencia de publicación:

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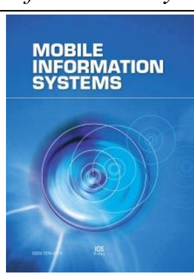
<tr><td rowspan="2">
</td><td colspan="4">Mobile Information Systems 10, (2014) 364-384</td></tr>
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Las nuevas tecnologías móviles han revolucionado las estrategias de marketing. Hoy en día, más del 75% de la población tiene un Smartphone conectado casi las 24 horas del día a internet. Por ello, las estrategias de marketing se centran en clientes móviles, ofreciéndoles aquello que quieren en el momento y lugar en el que el cliente está.

La tecnología de geolocalización permite a las empresas conocer donde están sus clientes y ofrecerles la mejor oferta cercana a los mismos. Los clientes buscan y desean recibir información de tiendas cercanas, ofertas y cupones descuento, donde uno de cada cuatro clientes utilizan estas ofertas en las próximas 24 horas tras la recepción de las mismas.

En este capítulo se presenta un sistema, denominado WingPosts, para publicidad. WingPosts es un sistema ubicuo que permite a los anunciantes difundir sus anuncios en cualquier momento y lugar y dirigirlos a los usuarios apropiados. WingPosts integra tecnologías NFC, geolocalización y tecnología gestual. Con este sistema, los anuncios estarán situados en postes virtuales que difundirán los anuncios en cualquier momento y lugar. Estos postes virtuales almacenan múltiples anuncios que contienen información textual, gráfica o multimedia. Estos anuncios son automáticamente mostrados en el teléfono móvil del usuario utilizando un proceso de notificación teniendo en cuenta la localización del usuario con respecto a los postes y considerando en todo momento las preferencias que han definido los usuarios para la recepción de anuncios.

6 A UBIQUITOUS AND NON-INTRUSIVE SYSTEM FOR PERVASIVE ADVERTISING USING NFC AND GEOLOCATION TECHNOLOGIES AND AIR HAND GESTURES

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ABSTRACT. In this paper we present a pervasive proposal for advertising using mobile phones, Near Field Communication, geolocation and air hand gestures. Advertising post built by users in public/private spaces can store multiple ads containing any kind of textual, graphic or multimedia information. Ads are automatically shows in the mobile phone of the users using a notification based process considering relative user location between the posts and the user preferences. Moreover, Ads can be stored and retrieved from the post using hand gestures and Near Field Communication technology. Secure management of information about users, posts, and notifications and the use of instant messaging enable the development of systems to extend the current advertising strategies based on Web, large displays or digital signage.

KEYWORDS. *Advertising, air hand gesture, geolocation, Near Field Communication, pervasive applications.*

6.1 Introduction

The concept of "Smart Cities" has attracted considerable attention in the context of urban development policies. The Internet and broadband network technologies as enablers of e-services are becoming more and more important for urban development while cities are increasingly assuming a critical role as drivers of innovation in areas such as health, inclusion, environment and business [1].

The evolution towards a future information and knowledge society is characterized by the development of personalized individual as well as collective services that exploit new qualities of infrastructures and components situated in a smart environment [2]. They are based on a range of ubiquitous and pervasive communication networks providing ambient computing and communication at multiple levels.

Ambient intelligence (AmI) represents a vision of the future where intelligent or smart environments and systems react in an attentive, adaptive and active way to the presence and activities of humans and objects in order to provide intelligent/smart services to the inhabitants of these environments. AmI paradigm aims to develop environments able to interact with the user in an autonomous way in order to make life easier for people in different fields [3]. Olaru et al. [4] see an Ambient Intelligence environment as a large number of devices that serve the needs of their respective users. The devices are mostly going to deal with information: delivering relevant information to interested users, aggregating, filtering and reasoning about the information.

Derived from the concept of Ubiquitous Computing introduced by Weiser [5], the term of Ambient Intelligence was coined at the beginning of the 21st century to describe a ubiquitous electronic environment that would pro-actively, but sensibly and non-intrusively support people in their daily lives [6].

A technology that facilitates the achievement of the AmI objectives is Near Field Communication (NFC) [7]. NFC simplifies the users interactions with the context-aware-services offered in intelligent environments, also promoting a new interaction model, called "*touch paradigm*".

It is difficult to talk about Ambient Intelligence without mentioning context-awareness. Context-awareness means that one is able to use context information. A system is context-aware if it can extract, interpret and use context information and adapt its functionality to the current context of use [8]. The term context-aware computing is commonly understood by those working in context-aware, where it is felt that context is a key in their efforts to disperse and transparently weave computer technology into our lives. One goal of context-aware systems is to acquire and utilize information in the context of a device in order to provide services that are appropriate to the particular people, place, time, event, etc. These systems aim to provide context-aware access to information, communication and computation.

The most critical aspects of context-aware are location. Location-awareness concerns the use of information about an individual's current location to provide more relevant information and services to that individual [9]. Location-awareness is a special type of context-awareness. Location-aware computing environments offer the capability for automatic, regular, and real-time sensing of a person's location with a high degree of spatial and temporal precision and accuracy. Together with technological advances in mobile computing and wireless communication, which enable rapid processing and communication of location information, these developments allow the location of mobile individuals to be tracked in a way never before possible.

This paper presents a framework called WingPosts [10]. WingPosts is a ubiquitous system which enables users to spread their ads at any time, any place and directed to the appropriate user. Thus, the visibility of your products and services is increased instantaneously. WingPosts integrates NFC technology, geolocatization and hand gestures. With WingPosts, the ads will be located in virtual posts which allow users to access ads anytime and anywhere.

Virtual posts built by users in public/private spaces can store multiple ads containing any kind of textual, graphic or multimedia information. Ads are automatically shown on the mobile phone of the users using a notification based process considering relative user location between the posts and user preferences.

The paper begins with a review of the research on digital advertising. It is followed by a description of the context. In sections 4, 5 and 6 we present the data model, the interaction model and the pervasive functional model respectively. Section 7 describes the system test. WingPosts system (Website and Mobile) is described at the Section 8. Finally, Section 9 presents the conclusions.

6.2 Related Works

Most people have become used to the traditional way of experiencing and consuming advertisements as part of their daily lives. The success of advertisements and their value for the individual is defined by type, content and placement (in terms of location and time) [11].

Mobile advertisements are effective due to user's immediate and personal attention to mobile devices. When combined with location-based information, the effectiveness is shown to be even higher. Many industry surveys estimate the potential market for mobile advertisements in billions of dollars per year. There is a need to design and evaluate artifacts to study mobile advertising and transactions [12].

Omntrakul et al. [13] reports a recent development of one advertising system (called AdTouch) based on QR barcodes. This paper offers a set of comprehensive services for advertisers and publishers to market their printable 2D-barcode ads in different media, including barcode-based ad posting, distributing, detecting and capturing using Android mobile devices.

Aalto et al. [14] introduce a novel B-MAD (Bluetooth Mobile Advertising) system for delivering permission-based location-aware mobile advertisements to mobile phones using Bluetooth positioning and Wireless

Application Protocol (WAP) Push. The system was not specifically designed with privacy and security issues in mind. Device address data sent form a Bluetooth sensor to the server is not encrypted.

Haddadi et al [15] introduce MobiAd, a scalable, location-aware, personalized and private advertising system for mobile platforms. They present a first proposal for personalized, localized and targeted advertising on smart phones. Utilizing the wealth of information available on the phone, MobiAd presents the user with local ads in a privacy preserving manner.

Location-aware mobile advertising involves sending content-rich messages to users in certain locations, where size of the location identified by advertisers or users, or to users in any location, using user preferences. The effectiveness of location-aware mobile advertising is high especially if these messages can be highly targeted and time-specific. The effectiveness of location-aware advertising can be further improved by using contexts derived from multiple sets of information.

The basic ideas behind context-awareness are to create pro-active and smart operation of artifacts by minimizing user efforts and interactions, creating a very high level of intelligence in the systems, adding adaptability and effective decision making, and increasing the level of customization and personalization for users [12].

6.3 Description of the Context

Dey et al. [16] proposes a general definition of context as: "*any information that can be used to characterize the situation of an entity*". An entity is a person, place or object that is considered relevant to the interaction between the user and an application, including the user and the application themselves and, if the application is context-aware, it should provide relevant information and/or services to the user, where relevancy depends on the user tasks.

Context definition implies the enumeration and full descriptions of all actors involved in the application. The depth and characteristics of this definition depend on the actors' nature and the tasks of these actors' development in the systems. Formal definitions of the context have been proposed [17] showing the complexity of this activity for pervasive and context-aware applications. Benou et al. [18] proposes that in order to facilitate the design and development processes of applications a solid perception of concepts and structures related to context capturing and management is required, defining that the context information of an m-commerce application is every piece of information which may be used to characterize a state of an entity, which can be considered to be relevant to the interaction of the user with the particular application. Authors classify the entities involved in the context in four groups: user domain, computing domain, environment domain and application-specific domain, and they propose the use of Entity-Relationship diagrams to represent the relationships between them, and also to classify the relationships in each of these groups, considering the group in which the main entity involved is. This is a rigid classification, so in the pervasive mobile application an entity can be considered in more than one of these domain groups, taking two aspects into consideration: a) the real location of the entity, and b) the virtuality of the entity, that is, if in the behaviour of the entity it acts as real or virtual.

6.3.1 The main elements of the context

Our proposal considers the following main entities (see Fig. 1): users, posts and ads, and two entities classified within the computing domain: the mobile device and the server side.

A user is any person using the application (here, we do not consider administrator roles). A user publishes ads and/or receives ads from the surrounding environment, that is, the real world. User preferences and user grants determine the behaviour of the user in the environment and how other entities can relate to the user.

The posts are signages used by users to publish ads. Signages are located in the environment and their properties characterize the type of ads that the posts can support and the way of the users can receive information from them.

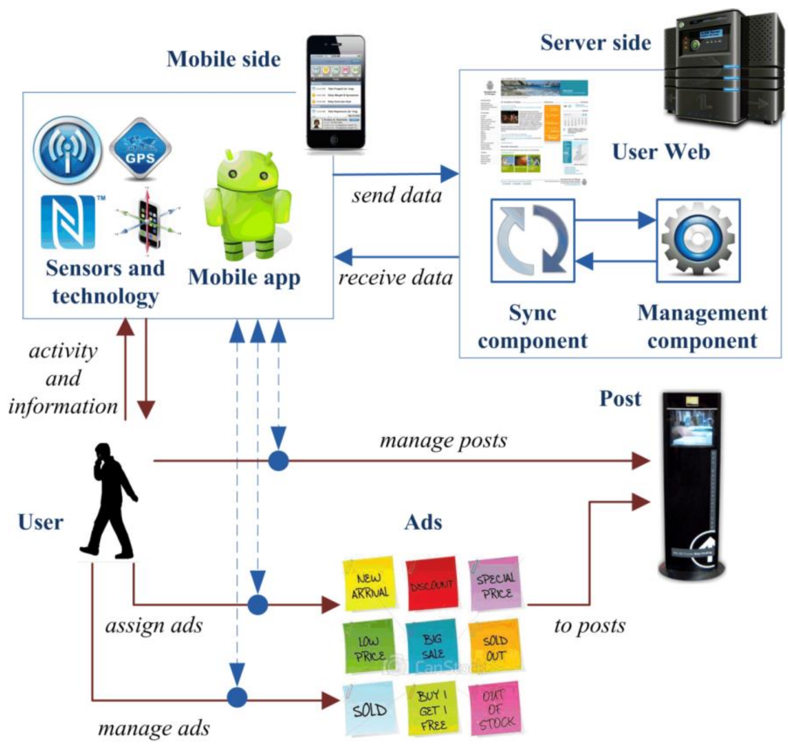


Figure 1. Context description showing the main entities and their relationships.

From the environment point of view, two types of posts are considered: a) real posts, and b) virtual posts. A real post is any physical pole or signage located in the real world (i.e. JCDecaux posts [19]), whereas virtual posts are not physical posts. Any of these types of posts have an associated a location in the real world, and a set of properties determining their relationships with users and ads, the actions that the users can perform with the posts, and how these actions can be carried out.

In our proposal, real posts can be located in indoor and outdoor spaces; however, virtual posts can only be located in outdoor spaces. Moreover, the interaction of the users with posts depends on the post type: a virtual post only supports gesture based interactions, while a real post supports gestures and NFC based interactions. On the other hand, posts can be public and private: a public post allows any user to use it to store ads, while a private post has its use restricted to its owner. Virtual and real posts can be either public or private.

Ads are advertising “hanging in the posts” by users with the aims of being disseminated to the largest number of people. Ads can contain any kind of information (textual, graphic, and multimedia) determining the user preferences as to how this information would be received.

6.3.2 The computing entities of the context

Two computing elements have been considered (see Fig. 1): a) the server side, and b) the mobile side. The server side is composed of a set of subsystems or applications aimed at the management of the information (management component), the communication with the mobile side (synchronization component) and the publicity of the information to the users (Web portal).

The management component is responsible for the context management. The information about the context elements is stored and managed by this component. The management component stores information consisting of identification, state, tasks and actions performed with other entities, so the mobile side is only in charge of managing the basic information necessary for the interaction of the user with the environment.

The synchronization component is responsible for the communication between the server and the mobile side. This communication ensures the reliability of the information allowing the interaction of the users with the remaining context entities. Finally, the web portal is devoted to the management of ads and posts information and user registration.

The mobile side is composed of two components: a mobile phone and the mobile application. The mobile phone should be provided with movement sensors, such as an accelerometer and a compass, in order to support air hand gesture based interactions, and NFC chip to supports Near Field Communication interactions. In addition, mobile phones should support GPS and wireless technologies.

Mobile applications running in the mobile phone is in charge of supporting user interaction with the environment and communication with the server side.

6.3.3 The relationship between the entities of the context

The entities of the context are related to each other by means of the user activity. User activity is gathered by the mobile device through the mobile application using different mobile components (movement sensors, GPS and NFC chip) and application interface.

Application interface allows users the management of personal information, and the information related to own posts and ads. The user creates ads and assigns them to public posts and posts created by the user, by means of the mobile application interface. Furthermore, the application allows the user to interact with the user Website.

In addition, the assignation of ads to posts can be performed according to the post characteristics. Indoor posts, always real posts, should support RFID tags devoted to storing tag identification. Thus, NFC technology is used for interacting with these posts: the user touching the post with the phone enabled with NFC can store and retrieve the ads from the post. In the case of outdoor posts (real or virtual posts), the user can interact with them using NFC, only if the post is augmented with a tag, and by means of air hand gestures. Gesture communication allows the user to interact with the posts without needing to touch it. Thus the user can store and retrieve ads from outdoor posts with two simple gestures: throwing, for storing, and shaking for retrieving ads.

Table 1. Relationship between the active entities of the model and description of activities and participating technology

Entity	Activities	Related Entity	Participating technology	Description
User	manage user data	*User Web, mobile phone*	Web, Wireless	*Interact with the user web portal for registration, management of personal data, information and download of the mobile application*
	manage posts	*Post, mobile app, sync component*	GPS, NFC, Wireless, Movement sensors	*get the user GPS to be used as post location* *store and retrieve post data and ads* *communicate with sync component sending and retrieving post data*
	show posts	*Post, mobile app, sync component*	GPS, NFC, Wireless, Movement sensors	*retrieve posts information based on user location from server side using the sync component*
	manage ads	*Ads, mobile app, sync component*	NFC, Wireless	*store and retrieve ads data* *communicate with sync component sending and retrieving post data*
	assign ads	*Ads, Posts*	NFC, Wireless	*store and retrieve ads data in posts* *communicate with sync component sending and retrieving information*
	show ads	*Post*	GPS, NFC, Wireless, Movement sensors	*retrieve ads information from posts based on user location from server side using the sync component*
Server side	manage data	*sync component*	Web, Wireless	*manage information in server database and respond to requests sending by the sync component*
Sync component	request dispatcher	*mobile app, server side*	Wireless	*receive request from mobile app, transfer the request to the server side, receive the response and send back the answer to the mobile app*
User Web	manage user data	*User*	Web, Wireless	*manage user data for registration and downloading of the mobile application*

Finally, users and the server side are related by means of the synchronization component. User actions of storing and retrieving are sent by the mobile application to the synchronization component. This component is in charge of initiating the necessary agents of the server side to respond to the user request, receiving the result and sending it back to the mobile application to be shown to the user.

In addition, the server side interacts with the mobile application using the notification system. User preferences determine the latency of this process consisting of sending information about the user location to the synchronization component (gathered from the GPS sensor) and user preferences. This information is used by the server side to retrieve information on ads and posts matching the query and send it back to the user as notifications.

While posts and ads are non-active entities, a set of activities or functionalities should be modelled for the remaining active entities. Table 1 shows the relationship between the entities for some of the main functionalities that the active entities should perform. Each activity requires the use of different technology to be performed. If technology is available in the mobile device, the mobile application should set it without user participation; if the technology is not available in the mobile device or it cannot be used for any reason, then the activity cannot be performed.

6.4 Data Model

The system described in this paper is basically a proposal for pervasive advertising based on the diffusion of personalized ads by means of virtual and real ads signages. The pervasive advertising is carried out using novelty technology such as geolocation, NFC, as well as easy user interfaces based on air hand gestures.

As Fig. 2 shows, the user information stored in the system is closely similar to any other instant messaging or web advertising system. Users are uniquely identified by different attributes defined as unique keys: a) *iduser*, system-defined user identification, b) *email*, and c) *phone*. Thus, no different users can be registered using the same email or phone number, because communication and advertising notifications to users are carried out using these attributes. The *Users* class also involves other attributes devoted to storing information about registration, status, user data, and so on.

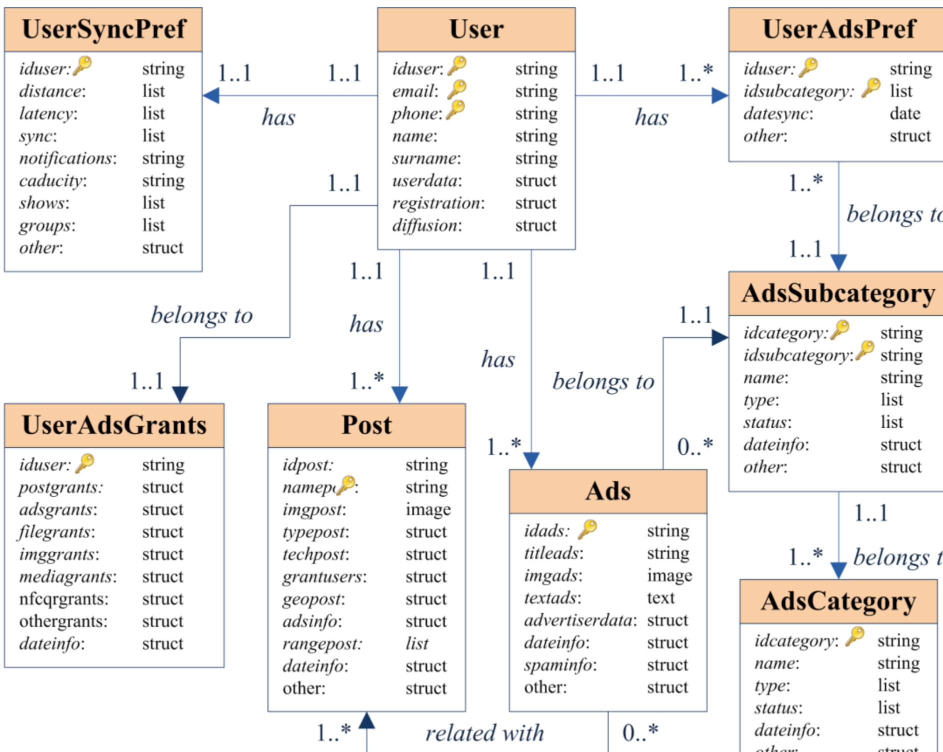


Figure 2. Main information objects of the system.

Communication between users, environment, mobile application and the server side is performed following the set of user preferences managed by the class *UserSyncPref*. The attribute *distance* stores information on the behaviour of the user in the environment, this attribute informs the range a user is able to detect a post. Thus, depending of the relative locations of the user and the posts, only some posts may be detected by the user.

Two other attributes, *sync* and *latency*, enable the refining of user behaviour in the environment. These attributes store the synchronization interval to communicate with the server side to send it the user location. The correct knowledge about the Information of user location will determine whether the user may detect a post or not, taking into account the fact that the user is usually moving. The attribute *latency* stores information about how quickly the user will receive the notifications. Notifications about detected posts may be received immediately or at an interval defined by the user. This attribute tries to avoid an overload of notifications at all times.

Other attributes of the *UserSyncPref* class are devoted to storing user preferences on the mobile application behaviour, for instance, how notifications should be shown or grouped, the number of notifications to be shown, notification expiry, etc.

The type of notifications the user may receive are also determined by the user preferences defined in the *UserAdsPref* class. This class stores the set of ad types wished by the user to be received. The types of ads are defined at two levels using the classes *AdsCategory* and *AdsSubcategory* as shown in Fig. 2.

Categories are defined in a set of predefined types as in any other advertising system. This is an open list managed by the system administrator. Each category is refined in one, at least, or many subcategories. This system, close to the well-known web advertising systems, allows easy and full classifying of any type of ads.

The other main objects of the proposal are the classes *Post* and *Ads*. The class *Post* describes virtual or real posts used to stored ads. Each post belongs to only one user, having a unique identification, and a set of information attributes devoted to its description (*namepost*, *imgpost*, between others). Posts have an associated location stored by the attribute *geopost*, and a set of attributes describing date information (creation, update, expiry, etc.) represented in Fig. 2 by the attribute *dateinfo*.

The attributes *typepost*, *techpost*, *grantusers* and *adsinfo* in the class *Post* of Fig. 2, represent a set of attributes aimed to store information about the post behaviour in the environment, and the type of interaction of the user with the post. Hence, the posts can be defined as public or private, allowing other users to be able to store ads in a post belonging to other owners. Moreover, posts can be virtual or real, and, therefore, they can include a tag or not. Furthermore, a post owner also determines if the post admits user interaction by gestures or not. For instance, the owner may wish that the user always touches a real post with a tag in order to read the post information as well as the ads poster, so gesture interaction would not be allowed because gestures could be performed far from the post.

Attributes *grantinfo* and *adsinfo*, shown in Fig. 2, describe a set of attributes also aimed to represent the behaviour of the user with the posts. Thus, a set of attributes are used to store the user activity allowed for the post. For instance, in public posts users could store ads or not, with only a maximum number of ads, ads without images, ads of predefined categories, etc. In addition, the attribute *rangepost* allows the post owner to define the visibility range of the post. Thus, post ads can only be accessed if the user is in the distance range defined by the post, regardless of the value of the attribute *distance* defined in the user preferences.

We can observe that the set of attributes or characteristics defined by the posts allows us to build pervasive and tailored advertising scenarios, by means of the posts characteristics determining their behaviour with the user interaction.

As Fig. 2 shows, the creation of posts and ads is independent. Users can create posts without any ads associated, and ads not necessarily associated to posts. Ads characteristics are described in the class *Ads* of Fig. 2. Each ad belongs to only one user and it is uniquely identified. Usual information on ads is considered such as: title, image and a text describing the ads in full. Furthermore, the class Ads store information about important date: creation, update, expiry, etc., and the visible information of the ad owner in order to be shown to other users when the ad is notified.

Finally, other attributes store add information about the tag, so ads can store web address, sets of images, videos, etc., the attribute *spaminfo* being used to specify how this information will be transferred and shown to the users.

6.5 Interaction Model: air hand gesture, location and NFC

The interaction of the user with the posts can be performed using two different interaction paradigms: "*TouchMe*" and "*PullMe*" paradigms (see Fig. 3).

The concept of physical browsing was suggested as a natural way to improve the usability of mobile devices and to enable interaction with digital services associated with real world objects in the environment. The concept of physical browsing supports three user interface paradigms: *ScanMe* (the phone device is used to scan an augmented object), *PointMe* (the user points to objects gathering information) and *TouchMe* (the user touches an object) [20][21].

TouchMe paradigm is proposed thanks to the development of the Near Field Communication technology (NFC). Thus, real world objects can be augmented with a RFID tag storing any kind of information or digital services, and users with a supported NFC mobile phone can gather that information and service from the object simply by touching it. The need for proximity between the object and the phone device guarantee the security of the transference process, allowing the application of this paradigm to a wide range of applications including the secure payment [22].

Gesture based interactions in pervasive systems using augmented scenarios has been widely considered lately, due to it being easy-to-use and quite intuitive. The idea is to replace or to improve the menu navigation and manual configuration of services by simple and intuitive hand gestures with the mobile phone. Similar to the *TouchMe*, *PointMe* or *ScanMe* paradigm, Heiske [23] proposes the *PullMe* paradigm.

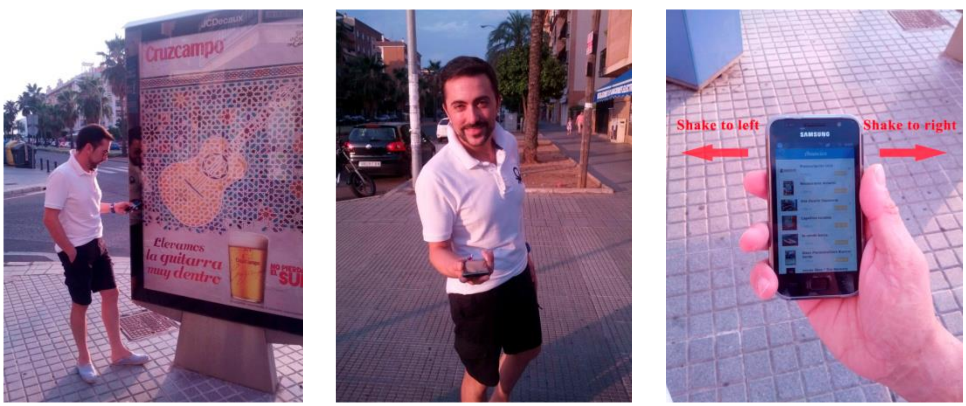
PullMe paradigm is based on the gathering of information or services from augmented objects disseminated in smart scenarios by simply performing a gesture of movement of the phone away with a swift pull-away gesture, respectively. The author describes an application of this paradigm to collect information from billboards. Billboards and phones equipped with RFID are enabled to detect each other, so the users move closer his/her phone to the billboard, detects the billboard by means of its RFID identification and he/she makes a “pull me” movement retrieving the information associated to the billboard. The main drawback to this application is the requirement of proximity. The user needs to touch or bring near his/her phone to the augmented object in order to gather the information from the object, so this approximation does not improve the TouchMe paradigm at all with standard NFC based applications.

Borrego-Jaraba et al. [24], extend the application of the *PullMe* paradigm in an application called WingTrapper. In this application, the user, performing a “throwing and catching” movement, is able to capture “Trappies” (gifts or rewards located in any place of the surrounding environment). Current user location and stored “Trappies” locations are considered by the system, as well as measurements of the phone sensors, in order to determine the capture or not of a gift by the user. Therefore, this proposal avoids the need for contact proximity between the user and the augmented object.

In the system described in this paper, *TouchMe* and *PullMe* interaction paradigms have been considered. The interaction model will depend on the post type and its characteristics. While real posts are real word objects existing in a real scenario, virtual posts do not exist physically. Real posts supporting RFID tags allows users to close the post and, by touching the tag with a NFC enabled phone interacting with it, write and reads ads. Thus, real posts support the *TouchMe* interaction model (Fig. 3a).

Furthermore, both real and virtual posts are uniquely identified and they have an associated unique location. The knowledge of both post and user location as well as the consideration of the user preferences allows us to apply the *PullMe* paradigm to the interaction of the users with any kind of post. Two types of interaction can be carried out by the user with the posts using the *PullMe* paradigm, as we will describe in depth in the next section: a) publish ads, and b) reads ads. These interactions are carried out by means of user air hand gestures; the user with the phone device in his/her hand makes an intuitive and non-intrusive movement.

Air hand gestures are detected using the movement sensor of the phone, by means of the accelerometer and compass. Fig. 3b shows the gesture modelled for the publishing ads interaction and Fig. 3c shows the gesture modelled for the read ads interaction.



(a) (b) (c)

Figure 3. Use of *TouchMe* and *PullMe* paradigm

Publish ads interaction is performed with a “throwing” movement. The user with the mobile phone in his/her hand makes a pull away movement to publish the select ad in one of the allowed surrounding posts (Fig. 3b). The permitted posts are determined considering the relative user and post location, the post grants (specified in the attribute *grantusers* of the *Post* class) and the user preferences on activity range (attribute *distance* of the *UserSyncPref* class).

Thus, after the "throwing" movement, the allowed posts are shown to the user in the interface of the mobile application, the user choosing the desired post from the list to publish the ads.

The reading of ads, as we describe in the next section, can be carried out by the user in two ways: a) by advising, and b) by searching.

Reading by advising does not require user hand gestures. Considering the user preferences, user location, location of the posts in the environment and the ads published in the posts, the user receives ad notifications in his/her mobile phone, deciding if he/she wishes to read them or not.

Reading by searching can be also performed without hand gesture, simply using the application functionality defined by the "search" process and/or a mandatory synchronization with the server side, and using hand gesture.

The reading by searching process based on gesture is composed of a simple gesture. Fig. 3c shows the searching gesture, in which the user makes a "shake" gesture with the phone in his/her hand in order to detect the ads and their corresponding post satisfying the search criteria or user preferences. This gesture allows recovery of the list of ads and post matching the search, shown to the user in the interface of the mobile application as new notifications.

The "throwing" movement user for publishing ads is a well-known movement previously used by different applications for transferring information between devices or users. That is an accepted movement needing just the measurement of the accelerometer sensor for its recognition.

The shaking gesture proposed by the searching and reading process is also a simple and non-intrusive movement. The user just only has to shake the hand and the process is initiated. The recognition of this gesture only requires the control of accelerometer sensor. Accelerometer is used for the recognition of a continuous hand movement of at least of 2 seconds.

6.6 Pervasive Functional Model

The system server component incorporates all the functionality for the management of ads and user posts. Logged users can manage this functionality from the mobile application as well as a laptop. However, a pervasive system should allow the users to interact with the environment in a more natural way.

Thus, the main functionality of our proposal is to publish ads and to receive, with or without user participation, desired ads from the surrounding real world. The user context defined by the user location determines the environment behaviour, consisting of sending notifications to the user about the desired advertising, as well as allowing the user the publication of advertising in a fully smart augmented environment.

Ads are the core of the system. Users can create ads using the mobile application, these ads being stored in the server database. Ads are independent of the posts, so they can be linked to posts or not.

Posts have an associated location, so the management of posts requires assigning to a post its latitude and longitude position. The GPS post position can be given manually by the user or gathered from the mobile device at the location where the user desires create a post.

Users can assign their ads to their posts using the mobile application interface without needing to be located near the post. Thus, the user selects an ad and assigns it to one or more of his/her own posts. However, users can also assign ads to public posts whether supporting or not NFC tags. If the post has a NFC tag associated, the process is quite simple. The user selects the ads from the mobile application and he/she touches the tag associated to the post, after which synchronization is established with the server and, if the process is allowed, the information is stored in the database.

If the post has no associated NFC tag, that is, it is an outdoor public virtual post, the user can use the web or mobile applications by selecting the desired posts to perform the process.

As observed in the sequence diagram of Fig. 4 (top), the first step is the location of the post using the searching process. This process can be performed using shake gesture or by means of the search function, gathering the list of posts located within the range of distance to the user location established by the user in its preferences. Next, the user selects the desired post from the list and, using a throwing gesture or an option of the mobile application, assigns the ads to the post. Once the public post has associated and user ads, the post is stored as user post not requiring the user to be near the post for later assignation of new ads or to delete the ads from the post.

Furthermore, the pervasive advertising system proposed in this paper is based on a tailored ads notification system. Based on user location and user preferences, the system sends notifications to the user corresponding with ads that fulfil user preferences.

This process is performed without user participation as is shown in Fig. 4 (bottom). Mobile application gathers user location at time intervals defined in the user preferences, synchronizing with the server. Next, server agents devoted to this process retrieve user preferences and the posts fulfil the distance range defined by the user. Finally, a matching between the ad categories stored in the database for the retrieved posts and user preferences is carried out, obtaining the ads to be notified to the user.

6.6.1 An efficient implementation of the pervasive notification process

The pervasive information system (PIS) [25] proposed in this paper requires an efficient implementation in order to provide a quick response to continuous user requests. As described in previous sections, the system should notify users about desired ads at the time the user is moving in the real world. Thus, in a real scenario, users go passing from one real or virtual post to another, and the system must gather the current user location and match user preferences about ad categories, with the ad categories associated to these posts closed to the user.

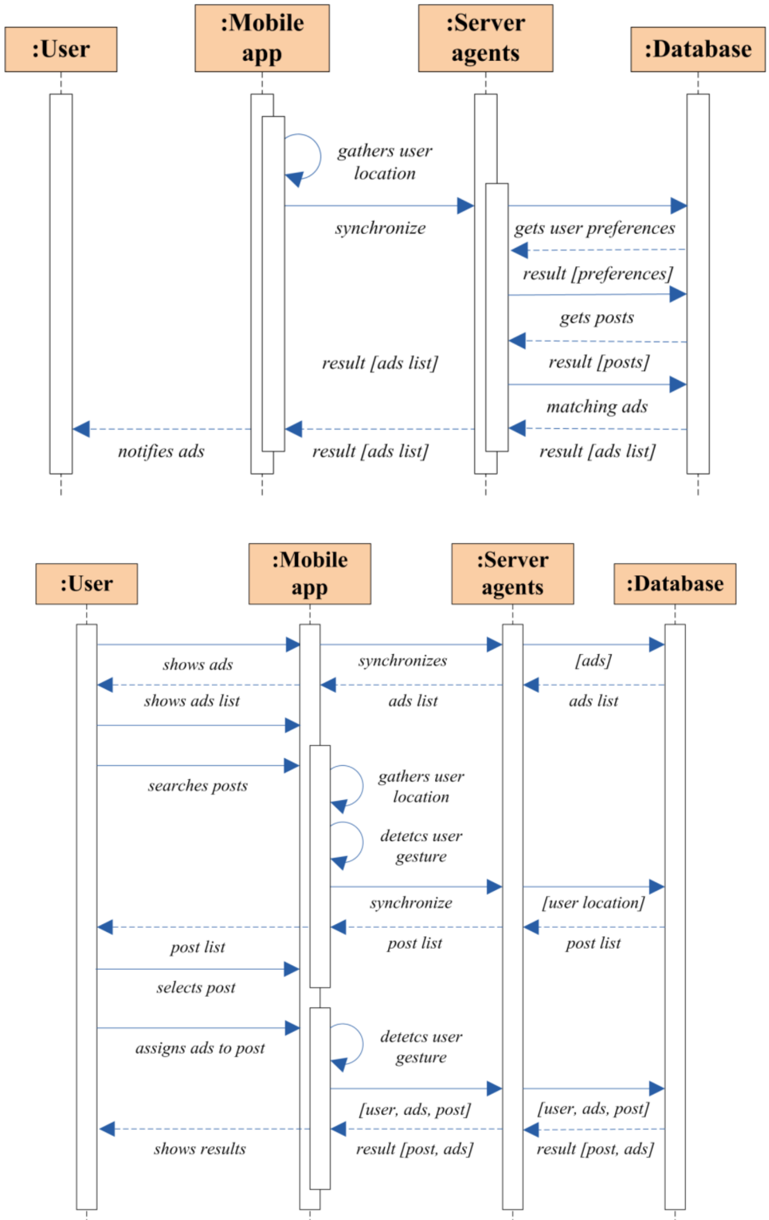


Figure 4. Sequence diagram of the assignation of ads to posts (top) and ads notification process (bottom)

These functional characteristics imply the design of efficient data structures in order to store user preferences, posts and ad information, allowing for fast data retrieving given a high or very high number of requests.

Thus, ads categories and subcategories have been encoded in a fingerprint data representation. Fingerprints are binary array structures used for solve a wide type of problems in computational applications. With this structure an object or entity is represented by a binary array of a predefined size. Each fingerprint element takes values 1 or 0, representing the presence or absence of a property or characteristic in the represented entity.

We have defined a 512 bits fingerprint, large enough to represent the set of all possible ad categories and subcategories. Thus, user preferences about ad notifications are stored in a fingerprint structure, where bits set to 1s represent a user desired category/subcategory. The encode/decode process is carried out by a devoted agent on the server side, updating the user fingerprint structure stored in the server database at the same time the user updates this information using the mobile application.

In addition, a fingerprint structure is also used to represent the category/subcategory associated to ads. Thus, *PostAds* object is defined in the server database to represent the relationship between ads and posts, storing the following information: a) post identification, b) ads fingerprint.

The fingerprint structure is composed of different slices. A first slice is used to represent the different categories. A bit set on in this slice represents the existence of at least one bit set on in the slice corresponding with the subcategory. Therefore, different fingerprint slices are also used to represent all the subcategories corresponding to a category. Bits set on in a subcategory slice represent the presence of a desired subcategory for a user or ads.

6.6.2 An efficient implementation of large geolocated database

Information about the posts is another complex problem to solve in an application where the number of posts can be huge, and it is necessary in real time to know the posts in the activity range of many different users. The activity range of the user is defined by the attribute *distance* of the *UserSyncPref* class (see Fig. 1), so ads notifications should be sent to the user for all those posts located within this distance value, taking into account the user location and the post location.

Post location is known and it is stored in the server database using the attributes *latitude* and *longitude* of the *Post* class. User location is gathered by the mobile application at an interval defined by the attribute *latency*, and this information is sent to the server at an interval defined by the attribute *sync*, both of the *UserSyncPref* class (see Fig.2). Thus, when the synchronization is made, the server needs the calculation between the last user location and posts' locations, selecting all posts within the user activity range.

Then, the process will consist of the calculation between two points (user location and post location) a high number of times (the number of posts can be very large). In order to diminish this calculation it is convenient to diminish the number of comparisons, selecting a subset of appropriate posts. The solution used has been to define points of reference (*PoR*).

A *PoR* is a virtual post system defined for referencing other closest posts by means of a 2D point on the meter scale. In order to have a high performance in the retrieving process we have meshed the locations where posts can be created. Thus, database structures storing information about the countries, cities and towns and for each town a square meshed has been built.

In this mesh creation process, a *PoR* is defined as the centre of each mesh, the number of meshes being determined by the size of the meshed (different for each two) and the distance between the *PoRs*. In most cases, this distance has been taken to 500 meters. In this way, for instance, for the city of Córdoba (Spain), we have initially created a meshed of 625 meshes in an area of 150 square kilometers. Later, this meshed was refined eliminating meshes without any interest, so a final meshed with 322 meshes was considered in the testing of the proposal described in the next section.

PoRs have assigned location information (latitude and longitude) and they are stored in a database structure containing information about their geographical information (country, city, town, meshed and mesh).

Finally, posts' information includes the reference to the closest *PoR*, in order to improve the retrieving performance. Thus, the data structures defined above allow increasing the speed of the matching process. This process is carried out by a devoted agent on the server side as follows:

1. The mobile application synchronizes with the server side when users update his/her user preferences. If preferences on desired ad categories/subcategories are modified, the server side modifies the data structure *UserFingerprint*. User fingerprint view stores user identification and the encoded user preferences.
2. The mobile application sends the user location at an interval of the *sync* attribute or when the user performs the search option. User latitude and longitude values are matched to the closest *PoR*.
3. Depending on the distance value defined for the user to gather information, the closest matched meshes are recovered, considering the size of the meshed.
4. Next, the posts belongs to the recovered *PoRs* are selected, and distance value between the posts values and user location is calculated. Next, posts within the user activity range are chosen from the *PostAds* structure.
5. Finally, a binary match between the user preference fingerprint and the ads preferences fingerprint corresponding to the chosen posts is performed, and those ads satisfying the user preferences are notified to the user.

6.6.3 Tailoring non-intrusive advertising

Intrusive advertising is an invasive marketing technique devoted to steering the consumer towards a product or service [26-29]. While different studies determine that the consumer is attracted to a product thanks to invasive and spam advertising, nowadays consumers consider it as bad marketing strategy and bad publicity, and developing an antipathy towards a business, meaning the marketing campaign has accomplished the opposite of its aim. However, the feeling of intrusive ads varies among consumers, so it is the preferences of each user that determines how intrusive or not the ads are.

Our system personalizes the ads received by users throwing different attributes defined in the user preferences. Thus, user defines the latency of notifications, determining the time interval the ads can be sent to the user automatically. These ads should match the preferences defined by the user about the type and ads content.

Moreover, other user preferences determine the frequency that same ads can be sent to the user. Thus, the user can choose to block ads in some ways: a) permanently, then the ads would never be sent again to the user anyway, b) temporally, so the user determines the interval of time an ad may be sent to the user again.

This information is also stored in the server database, so when a notification with news ads is sent to the user, automatically or by user mandatory, selected ads retrieved considering the user request and user location allocated in the matched posts are filtered regarding to the user ads blocked.

This method avoids spam with repeated and undesired ads to the user, at the same time as reducing the number of notifications to the users when a synchronization of search process is performed.

6.7 Testing the system performance and reliability

We have carried out the feasibility of the proposed data structures and system functionality carrying out many experimental tests. In this section we show the results for two experimental testing the behaviour of the system for the two different scenarios. Processing times have been obtained using a computer with the following characteristic: Intel® Core™ i5 CPU M 480, 2.67GHz, 6 GB de RAM.

6.7.1 First use case

Goal

The objective of this test is to check the performance and robustness of the developed data structures and algorithm for gathering the appropriate posts existing in the scenario to a distance given by the user preferences. In this test, we are going to consider that all ads allocated in the gathered posts match the user preferences. Hence, we only consider the performance of the process to recover those posts that would allocate ads to be sent to the user, not the ads content allocated in those posts.

Scenario

The simulated scenario is the city of Córdoba. Córdoba is medium size city of Spain with a population of around of three hundred thousand, an overall size of 576 km^2. The downtown size is around 16 km^2 and the centre is located at 37.884722°, -4.778889°.

Posts

In this scenario we have studied the performance of the posts recovery for different number of posts. Thus we have considered posts numbers from 10^3 to 10^6 with both random and Gaussian distribution from the centre point of the selected scenario.

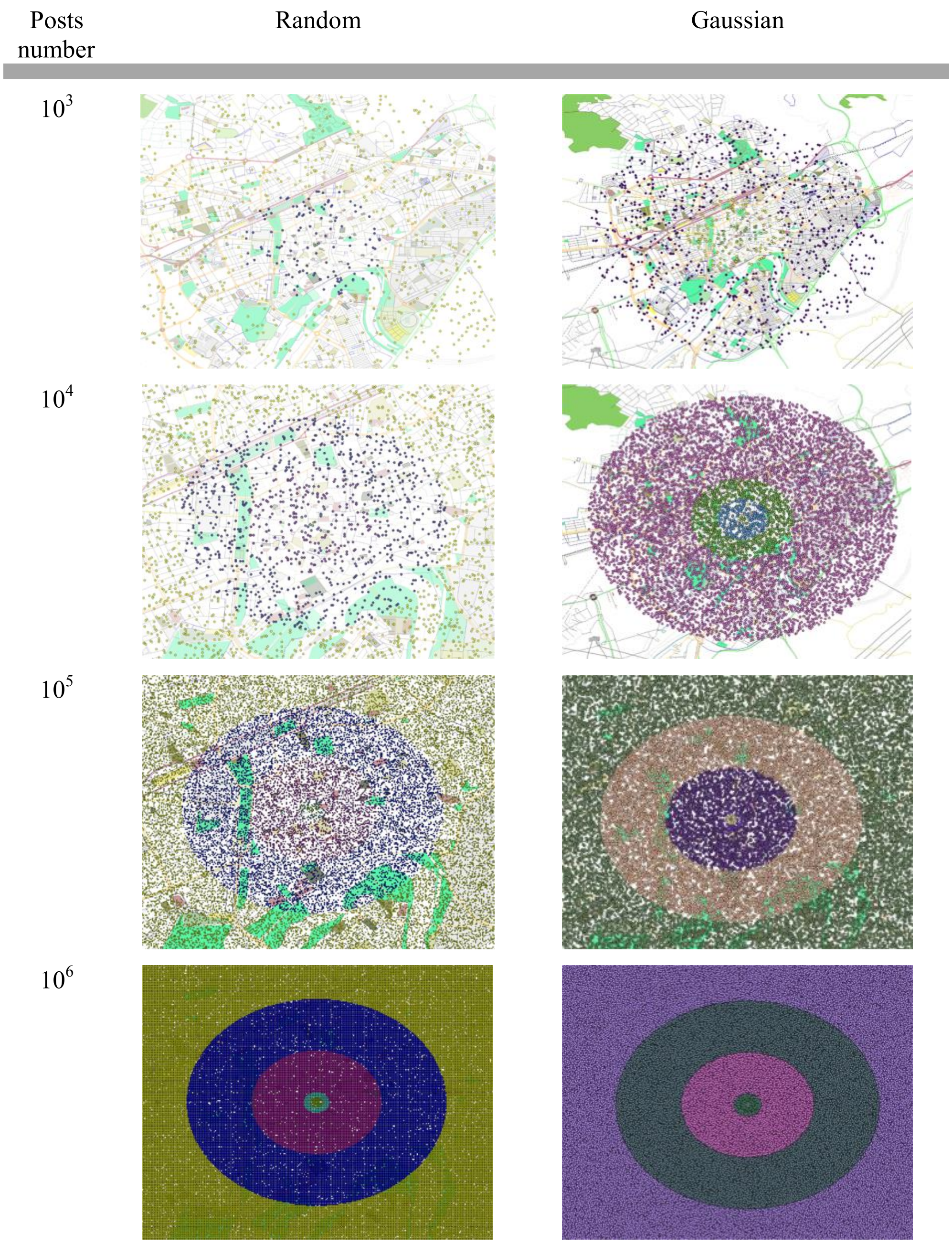


Figure 5. Scenario for the second test use case

Figure 5 shows the different post distributions for 10^3, 10^3, 10^5 and 10^6 posts for a circular post location in the scenario using random and Gaussian distribution for post creation. For all the posts, the attribute *rangepost* has been taken to "*undefined*", in order that all posts can show their information at any distance from the user, the value of the attribute *distance* in the user preferences being what determines the post visibility.

User locations

Five different user locations and four different values of the *distance* attribute have been taken in order to analyze the performance of the recovery process. User locations are distributed in the scenario area, and we have selected distances of 50, 100, 500 and 1.000 meters for the value of the distance attribute defined in the user preferences.

Results

Table 2 shows the results obtained in the study of the performance in the process of gathering the existing posts in a circular area to a given value of the *distance* attribute defined in the user preferences.

As observed in Table 2, no significant differences exist for random and Gaussian distribution for the same value of the distance and number of posts in the scenario. Although for each distribution the percentage of posts closest to the user location is slightly different, the recovery times for a set of posts are close similar for both distributions for a similar number of posts recovered.

Moreover, the same behaviour is observed for the percentage of error obtained. The percentage of error has been measured as the addition of false positive and false negative; that is, those gathered posts that do not have to be considered and those not gathered posts that should be considered, respectively. We have obtained for all cases a percentage of error less than 0.2% in the worst situations. That is, in the recovering of 10.000 posts, for instance, only 20 posts were badly recovered. The error is always due to those posts located in meshes on the border of the distance value.

Table II. Study of the recovery performance for random and Gaussian posts distribution. User locations: UL-1: (-4.779536, 37.884466), UL-2: (-4.779407, 37.878868), UL-3: (-4.76448, 37.87217), UL-4: (-4.789524, 37.8885), UL-5: (-4.772224, 37.889088).

	User locations	distance = 50 m		distance = 100 m		distance = 500 m		distance = 1.000 m	
		Posts	Time (ms)	Posts	Time (ms)	Posts	Time (ms)	Posts	Time (ms)
Random distribution	**Scenario with 1.000 posts**								
	UL-1	1	16	2	16	27	16	101	25
	UL-2	0	15	0	15	30	16	110	26
	UL-3	0	15	1	15	31	15	109	26
	UL-4	0	15	0	15	28	15	116	27
	UL-5	0	15	2	16	16	15	91	28
	Scenario with 10.000 posts								
	UL-1	3	22	13	18	290	18	1134	34
	UL-2	2	21	13	17	282	18	1098	35
	UL-3	4	22	7	16	270	17	1101	34
	UL-4	5	22	13	17	284	17	1150	35
	UL-5	2	22	12	17	261	17	1081	36
	Scenario with 100.000 posts								
	UL-1	28	40	121	35	2757	40	11034	105
	UL-2	21	1	105	35	2668	40	11068	112
	UL-3	32	38	106	33	2667	37	11010	107
	UL-4	30	37	115	31	2672	36	10890	111
	UL-5	26	37	102	32	2824	37	11067	115
	Scenario with 1.000.000 posts								
	UL-1	269	360	1086	364	27547	423	111369	1397
	UL-2	273	356	1100	361	27652	417	111250	1480
	UL-3	284	307	1103	312	26820	371	111111	1386
	UL-4	282	306	1130	312	27334	373	110906	1486
	UL-5	257	311	1126	314	27704	374	111248	1526
Gaussian distribution	**Scenario with 1.000 posts**								
	UL-1	8	17	44	17	673	18	989	30
	UL-2	1	16	5	16	255	16	829	31
	UL-3	0	15	0	14	0	14	0	26
	UL-4	0	16	1	15	45	16	450	29
	UL-5	0	15	4	15	104	16	620	31
	Scenario with 10.000 posts								
	UL-1	119	38	441	37	6746	47	9906	82
	UL-2	17	31	70	31	2425	36	8175	82
	UL-3	0	21	0	21	0	21	22	52
	UL-4	1	23	6	23	443	24	4504	73
	UL-5	7	26	27	26	1092	28	6403	79
	Scenario with 100.000 posts								
	UL-1	1111	244	4396	247	66796	346	98873	622
	UL-2	175	182	744	183	24017	223	81910	622
	UL-3	0	96	0	93	0	92	221	343
	UL-4	21	107	67	109	4405	116	44828	549
	UL-5	53	132	219	132	10578	146	63714	595
	Scenario with 1.000.000 posts								
	UL-1	11414	1863	44250	1908	668744	2991	989092	4046
	UL-2	2017	1158	8063	1167	238733	1572	820469	3671
	UL-3	0	18	1	16	5	16	2341	257
	UL-4	152	349	603	349	44630	439	450595	2713
	UL-5	546	569	2261	577	104865	756	635533	3193

In addition, Table 2 shows the recovery time spent in the process. Obviously, the time increases as the number of posts present in the scenario and the value of the *distance* attribute increases, so also the number of posts to be recovered increases.

However, the time of process is markedly low. For distance value of 100 meters, possibly the most used by the users in proximity advertising search, the time spent by our algorithm is around 1s recovering more than four thousand posts (using a personal computer).

The proposal of the meshed environments is the reason for this low recovery time. If we do not consider meshed scenarios, the time spent on the recovery of a set number of posts increases up to 400% considering the same conditions.

6.7.2 Second use case

Goal

In this test we check the capacity of the proposal to recovery the information allocated to the posts satisfying the user preferences. Posts can be allocated a not predefined number of ads containing information of different categories and, as well, the user has defined preferences on categories of ads he/she wishes to receive.

In this test, we test the performance and correctness of the recovery process for different user locations, values of the distance attribute, number of posts and ads in the scenario.

Scenario

The scenario for the test was the same as that used in the above commented use case.

Posts

Because the behaviour of random and Gaussian post distributions is very similar, in this use case we only show the results for a random distribution of the posts in the scenario. As with the previous use case, we have considered posts number from 10^3 to 10^6 with random distribution from the centre point of the selected scenario.

Ads

We have built 10 ads of different type and content, that is, they have assigned a different value of the attribute *AdsSubcategory*. Only one of these ads matches the user ads preferences, having assigned the same value of the *AdsSubcategory* attribute as that defined in the user preferences. Later, we randomly selected five ads to be allocated in the posts present in the scenario. Therefore, not all posts contain ads matching the user preferences.

Thus, in this use case, the scenario will contain five times more ads than the number of posts that is from 5×10^3 to 5×10^6 ads, randomly distributed depending on the ad type.

User locations

The same values, as the first use case, of the attribute distance (50, 100, 500 and 1000 meters) defined in the user preferences have been taken.

User preferences

We have considered one value of *AdsSubcategory* attribute (see Fig. 2) in the user preferences, so we will check the type and content of the ad recovery, for the post must match the user defined preferences.

Results

Table 3 shows the results obtained in this study. Performance of the process is measured by means of the time spent in recovery of the ads satisfying the user preferences and allocated in those posts located in the range of the distance attribute defined by the user (50, 100, 500 and 1.000 meters).

Table 3. Study of the recovery robustness for Gaussian posts distribution and random ads distribution. User locations: UL-1: (-4.779536, 37.884466), UL-2: (-4.779407, 37.878868), UL-3: (-4.76448, 37.87217), UL-4: (-4.789524, 37.8885), UL-5: (-4.772224, 37.889088)

User locations	distance = 50 m		distance = 100 m		distance = 500 m		distance = 1.000 m	
	Posts	Time(ms)	Posts	Time(ms)	Posts	Time (ms)	Posts	Time(ms)
Scenario with 1.000 posts and 5.000 ads								
UL-1	0	15	1	15	20	15	57	15
UL-2	0	13	0	13	19	15	56	15
UL-3	0	13	0	15	14	15	49	15
UL-4	0	13	0	13	17	15	71	15
UL-5	0	13	1	15	16	15	53	15
Scenario with 10.000 posts and 50.000 ads								
UL-1	1	36	10	36	157	37	656	38
UL-2	0	36	9	36	176	37	636	38
UL-3	2	36	5	36	160	37	630	37
UL-4	7	36	12	36	178	37	651	38
UL-5	1	36	7	36	167	37	630	38
Scenario with 100.000 posts and 500.000 ads								
UL-1	19	251	79	251	1762	259	6814	277
UL-2	11	255	49	251	1689	258	6913	282
UL-3	22	254	58	251	2636	259	6660	284
UL-4	28	253	83	252	2663	260	6784	280
UL-5	15	249	69	249	1693	261	6747	285
Scenario with 1.000.000 posts and 5.000.000 ads								
UL-1	156	2410	611	2416	16837	2486	68049	2671
UL-2	155	2408	686	2426	16926	2498	67767	2694
UL-3	184	2414	703	2441	16276	2499	67382	2681
UL-4	161	2414	679	2427	16763	2489	68077	2687
UL-5	152	2423	678	2427	16816	2498	67667	2686

As observed in Table 3, the times spent on the recovery of ad information are very similar to those shown in the first scenario. The data structures used by our proposal allow us to recover the ad information allocated in the posts without a valuable computational cost.

In addition, the process error is very low. The ad error percentage is measured as the addition of false positive and false negative; that is, those gathered ads that do not have to be considered, because they do not match the user preferences, and those not gathered posts that should be considered, respectively.

We have computed that the error is lesser than 0.2% and only error recovery is due to false negative, that is, some posts in the range are not considered due to the fact that these posts are on the border of the distance consideration. As we observe in Table 3 our solution is able to recover in 2 seconds, using a personal laptop (PC Intel i3 with 4 MB Ram) more than five million points and to carry out a proximity matching considering preferences.

6.8 WingPosts: a publicity ubiquitous system

WingPosts have been developed using different technologies in order to be operable for different mobile operating systems. Technologies such as HTML5 [30] and CSS3 [31] for mobile application development. The PhoneGap framework [32] has been used to access the hardware of mobile devices. For the web server, the framework Ruby on Rails [33] and PostgreSQL databases [34] have been used.

Mobile application can be downloaded from the user web portal and in the installation process the user must register, no anonymous users are allowed by the system, so the user must sign a contract, taking responsibility for the use of the system and its ads content. Because WingPosts use the notifications systems belonging to the operating system of the mobile phone, users should register in the corresponding notifications system. Thus, for instance, for Android mobile phones, the user should have a Gmail [35] mail address.

Figure 6 shows some snapshots of the mobile application. The main screen (Fig. 6a) shows the last ads received by the user in the last synchronization process. Mobile application allows the users to manage their preferences. Users decide what type of categories and subcategories should have the ads allocated in the posts in order to be received (Fig. 6b). In addition, the user decides the value for other preferences devoted to determining the notification activity. Thus, as shown in Fig. 6c the user assigns values for the attribute distance, latency, number of notifications, style and order the notifications are shown, etc.

Notifications about ads are received by the user automatically by means of notifications at intervals determined by the latency attribute. These notifications correspond to ads allocated in the posts located within the value of the distance attribute defined by user and containing information matching the desired type of ads defined by the user by means of the *AdsSubcategory* attribute (Fig. 6c). However, the mobile application allows the user to change these preferences using a mandatory search. Fig. 6d shows a screen of this functionality. Users select the desired ads content writing a text and the desired ads category and a personalized search is processed. The result of the search is a list of ads fulfilling the user preferences, as shown in Fig. 6e. Then the user can choose one ad and visualize the detailed ad information (Fig. 6f).

As shown in Fig. 6f, detailed ad information includes information about the advertiser, so the user can make a phone call, write an email, connecting with the advertiser website or social network, etc., depending on the information included in the ads.

In addition, as shown in Fig. 6g, information about the post where the ad is allocated can be visualized by the user. Touching the ad image or displacing the screen to the right, a map with post location and post information is shown on the screen. Thus, the user can get information about the post creator and even access to its website.

Furthermore, in order to simplify the user interaction, computational gesture is considered for the search process. Thus, by simply shaking the mobile phone, the search is initiated using the defect or defined preferences. This gesture permits expedite and simplifies the process allowing the user to carry out a search quickly without having to wait for the next synchronization time.

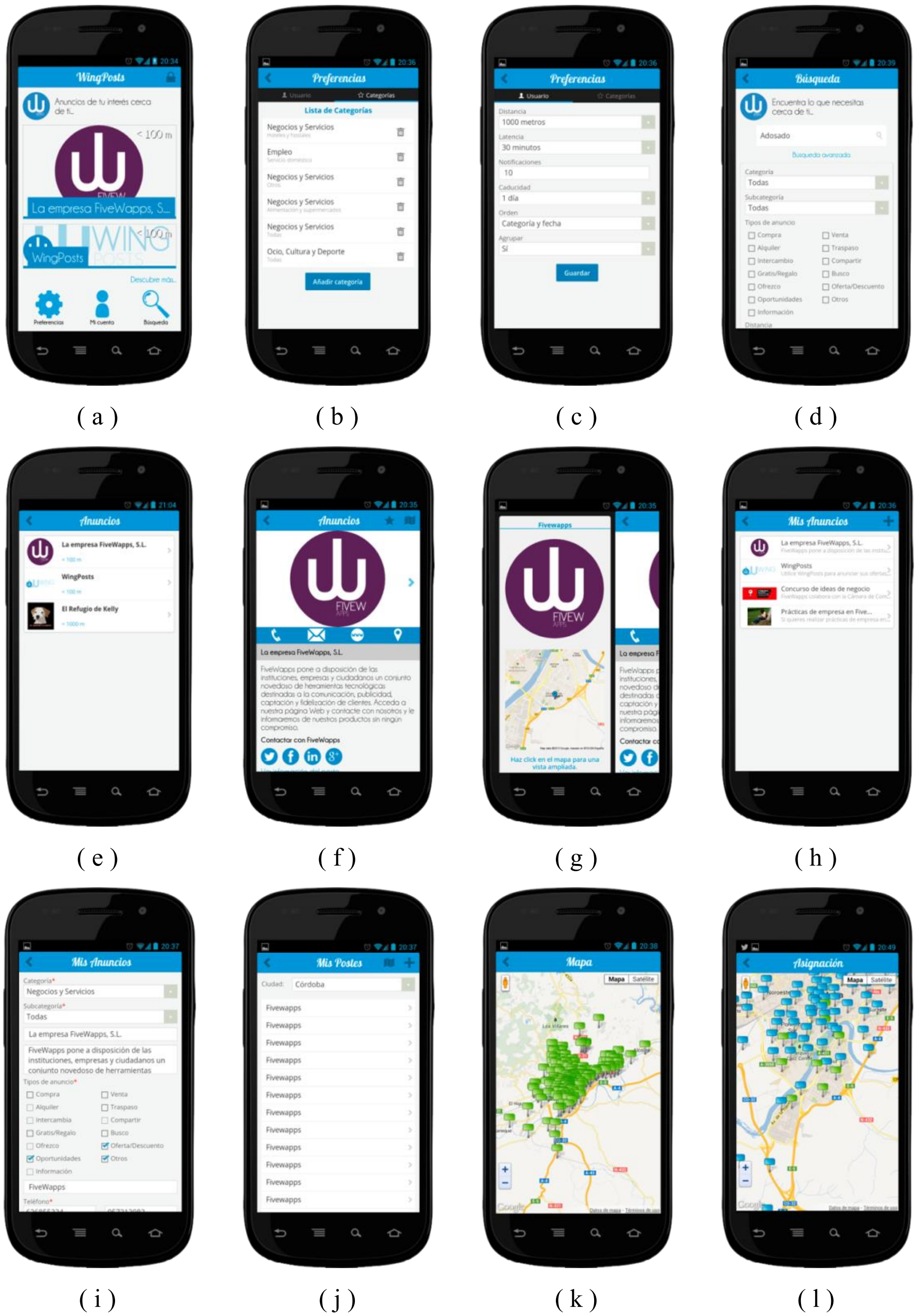


Figure 6. Some snapshots of the WingPosts mobile application

Mobile application also integrates all the necessary functionally for users to manage their own ads and posts. Users can visualize their created ads (Fig. 6h) and edit them using a simplified form (Fig. 6i). Posts also can be managed by the user (Fig. 6j), and users can visualize on a map their own posts as well as other closer public posts where the user can allocate one or several ads (Fig. 6k).

Moreover, users can assign ads to posts using a simple screen (Fig. 6l) and also using a hand gesture. Thus, users can select an ad and, simply using a throw away gesture with the mobile phone, the selected ad is allocated to the nearby private posts and nearby publics posts. This natural movement is simple and speeds up the quick ads allocation in posts when the user desires public ads in closer locations to his/her actual position in scenario.

Furthermore, WingPosts website (Fig. 7a) includes the full user functionality for users to manage their advertising information. Registered user can create ads (Fig. 7b) including text, images, videos, links, etc. These ads contain short and detailed descriptions (Fig. 7c), so the users can test how this information will be shown to other users in the mobile application.

As well as users managing ads, they can manage posts. Users create posts using an easy and graphic interface based on maps. Users create posts allocating their position in a map (Fig. 7d), and users can delete the posts or to change their position at anytime. The post lists created by the users are shown in the interface and on the map the user can visualize their exact position.

Once the user has defined posts and ads, he/she can allocate these ads in their own posts as well as the public posts (Fig. 7e). Using a form including a map, the user can assign and visualize which of their ads are assigned to one or several of the allowed posts. Moreover, the full managing of ads and post can be performed using forms (Fig. 7e). This form allows the user to create, delete and change information on ads, posts and their relationships.

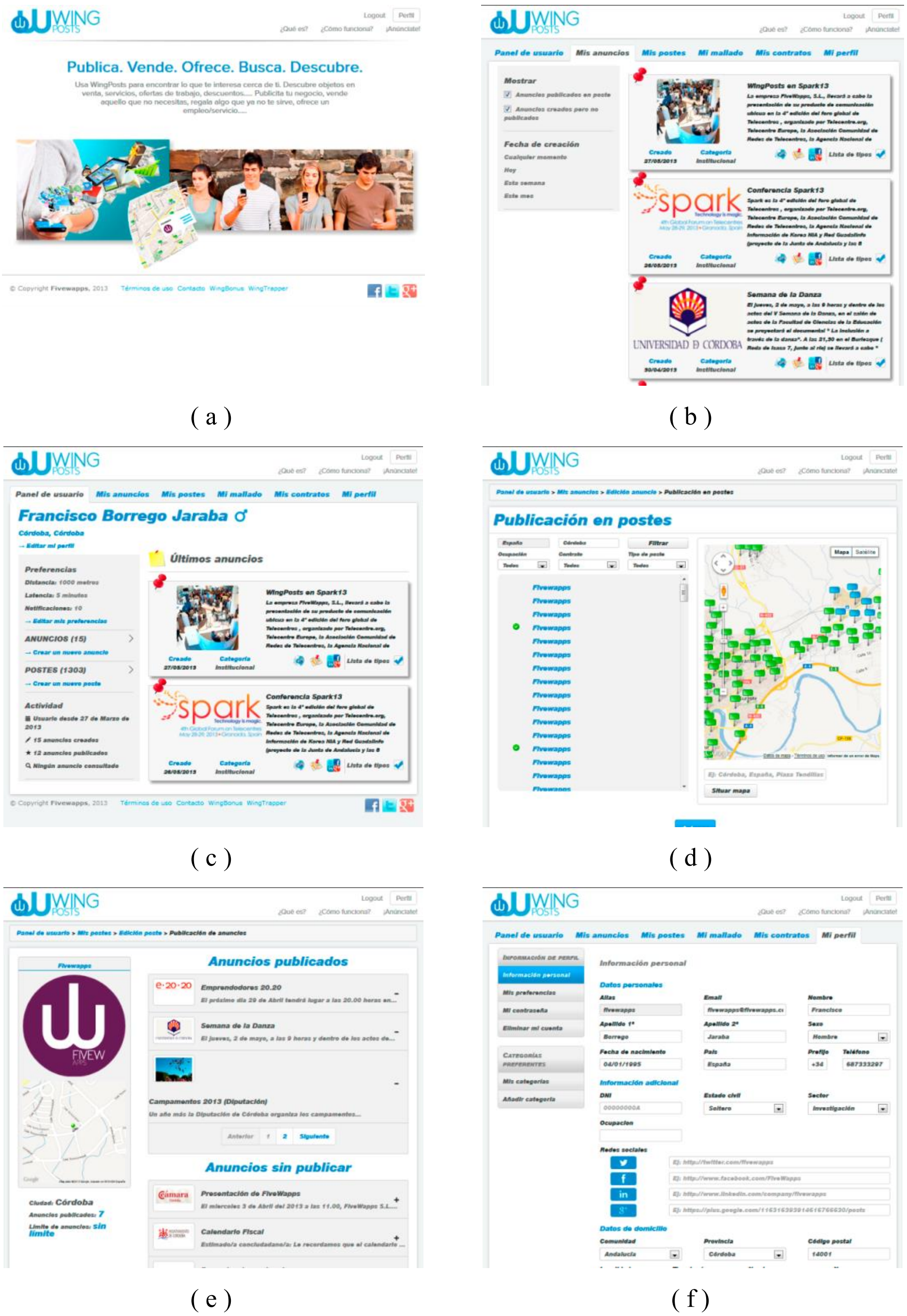


Figure 7. Some snapshots of the WingPosts website

The interface of WingPosts website is conceived to be clear and easy to use, taking into account that users can create any number of ads and posts, posts can be assigned any number of ads, users can also assign ads to public posts created by other users and their own WingPosts, etc. Thus, the number of elements that a user can manage can be large and very changeable in the time, therefore a simple interface and map-based is highly recommendable.

6.9 Discussion

In this paper me have described a very efficient solution for ubiquitous publicity using different mobile technologies.

Our proposal allows users to create cities of virtual totems or posts and to attach to these totems any contents or ads. Posts can be assigned to real posts or not, and ads can include any kind of content, texts, social networks info, images, and so on. In addition, the posts can include multimedia information about the post owner.

Both, Web and mobile application allow users, the full management of posts and ads. Thus, posts can be created, updated and even moved from one side to another of the “world” with just a simple user click. Moreover, users can allocate or deallocate ads to posts by means of a simple click, thanks to a useful and easy mobile and Web interface.

In order to give answers to the problems of the management of a huge number of posts and ads we have designed and built an efficient database. Environments and cities have been meshed. So, posts are referenced to their corresponding closest points in the nearest mesh. We have tested our database in experimental and real tests and we have demonstrated that we are able to retrieve the information with a depreciable error in less than a second for more than a million points, using a personal computer.

The system is a real and operative system operating in some Spanish cities. Currently, we are working to extend the system to main Spanish and European cities.

6.10 Acknowledgments

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7 | Conclusiones

7 CONCLUSIONES

La visionaria idea de Mark Weiser acerca de la computación ubicua o pervasiva está emergiendo gracias al avance en tecnologías móviles y redes inalámbricas. Este paradigma ubicuo permite el desarrollo de entornos activos y móviles que proporcionan gran cantidad de información y el procesamiento de la misma.

Esta idea de computación ubicua ha sido incluida en un paradigma más genérico conocido como *Ambient Intelligence* (AmI, Ambientes Inteligentes) que consiste en la creación de entornos inteligentes donde los usuarios interactúan de forma natural e intuitiva con servicios que le ayudan a realizar tareas de la vida cotidiana.

La tecnología emergente en los últimos años y que posibilita el desarrollo de sistemas pervasivos es la tecnología NFC (*Near Field Communication*), que proporciona una interacción natural entre el usuario y su entorno, por lo que la hace una tecnología ideal para el desarrollo de estos ambientes inteligentes. Además, NFC es una tecnología útil para el desarrollo del Internet de las Cosas (*Internet of Things*, IoT) generando aplicaciones para cualquier servicio en cualquier entorno o escenario.

En el conjunto de las investigaciones realizadas en la presente tesis, donde se proponen distintas aplicaciones de la tecnología NFC, principalmente, y otras tecnologías móviles, se considera que se han alcanzado todos los objetivos propuestos al inicio del período investigador, ya que se han llevado a cabo estudios y se han propuesto modelos y desarrollos para mostrar las bondades y aplicaciones de la tecnología NFC en el desarrollo del Internet del Futuro.

En el transcurso de la investigación se han propuesto y evaluado modelos de interacción haciendo uso de la tecnología NFC creando, por tanto, escenarios inteligentes en los que el usuario interacciona de forma autónoma y personalizada con objetos físicos, aumentados con tags NFC, con el objetivo final de facilitar tareas de la vida cotidiana. Para llevar a cabo dichas interacciones con el entorno, se han desarrollado un conjunto de productos que permiten la construcción de estos escenarios inteligentes ofreciendo servicios a través de los objetos cotidianos. Mediante estas interacciones NFC se captura de forma transparente la información y conocimiento a través de servicios para el procesamiento de la información y adaptar estos servicios a las necesidades del usuario.

En el *Capítulo 3* de la presente tesis, se propone un sistema generalizado para navegación en áreas urbanas y para localización de puntos de interés haciendo uso de la tecnología NFC. Mediante esta propuesta, el usuario únicamente necesitará disponer de un teléfono móvil dotado con tecnología NFC que le permitirá interactuar con objetos físicos (en este caso *Smart Posters*) diseminados a lo largo de la ciudad. Estos Smart Posters, aumentados mediante tags NFC, presentarán información al usuario de puntos de interés mediante imágenes, las cuales están asociadas a tags NFC que le ofrece al usuario servicios para obtener información adicional sobre los puntos de interés (página web, localización, ruta para llegar al punto de interés, etc.). Se trata por tanto de un sistema fácil e intuitivo para el usuario, ya que lo único que necesita es disponer del sistema instalado en su dispositivo móvil e interactuar con estos objetos inteligentes.

La combinación de un paradigma intuitivo para la interacción con el usuario (*Touching Paradigm*), el uso de interfaces simples y claras y el sistema desarrollado ofrecen al usuario todos los servicios solicitados para el cumplimiento de los requisitos básicos de un sistema ubicuo: dónde estoy, qué es, cómo puedo conseguirlo, dónde puedo encontrarlo, qué tengo a mi alrededor, etc., todo a través de mapas e información textual. El resultado de las pruebas del sistema desarrollado han sido bastante favorables, evaluando muy positivamente la simplicidad de uso y la ayuda que este tipo de sistemas ofrecen a los usuarios.

Con la finalidad de ayudar a los estudiantes a alcanzar los objetivos de aprendizaje planteados en sus planes de estudio, se ha llevado a cabo el desarrollo de un sistema pervasivo y consciente del contexto para facilitar el acceso a fuentes bibliográficas. La solución propuesta está basada en un modelo ontológico para definir el proceso de aprendizaje y su relación con las fuentes bibliográficas (*Capítulo 4*). El resultado obtenido es un sistema, denominado PINAKES, mediante el cual los usuarios necesitan disponer de un teléfono NFC para interactuar con objetos inteligentes diseminados por el entorno universitario. Para la investigación propuesta, estos objetos inteligentes son las fuentes bibliográficas de una biblioteca las cuales han sido aumentadas mediante tags NFC para realizar la interacción con el teléfono móvil del usuario.

El modelo de aprendizaje basado en la declaración de Bolonia impulsa a los estudiantes a adquirir las habilidades necesarias para alcanzar el conocimiento requerido, para lo cual es casi obligatorio el uso de fuentes bibliográficas que completen su aprendizaje. Con este objetivo, PINAKES se convierte en una herramienta útil para los estudiantes ya que le proporciona acceso a información necesaria de las fuentes bibliográficas que están relacionadas con asignaturas o cursos en los que el usuario está matriculado. Además, el sistema permite, de una forma pervasiva, acercar la relación profesor-alumno intercambiando información referente a su aprendizaje.

La aplicación de NFC en modelos de marketing de las empresas ofrece muchas ventajas sobre los tradicionales modelos existentes. Existen multitud de empresas que ofrecen descuentos a sus clientes, pero, sin embargo, la utilización de estos descuentos no siempre resulta ser fácil. El principal punto débil que se encuentran los usuarios es la inexistencia de interacción del usuario con la empresa que proporciona el producto o servicio. El uso de tecnología NFC y su aplicación en dispositivo móviles ofrece a los usuarios una forma sencilla de obtener, almacenar y usar vales descuento, convirtiéndose, además, este proceso en un proceso sencillo, seguro, eficiente y transparente para el usuario.

Tal y como se describe en el *Capítulo 5* de la tesis, el sistema propuesto tiene la ventaja de considerar distintos tipos de vales descuento y tarjetas de fidelización. Además, permite la gestión de distintas campañas de marketing de empresas. El sistema, denominado WingBonus, proporciona una poderosa herramienta de difusión para las actividades de marketing de las empresas y una forma sencilla de que sus clientes gestionen sus ofertas.

WingBonus permite a los consumidores gestionar las ofertas que hacen las empresas, lo que garantiza un incremento del uso de las mismas por parte de los consumidores ya que sus ofertas y tarjetas de fidelización siempre las llevan en su dispositivo móvil sin posibilidad de fraude, pérdida u olvido. Para las empresas, WingBonus ofrece grandes ventajas: reducción de costes, eliminación de soporte papel y plástico, obtener más clientes, eliminación de falsificaciones, análisis de su campaña, estudio de tendencias de los usuarios, etc., además de la rapidez y seguridad del proceso de utilización de los vales descuento y tarjetas de fidelización.

Debido al incremento del uso de los dispositivos móviles y el uso de las redes de datos móviles, cada vez son más las empresas que utilizan estos dispositivos como medio de comunicación de campañas de marketing y publicidad. Sin embargo, hay que tener en cuenta que la eficiencia de estas campañas estará muy determinada por lo intrusiva que sea y por el interés que presentan los usuarios a los que esta publicidad llega. Es por tanto necesario definir estas campañas de publicidad de forma que no sean intrusivas y siempre lleguen a los usuarios a los que realmente interesa dicha publicidad.

En el *Capítulo 6*, se describe una solución eficiente para publicidad ubicua utilizando diferentes tecnologías móviles (NFC o geolocalización, por ejemplo). Esta solución permite a los usuarios sembrar las ciudades con postes virtuales a los que se le añaden contenidos (anuncios): texto, redes sociales, imágenes, etc. Los usuarios, a través de una plataforma web o a través de su dispositivo móvil, podrán crear sus postes virtuales, sus contenidos y asignar estos contenidos a los postes. Además, cuentan con la posibilidad de asociar sus postes a postes físicos ubicados en los entornos urbanos. Para este tipo de postes físicos, los usuarios podrán crear sus contenidos vía su aplicación móvil y, mediante una interacción NFC, asociar su contenido al poste físico.

Los anuncios o contenidos llegarán, a través de notificaciones *push*, a los usuarios adecuados, ya que esta difusión de contenidos tendrá en cuenta las preferencias de los usuarios, convirtiéndose por tanto en difusiones no intrusivas. Solamente tendrán que estar cerca de algún poste virtual para que llegue la información al usuario.

Esta propuesta presenta una solución eficiente al problema de la gestión de un gran número de postes y anuncios, realizando un proceso de mallado de las ciudades y poblaciones. Los resultados de test experimental de la base de datos con datos reales nos ofrecen resultados demostrados de recuperación de información con un error despreciable en menos de un segundo para más de un millón de puntos.

Los resultados de estudios de usabilidad con usuarios reales muestran gran aceptación de la propuesta, resaltando el potencial y buen funcionamiento de la aplicación móvil, y el tiempo de ejecución de todas las tareas se considera apropiado en cuanto a la complejidad de cada actividad. Por último, destacar que el sistema está operativo actualmente en algunas ciudades españolas.

Como se ha podido observar, la presente tesis se presenta por compendio de publicaciones en revistas con índice de impacto a nivel internacional, por lo que la investigación queda avalada con dichas publicaciones. Además, a lo largo de los *Anexos I-IV* se presentan otros trabajos presentados en congresos y publicaciones en libros donde queda constancia del trabajo realizado en esta investigación del uso de la tecnología NFC en distintas áreas: turismo, educación, marketing y publicidad. Actualmente se continua trabajando en esta línea de investigación, fruto de la cual, dos nuevos trabajos se han sometido a revisión en revistas de impacto (*ANEXO IV*).

El trabajo desarrollado en esta tesis abre, además, nuevas líneas de investigación y/o desarrollo orientadas a: (1) la tecnología NFC puede convertirse en una revolucionaria tecnología en ámbitos como el turismo o el marketing y publicidad en el desarrollo futuro de las denominadas *Smart Cities,* donde se ofrezcan a turistas y residentes multitud de servicios a los que podrán acceder a través de interacciones con objetos del mundo real; (2) definición de servicios personalizados para los usuarios, de forma que el comportamiento de estos servicios ofrecidos varíe según el usuario que realice la interacción y el entorno en el que se produce la misma; (3) mejora y ampliación de la seguridad en estas transacciones de información, ya que existe un continuo envío y recepción de información hacia y desde el dispositivo móvil con el que se interactúa.

El principal avance en estas líneas de investigación es solucionar la problemática existente con el Elemento Seguro (*Secure Element*) con el que la tecnología NFC puede interactuar. En este elemento seguro se pueden almacenar todos aquellos datos sensibles para el usuario (datos bancarios, por ejemplo), posibilitando el auge de aplicaciones basadas en NFC mucho más potentes y útiles para los usuarios: pago por móvil, firma electrónica, etc., ya que este elemento garantiza que los datos están encriptados y difícilmente accesibles. Este elemento seguro puede estar integrado en la propia SIM del teléfono, en el propio dispositivo móvil, o a través de hardware externo que se añade al dispositivo móvil.

Anexo I | **Discount Vouchers and Loyalty Cards Using NFC**

El contenido de este anexo aparece como capítulo de libro en:

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I. Discount Vouchers and Loyalty Cards using NFC

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Abstract. This paper describes a framework using Near Field Technology for the full management of mobile coupons. The system is responsible for dissemination, distribution, sourcing, validation, and managing of vouchers, loyalty cards and all kind of coupons using NFC technology. Security of voucher is granted by the system by synchronizing procedures and a secure encriptation algorithm.

Keywords: *NFC, mobile coupons, vouchers, marketing.*

I.1. INTRODUCTION

The current global crisis is pushing citizens to save money and to seek cheaper prices when they purchase products and services. Thus, marketing and loyalty techniques are change help by extending of the smart phones over traditional mobile phones, creating the concept of m-coupons or mobile coupons.

In the market, we can find some mobile coupons applications. Hsueh and Chen [1] propose a mobile coupon sharing scheme that uses mobile devices to distribute coupons among existing social networks increasing mobile coupons exchange. In this scheme, the company first selects targeted members and then sends a virtual coupon book and a virtual sharable coupon book to each of these targeted members.

Systems such as Groupon [2] offer deals in most of markets around the world. This type of offerings is known as “deal of the day”. The user pays first and then he/she gets the coupons that will be able to exchange at the indicated establishment. These types of deals are exchange through the traditional paper coupons or through its mobile application using QR codes [3] that the partner establishment reads using a QR reader or checking and writing down the coupons code.

Although some existing systems are devoted to the elimination of the tradition paper voucher using new technologies and mobile devices, some challenges are unsolved yet. Valuables aspect required to pervasive systems like mobile applications are not considered, such as:

- *Security*: vouchers are managed in the mobile devices as real coupons. Once the voucher is bought in the provider website, security can be only checked by the commerce system. Aspects regarding to the loss of the vouchers, error in the redemption process, error in the manipulation process by the user or device, fraudulent copying, etc., are not well solved.

- *Voucher type*: current systems usually consider just one type of vouchers: discount coupons that users must pay in advance and later redeemed at a setting establishment. However, the provider vouchers and commerce need a more wide type of vouchers.
- *Architecture*: websites are in charge of the voucher publicity, provisioning and payment, and the commerce infrastructure, if there exists, is in charge of the checking and exchanged. Thus, current proposals are not open to providers' requirement where providers system can be involved in the process having in charge any or several of the process chain.
- *Loyalty cards*: because the above mentioned problem, consideration of the loyalty card corresponding to providers and/or commerces are not considered. Thus, these systems not integrate in a unique product all type of vouchers and loyalty products.
- *Adaptive vouchers*: current systems do not consider user preferences in order to offer and supply vouchers. Because of the above mentioned paradigm "deal-of-the day", they are offering just a few vouchers each day that do not adjust to the user preferences but only the city selected for the redeem process.
- *Getting vouchers*: as mentioned above, current systems supply vouchers only by the website. This does not adjust to a pervasive system. Thus, the process of getting vouchers should be distributed by getting them anywhere easily with a smart phone.

This paper presents a framework aimed to solve all the above commented problems. The framework, called WingBonus [4], is not only an application devoted to mobile coupons management. WingBonus is an ecosystem that can be fully tailored to providers, commerces and users' requirements. Thus, vouchers publicity, sourcing and redemption can be performed by any infrastructure belong to any of the actors. By other hand, security of voucher is always granted through unique secure keys, information encryption and double or triple secure validation using WingBonus, providers and/commerce infrastructure.

Finally, WingBonus integrates NFC (and QR) technology allowing the sourcing and redemption of any kind of vouchers using the available technology: smart posters, NFC readers and QR readers for commerces, environment and user devices.

I.2. WINGBONUS CHARACTERISTICS AND INFRASTRUCTURE

Our proposal is open to a wide type of infrastructures in order to the management of the whole chain of processes with vouchers.

In first, the vouchers advertising and sourcing can be made by:

- *Providers*: providers can use proprietary infrastructure as website to advertising the vouchers.
- *Commerces*: using NFC readers, RFID Tags and NFC/QR posters, commerces can offer to users any kind of vouchers.
- *Environment*: providers and commerce can use Smart Posters spread up anywhere in the environment containing vouchers.
- *WingBonus website*: this system manages all kind of vouchers, providers and commerces campaigns.

In second, the processes of redemption and validation can be made as follows:

- *Providers*: in the exchange process website infrastructure can check the voucher use, granting or rejecting the process.
- *Commerces*: the redemption point can establish any kind of added validation process.

WingBonus is composed by two main systems: WingBonus website and WingBonus mobile application. WingBonus website has been developed using HTML5 and CSS3. We have followed one-page development paradigm using Javascript and Backbone.js [5] complemented by JQuery and libraries such as Underscore of Require.js. The server side processing has been developed using PHP.

Communication with web services necessary for synchronization with the mobile client has been implemented using JSON [6]. The database engine has been MySQL. In order to provide security to the information stored on both the server and the mobile device, we have decided to encrypt the information using Blowfish [7] symmetric cipher.

WingBonus mobile application currently runs over Android and RIM operating systems (currently IOS does not support NFC). WingBonus considers different type of RFID Tags and NFC readers like Topaz 512 and ACR 122u [8] and any QR readers.

Lifecycle of Mobile Coupons

Three different types of vouchers are managed by the systems: a) *Coupons*: a coupon allows the end customer to acquire an offer with a certain discount, b) *Bonds*: a bonus is a set of coupons, so user can take advantage of a bulk purchase of coupons obtaining a notable discount, and c) *Chits*: a "chit" is a small reward for the purchase of a product or service. Moreover, WingBonus manages *loyalty cards*, any loyalty card can be managed as an independent folder allowing entry and withdraw movements.

Vouchers are defined at different status depending of the process performed over them by the actors participating in the system. Figure 1, shows a sequence diagram of the voucher lifecycle and the process in charge of move a voucher from a status to another one.

When a voucher is marked by a user, the voucher passes to the "*Voucher marked*" status and a unique identification is given for it, considering the user and voucher identification. Sourcing of voucher can be performed automatically or by user demand. When a voucher is sourced to the user phone, the voucher passes to "*Voucher sourced*" status. Voucher sourcing is performed by a synchronizing process belong to the WingBonus mobile application. Finally, the voucher passes to "*Voucher exchanged*" status when the voucher is redeemed by the user in some of the accepted shops. In the redemption process synchronization can be carried out of several ways depending of user and shop infrastructure.

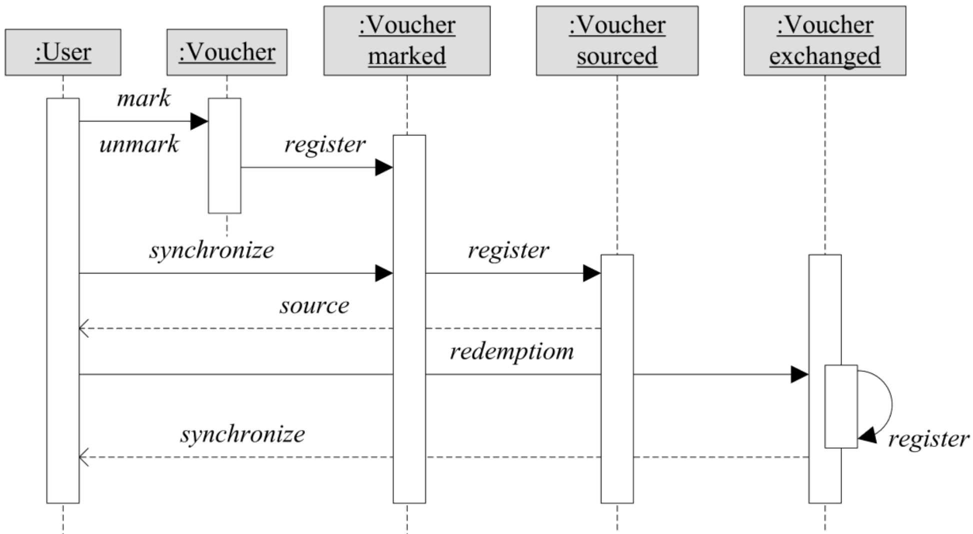

Fig 1. Sequence diagram showing the voucher lifecycle

WingBonus database stores information of whole voucher lifecycle. Vouchers have a unique identification in each status and all voucher statuses are each other related. Synchronizing process validates mobile and server database, maintaining unique and congruent information over user vouchers in their different status.

Depending of voucher security properties, mobile and server database can store a different image of user vouchers. For instance, a voucher with low secure requirements, can be sourced from a Smart Poster by many users and users even can exchange those vouchers in shops with the security level established by themselves (for instance, vouchers spread up in Smart Posters around a city, chits of the own shop, etc.), even in this case, each voucher is uniquely identified. However, in next synchronization process mobile and server database will be consolidated.

Management of Mobile Coupons

Management of vouchers depends of the security properties defined for each voucher type (see Fig. 2). Security level is defined for each of the main process performed with the vouchers by the system and user, that is: selection, sourcing, redemption and transference. The security level defined by a process determines the security of the next process in the voucher lifecycle. Security level has in to account user identification as well as the grants to perform a process by the user. Furthermore, security level determines in what voucher lifecycle the system grants the voucher authentication and therefore the system stores all information about the voucher, process and participating actors.

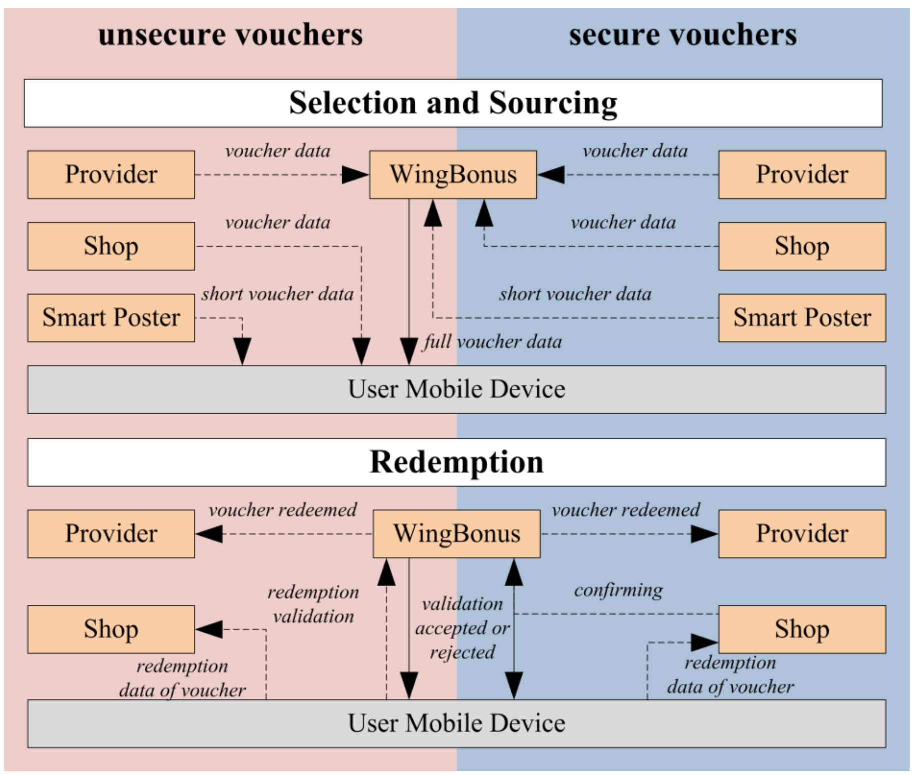

Fig 2. Flow of information between the systems actors for secure and unsecure vouchers

Vouchers can be defined as unsecure for sourcing. Thus, identified and unidentified users can get vouchers. Selected and sourced vouchers from WingBonus website are stored in the system database. When users access to provider website, they can select and download voucher, in this process provider website sends a request to a WingBonus server service being WingBonus system in charge to source the voucher to the user and storing the information in the system database.

By other hand, user can get vouchers from Smart Posters. Smart Posters can store full or partial information of the voucher depending of the source security property. If the voucher is secure for sourcing, the partial information got from the Smart Poster is sent to the system and full voucher information is send back to the user. These vouchers cannot be sourced in the mobile device until synchronization with the system is performed, although temporary information about the selected voucher is stored in the phone. If the voucher is unsecure for sourcing, the mobile application generates unique voucher identification, which is temporal until the next synchronization is performed. Shops are considered as Smart Posters although infrastructure as NFC readers was used.

Redemption process (see Fig. 2) also can be performed by identified and unidentified users. In this process the user shows the voucher to the shop to be exchange by a product or service. If security is not defined for redemption, user can exchanged a source voucher in the allowed shop. For that, information of allowed shops for redemption the voucher must be stored in the mobile phone, otherwise synchronization is need, and in this moment the voucher is validated, or not, updated in the mobile phone and stored in the server.

If security is defined for redemption, the voucher must be validated previously to the redemption. In this process, validation codes are sent the mobile application in order to generate the QR code or NFC keys corresponding to the voucher.

Sending and receiving information between mobile and server sides has been implemented by encapsulating information in JSON (Javascript

Object Notation) objects. Unlike as usual, web services have been used in both directions: to initiate and to finish the communication.

When the user performs a voucher exchange by NFC, the mobile application transmits all the voucher data to the controller installed on the shop. This requires sending to the server of the received data with the purpose of verifying the authenticity of the voucher. Once the data, originally sent by the shop are on the server, it decrypts the digest and verifies that the digest corresponds exactly with the provisioned voucher data. The server checks also that the user who is trying to redeem the voucher is the owner of it by checking the database. If integrity is maintained and the voucher is valid, the server sends a confirmation message to the controller; otherwise it sends an error message. When the redemption is made using QR codes, the procedure is similar. The redemption of vouchers with bar codes does not support this verifying method.

I.3. WINGBONUS SERVER AND MOBILE APPLICATIONS

WingBonus server is composed by several functional components: a) the website responsible for the web interaction with the user and the administrators, b) the database storing all the information on users, vouchers, clients, establishments, etc., and c) a set of web services that compose an API that is consumed by the mobile application and the web-client side. Users can view offers classified for different items: coupons, bonds, chits (Fig. 3 left-upper). In addition, offers can be view by companies, marketing and loyalty cards simply selecting the desired option in the upper selection bar.

Selecting a voucher, a detailed view is shown in Fig. 3 left-down. Then user can “mark” the voucher to be later provisioned in the next synchronization process from the mobile application. The full user activity is stored in the database. Thus, security of marked and provisioned user vouchers can be checked before the exchange process. In addition, the server system provides to the user information about the user activity. Moreover, WingBonus server provides a complete administration tool for the management of the information.

Fig 3. Some snapshots of server and mobile applications

The main menu of mobile application is shown in Fig. 3a. From this menu, users can perform any operations implemented in WingBonus system. Thereby, users can download vouchers (see Fig. 3b), view a single voucher detail (Fig. 5c), remove vouchers, use a voucher or download a loyalty card (Fig. 3d) among others.

As Fig. 3e shows, vouchers are organized in containers, identifying the different provider marketing campaigns. In addition, containers could be organized in folders. By default, the application installs the WingBonus container. Installation of any other container or folder is automatically performed during the synchronization process when a voucher belongs to the container or folder is provisioned. Loyalty cards also are stored and shown to the users like folders. Both containers and folders are easily accessible from the main menu.

In addition, vouchers also can be acquired using Smart Posters. The storage capacity of an RFID tag is enough to store a complete electronic voucher. The most important feature of WingBonus is the secure exchanging of vouchers using NFC (Fig. 3f). A voucher that has been already provisioned and stored in the mobile phone database can be exchanged selecting the appropriate option from the detailed view of such voucher. The mobile application supports two ways to redeem vouchers:

- Using the NPP (NDEF Push Protocol) in order to send the information of the voucher to the NFC reader, and wait by a response that is sent from the server to mobile phone through the NFC reader in order to complete the P2P communication.
- Although the ideal is exchanging via NFC, redemption can be performed through QR codes and traditional barcode. WingBonus uses the ZXing core, in order to generate the QR barcode that contain all the information necessary to redeem the voucher. Furthermore, in order to facilitate the integration of the application on the market, but is strongly discouraged, WingBonus mobile also support traditional barcode like EAN13.

I.4. DISCUSSION AND REMARKS

The combination of NFC with the growing success of mobile technology, will allow in the near future the development of "ideally" smart environments conceived decades ago.

The application of NFC to mobile coupons offers many advantages over existing systems. There are several and important companies that provide discount and offer services. However, getting and using coupons is not always easy. The main weak point is the client's interaction with the coupon and the company or system that serves the product or service. The use of NFC and its application in mobile devices provides to users an easy way for acquisition, storage, management and use of coupons. Besides, these features make the process fast, secure, efficient and transparent.

WingBonus allows consumers to take advantage of all offers made by companies. This guarantees a huge saving on the purchase of consumption products. Vouchers and loyalty cards are transported in the mobile phone without any possibly of lost or forgotten.

For partner companies, WingBonus could offers great advantages: reduction of costs, elimination of paper and/or plastic support, to reach more customers, elimination of forgeries, real time tracking, market analysis, study of trends, to build loyal customers, etc. Moreover, the commerce where the vouchers are adopted benefit from the speed and safety of the process.

I.5. ACKNOWLEDGMENTS

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Anexo II | Tailorign User Visibility and Privacy in a Context-Aware Mobile Social Network

El contenido de este anexo aparece como capítulo de libro en:

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Location: Vitoria-Gasteiz (Spain)

II. Tailoring User Visibility and Privacy in a Context-Aware Mobile Social Network

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Abstract. In this paper we describe a context-aware approach for the management of phone address books in mobile social networks applications. User preferences for visibility and privacy are defined for contacts and groups depending on the user's context. User's context is defined through the user's status, assigning different roles to each contact. Virtual and dynamic information about contacts is stored in the mobile phone book allowing the smart server application to manage secure and private communications among users.

Keywords: *Mobile social networks, instant messaging, NFC, address phone book.*

II.1. INTRODUCTION

Lately, interest in mobile applications and web portals oriented to message and talks exchange among users have experienced a great increase, resulting in the development of a large number of applications oriented to social networks and instant messaging. In fact, a social network is a new way of content sharing between people located anywhere in the world. Besides, the rising of mobile technologies with new smart devices able to support these applications allow users to share information, experiences anywhere and anytime.

Users can use social networks applications like Facebook[2], Twitter[3] and so on with their smart phone at anywhere trough 3G/WiFi technology, exchanging any comment or situation lived, images, files, etc. with selected contacts, or simply discuss about other user comments. In other applications, like WhatsApp[4], these wireless technologies are oriented to the communication between users, establishing conversations between couples or groups of users stored in the user's address book.

Thus, applications such as Smart Contacts[5], Contapps[6] or Youlu address book[7], available for the most common mobile operating systems, allow users to manage their address book, already synchronized in the cloud, to display and search the most frequent contacts and to link each contact with social networks, so they can publish contents, create notifications, chat with users or groups, etc.

[2] Facebook url: http://www.facebook.com
[3] Twitter url: http://twitter.com
[4] Whatsapp url: http://www.whatsapp.com
[5] Smart Contacts url: https://play.google.com/store/apps/details?id=com.bondaii&hl=es
[6] Contapps url: http://www.contapps.com
[7] Youlu address book url: https://play.google.com/store/apps/ details?id=com.youlu&hl=es

Nowadays, WhatsApp Messenger is the most used application for message exchange. It is a free and multiplatform application that allows users to manage contacts, groups, conversations and send messages including text, images, video and audio. This application uses instant messaging (push/pull) avoiding the loss of information even when the application is not running.

Although these systems allow certain degree of tailoring, the customization is restricted to the management of the contacts, from the phone address book, and to personalize the user's status, displaying some characteristics or information about the user.

This trivial and basic personalization of user communication has not taken into account some of the most important preferred characteristics of context-aware systems, for instance:

- In these systems, the communication between users is always user guided.
- Contact visibility or contact status has simply an informative context.
- User privacy is lost once other users have stored his/her data.
- Context is never considered, so users receive messages from other user independently of the sender and receiver status, the type of message or the message content.

In this paper, we describe a context-aware instant messaging system that overcomes the aforementioned lacks of current applications. WingContacts is a mobile application which manages user's visibility and privacy while having into account user's context. The system allows users to manage a private phone book, to define groups and visibility for the user and the groups depending on the current context. Context is managed by the user through user preferences. These preferences have into account the user's status as well as the current environment or scenario where the used is located.

Thus, WingContacts allows the user to collect information from the environment through mobile sensors, such as GPS, and NFC tags associated to any smart object of the scenario, define user's preferences, update user's visibility, and tailor the message exchange.

After a discussion of related works, in section 3 of the paper we describe the architecture of the system. Alson, in section 3 we describe the WingContacts database showing the relationships between user's contacts and the preferences in charge to manage the user's visibility and privacy. Finally, we show some characteristics of the mobile applications and results are discussed.

II.2. RELATED WORKS

Mobile social networking has been an active field of research in the past years, where a wide variety of proposed systems have being developed. Sadeh et al. [1, 2], describe an application that enables cell phone and laptop users to selectively share their locations with others, such as friends, family and colleagues.

Ankolekar et al. [3], have designed and implemented *Friendlee*, a mobile social networking application for close relationships. *Friendlee* analyzes the user's call and messaging activity to form an intimate network of the users' closest social contacts while providing ambient awareness of the user' social network in a compelling, yet non-intrusive manner.

Veneta [4] is a mobile social network platform able to explore the social neighbourhood of a user by detecting common friends of friends which are in the user's current proximity detection having into account the user phone contact entries. Similarity, *WhozThat* [5] is a system that ties together online social networks with mobile smart phones to answer the common and essential social question *"Who's that?" WhozThat* offers an entire ecosystem on which increasingly complex contextaware applications can be built; that is, once the environment knows who one is, the environment can adapt its content based on the individual's identity or even the collective tastes of a local group.

Ziv and Mulloth [6] describe *Dodgeball* a case study of a mobile social network. *Dodgeball* is a New York City-based service that merges location based services with social networks helping users to connect with the people and places around them. *Dodgeball* is a mix of social networks tools, simple cell phone messaging, and mapping software.

In *PeopleTones* [7], users get an alert whenever a friend or buddy is in close proximity. The goal is simply to be informed about such a "nice to know" situation and to be able to contact with other user directly, enabling some kind of spontaneous interaction not possible before (e.g., to have a cup of coffee together right now). As the goal is to support spontaneous activities whenever there is time for it, the alert can be unobtrusive (e.g., by phone vibration) not requiring the user to look the phone constantly, or to be disturbed by alerts or notifications.

A remarkable contribution from the academic world is the *Social Serendipity* project [8]. The *Serendipity* system senses a social environment and cues informal interactions between nearby users who don't know each other, but probably should. The system uses Bluetooth hardware addresses to detect and identify proximate people and matches them from a database of user profiles.

Finally, Li et al. [9], propose *FindU*, the first privacy-preserving personal profile matching schemes for mobile social networks. In *FindU*, an initiating user can find from a group of users the one whose profile best matches with his/her; limiting the risk of privacy exposure, only necessary and minimal information about the private attributes of the participating users is exchanged.

II.3. WINGCONTACTS ARCHITECTURE

WingContacts is composed by two subsystems: the server and the mobile applications.

WingContacts Server

The server side is the core of WingContacts. This application is in charge of the messaging and user management. User information and messaging traffic is managed by this subsystem which stores and updates the user's phone book, preferences and visibility. User's messages are collected by the WingContacts server and forwarded to the target after being analyzed and screened taking into account the context of both the user and the target as well as the user's preferences.

The main functionality of the server is storing and retrieving personal user data, list and groups of personal contacts, preferences, the different status and roles defined and conversations with users or groups of users. This information, described in the next section, is fully stored in the server side, while the only information stored in the mobile database is the user personal information and contacts information that satisfies the defined preferences on privacy and visibility. Besides, the server provides services oriented to the intelligent management of the communications with users or groups of users.

WingContacts Database

The server side is responsible of the management of all information about users and the communications among them. As will described in the next section, the mobile application does not store the full information about the user contacts, but the information that can be collected from the contacts depending on the role defined for them by the user.

Figure 1 shows some of the main database objects of the system. *User* class stores all personal user data, information about the social network of the user, information about the user's identification, phone, registration, and so on. Therefore, user's personal data can be hidden at anytime from other users/contacts depending on the visibility and privacy defined by each user.

Preferences defined by the user are management by the *Preferences* class: communication and synchronization functionalities, device phone, etc.

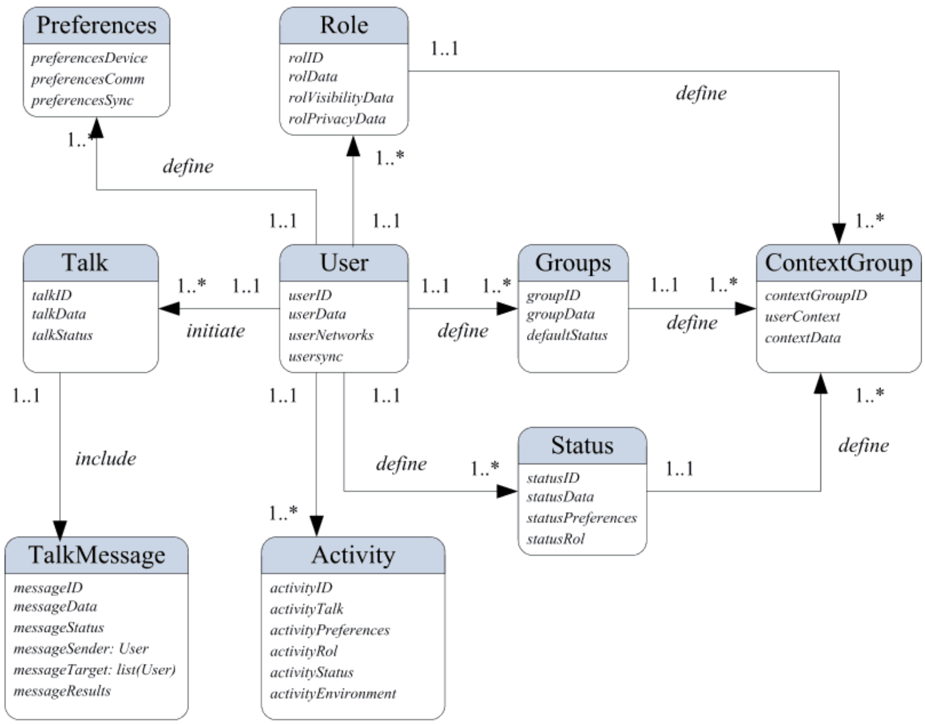

Fig 1. Main database structures of WingContacts

Users can define a set of contact groups. By default, there is always a default group maintained by the *Groups* class. The default group includes all the contacts defined by the user. Each group has assigned a default user status. Users can define as many statuses as needed (see class *Status*). A status represents a user context, for instance, ‘at work’, ‘sleeping, ‘looking for party’, etc. This personalization is improved by means of the definition of roles. The class *Role* allows users to define a set of pre-established roles. Therefore, for each user’s status, a different role can be assigned to each group, thanks to the class *ContextGroup*.

The relationships between groups, roles and status allow users to manage their visibility and privacy preferences for each contact or group. Hence, the user context is at real time personalized.

WingContacts Mobile Application

The mobile subsystem is an application developed for the Android operating system. With this application, users define and manage information about contacts, preferences and messages through an user-friendly interface; storing all the information in a SQLite database. In this database, the user's personal information is stored, that is: personal data, roles and defined status. Although this personal information is managed by the user, contacts' information is also managed on the server side.

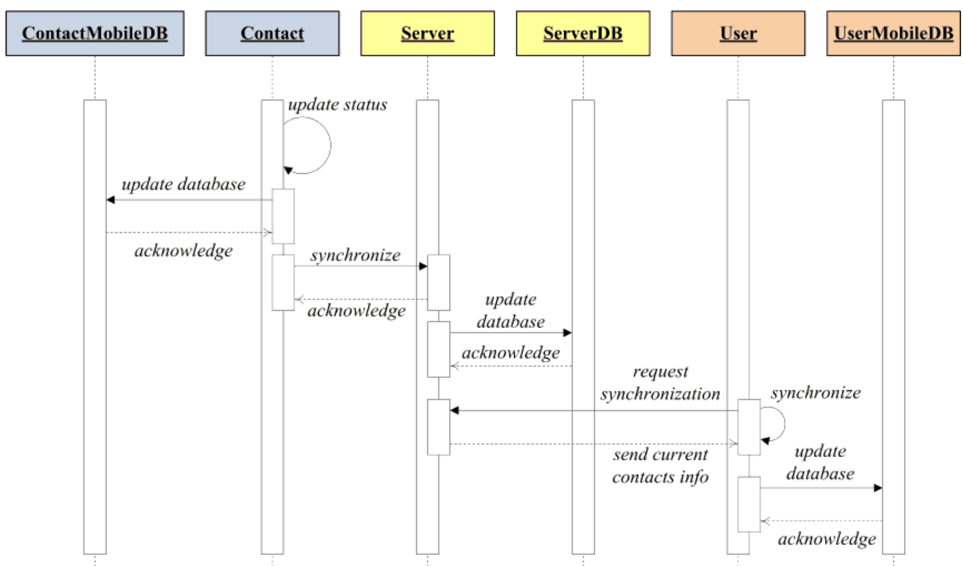

Fig 2. Preference management used for tailoring user's visibility and privacy

As user's contacts can change their status and roles assigned to other users, the information that a user can manage about his/her contacts list is always determined by the contacts and neither by the owner of the address book. After each synchronization, the information about the contacts is updated depending on the current preferences of each contact.

This operational protocol allows users to manage the context-awareness of their preferences. Users' visibility and privacy is determined by his/her current context. Thus, it can be considered that the user manages a virtual phone address book of contacts. Contacts as well as their information can change depending on the contacts' context, that depends on the contact's defined status and role for the user or group where the user has been allocated by this contact.

Figure 2 shows the sequence diagram of the processes guiding the context management of the user's visibility and privacy. As it can be seen, when a contact (any user of the system) modifies its preferences (that is: his/her information about visibility, privacy, role, status and the assigned values to any contact or contact group stored in his/her phone book database) this information is firstly updated in the mobile database. At the same time, synchronization with the server is mandatory, sending the updated information to the WingContacts server and updating the contact information in the server database.

In the synchronization process with the server, updated information about contacts is send back to the users, updating their phone address book and so, the contact's information is modified with the new established values. Therefore, the current context of a contact is set by the current defined status and role assigned for other users, determining the visibility and privacy of the users for any other system users.

Users must synchronize with the server side before executing some functionalities of the mobile application, for instance, looking for contacts. Furthermore, if synchronization is not required for some mobile functionality like, for instance, sending a message, the information stored in the server database prevails over that existing in the mobile database.

Figure 3 shows some snapshots of the mobile application. The main menu (Fig. 3a) allocates the main functionalities: access to the address book, chats, definition of the status and roles and assignment to contacts and contact groups, as well as to search contacts.

Fig. 3b shows the functionality related to contacts' management. The contacts' information stored in the user's phone address book is always dynamic. This information changes when the contact's status changes, and therefore modifies the visibility and privacy of the contact. Users can define contact groups (Fig. 3c), and assign a defined status to each group (Fig. 3d). Although the system includes many predefined status and roles, the user can define as much status as desired or modify the existing ones. Fig. 3e and Fig. 3f show the user friendly interface developed for these functionalities. Search functionality allows the users to view information about known (contacts) and unknown users of the system in a map. Users can select some search criteria based on user's status resulting in a map that contains the user location.

The information shown in the map (see Fig. 3g) about the users depends on the users/contacts current status and, therefore, on current privacy and visibility preferences.

Through the map users can establish chats with known and unknown users using the contacts list or the chat functionality in case the contacts' status of the receiver allows it. Fig. 3h shows a snapshot of a chat, which is similar to other well-known mobile instant messaging applications. The main difference with other applications is that the management of the chat depends on the visibility and privacy settings defined by the status of both the receiver and the sender.

Hence, a user can select a set of contacts as receiver of a chat, and: a) different receivers can receive different personal information about the sender, depending on the role defined by the sender for the receiver or group assigned to the receiver, b) different receivers can manage the sender information on different ways, for instance, using this information to be stored in the phone address book or not, c) receivers can use the list of users of the conversation in very different ways, depending on the status defined for each user of the list, and so on.

The application uses geo-located augmented objects by automatically update the user's context information. Thus, when a user touches a tag, for instance, at the university library, a predefined status "at the library" is set, updating the visibility and privacy of the user for the other users as defined in the roles assigned to that status.

(a) (b) (c) (d)

(e) (f) (g) (h)

Fig 3. Some snapshots of the mobile application

II.4. DISCUSSION AND REMARKS

Manage user visibility and privacy in instant messaging or social networks mobile applications is a problem not yet solved by the current and most used applications. These applications have not taken into account that users need to personalize their private information depending on the current context, that is, depending on aspects related with the scenario, current location, contacts characteristics, activity, mood and wishes, information transmitted in the chat, etc.

In this paper we have described a system proposal, called WingContacts, oriented to the context-aware management of the user's information in instant messaging applications. The proposal is based on the definition of users' status and roles as preferences assigned to user's contacts or user's contact groups. Visibility and user privacy are specified by the different roles defined. User's statuses defined for other known or unknown users are context updated, changing the information about a user that can be knows by other users. Contacts management information is stored in a virtual phone address book. Thus, this information is updated when the status defined by the contact is also updated.

Currently, WingContacts is an operating prototype that has been proposed for the analysis of its deployment.

II.5. ACKNOWLEDGMENTS

The Ministry of Science and Innovation of Spain (MICINN) supported this work (Project: TIN2011-24312).

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Anexo III | Mobile Solution Using NFC and In-Air Hand Gestures for Advertising Applications

El contenido de este anexo aparece como capítulo de libro en:

AMBIENT INTELLIGENCE – SOFTWARE AND APPLICATIONS presented at the V International Symposium on Ambient Intelligence
Date: 4–6 Junio 2014
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III. Mobile Solution Using NFC and In-air Hand Gestures for Advertising Applications

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Abstract. In this paper we present an application based on Near Field Communication technology and oriented to advertising and user loyalty fields. The system combines NFC and in-air hand gestures with the purpose of creating an attractive leisure activity where customers are rewarded by shops with the possibility of obtaining a prize or discount on the purchases made. NFC is used for securing the participation of the user in the activity and for exchanging the prizes obtained. During the activity, users perform a fishing gesture (throwing and catching) with the mobile phone, simulating the capture of a prize that could be located anywhere in the shop. This gesture is recognized by mobile sensors. The tailoring of the system to specific business marketing strategies is also managed by the proposed solution.

III.1. INTRODUCTION

Near Field Communication technology [1, 2] is widely used in marketing and advertising applications. Most of these applications are based on the use of PoS (Point of Sale) as augmented objects with a tag providing the user with some in-formation, discount vouchers or whatever other type of service needed with the aim of promoting a commercial product. In these applications, when users with a NFC enhanced device touch the PoS, they immediately receive the information related to the marketing campaign.

In the last years, several applications have been developed using NFC for marketing and advertising [3, 4] purposes. WingBonus [5] manages different types of discount vouchers (coupons, bonds and chits) that users can freely download from the Web portal or by simply touching a tag located in a shop or PoS. In this system, the vouchers' life cycle is fully managed (from downloaded the exchanged status). Security of vouchers is managed by means of synchronization processes with the server. Users can exchange the vouchers in the allowed shops by touching a NFC reader, a tag in the shop (or using QR technology). WingBonus also manages loyalty cards. Any number of loyalty cards can be managed by the mobile application while deposit and withdraw operations are performed in the same way as with vouchers.

Different applications have considered the useful application of NFC to advertising, marketing or user loyalty [6] purposes. Hence, objects or screens augmented with tags are used to provide users with information about products, sales or services. The secure element or SIM has been the main proposed way to support the credit or loyalty cards identification.

Besides this, the use of gestures in mobile computation has been generating a growing interest in recent years [7]. The idea is the development of interfaces close to the human behavior for the building of easy and more adaptable pervasive applications. Researches and developments in gestures cover two main areas: camera-based and movement sensor-based [8]. In camera-based applications, body or face user's movements are captured by cameras in order to determine the user's activity, interest, felling and so on. Thus, for instance, large screens used for advertising can show information to users when they are detected by a camera or the display can change the information when the camera detects a specific face expression in the user. Gesture applications based on movement sensors are mainly oriented to the management of touch screens. Different finger movements can be detected by the device's sensors in order to facilitate the communication with the applications. Other types of movement sensor applications are based in body movements. In these applications, measurements from the compass and accelerometer of the mobile device are used as input to calculate the movement per-formed by the user; for instance, walk, lift or turn the phone, etc. Using the information gathered from the mobile sensors (as well as user location) these applications can guide the user in a city or a museum, exchange files, connect different devices, or control them (TV, radio, lamps, etc.), perform user identifications, etc. [9].

In this paper, we describe a system called WingTrapper that combines both aforementioned technologies: in-air hand gestures and NFC. WingTrapper is an application oriented to advertising and user loyalty purposes; offering companies the capacity to distribute discount vouchers or any other kind of offers in an easy and amusing way.

In this system, shops provide to users participation tickets following their marketing strategies. Tickets can be distributed by means of RFID tag, NFC readers or even QR codes. By touching the tag, users gather the participation ticket that is managed by the mobile application. Afterwards, users can use this ticket by following its requirements in order to get the prizes of the marketing campaign established by the shop.

The use of a ticket is performed by means of gestures; a fishing gesture (throwing and catching) should be made by the user, simulating the capture of a prize located at any place in the shop. Finally, if the prize is obtained by the user, this prize is stored by the mobile application allowing its later exchange in the shop, again using NFC technology.

In this paper, we describe the architecture of the systems, and the characteristics of the application context. The mobile application is also described showing an indoor application scenario.

III.2. SYSTEM ARCHITECTURE

At first, WingTrapper was created as a new utility of an application oriented to the management of m-coupons and loyalty cards called WingBonus [9]. WingBonus manages any kind of m-coupons or vouchers allowing companies to promote their products thanks to the use of discount vouchers. Vouchers and loyalty cards are stored in the mobile phone; therefore, they are available to users at anytime without the risk of losing or forgetting them.

In WingBonus, users can obtain the vouchers in different ways: a) downloading them from the Web portal, b) touching a tag or reading a QR code located anywhere, and c) using NFC or QR technology from a PoS. WingBonus's mobile application allows the user to fully manage the vouchers and loyalty cards stored in the device. Marketing campaigns are managed in different folders by the mobile application and the users can consult the voucher details and exchange them in any of the allowed shops. Moreover, shops provided with NFC readers can gather information from the mobile application applying, without user intervention, the discounts that match the stored vouchers.

WingTrapper extends WingBonus functionality, although it can also be used as an independent application, allowing any shop or company to develop tailored marketing campaigns oriented to product advertising and user loyalty. WingTrapper is composed by two main components: the server and mobile subsystems.

As shown in Figure 1 the server is composed of different components. The administrator Web portal is in charge of storing the information corresponding with the marketing campaign. This component is used for the management of the in-formation about companies, shops, participation tickets, users, marketing campaigns and prizes.

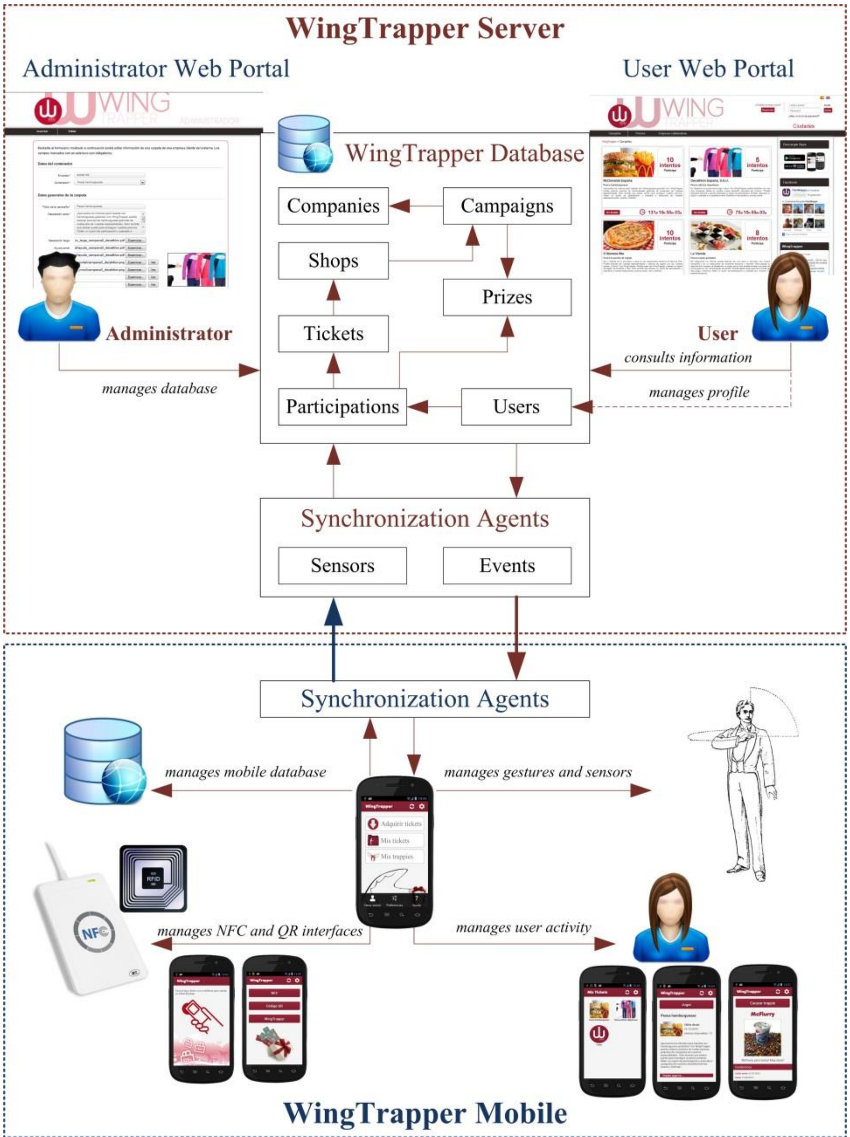


Figure 1. WingTrapper Architecture

The user Web portal is only an advertising portal related to the active marketing campaigns. This portal shows information about the marketing campaigns and prizes to the users, allowing them to download the mobile application and register with it.

The server side includes a synchronization component in charge of synchronizing the mobile and server databases. All the information about users, tickets, participations, prizes, etc., is securely stored on both sides. User's activities are gathered by the mobile application and synchronized with the server side in order to ensure data reliability.

The mobile application is the core of WingTrapper. This application has been developed in Java. Users equipped with a NFC phone can gather participation tickets corresponding to marketing campaigns distributed by the shops. These tickets are stored in the mobile phone allowing the user to participate in the campaign and to try to obtain one or more of the prizes offered.

Figure 2. Fishing gesture

The participation consists in trying to fish a prize, this prize could be located anywhere in the shop. Therefore, by performing a throwing and catching movement with the mobile phone, as shown in Figure 2, the user participates in trying to catch the prize. The user has as many attempts as allowed in the participation ticket. If a prize is captured, information about the prize is stored in the mobile application for their later exchange in the shop. Prizes can correspond to some product, discount or even vouchers or money for the loyalty card managed by WingBonus; in this case this information is also stored by the WingBonus application.

The Context in WingTrapper

WingTrapper is a system though as a different and funny activity for promoting advertising and user loyalty products. Customers are rewarded with the possibility to win some gift or bonus when they carry out some purchase in the shop. The system can be used in indoor and outdoor scenarios allowing a fully customization of the marketing business strategy. The main elements involved in the system are described below:

Marketing Campaigns

WingTrapper manages any type of marketing campaigns consisting in offering users any kind of prizes. For instance, when the user makes a purchase from a shop of a certain quantity, or a specific number of times or number of products, during the happy hour or day, etc., the shop offers the user a participation ticket to win some of the offered prizes.

Each marketing campaign is managed in a different folder, and it has textual and graphic information associated, allowing easy identification by the user.

Each campaign has an associated a validity date, information about the participation tickets, the prizes, the way the prizes are distributed throughout in the environment and the requirements for their capture. This information allows companies to tailor their marketing campaigns, even at each shop level.

The prizes

Prizes are anything the company can offer users as a reward for its loyalty or purchase. Prizes are associated with campaigns being uniquely identified by the system, also storing the private identification used by the shop. WingTrapper stores textual and graphic information of prizes and other information oriented to the customization of the campaign to the marketing strategies, as follows:

- Assignation of specific prizes to different shops.
- Location of each prize in the shop.
- The distribution frequency of each type of prize: a) attempts by ticket, b) number of distributed tickets, c) attempts by user, d) characteristics of random distribution, e) characteristics of user loyalty, f) etc.

Prizes' location in the shop allows companies to improve their advertising strategy, moving customers to specifics areas or sale zones in order to improve their possibility of capturing some prize.

The tickets

Participation tickets are distributed to the users depending on the company's marketing strategy. Tickets can be downloaded from any Web portal and gathered by the user from a NFC reader or tags located in PoS or anywhere.

Tickets store information about the campaign. Each ticket is uniquely identified and allows the user to participate in the prizes' capture. Each ticket has the associated number of permitted attempts, validity dates, allowed shops and, in order to customize the business strategy, tickets can have private information such as: whether the ticket has associated or not a prize or the number of attempts to get the prizes, among others.

Brief and detailed information about tickets is managed by the mobile application. User can consult their own tickets, the remaining participations, the prizes obtained, etc. This information is stored in the server, so users cannot lose it even if they delete it.

Moreover, ticket security is managed by the system in two ways: a) the ticket identification is double; the server side assigns a unique identifier to the ticket (always hidden to the user) and the own ticket identification managed by the shop, b) the use of the tickets can be restricted to a validation process (depending on the information defined in the marketing campaign). This process is carried out by the server and the mobile application and it may need the participation of the shop.

The prize capture

The capture of prizes is performed by means of a gesture, as shown in Figure 2. User performs a fishing gesture simulating the catching of an object that could located in some place of the surrounding environment. By doing a movement of throwing and catching with the mobile phone in the user's hand, WingTrapper detects the gesture, gathering the information from the accelerometer and compass mobile sensors, as well as the GPS user location (when needed).

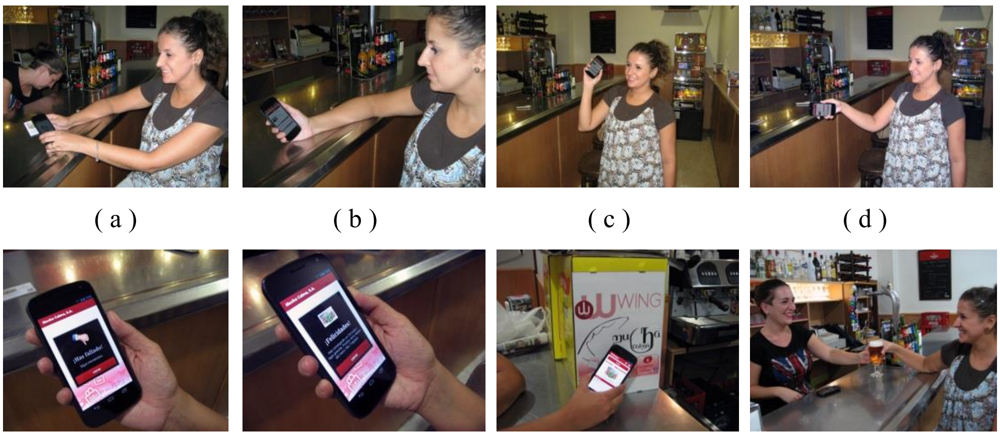
Information of sensors, shop, user and ticket is sent to the server side for analysis and validation. Once the information is validated, the participation event is tested against the campaign characteristics stored in the database. Finally, the result is sent back to the user and if a prize has been obtained, its information is stored in the mobile phone.

III.3. A REAL APPLICATION SCENARIO OF USING THE MOBILE SOLUTION

In order to show the characteristics of the system, we describe in this section one of the application scenarios where the system has been applied. We describe the characteristics of the environment and the marketing strategies proposed by the shop.

The scenario and the marketing campaign

The indoors environment is a pub in the city of Córdoba. The pub rewards its customers with a participation ticket for each drink/course. The number of attempts included in the participation ticket depends on the value of the bill. Thus, tickets that range from one to five attempts have been generated. As many customers did not own a NFC enhanced phone, the participation tickets were cards including a NFC tag and a QR code. The prizes won by customers are also exchanged in the pub using cards with NFC tags and QR codes. Users' mobile phone should be connected by GPRS or WiFi at any moment.



(a) (b) (c) (d)

(e) (f) (g) (h)

Fig 3. Some snapshots of ticket dispatching

The customer is told that the prizes are flyer bonds flying inside the pub, so he/she will try to fish one of these flyer bonds with a throwing and catching gesture performed with his/her mobile phone.

Different type of prizes were defined: a) discount vouchers from 5% to 10%, b) free drinks (wine, beer or soda), and c) WingBonus chits (from one to three chits), that is, a kind of voucher considered in WingBonus application, consisting in points to be exchanged in the pub for some service.

Showing the activity

Figures 3 (a) to (h) show some images captured from the use of WingTrapper in this scenario. Figure 3 (a,b) shows how the participation ticket is given to the customer. The ticket is stored in the mobile phone and server databases and the user can review it.

Figure 3 (c,d,e,f) shows the user participation and the result obtained. The user tries to catch some trappy in a funny experience with a bad result. Finally, in the last attempt the user wins a trappy consisting in a free drink.

Finally, Figure 3 (g,h) shows some snapshots of the prize management by the mobile application and the exchange process of the prize in the pub. In this process, the user selects the prize in the application and he/she touches the exchanging tag. In this process the information is sent to the server and a “receipt” is sent back to the application in order to be confirmed by the pub manager.

III.4. CONCLUSION

In this paper we have described the combined use of Near Field Communication technology with in-air hand gestures recognition for the building of pervasive advertising and loyalty systems.

Near Field Communication technology is used for the management of the user participation in the event, the ticket validation and collection of the prizes obtained. The event consists in the capture of prizes disseminated in the surrounding environment. In order to capture a prize, the user should perform a fishing gesture with the mobile phone in his/her hand; simulating the attempt to catch a flyer trappy. Once the prize has been obtained, the user can exchange it using NFC technology again.

Information and prize security is managed by the server and the mobile phone databases, synchronization processes, and unique object identification exchanged in the NFC transactions.

Marketing campaigns are tailored according to company strategies. Thus, WingTrapper allows the customization of the number and type of prizes and its location, user’s participation rules, rules of prizes assignation such as user loyalty, value of the user purchase, date, hour and user location, shop, etc.

The combined use of NFC and in-air hand gestures allow us to propose a fresh and funny system oriented to improving companies’ strategy for products advertising and user loyalty; offering customers rewards of any type, at the same time as capturing the attention of other customers when watching people being entertained during the event.

III.5. ACKNOWLEDGMENT

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Anexo IV | **Otras Publicaciones**

IV. Otras Publicaciones

Además de las publicaciones incluidas en esta tesis, y que completan el trabajo realizado, a continuación se relacionan otras publicaciones que están en proceso de revisión en revistas de impacto o fueron presentadas en congresos internacionales.

IV.1. EN REVISIÓN

- Gonzalo Cerruela García, Francisco M. Borrego Jaraba, Irene Luque Ruiz, Miguel Angel Gómez-Nieto. An Ubiquitous Solution for Advertising and Loyalty Purposes Using NFC Technology. Sometido a “International Journal of Ad Hoc and Ubiquitous Computing”.
- Francisco M. Borrego-Jaraba, Gonzalo Cerruela García, Irene Luque Ruiz, Miguel Ángel Gómez-Nieto. Pervasive Mobile Marketing: customer attracting and loyalty through publicity, offers and social networks. Sometido a “Journal of Ambient Intelligence and Smart Environments”

IV.2. PUBLICADAS

- Irene Luque Ruiz; Pilar Castro Garrido; Guillermo Matas Miraz; **Francisco Borrego-Jaraba**; Miguel Ángel Gómez-Nieto. Un modelo de desarrollo de escenarios para interacciones NFC sensibles al contexto. Actas de las 3ª Jornadas Científicas sobre RFID. Sociedad Española de Trazabilidad, Ciudad Real (España), 2009, pp. 173-179.
- Guillermo Matas Miraz; Pilar Castro Garrido; **Francisco Borrego Jaraba**; Irene Luque Ruiz; Miguel Ángel Gómez-Nieto. Ubiquitous Services for Future University. Proceedings of International Technology, Education and Development Conference, INTED 2010. IATED, Valencia, 2010, pp. 5486-5495.

- Irene Luque Ruiz; Pilar Castro Garrido; Guillermo Matas Miraz; **Francisco Borrego Jaraba**; Miguel Ángel Gómez-Nieto. University of Things. Towards the Pervasive University in Near Field Communications Handbook. Taylor & Francis, 2011, pp.153-174.
- **Francisco Borrego-Jaraba**, Irene Luque Ruiz, Miguel Ángel Gómez-Nieto. NFC Solution for Access to Bibliographic Soruces. Proceedings of IEEE International Conference EDUCON 2012, 17–20 April 2012, Marrakesh (Morocco); pp. 1087-1093.
- **Francisco Borrego-Jaraba**, Irene Luque Ruiz, Miguel Ángel Gómez-Nieto. NFC Solution for the Development of Smart Scenarios Supporting Tourism Applications and Surfing in Urban Environments. LNAI (6098) presented at the 23rd International Conference on Industrial Engineering and Other Applications of Applied Intelligent Systems 2010 (IEA/AIE 2010), 1–4 June 2010, Córdoba (España); pp. 228-239.