A CONTEXT-AWARE MOBILE MASH-UP PLATFORM FOR UBIQUITOUS WEB

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Abstract

Context-aware systems allow users to access services and multimedia data according to their current context (location, identity, preferences). We deem that applying Web 2.0 and Ubiquitous Web concepts as guiding principles to design middleware infrastructure may ease the development and deployment of context-aware systems and, so, result in a wider adoption of intelligent environments. Our work combines social context-aware annotation of objects and spatial regions with sentient mobile devices in order to enable advanced context-aware data and service discovery, filtering and consumption for both indoor and outdoor environments.

1 Introduction

Archetype intelligent environments are usually instrumented with a plethora of sensors and actuators in order to proactively provide users with smart services that enhance their daily activities. Unfortunately, this heavy infrastructure requirement (costly and difficult to install and maintain) has been the reason why intelligent environments, even in the indoors case, are still far from being the norm.

Nowadays, a user is usually accompanied anywhere at anytime by a constantly more capable mobile device that can act as his proxy/intermediary by sensing (GPS, RFID, barcode reading) and communicating (Wi-Fi, Bluetooth, GPRS/UMTS) with the surrounding environment, and so enabling rich interactions with it. Conventionally, either the user explicitly controls through the device services discovered in the environment (explicit interaction) or the environment triggers autonomously services based on users' context, profile and preferences published by the device (implicit interaction). In all these situations, context acts as an important source to filter down and select the most suitable services for the user at his current contextual situation.

However, it would be desirable that users accompanied by smart mobile devices could profit from smart services without having to be within an intelligent highly instrumented environment. In fact, a key aspect for the successful massive adoption of intelligent environments will be to foster the use of off-the-shelf globally accessible infrastructure, without imposing costly investments and cutting edge infrastructure deployment and installation hassles.

Sentient Graffiti (SG) is our proposition for providing such a globally accessible Ubiquitous Computing infrastructure. It is a Web 2.0-based platform which converges mobile context-aware computing with Ubiquitous Computing concepts and techniques. Ubiquitous Web (UW) can be defined as a pervasive web infrastructure where all physical objects are resources accessible by URIs, providing information and services that enrich users' experiences in their physical context.

The main aim of the SG platform is to lower the barrier of developing and deploying context-aware systems providing and consuming smart services in any indoor or outdoor environment. It is based on the spontaneous annotation by a community of users of objects, places or even other people with web accessible multimedia content and services which can then be discovered and consumed by mobile users, whose contextual attributes match those of the annotations.

Sentient Graffiti is the result of combining the following four unrelated but complementary aspects: a) last generation sentient mobile devices, b) the Web 2.0 as an application enabling platform, rather than just as a collection of hyperlinked documents, c) the UW concept where physical object services are published, discovered and accessed; and d) social annotation of the physical environment. The following facts clearly indicate that such a combination constitutes a promising approach:

- Current mobile devices multimedia (e.g. camera and media playback), sensing (e.g. GPS, Bluetooth, RFID and barcode readers) and communicating (e.g. GPRS, UMTS, Bluetooth, Wi-Fi) capabilities make them ideal sentient intermediaries between us and our environment. Good examples of such devices are Nokia N95 (includes built-in GPS, high resolution camera, Wi-Fi, Bluetooth, GPRS/UMTS) or Nokia 6131 (includes built-in RFID reader, high-resolution camera, Bluetooth and GPRS).
- Mobile Web 2.0 mash-ups, where users contribute with content and create integrated mobile applications

mixing information from diverse distributed sources will increasable become commonplace and be presented as smart services in an environment.

- The web of everyday physical resources proposed by UW suits perfectly to Ubiquitous Computing, making the UW development interlinked to a more extensive adoption of intelligent environments in previously unconsidered settings such as cities or cars.
- Folksonomies, i.e. automatic taxonomies generated from social annotations, linked with context information (identity, location, profiles) provide efficient discovery, filtering, and consumption mechanisms for the massive web of resources (smart services provided by physical objects) which constitute UW..

2 Related Work

The two most remarkable features of Web 2.0 [12] versus the traditional web are:

1. Read/Write Web, the user stops being a passive subject, a consumer of data published by others, but he contributes continuously with new information (e.g. blogs, wikis) and
2. Web as a platform, the web can be seen not only as a huge collection of interlinked documents but as a set of web applications offering open APIs (REST or Web Services) that can be composed to create sophisticated applications combining data from diverse sources, namely mash-up web applications.

Lately, significant research and industry effort [7] is underway in order to translate the Web 2.0 paradigm to mobile computing. In this work we propose to go a step further progressing from Mobile Web 2.0 into Mobile Context-Aware Web 2.0, which should ease the discovery and consumption of smart services from mobile devices.

The concept of Ubiquitous Web was first considered on the W3C Workshop on the Ubiquitous celebrated on March 2006 [16]. However, before this workshop initiative, other researchers had already considered the convergence of web-related technologies and ubiquitous computing. A fine example of this was the CoolTown project [8]. Its main goal was to support "web presence" for people, places and things. They used URIs for addressing, physical URI beaconing and sensing of URIs for discovery, and localized web servers for directories in order to create a location-aware ubiquitous system to support nomadic users. This vision resembles very much the definition of Ubiquitous Web as a net of knowledge where every physical object is web-accessible and interlinked. Sentient Graffiti is a Web 2.0-based platform also following the UW approach, but emphasizing the need to minimize the deployment requirements (making use of off-the-shelf hardware and sensing technology) on the environments and stressing the importance of user collaboration. CoolTown did not deal with the communicatory, social and navigational implication of the mass usage of a context-aware information system, as it is the case of SG and other related research such as GeoNotes [4] or InfoRadar [13].

Several research projects have also attempted to lower the barrier of deploying simple context-aware applications anywhere, both within controlled indoor and uncontrolled outdoor environments. Some good examples are stick-e notes [1], GeoNotes, Active Campus [4], CoolTown, InfoRadar, Place-Its [15], Mobile Bristol [6] or Semapedia [14]. A common feature of these projects addressed to non- or lightly- instrumented environments has been the adoption of the "virtual Post-It metaphor". This metaphor was first proposed by the stick-e notes project, which defined an infrastructure enabling the edition, discovery and navigation of virtual context-aware post-it notes. Everything (a location, an object or even a person) can be augmented with an XML document (stick-e note) which can later be discovered and matched, taking into consideration the contextual attributes associated to a tag. A key aspect on mobile mass annotation systems as these is to address the trade-off between creating an open and social information space while still enabling people to navigate and find relevant information and services in that space. The more contextual information used in the content matching process the better filtering results that are obtained.

Sentient Graffiti is in our opinion the only of the above mentioned systems which successfully combines several context attributes (identity, precise and proximity location) and keyword-based user preference filtering. SG stresses the importance user participation; users create graffitis, tag them with keywords and then comment or add further tags to other users' annotations. It can associate graffitis to objects tagged by TRIP [11] ringcodes or RFID tags, precise location (GPS) and to Bluetooth coverage areas (proximity attribute). Similarly to InfoRadar, it usefully deviates from the Post-It metaphor in that notes can be posted and retrieved remotely and to remote places through a Web 2.0 site. Finally, previous ubiquitous context-aware messaging systems do not provide an open API which enables third party applications to use SG's capabilities to mash-up context-aware application. This feature gives SG a platform rather than a simple application nature.

A few commercial systems such as Navizon (http://www.navizon.com), Socialight (http://socialight.com) or Tagzania (http://www.tagzania.com) have also combined the "Post-It metaphor" and Web 2.0 approaches. However, the context-based filtering they propose is limited, it only encompasses location and keyword filtering. They disregard other interesting context attributes as object identity, proximity, advanced privacy control (who is allowed to receive what notes) or complex temporal restrictions (lifespan, validity timetable and garbage collection), which are all addressed in Sentient Graffiti. Besides, their mobile clients compared to the SG are very limited: a) they are not able of presenting web services, only simple multimedia content, b) only offer list-based

views and not more intuitive map views, c) only work outdoors (GPS) or through coarse-grained Wi-Fi based indoor location [9], and d) allow for very limited user participation.

For a few years now, other researchers have also noticed the importance of providing middleware support for aiding on context-aware application development and deployment. Some good examples of this are the Context Toolkit [3] and Context Tailor [2] systems. Compared to these two systems, Sentient Graffiti is more generic and simple, it does not require any special purpose development and deployment of widgets or context-sensing and inferring infrastructure. Sentient Graffiti already provides the context repository and inference infrastructure.

Few research works have attempted wide-scale ubiquitous computing deployment. To date, most 'ubiquitous' computing experiments have been far from ubiquitous, generally restricted to specific laboratories or research groups. Pioneering work on this area was carried out by the Active Campus [4] and Mobile Bristol [6] projects, which chose a university campus and a city respectively as ideal settings for wide-scale deployment. With Sentient Graffiti we also attempt to encompass global uncontrolled deployment settings such as a city (outdoors) or a faculty building (indoors).

3 Sentient Graffiti: definition, concepts and functionality

Sentient Graffiti enables mobile users to profit from the benefits of Ubiquitous Computing in uncontrolled environments, only requiring in exchange, the participation in a community of users interested on publishing and consuming context-aware empowered annotations and services. Users annotate objects and spatial regions with multimedia data or web services which are only made available to other users when those match the context attributes (location range, period of time, and so forth) previously assigned to the resources.

3.1 Sentient Graffiti Concepts

In the following subsections we explain some important theoretical concepts used in SG.

Virtual Graffiti

A virtual graffiti can be thought of as a virtual post-it note in the form of an XML document which combines some content (multimedia presentation or web service front-end) with some keywords summarising the content, and some contextual attributes (profile of creator, location, time interval and so on) which restrict who, when and where can those annotations be seen.

Graffiti Authoring and Bookmarking

Virtual Graffitis are edited through a PC web browser or, on the move, through the Sentient Graffiti mobile client and then published on the back-end. We currently support two types of graffiti content: multimedia presentations in SMIL format (including video, audio and images) and URLs pointing to web service front-ends.

Before a graffiti is edited it has to be associated to a spatial region, using more accurate (GPS) or proximity (Bluetooth) location, or to an object using its identity given by a barcode (see TRIP [10] ringcode in Fig. 2) or a RFID tag.

Users bookmark graffitis with keywords. Although a user may always create new keywords, the system suggests previously chosen keywords to encourage keyword sharing.

Graffiti Filtering, Triggering and Querying

In order to prevent users from being overloaded with all the graffitis associated to a location or object, only those with contextual attributes that match users' current context are provided. Contextual attributes input into the system are: filtering keywords, graffiti presentation distance range selected, location and identity of user.

Graffitis should be returned ordered by usage, i.e. most visited and recently created graffitis come first. Thus, it is very important to track community usage of graffitis. On the other hand, an important issue to tackle in mass annotation systems is that of spam. Users should reject inappropriate graffitis so that the system stops providing them. In conclusion, Sentient Graffiti aims to undertake both context and usage-based filtering.

Graffiti Consumption and Archiving

Sometimes it will be interesting to consume a graffiti only once whereas other times a fixed number of times or indefinitely. Besides, a graffiti may be valid forever or only for a certain period of time. Sentient Graffiti takes into account all these criteria in order to clean up expired or consumed graffitis. Those grafittis removed are archived in order to keep a historical of graffitis and allow past graffiti context retrieval.

WikiGraffitis

An interesting extrapolation of Web 2.0 principles to Sentient Graffiti is what we have called WikiGraffiti, i.e. graffiti consumer participation on a graffiti by adding personal comments, additional multimedia content or keywords. This idea may be useful to encourage user participation and the creation of communities of graffiti-ers.

Graffiti Domain

A graffiti domain is a group of user-set related keywords qualifying a graffiti category. Graffiti domains are

interesting for graffiti filtering. For instance the graffiti domain Deusto_University may be associated to the graffiti qualifying keywords university, engineering, deusto, student, computer_science and so on. A user registering his interest on viewing only Deusto_University domain's graffitis will automatically view only graffitis qualified by at least one of its set of associated keywords.

3.2 Sentient Graffiti Functionality

Sentient Graffiti presents a client/server architecture where users run a SG client in either their mobile device or a computer's web browser, whilst a server-side component, namely Sentient Graffiti Server, stores, indexes and matches user annotations against user's current context published by SG clients.

From a user's perspective, the modus operandi of Sentient Graffiti can be described as a two-fold process:

- *Graffiti annotation*. Users of SG clients (mobile- or web browser-based) add annotations to objects or spatial regions consisting of:
  a. Descriptions (e.g. multimedia content or web service front-end URL)
  b. Keywords, describing annotated resources and enabling their classification and
  c. Contextual attributes which define the conditions to be met by consumers of those annotations. Some of those attributes will be set automatically by the SG client (who created the annotation, where and when) whilst others will be explicitly set by the user (location range where the tag should be viewed, who can see it, when and for how long).
- *Graffiti discovery and consumption*. Users equipped with a mobile device or remotely through a web browser running the SG client, move (physically or virtually) through an annotated (virtually graffiti-ed) environment, browse and consume the available annotations matching the user's current context, profile and preferences. This interaction may take place in an explicit, i.e. the user interacts with the application requesting available annotations, or implicit manner, i.e. the system alerts the user when new annotations are available corresponding to his current contextual attributes.

From a system's point of view, SG can be seen as both a Context-Aware Folksonomy and a Context-Aware Mobile Mash-up. As a Context-Aware Folksonomy, SG establishes a spontaneous classification of the objects and spatial regions annotated and their relationships. Thus, it is possible to link annotations of resources sharing all or a subset of keywords. As a Context-Aware Mash-up, the mobile and web-based SG clients combine geographical information in the form of maps (e.g. obtained from GoogleMaps) and the SG back-end supplied descriptions.

3.3 Sentient Graffiti Deployment

Fig. 1 shows a deployment of the Sentient Graffiti infrastructure. A cluster of central servers stores graffitis together will all their metadata so that appropriate filtering, discovery and triggering of them can be carried out.

A user equipped with a PC browser may comfortably access the SG back-end from his office or home, as shown on the right hand side of Fig. 1. By means of an advanced Web 2.0 front-end, the user may create, discover and consume graffitis, commenting or adding new content to them.

A user equipped with a last generation mobile device including a camera and Bluetooth, and optionally with a Bluetooth RFID reader (see Fig. 2), may in an indoor environment (see centre of Fig. 1) access either through a global access network such as GPRS/UMTS or a locally available network (Bluetooth or Wi-Fi) to the SG back-end. The sentient capabilities of a mobile device (camera enabling image processing of barcodes or RFID reader), enable the user to associate graffitis to tagged objects or review the graffitis attached to those objects. Noticeably, an organisation may deploy within its premises a network of Bluetooth accessible SG Server Bridges. These bridges enable users to create, discover and consume graffitis only active within the bridges' Bluetooth access point coverage. The bridge itself caches the last accessed graffitis associated to its domain. Thus, even users not equipped with sophisticated camera phones or Bluetooth-accessible RFID readers, can still profit from the Sentient Graffiti infrastructure without incurring in network communication costs (GPRS or UMTS).

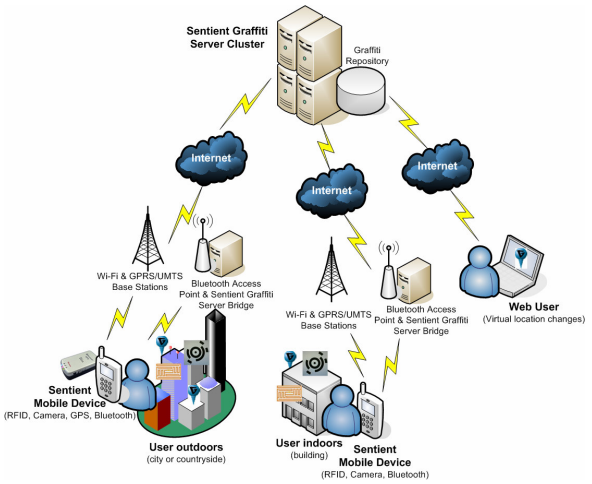

Fig. 1. Sentient Graffiti Use Scenarios

Likewise, a user in an outdoor environment may use its advanced mobile device to annotate objects and spatial regions, discover and consume graffitis in his surroundings. In these outdoor environments, the user may also use the sentient capabilities (accurate location) provided by a built-in or Bluetooth-enabled GPS device

attached to his mobile device (see Fig. 2), or the previously commented sensing capabilities (TRIP, RFID and Bluetooth proximity) to annotate, discover and consume graffitis.

Fig. 2. Advanced mobile device including Wi-Fi, Bluetooth, GPRS/UMTS and camera (center), TRIP tag and Bluetooth GPS device (left) and RFID tag and Bluetooth RFID reader (right).

4 The Sentient Graffiti Platform

In this section, we explain why Sentient Graffiti is in fact a platform rather than an application and offer some implementation details.

4.1 Graffiti Notification and Query

Two components within SG help on the graffiti filtering process: Graffiti Triggerer and Graffiti Querier. The mission of the Graffiti Triggerer is to infer suitable graffitis for a user and filter out all the ones unlikely to be of interest. The Graffiti Querier allows for the on-demand context-aware interrogation of the Graffiti Repository.

In the Graffiti Triggerer, an ECA rule based [9] inference engine at the back-end populates its knowledge base with contextual attribute changes received from users' SG clients, and infers sets of active annotations which have to be notified to those users' SG clients, where they are depicted. The graffiti inference is supported by a set of generic rules stored in a rule base which embodies the intelligence of SG. Those rules do not only determine what new annotations need to be transmitted to a SG client but they are also in charge of garbage collecting expired annotations. This component enables a SG client to operate on a PUSH manner, without user intervention. On the other hand, the Graffiti Triggerer enables a SG client to operate on a PULL manner, communicating with the back-end under user's explicit command.

4.2 Sentient Graffiti HTTP API

Sentient Graffiti is not only thought as a practical mobile context-aware application. More importantly, we attempt to provide with SG a platform useful to construct real-life context-aware applications. The functional requirements addressed by this platform on behalf of applications are:

- Model every physical object (identified by TRIP or RFID tag) or spatial region (GPS or Bluetooth proximity) whose information or services may be consumed.
- Make available to users only the annotations associated to surrounding resources available under their current contextual conditions or desired filtering requirements.
- Facilitate explicit user-controlled interaction with the smart object and spatial regions encountered by a mobile user or a web user, both in a PUSH and PULL manner.

As a proper Web 2.0-based system such as Google Maps or Flickr, Sentient Graffiti offers an HTTP-based API which enables third-party programmers to develop applications that profit from its functionality. The HTTP API provided requires third-party clients to issue HTTP POSTs with a Content-Type header set to application/octet-stream, where the body content is a binary data chunk including any of the following methods and their associated parameters: `LOGIN_USER`, `GET_GRAFFITIS`, `GET_GRAFFITIS_BY_TRIP`, `GET_GRAFFITI_DETAILS`, `GET_MAP_TILES`, `SET_USER_LOCATION`, `SET_USER_FILTERS`, `SAVE_GRAFFITI`, `CANCEL_GRAFFITI`, `LOGOFF` or `ACTIVATE_PUSH_MODEL`.

Fig. 3. Sentient Graffiti Web Interface: a) setting time and tag restrictions to a graffiti (top left), b) adding content to a graffiti (top right), c) setting location range and user constraints (bottom left) and d) viewing a graffiti (bottom right).

4.3 Sentient Graffiti Implementation

A Java implementation of the SG server-side has been completed which runs on a Tomcat application server and uses the Java EE frameworks Tapestry and Hibernate,

Java expert system shell (Jess), Google Maps API and MySQL. A Web 2.0 front-end client for SG, using the Dojo AJAX framework, has also been completed. Fig. 3 shows some snapshots of such front-end, illustrating how to create graffitis, assign contraints and view them.

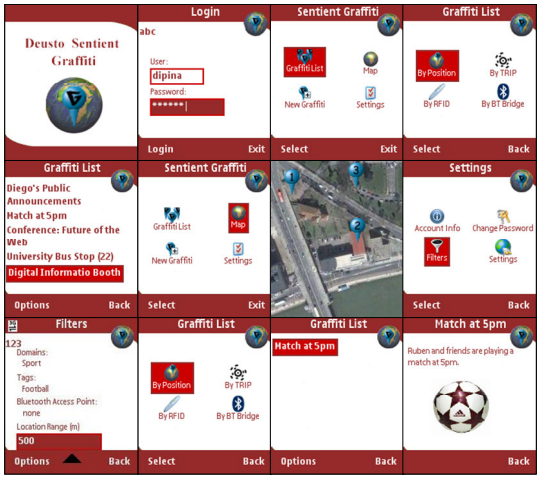

Fig. 4. A logged in user searches for graffitis by location, views all the graffitis available in its location, and repeats the graffiti search after establishing a keyword and location filter.

A Java ME Sentient Graffiti client is also available which enables the creation, search, discovery and play-back of graffitis from mobile phones. Fig. 4 depicts a scenario where a user with a mobile device and a GPS first discovers graffitis in its surroundings by position, secondly obtains a map view of the graffitis around him, and finally repeats the search by position after having established tag and location filters

5 Sentient Graffiti Examples

This section describes several proof of concept applications which have been developed with the help of Sentient Graffiti in order to prove the usefulness of this Web 2.0 platform.

5.1 Marker-associated Graffitis: Virtual Notice Board

In a university building, professors and researchers are usually scattered through several offices and labs in different floors. Students, researchers and academic staff often go for tutorials or comments to other staff offices. A common pattern followed is to leave a Post-It note outside an office to warn people with whom there was an appointment about the temporal absence from the office, when someone will be back and where that person is at that moment. Unfortunately, those notes are not very aesthetic and even more annoyingly are often seen by people that should not be aware of them.

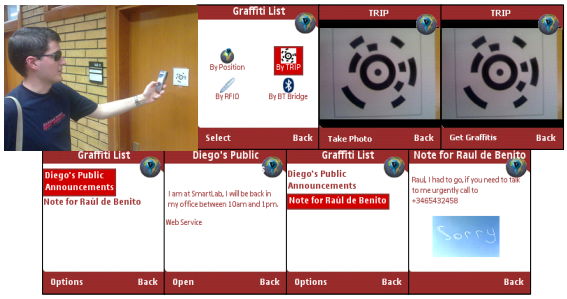

Fig. 5. A user arrives to an office, discovers a TRIP marker and through the mobile SG client finds out the graffitis associated to that marker and reviews them

The Sentient Graffiti platform is a perfect tool to improve this scenario. A person only needs to place a distinctive marker (TRIP or RFID tag) on the door of his office. From then on, he can associate graffitis to that marker, creating immediately a context-aware virtual notice board. Graffitis associated to that marker can act as announcements addressed to office visitors. The main advantages of using SG over the traditional use of Post-Its, are:

- Each announcement can only be viewed by the people marked as possible viewers. On graffiti creation we can identify whether the graffiti is public, only viewable by a group of specified users or our contacts.
- The graffiti has an expiration time or a number of maximum views associated that ensures it does not lie on the virtual board forever.
- A user can remotely create or view a graffiti. If a user is off sick, he can remotely from home, with the help of the web SG client, create a graffiti associated to his office TRIP marker. Besides, people aware of this user's virtual notice board may remotely check his notes.
- Graffitis enable user participation, since users can add comments, new content or even associate new keywords to a graffiti. So, a user visiting the office of an absent colleague could leave a comment.

Fig. 5 shows how a user obtains through a camera phone running the SG mobile client a list of two graffitis. One of them is public and viewable by everybody, whilst the second one is addressed directly to him. Placing a marker on an object, indoors or outdoors, turns such item into a smart object offering a myriad of services in the form of graffitis linked to such marker. For instance:

- A lecturer could leave a graffiti which as content included a pointer to a web service front-end through which students visiting that office could book an appointment.
- A deamon using the SG HTTP API could annotate the TRIP marker with a graffiti indicating whether the user is currently in his office or not. The user presence in the office could be determined by different mechanisms, e.g. Ubisense or RFID.

Obviously graffitis can be assigned to a marker with very different purposes. An easy way of distinguishing them is

by graffiti keyword or domain filtering. For instance, graffitis used as notes in a board could be tagged with the keyword NOTICE_BOARD, whereas graffitis used for location purposes could be assigned the keyword USER_LOCATION. Thus, it would be possible to create a location service which inspected all the graffitis in a setting of type USER_LOCATION, and produced a view of them over a building map.

5.2 Bluetooth-range Graffitis: University Services Booth

The Faculty of Engineering of the University of Deusto is equipped with several digital information booths (see top left frame in Fig. 6.), each hosted in an embedded computer with a tactile screen, from where students and visitors get university information and access academic services, e.g. course registration, marks look-up and so on. We have enhanced these digital booths by attaching to them a Bluetooth access point and installing the SG Server Bridge software. The faculty webmaster regularly publishes graffitis bound to the Bluetooth MAC addresses of these booths, only visible in their Bluetooth coverage:

- Public graffitis are used to provide nearby users announcements of general interest, e.g. a conference notice, university news and so forth.
- Graffitis addressed to specific groups, e.g. students registered for a course who are alerted about a lecture cancellation.
- Graffitis for a specific person, e.g. exam mark notification.
- Graffitis associated to a tag, e.g. OPEN_DAY, so that potential students visiting our university get an overview about interesting facts in the university in the form of graffitis. The lifespan of those graffitis is usually set to one day, so that immediately after the open day those graffitis are removed.

On the other hand, our SG-aware booths also enable students and staff to create their own graffitis. For example, users may create new graffitis tagged with the keyword ACOMMODATION so that students looking for housing can view them.

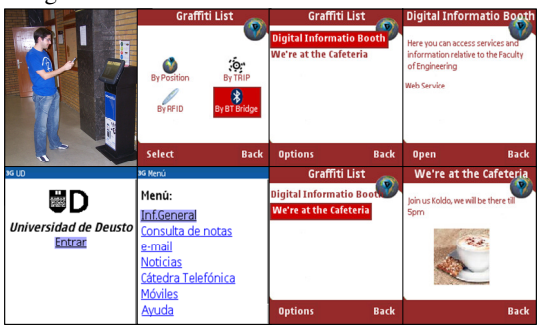

Fig. 6. A user nearby a Digital Booth obtains: a) generic university information offered as a web service graffiti, b) information specifically addressed to him through a multimedia graffiti.

Something important about the SG booths is that they only enable the creation, discovery and browsing of graffitis attached to their Bluetooth MAC address. Their main advantage is that it is absolutely free for the student, given that all the communication is carried out through Bluetooth. Fig. 6. shows a user with a Bluetooth-enabled mobile device discovering both a public web service graffiti and a private multimedia graffiti.

5.3 Outodoor Graffitis: Urban Computing

Sentient Graffiti can also be applied to Urban Computing scenarios where the precise location information of the user is known either by GPS or using marker technology (TRIP or RFID).

We have prototyped a Bus Position Alerter which informs to users present nearby a bus stop about the arrival time of forthcoming buses. A specially designed server-side application communicates with the SG platform through its HTTP API in order to periodically publish a graffiti announcing the waiting periods for next buses arriving to bus stops. Those graffitis are constantly updated with new bus location information. The information shown is retrieved from the Web 2.0 site http://www.bilbobus.info which offers real time data about the location of buses in the city of Bilbao

This prototype could further be extended to offer users in a bus stop alternative transport options, such as nearby available taxis or underground stations. All those graffitis would be tagged with the same keyword in order to foster filtering, e.g. `BILBAO_TRANSPORT`. Other interesting applications scenarios enabled through Sentient Graffiti for Urban Computing could be context-aware city tours or publicity campaigns.

Note that Sentient Grafftiti encourages third parties to create mash-ups which access to its infrastructure by means of the SG HTTP API and mix the data obtained with info from other Web 2.0 applications.

6 Conclusion and Further Work

Platforms such as Sentient Graffiti should lead us towards the creation of mobile social communities, where users both real and virtual may discover based on their current context everyday physical objects and regions augmented with virtual multimedia and service annotations, with which they can interact. Moreover, those platforms should promote a more extensive adoption of intelligent environments in previously unconsidered locations (cities, cars, hospitals, homes) without imposing important deployment and maintenance hassles.

Binding graffitis, authors and consumers to an ontology would enable associations among different author graffitis, the author themselves and graffiti consumers. We are currently planning to automate, as an off-line process, the association of tag and user entries to Dublin Core and FOAF ontology entries, respectively. For that purpose, we are currently working on the Folk2Onto tool which converts the Sentient Graffiti folksonomy, i.e. the user-

created spontaneous taxonomy of graffitis based on the keywords assigned to them, into an Ontology combining the vocabularies of Dublin Core (for graffitis) and FOAF (for users).

Further work is required to ease the provision of graffitis to consumers. Currently all the available graffitis according to a user's current context are offered. However, it would be desirable to offer those graffitis sorted by their specific importance for users. Such sorting of graffitis could be possible if graffiti consumption patterns were identified. In essence, we aim to adopt some of the mechanisms used by search engines to offer the most relevant pages as first results to the graffiti domain.

Finally, we plan to pass from the proof of concept scenarios explained to a real deployment of the Sentient Graffiti within our university campus. In fact, we are interested on analysing the role this system may play on constituting a mobile context-aware social network of our students sharing their knowledge as an ecosystem of annotations.

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