# Digital Broadcasting for Context-Aware Services in Tourism

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***Abstract*—Tourism sciences represent a very active research field in Computer Science today. In particular, in the realm of ubiquitous computing. The evolution of mobile devices and their proliferation in society, the advancement of communication technologies and the trend toward creating hybrid spaces (symbiosis between nature and technology) will trigger a radical change in the way persons involved in mobility, visitors in operative terms, interact with their environment.**

**Tourism is a well-suited application domain for contextual computing services, since visitors, can greatly benefit from being automatically assisted while on the move through their mobile devices. Existing applications are usually connected to sources of information by means of traditional communication technologies, which present the following limitations: firstly, the price of connection is relatively high, especially under roaming conditions (up to EUR 1 per Megabyte). Secondly, these technologies are real connection (pull) technologies, i.e. users have to actively search and retrieve the information they require. In addition to this, given that the amount of information on the Internet continually grows at exponential rates and the interaction restrictions posed by the small size of screens and keyboards in mobile devices, the question is: would there be a way to automatically send relevant information to visitors overcoming the aforementioned constraints?**

**Considering this background, the paper explores the extent to which digital broadcasted tourism information can be contextualized to provide relevant context-based information to support human mobility. Its contributions are threefold.**

**First, a new theoretic approach to the theory of context is proposed, which provides a new framework (named CONCERT) for contextual computing within the realm of human mobility.**

**Secondly, CONCERT, suggests gathering contextual information from Web distributed and heterogeneous information sources. No external sensors shall be used, except for the ones embedded in mobile devices. Content gathered in the Web will then be adapted for broadcast. This constitutes a substantial advancement with respect to existing context-aware approaches, since the use of applications in this case is not limited to sentient environments, i.e. they can be used anytime and anywhere, following the promises of ubiquitous computing. This is CONCERTs first level of interoperability.**

**Thirdly, CONCERT implements an ontology-based model of context, using networks of ontologies in order to increase the models consistency, reasoning capabilities, modularity, interoperability, re-use and sharing. The ontology will particularly focus on modelling visitors according to tourism established vocabulary and will implement a rule-based reasoning engine to filter incoming broadcasted information. This constitutes CONCERTs second level of interoperability, i.e. interoperability at the model level.**

**Both the technical and user experiments performed provide evidence that digital broadcasting may be processed by means of ontologies and that has a high degree of perceived usefulness by visitors.**

***Keywords*-Contextual Computing; Semantic Web; Ontologies; Digital Radio Broadcasting: Tourism;**

## I. Introduction

The tremendous increase on 4G, 3G, UMTS, WiMAX and GPRS/HSDPA communication technology-based download and streaming services, and the decrease in price of hard memory in mobile storage and player systems (e.g., iPod[1]), give rise to the following questions: does any other communication technology make sense? Would particular sectors (due to their features and characteristics) require another kind of technology that better suits their nature? Would in this case, due to its *push* nature, digital broadcasting-based information-intensive services make sense? Would digital broadcasting be an appropriate communication channel in order to distribute tourism information to support human mobility?

In this sense, two trends have been identified. One of them is related to migration of connection services to 4G technology in mass markets in order to reduce operational costs. These are on-demand services and require active user interaction to generate more data transfer on the network, i.e. the user is actively looking for information to download. These kinds of services focused mainly on mass markets and are the typical example of *pull* based or *lean-forward* services. One of the key factors for success of these services is the great initial investment in infrastructure to guarantee a high quality of service (QoS). Nowadays, 3G data service distribution systems are reaching saturation in markets where there is a high subscriber density. For example, Verizon network subscribers in some cities in the US and DoCoMo network subscribers in Japan have experienced some network collapses due to data traffic overload. In these cases, migration to 4G based systems is essential in order to maintain the QoS and to be able to support the enormous

[1]http://www.apple.com/es/ipodclassic/

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amount of current data traffic and the massive increase of traffic expected in the short and medium terms.

The second trend is digital broadcasting (both terrestrial and satellite) services, as well as the evolution of broadcasting as complementary technology for analogue broadcasting. Digital broadcasting systems aim at maintaining and, if possible, increasing their market share by providing high quality sound, grater ease of use for the final users (stressing on one of their key-issues for success, i.e. ease and convenience of use) as well as providing additional data services that generate a differential added value and a greater attraction for the user.

These kinds of services are well suited for markets complementary to mass-consumption connection-based markets. Digital broadcasting services aim to easily and conveniently fulfil the requirements of *push* niche markets in which preselected, up to date and time-distributed content is what the user really desires. Thus, the automotive, transportation, traffic information, tourism (information-intensive) and entertainment niche markets are more adequate for digital broadcasted consumption schema than interactive (*pull*) services based on a real connection. Definitely, the cities and the diverse environments will be structured under different technological frameworks, such as the Future Internet, Cloud Computing, Ambient Technologies, digital broadcasting and so on.

The remaining of the paper is divided as follows: Section 2 briefly presents the state of the art. Section 3 justifies the use of digital broadcasting for tourism and context information dissemination. Section 4 presents what Contextual Compunting in tourism is. Section 5 presents the system architecture by providing first an overview of a typical broadcasting architecture, then the CONCERT architecture and finally, the combination of both. Section 6 presents how reasoning is performed in information that has been broadcasted by the context ontology and finally, Section 7 concludes the paper.

## II. Literature Review

Digital broadcasting has been chosen as the communication technology to disseminate both context and tourism information from their sources to mobile devices. There are three standards in this realm, namely DAB, DRM and DRM +.

DAB is the first terrestrial digital radio broadcasting standard system and is intensively used in Europe. It was designed during the 1980s in Germany and is considered to be the digital equivalent to FM (Frequency Modulation), well known for its high quality sound transmission. However, due to some commercial problems, this standard has not yet been widely implemented. Nonetheless, there are some signs of recovery. For example, in the case of UK the segmentation of different contents and the inclusion of data-based services complementary to audio services, have produced a 20% increase of the DAB market share. In Germany, the intensive adoption of information-based systems by the strategic automotive sector in terms of real-time traffic information, multi-channel audio and embedded receptors in (very) high-range automobiles, has mobilised a number of agents within the value chain, from chip manufacturers to both private and public broadcasters. As a consequence, and given the official support provided by governmental institutions and regulations, the coverage of DAB has increased up to 90% of the territory.

On the other hand, DRM is intended to complement AM (Amplitude Modulation). AM was implemented at the beginning of the 20th century. The number of broadcasters and users suffered a dramatic increase, and as a consequence there are over 2 billion AM users worldwide nowadays. Thus, most of the regions in the world have access to at least basic AM radio services. In addition, these services are not only received from the country of their origin and therefore, there are an important number of programmes in long-, medium-, short-wave bands under AM frequencies.

Finally there is the DRM+ standard which can be considered an extension of DRM, since it is based and supports all DRM services and characteristics. The main difference lays in the fact that it works on frequencies up to 174 MHz, occupying spectral bands up to 100 kHz, whereas DRM works on frequencies up to 9 or 10 kHz and in a spectral band of up to 30 MHz. Summing, this is translated in a lower coverage range than DRM but a wider bandwidth up to 100 kbps.

In the framework of this paper, the Digital Radio Mondiale (DRM) terrestrial digital broadcasting standard has been chosen as experimental tourism and context information distribution channel. In addition to that, a prototype based on DRM has been developed to show the potential this communication standard has in order to meet the needs and requirements of the tourism sector, and in particular of the CONCERT framework, providing a differentiate value in various ways.

DRM uses frequency bands up to 30MHz. The frequency bands used for broadcasting below 30 MHz offer portable and mobile reception and large coverage areas - especially high frequency (HF) bands, which offer the possibility of international broadcasting without using local repeater stations (contrary to mobile telecommunication technologies). However, broadcasting services in these bands, which use analogue techniques, have a low audio quality and are subject to considerable interference.

The DRM consortium[2] was founded in 1998. It is an international non-profit organization composed of broadcasters, network providers, transmitter and receiver manufacturers as well as universities, research centres and other kinds of organizations. The DRM system was first standardized in

[2]http://www.drm.org

2001. DRM's main goal is to set a worldwide standard for digital radio in long-, medium- and short- wave bands, in order to increase the reception quality in all bands below 30 MHz.

The International Telecommunication Union (ITU)[3] recommends DRM digital transmission system, since it does not only offer audio broadcasting in near-FM quality, but also different types of multimedia data services, which are particularly interesting for the realm of information-based tourism services, where information can be sent in form of pictures, videos or podcasts, for example. The system can be applied to all AM broadcast bands below 30 MHz (LW, MW and SW) and it is understood as a one-to-many delivery system, allowing to increase the number of concurrent users, ideal for use by people on the move and not subject to real connection technologies, dependant on server infrastructures, potentially increasing the risk of failure, that minimizes the amount of concurrent users.

DRM meets all stringent requirements laid down by the ITU for digital broadcasting systems, as included in ITU Recommendations BS 1514[4]. It is also an agreed European Standard (ETSI ES 201 980) and is adopted by the European Telecommunication Standards Institute[1].

DRM is intended to substitute the current analogue AM transmission systems, thanks to the improvements its use involves. While it is true that AM allows simple receivers and has an average of 2.2 billion receivers worldwide, it also faces a number of challenges. Its poor audio quality (due to a small bandwidth), its out-dated receiver handling (no station label, no automatic frequency switching) and its high power consumption for transmission are just some of the important issues the DRM consortium is currently working on. FM has a good audio quality compared to AM, but a far smaller coverage area.

Compared to conventional analogue systems, DRM offers very important benefits for the users. Some of them are detailed here:

- Interference free reception on short, medium and long wave.
- High audio quality ('full audio frequency spectrum; comparable to FM quality).
- Sender label, text messages, data services, multimedia.
- Automatic frequency switching  simple user interface.
- One receiver for worldwide operation large coverage areas - e.g. reception of home radio stations on vacation.
- Inexpensive receivers available in the near future.

In addition, broadcasters (who in the case of the framework of this paper would be tourism boards and commissions and Destination Management Organizations (DMOs) can also largely benefit from this standard in the following way:

- Support of ground wave, sky wave and NVIS (Near Vertical Incidence Skywave).
- Bandwidth support for 4.5, 5, 9, 10, 18 and 20 kHz transmission channels.
- Support for single frequency networks.
- Up to four programmes/services on one frequency.
- Consumed transmission power only 1/4 of analogue AM.

| | f | Power | Coverage | Data Transmission |
|---|---|---|---|---|
| DAB | >30 MHz. | 50 kW | Low | <350 kbps |
| DRM | 20 +/−10 MHz. | 50 kW | Medium | 48-180 kbps |
| DRM + | 30 - 174 MHz. | 50 kW | Large | 40 - 186 kbps |

Table I
DAB vs. DRM

## III. Justification of Use of DRM

Considering what has been said about digital broadcasting so far and bearing in mind CONCERT's main objectives, the following arguments are provided to justify the election of this standard amongst the various existing ones:

- DRM is an open and free standard and does not entail royalty or licensing fees for its use to users and/or receptor manufacturers. Nonetheless, there may be other licences or royalties related with coding systems, or patents on DRM-based systems that need to be paid in case of use.
- DRM systems operate on a frequency band up to 30MHz, which makes this technology ideal in order to broadcast content in large areas in relation to the power and energy needed for these transmissions. This would be a good characteristic to take advantage of in the realm of tourism, since broadcasted information could be received in any country without concern on roaming prices.
- Although the following is a general characteristic of broadcasted services in comparison to other connection-based (*pull*) communication systems, the robustness of the DRM channel is especially remarkable in low and medium wave transmissions. In fact, in critical situations, such as natural disasters or events of war, short and medium wave band radio have been used as communication channels towards the people. These characteristics make out of DRM an ideal standard in order to broadcast not only tourism related information, but any other critical information independently from complicated infrastructures. It is important to bear in mind, that the tourism sector is especially sensitive to all information related to security, especially in particular destinations in the World, therefore, this feature of DRM is not trivial.

[3] http://www.etsi.org
[4] http://www.itu.int/md/R00-WP6E-C-0126/es

| | Comm. Technologies | DRM |
|---|---|---|
| Price | High - up 10 EUR 1 per MB | Low - free[5] |
| Coverage | Country - shades | Various countries[6] |
| Data Transfer | High | Low |
| Infrastructure | High | Low |
| Nature | Pull | Push |

Table II
COMPARISON: COMMUNICATION TECHNOLOGIES VS. DRM

- Another key characteristic of DRM as ideal communication system in the realm of tourism is its competitive positioning from the access and economic points of view, against other existing communication systems nowadays. The CONCERT based application developed in the framework of this research work covers the gap left in terms of coverage by cellular technology or VHF on the one hand, and the gap left by satellital DRM due to high cost of use reasons.

## IV. CONTEXTUAL-COMPUTING IN TOURISM

### A. Definition of Context and Contextual Computing in Tourism

A sound definition of the notion of context in the realm of human mobility is needed in order to clearly delimit the scope of the context framework presented in this paper and most importantly, overcome the drawbacks of current theoretical conceptions. Traditional approaches to context have been undertaken under various distinct perspectives such as human computer interaction[2], intelligent software agents [3] or distributed systems [4] and have therefore considered context as secondary research variable. Only particular environments (the ones populated with networks of sensors) are considered within the previous notions of context and they are modelled including the application that runs in them. Thus, existing approaches are too restrictive and make scalability of the concept to other domain applications very cumbersome.

Therefore, there is a need for a wider and more general conception of the notion of context. This conception needs to consider context as main entity and has to study it on its own right within the framework of human mobility. In addition, it seems that focussing on individuals rather than on systems and their corresponding functionalities can increase the level of abastraction of the system, and as a consequence it makes the framework more general and potentially more escalable.

Considering the previous approach, a new definition of context that suits the requirements of people on the move needs to be put forward. The intention is to adapt and integrate already existing definitions and make them more operative for the tourism domain. Thus, based upon Deys definition [2] context in the framework of human mobility is defined as: *any relevant information that characterizes the situation of a visitor. A visitor is a traveller taking a trip outside his/her usual environment and her situation is specified by data concerning a) the individual itself, b) the individual's environment (and surroundings) and c) the individual's objective at a particular moment of time. This information can be of use for a computing-application in order to support the visitor's mobility* [5].

Accordingly, *Contextual-Computing in Tourism is the scientific approach that studies and observes the context of an individual on the move and pursues to generate knowledge out of that observation in terms of how to model an individuals Context and how to manage information originated in that Context. It also explores how that information can be processed in a way that is useful to assist the visitor. Furthermore, it provides the foundational means to study the way visitors will interact in future complex (digital) environments.*

## V. SYSTEM ARCHITECTURE

### A. Overview of DRM Systems

For the broadcast signal, the DRM system uses a high number of QAM (Quatrature amplitude modulation)[6] modulated carriers spread over a regular AM (SW, MW, LW) spectrum channel. In order to generate the signal in the air on the transmitter side, the DRM transmission block diagram consists roughly of the stages explained next:

- First of all, on the source encoder and data precoder, the signal is adapted to an appropriate digital format. This source data stream is then combined in the multiplexer with descriptive information about the RF-signal (radio frequency signal), the transported data and services and additional functions. The multiplex can support up to four audio/data streams.
- The next step is the channel encoding, which adds redundant information in order to permit the receiver to reconstruct a distorted signal and defines the mapping of the digital encoded information (the DRM multiplex which is provided by the DRM Content Server) onto QAM cells. After that, a set of QAM symbols is interleaved, so that adjacent QAM cells are spread, before the transmission, across the carriers and re-ordered again in the receiver in order to avoid possible long blocks of lost data. Thus, the robustness of the bit stream to channel errors is highly improved. Then, in the OFDM (Orthogonal Frequency Division Multiplexing)[6] cell mapper, the different types of QAM cells are collected and placed on the time/frequency grid. OFDM symbols are separated by guard intervals between every symbol.
- And finally, the modulator converts the digital representation of the OFDM signal into the analogue base band signal.

Based on the previous, figure 1 shows the overview of a typical broadcasting service architecture adapted for the

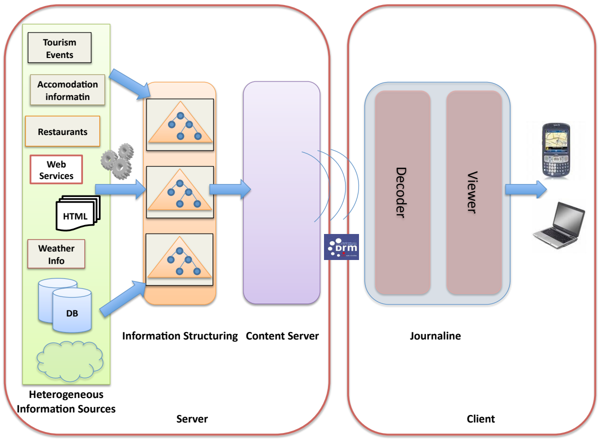


Figure 1. Typical Digital Broadcasting architecture

particular case of the CONCERT framework. The server side gathers information from heterogeneous distributed sources in Internet. This information may contain data about tourism sightseeing offers, restaurants, accommodation, agenda, museums, as well as other context information, such as weather information and so on. These sources can be simple (unstructured) Websites and/or XML files[7], or official structured destination management organizations' (DMO) data specifically uploaded for public consumption.

Once this information has been gathered, it has to be structured in XML file that follows a specific schema. This schema has to be compliant with the defined Journaline schema[1], so that it can be uploaded to the content server[7]. The Content Server compresses and reformats this file into a JML (Journaline Markup Language)[1] and finally broadcasts it via MDI (Multiplex Distribution Interface)[8]. This has to be done in this way, since broadcasting bandwidth is often limited by the configuration of the Content Servers carousel.

The Journaline module, which is located on the client side (in the case of the CONCERT framework, on the visitors' mobile device) receives the information that is being continuously broadcasted by the Content Server. Journaline implements two functionalities:

- First, it decompresses the information that has been received in JML format back to XML in the decoder module.
- Then, the resulting XML file is further transformed into HTML and the file would then be ready to be browsed in a typical Web navigator located in visitors' mobile devices.

[7]http://www.w3.org/XML/

Journaline is the standard developed by the Fraunhofer Institute for Integrated Circuits[8] (Fraunhofer IIS) for data transmission for DRM broadcasting channels, as well as for other digital broadcasting systems such as DAB/DMB[1]. The use of Journaline guarantees the optimized use of the radio channel for information distribution through the JML (Journaline Markup Language), a simplified version of the XML. It also assures service compatibility with DAB/DMB in all kinds of mobile devices such as Smartphones, PCs, music players, PDAs enabled with DRM/DAB/DMB receivers.

### B. CONCERT Architecture

The CONCERT contextual computing architecture (Fig.2) is based on a layered distribution in order to separate different important tasks involved in any context-based application, i.e. context gathering by context providers and context processing modules.

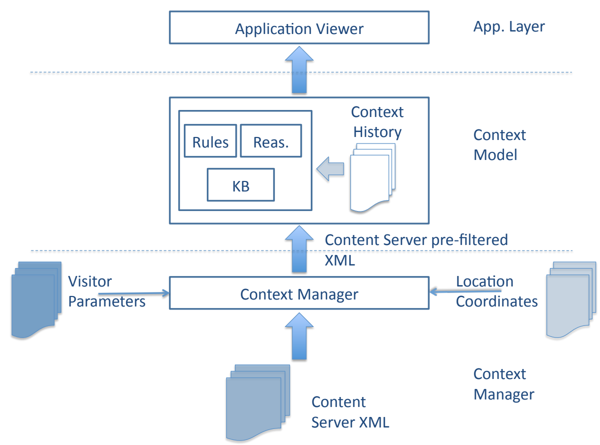


Figure 2. CONCERT Contextual Computing architecture

The different modules and components in the architecture are interconnected as shown in figure 2. Its constitution has been highly influenced by the theoretic conception of the CONCERT framework. The three theoretic contributions of this paper have direct implications in the CONCERT architecture as follows:

- *Definition of context*: The new theoretic approach to context explained earlier, led to a new definition of the notion of context[5], which at the same time, determines the input parameters to the context manager. These input parameters are visitor parameters, general context and tourism information from the Internet (specified in this particular case but not subject to the Content Server XML file), and location coordinates or

[8]http://www.iis.fraunhofer.de/index.jsp

other potential sources of information directly provided by user devices.

- *Interoperability at the infrastructure level*: The fact that no sensors are used allows to use a less complex architecture in terms of hardware, since all incoming information from the Internet is reduced to one XML file.
- *Digital broadcasting*: The fact that the CONCERT framework experiments with digital broadcasting implies that visitors must use laptops, since no DRM receiver has been yet made available for mobile phones. This means that the CONCERT architecture will be hosted in the client, and allows the context network of ontologies to be larger than it would if it had to be hosted on a real mobile phone type of device. In addition, the interface provided by the CONCERT Viewer allows users to intuitively introduce their personal parameters. These personal data shall be hosted in the client.

The context model used in CONCERT does not have any effect in the architecture, since it is located in a middle layer (see figure 2) and is not part neither of the input nor of the output of the architecture. In addition, it is important to remark that this architecture is not only independent from the context gathering infrastructure, but also from the particular sources of context information, as they reside on the Internet. All context and tourism information constitute an input parameter to the context manager and contribute to provide the CONCERT architecture independence from any fixed infrastructure.

The components of the contextual computing module shown in Figure 2, are explained following (some of the components have been omitted from the figure for clarity):

- *Context Manager*: This is the central component of the Contextual-Computing layer. This software module is a background process that runs on mobile devices (client). The Context Manager receives information from the Context Providers (information input), such as the location sensor embedded in the mobile device, the wireless broadcast source and the user preferences, provided manually by the user. The Context Manager pre-processes all of the gathered information and consequently feeds the Knowledge Base with that information triggering the flow of events, which are necessary to provide visitors with relevant information for their needs. It offers a centralised way to access context data sources. In addition to this, the Context Manager also runs another service, which consists of removing every certain time all of the incoming information in order to avoid information overloads.
- *Context Providers*: Context Providers are software adapter modules, which specialize in a specific type of context information. They capture the information and send it to the Context Manager defined earlier. There are three context providers in the CONCERT architecture, from which one of them can be treated as a multiple context source, since it provides information from various distinct information sources in Internet:
  - *Location information*: The Location hardware present in the mobile device, feeds the system with visitor location information. It provides the information in typical GPS coordinates format. This information is then transformed into "logic location" and added into the knowledge base this way. It is important to remark that in case of GPS failure, the location can be introduced manually.
  - *Visitor Information*: Another context provider is in charge of maintaining an up-to-date list of user preferences, that visitors are expected to provide to the system via the CONCERT viewer. The application layer features an interface where users can update their personal parameters such as preferences, motivations, and so on, to enhance the information filtering process. It is worth mentioning again that the visitor information corresponds with the guidelines provided by the UNWTO.
  - *Sources of information*: Finally, a third context Provider handles the reception of Internet based context and tourism information. In the case of the CONCERT framework, the Journaline XML file received by means of digital broadcasting provides this context information. External entities are used to acquire context data from heterogeneous sources, e.g. Web sources, such as weather Web services, or from the travellers mobile device, e.g. profile, location. This XML information, together with the other context information is fed into the context manager for its pre-processing and aggregation in the knowledge base. This is one of the novelties within the CONCERT framework: the use of potential CONCERT-based application is not going to be limited to a particular predetermined sensor-populated location. On the contrary, it could be used anywhere there is telephone network coverage (in this particular case, digital broadcasting coverage) that enables access to information sources.
- *Knowledge base*: The knowledge base is the core part of the CONCERT architecture. The Knowledge Base configures the second layer of the CONCERT framework and it contains the following components:
  - *ContOlogy*: This is the network of ontologies that comprises the ontologies themselves and instance data, which models visitors context. Initially, the knowledge base is populated with static information regarding the environment and the services

offered in the environment where the application is running. Gradually, as the dynamic flow of context information reaches the context manager, it is sent to the knowledge base after pre-processing. The context manager checks whether a particular class of an ontology within the network has already been instantiated. If it is the case, it then checks the value of the instance and compares it to the new one. If they are equal, the context manager does not perform any action, else it first removes the existing variable, sends it to the context history database and then inserts the new one.

- *Rules*: The rules have been implemented on top of the network of ontologies in order to filter tourism information according to the particular value of context at a given moment of time. They are used by the reasoning/inference engine.
- *Inference engine*: It is used to obtain high level context (situations) based on defined rules and the semantics of information that has been gathered and stored in the Knowledge Base. As dynamic context information reaches the network of ontologies, the reasoning engine filters tourism information based upon the rules that govern its behaviour. It uses the specific values of context constituents at that moment in order the filtering to match users' requirements at that same moment of time. It stores all the statements about tourists context by the use of ontologies.
- *Context History*: The context history repository contains data about past values of context. This information can be of use to support and enhance the filtering process. The context history can also be useful to predict future traveller situations by the use of the Context History Exploitation Engine or to reason over current values of context variables. One possible application of use can be the following: for example, if the coordinates given by the mobile device GPS incorporated sensors correspond to Athens and they do not exist in the Context History database, therefore, the knowledge base can further infer that the traveller is in Athens for the first time.
- *Access manager*: It manages the interaction between the platform and the application layer. This interaction can be in a request/response manner or in subscription basis, where the platform sends context information according to defined events (context changes, time intervals).
- *Query engine*: It allows queries about context information, as location, temperature or higher level context.
- *Privacy, Trust and Security Control*: Given that contextual information may contain very sensible private information, a security and privacy module needs to be implemented within the architecture. This way, travellers themselves are the owners of the information and can decide the extent to which they want to share personal information either with others or with the system. Past context-aware initiatives have also worked on data privacy[3][9].

• *Application Module*: The third level of the context architecture is composed by the application layer, which consists of the presentation logic that interfaces between the contextual computing system and the user. The application features an embedded Web browser where the result of the filtering (an output HTML file containing only context-based information) is displayed in the CONCERT Viewer.

### C. Combined Architecture

One of the general research questions suggested throughout the realisation of this research work suggests whether digital broadcasting can be used in order to provide context-based information to people on the move. Previous sections have described and analysed both the CONCERT architecture and the digital broadcasting architectures, as well as the requirements in terms of information structure. The issue now is how to combine these two architectures to provide visitors with semantic-based contextual information using digital broadcasting as communication technology.

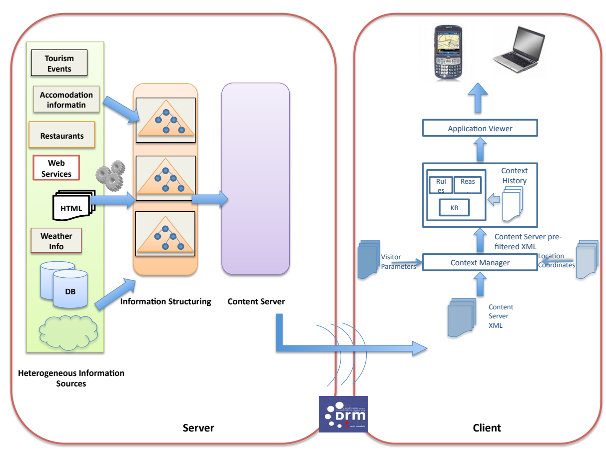


Figure 3. CONCERT digital broadcasting architecture

The objective is to filter all the incoming information by means of the rules defined on top of the ontology in order to only display on the screen of mobile devices the piece of information that is really relevant to tourists given their current context.

Considering only the digital broadcasting architecture shown in figure 1, the information shown in the mobile device on the client side without any further processing other than the one specified in the architecture, would correspond to all the information broadcasted, i.e. relevant and non-relevant information. This would not be of significant support for visitors, since they would have to actively browse all the information, looking for the particular piece they are looking for, not even exactly knowing what is that they are looking for. This would create a cognitive overflow and would discourage users to use a CONCERT-based application.

So, if an approach could be found to combine the digital broadcasting architecture in figure 1 with the CONCERT architecture in figure 2, there would be a way to further process tourism broadcasted information by means of context values. Thus, figure 3 presents the conceptual approach to the semantic-based broadcasted information filtering process that takes places with the combination of both architectures.

The CONCERT architecture seats on top of the broadcast architecture on the client side in another layer. It receives DRM signal and acts as a filter over the decompressed XML file received by the Journaline module through semantic processing automatically providing visitors with context dependent information. The details of how this architecture works are thoroughly described following.

## VI. Context modelling ontology in tourism: ContOlogy

The context ontology ContOlogy [10] is the core element of this framework. It represents the translation of the conceptual notion of context presented previously, into a computing model through an ontology language capable of checking the model's consistency and providing relevant information through rule-based reasoning. Despite the fact that there are already various context modelling ontologies [11][12][13][14][15], they are still in an early experimental phase. As is the case with most of the work on context-awareness up to now, those ontologies have been developed for different specific uses and cover different domains, but they are not general enough and their extensibility and re-use within the framework of humen mobility poses serious difficulties.

Since the objective of this framework is to assist visitors anywhere, anytime (following the promises of ubiquitous computing) and existing ontological resources do not fully fulfil this framework's requirements, a new ontology structure needs to be found. A possible approach to overcome this obstacle is to use networks of ontologies [16]. A network of ontologies is a collection of ontologies that are related by properties. Therefore, this approach to context modelling is different from others in that it does not have a double ontology conception of context consisting of a core ontology and other domain ontologies that align to the core ontology. Rather, it focuses on the different constituents of context and develops an ontology for each of them. Networks of ontologies enhance ontologies modularity and flexibility and hence make their interoperability and re-use much simpler and less dependant on the specific purpose of the ontology.

| Concepts | Definition |
|---|---|
| Visitor | Characteristics of the human being in mobility |
| Preferences | Information that describes the visitor's personal characteristics |
| Role | The role a visitor plays at a given moment |
| Activity | What the visitor is doing |
| Environment | The surroundings of the visitor, weather conditions at the location |
| Device | Physical object the visitor carries |
| Network | Infrastructure to connect devices and convey information |
| Motivation | Reason why the visitor is travelling |
| Location | Coordinates that define the visitor's location |
| Time | Physical dimensions that measures spam between facts |
| Tourism | Tourism services provided at a given environment |

Table III
Context ontology: ContOlogy

The components of the network of ontologies, i.e. Context constituents, have been determined considering the definition of the notion of Context put forward earlier in the paper and its architecture. Each of these constituents will determine each one of the ontologies of the network and based upon the objective pursued by the prototype, the relationship among them will be determined.

### A. Context Reasoning

A specific use case scenario shall be used in order to explain the role of reasoning within this context framework. An individual (Carlos) participating in a conference that takes places at the San Sebastián Technology Park is considered. The Context Manager provides this individual the role *AttendingConferenceVisitor*, since it reads in Carlos' calendar the word 'conference'. Carlos has arrived on his own, however he has a busineess lunch scheduled after the conference. This information is also retreived from Carlos' calendar.

The conference finishes at about 1 pm. and it is time for lunch. Carlos meets the person he is having lunch with and the system begins the reasoning process. It is the first time that Carlos has been to the San Sebastián Technology Park, so he does not know what restaurants can be found in the area. The meeting Carlos is having is an important one and he wants a good restaurant. The context manager gathers Carlos' personal information, Carlos' location and the XML file received through digital broadcasting.

The Context Manager filters the XML file by location and sends the resulting XML, together with Carlos' personal information on to the ontology. This mapping is done through pre-defined keywords, and the information of the XML is filled on the ontology as individuals in their corresponding classes. The properties and restrictions have been defined within the ontology in a way that if Carlos is using his mobile device, that is connected to the Technology Park main Wi-Fi WLAN, then Carlos is in the environment of the Technology park and should be recommended one of the restaurants in that environment. The restrictions, in this case his role, environment and price of the restaurant are also taken into account in the reasoning process, thus Carlos is offered one of the best restaurants in the Park. Figure 4 shows a screen shot with the result of the filtering process.


Figure 4. Display of Context based Tourism Services

## VII. Conclusions

The literature review in the realm of context-awareness shows that (i) neither does consensus exist on a definition for the notion of context nor do existing ones suit the requirements to support human mobility, (ii) a sufficiently agreed model for context and methods for contextual information management do not exist, (iii) existing works reveal the need for a scientific approach to study context as a scientific discipline on its own right and (iv) the use of sensors to gather contextual information poses serious limitations and pre-requisites for making contextual-computing systems universally utilized.

The specific contributions of this piece of research tackle these problems from three different perspectives. Firstly, the paper provides a new defintion of the notion of context within the framework of human mobility. This adapted definition of Context is human-centred and contextualizes the visitor and the visitors location. It observes the nature of human mobility and opens new chances to study complex scenarios in highly digitalized and hybrid spaces.

Secondly, this approach gathers contextual and tourism information from broadcasted Web information sources instead of using networks of sensors. This way, there are no restrictions with respect to the area where the framework can be used, since digital broadcasting is more powerfull than networks of sensors in terms of area covered. Nonetheless, since digital broadcasting is a push-based information service, it shows to be rather adequate for the tourism domain. Digital broadcasting will make receiving information a lot cheaper for visitors than standard connectivity technologies, especially to those under roaming conditions. Still this technology is in its early stages with respect to data transfer and there are a number of issues that have to be considered. Apart from the low data transfer rate, typical mobile phones are not yet equipped with digital broadcast decoders. How this framework can work with other connectivity technologies at the same time is also an open issue. More research is necessary as well on middleware technologies and platforms to find out the extent to which they can support Contextual-Computing applications efficiently, for example, using Wi-Fi, RFID or Bluetooth as uplink channel and processing part of the reasoning in a remote server.

Thirdly, by using networks of ontologies to model the visitor taking into account established tourism parameters, a framework for interoperability for other kinds of systems is provided, since ontologies have shown to be an appropriate tool for data exchange and integration. Besides, ontologies provide reasoning capabilities, which are particularly interesting for data inference, consistency checking and detection of data duplicity. As a consequence, the amount of imposed preconditions with regard to existing research approaches is greatly reduced and the resulting model adapts better to the framework of mobility. All in all, the amount of imposed preconditions with regard to existing research approaches is greatly reduced and the resulting context framework adapts better to human mobility. In addition, the network of ontologies allows to define a number of rules that will be used in order to filter all of the incoming information and provide context-based information.

The results of this research work are expected to have a significant impact on contextual computing in general and on contextual computing in tourism in particular, that boost the relationship of humans with their ever more digital environment. Therefore, context-based applications will not only shape the future of tourism services, but will also provide with the opportunity to better understand human behaviour in the digital society of the future.

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