Context-based Experience of the City via Broadcasted Content Retrieval

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ABSTRACT[1]

In this paper we propose a new service platform for the distribution of location and time-sensitive data that augments and enhances real-time experience of the city using mobile digital TV broadcasting technology. The limitation of the unidirectional communication is alleviated by the proposal of introducing context-based filters-applied locally-that allow for automatically selecting the most relevant information to be viewed by the retrieving/receiviother ng party.

Categories and Subject Descriptors

J.7 [**Computer Applications**]: Computers in Other Systems – *Consumer products and Real time.*
D.2.10 [**Software**]: Design – *Methodologies and Representation.*

General Terms

Design, Experimentation, Context-based Services, Digital Content Dissemination/Acquisition, Human Factors, Urban Dynamics.

Keywords

Urban information systems, digital TV broadcasting, DVB-H, user generated content, context-based filtering.

1. INTRODUCTION

Currently, several research and applications both in industry and academia are focused on monitoring of urban processes. This includes using information generated as a by-product of city dynamics in real-time, such as mobile phone usage, transportation networks [1], and user generated content [2]. The ultimate goal is to provide urban planners and top-tier decision makers with new tools for understanding urban dynamics, enabling them to better analyze the current processes, and predict future trends, towards an anticipatory design, development and management of our cities.

Some projects have explored ways to complement these efforts and study the potential of this information once provided back to citizens. For instance, WikiCity Rome [1] allowed people access real-time data inferred from dynamics that occur in the very place they find themselves in, creating the intriguing situation that the map is drawn on the basis of dynamic elements of which the map itself is an active part. Two interfaces were developed to provide the information in the form of maps: a public screen and an applet accessible via web.

Even if this implementation was rather prototypical, it was already noted that Internet-based solution for content sharing has limitations for this kind of applications. In fact, if several million of people want to retrieve the same information simultaneously, this could cause bottlenecks in the data transmission network because of the need to send the same data packages for many individual clients. The problem becomes even more relevant if the clients use 3G or GPRS mobile devices since the current cell-phone networks are not generally designed to support such high volume traffic, with the consequence of limiting the access to regular calling services.

On the other hand, the transition from analog to digital mobile TV is becoming pervasive at a global scale. This transition involves considerable investment in infrastructure and new services that allows for new mode of data connectivity and real-time delivery of content. Mobile digital TV can be considered as a substantial addition to available technologies of pervasive computing, data transfer and global connectivity in terms of bandwidth and reachability of prospective recipients. Despite all the possibilities, current commercial scenarios do not live up to the potentials of the technology. There is little experiment in utilizing mobile digital TV as the medium of choice in mediating experience of major events or festivities or enhancing how urbanites inhabit the city or navigate it. This short coming is partially due to lack of a viable business model for new services and the constrains of the technology including the unilateral data connectivity which has limited designers in envisioning services that require user-input/user-interaction in determining parameters pertaining to what, when and how should be delivered to retrieving/receiving parties.

In this paper we try to focus on a vision for the future of Internet services incorporating mobile digital TV. We propose a new service platform for the distribution of location and time-sensitive data based on the mobile digital TV broadcasting technology. The limitation of the unidirectional communication is alleviated by the idea of introducing locally operational context-based filters that allow for automatically favoring information that is most relevant to the real-time context of the users. The question is how to utilize the new possibilities offered by this platform and cellular networks in the most efficient and user-friendly way, providing context sensitive, broadcast-on-demand and interactive services on mobile phones or other terminals of choice. On the other hand, from content point of view, the question is how user-generated content can be shared and delivered via a hybrid platform that incorporate the potentials of all available broadcasting and communication standards.

2. MOBILE TECHNOLOGIES FOR CONTENT DISTRIBUTION

The most commonly adopted solution for mobile content distribution use the Internet or broadcasting networks. While acknowledging the possibilities offered by Internet-based solutions here we would like to focus on broadcasting alternatives

2.1 Broadcast-based technologies

Broadcast networks are characterized by one-to-many transmission and high capacity. The main advantage of the mobile broadcast platform is that video/TV is transmitted within the broadcast networks and that one person's use of video/TV services doesn't influence the use of others. This is a very important advantage for the video/TV services with mass appeal. An important drawback of these platforms is that it needs specific mobile terminals which can connect to broadcast networks.

By combining broadcast and a return channel (offered by a mobile operator), the service provider can split the services into different

elements and transmit the elements with high capacity requirements and mass appeal within the broadcast networks. This combined platform enables service providers to develop new services including high quality video/audio components and interactive services.

A number of different standards for mobile broadcast platforms [6] exist on the market. Apart from the technological efficiency issues, a number of other issues are related to the mobile broadcast standards. The spectrum issue is a main problem for literally all mobile broadcast standards, in particular the ones like DVB-H, which preferably use the UHF spectrum.

2.1.1 DVB-T

Digital video broadcasting terrestrial (DVB-T) [4] is the European based consortium standard for the broadcast transmission of digital terrestrial television. In this system compressed digital audio, video and other data is broadcasted in an MPEG [7] transport stream, using COFDM (Coded Orthogonal frequency-division multiplexing) modulation. DVB-T for stationary reception has a bandwidth of about 20 Mbps in 8MHz channel: the bandwidth when designed for mobile reception is about half of this. Thanks to its bandwidth features, DVB-T is very useful in mobility. In fact, in contrast to other multi-channel infrastructures (cable and satellite) DVB-T makes mobility and nomadic use (indoors as well as outdoors) possible. This is valid when it concerns nomadic as well as mobile use of TV in camping vans, cars, busses and trains and, due to the rapid technological development, when it comes to pocket mobile terminals, PDAs, etc.

2.1.2 DVB-H

DVB-H [3] is an upgrade of the terrestrial version (DVB-T) for mobile reception; it reduces the power consumption and enables better performance in a multi path environment. In November 2004, DVB-H was adopted as a European Norm by ETSI and there is political support from the EU to use DVB-H as the preferred technology for mobile TV in Europe.

A single DVB-H carrier of 8 MHz in a typical operating environment has a bandwidth of about 10 Mbps and can carry between 20 and 40 channels of good quality with video encoded in H.264 and sound in AAC. Statistical multiplexing is also possible in DVB-H, ensuring optimum use of bandwidth to deliver services. DVB-H is designed for use in Bands III, IV and V as well as the L- band.

DVB-H technology is ideal for delivering broadcast digital TV to large numbers of receiver in an efficient and cost-effective way.

DVB-IPDC [5] is the set of specifications that allows for IP Datacasting, needed for deploying commercial mobile TV services based on Internet Protocol. DVB-IPDC was originally designed for use with DVB-H physical layer that can ultimately be used as higher layer for all DVB mobile TV systems, including DVB-SH and any other IP capable system (2G/3G network).

3. CONTEXT BASED EXPERIENCE OF THE CITY

In this paper we try to focus on a vision for the future of Internet services incorporating mobile digital TV. The question is how to utilize the new possibilities offered by these platforms and cellular networks in the most efficient and user-friendly way, providing context sensitive, broadcast-on-demand and interactive services on mobile phones or other terminals of choice. On the other hand from content point of view, the question is how user-generated content can be shared and delivered via a hybrid platform that incorporate the potentials of all available broadcasting and communication standards.

A quick online search indicates that considerable resources are dedicated to user-generated content sharing platforms that allow users to upload and share media documenting their day-to-day experiences with others. In short, numerous online platforms facilitate sharing multi-modal content with others and during the last decade we have witnessed gradual consolidation of this culture of collaborative content generation and sharing by users that has resulted in creation of cultural capital through crowd outsourcing of content generation.

On the other hand, smart mobile phones with 2.5G and 3G connectivity are becoming pervasive. Mobile phones are embracing and embedding feature after feature transforming to personal communication, entertainment, transaction and navigation centers. Mobile devices and Internet allow the users to broadcast multi-media content pertaining to their real-time experience of the city as well as additional contextual information acquired from embedded or added digital sensors. Thus, any individual with a 3G smart phone can be considered a possible contributor as long as that entity is willing to generate and share multi-media, multi-modal digital content. The content can be uploaded to central servers in real-time or post-production via an IP-based connectivity protocol that allows for sufficient data bandwidth for seamless broadcasting – in case that the content is being shared in real-time.

We propose a new service that allows for acquiring and managing collaborative information and distributing it based on user's context. The system is based on delivery of relevant real-time content about the city and its events. It can include: what is generated and contributed by participating users such as real-time video streams from mobile phones; the content that is produced, administered and shared by city such as real-time crowd spotting that shows which zones of the city are populated more in real-time, traffic information or real-time information about public transport, bus routes and real-time location of busses on the routes, or material produced by production agencies and networks, or material contracted by businesses and commercial entities in form of location-based advertisement.

The content is broadcasted and urban citizens can get access to the broadcasted content via mobile TV-enabled devices. The broadcasted content is then filtered locally on the device based on a relevance level set according to the user's context. According to Day at al. [2], we define the context as any information that can be used to characterize the situation of entities (i.e., whether a person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, temporal information, identity and state of a user (e.g. user's profile), or computational and physical objects (e.g. device specificities). In particular user's profile includes the user specified preferences as cultural events (theatre, opera, live), locations (e.g. parks, shopping centers), transportation (e.g. public transportation, taxi, and car), and browsing history (e.g. the user previous navigations).

In our proposed system the context that set the criteria for filtering the broadcasted content locally on the device includes the following: the specificities of the receiving device –whether it is a mobile phone, an embedded receiving unit in digitally augmented furniture such as bus stops or in smart navigation systems for vehicles-, user specified preferences stored on the device locally as user profile, user history of choices and content navigational pattern stored on the device locally, real-time location of the receiving device that indicates how the location sensitive content such as location based advertisement or event reporting should be filtered, current time of navigation session that indicates the temporal criteria of filtering for content that has temporal relevancy, and user initiated input such as search queries.

Some scenarios that explain the proposed context based filtering are presented in section 5.

4. SYSTEM ARCHITECTURE

The envisioned goal of the system is to acquire user and city's contents from different/hybrid providers and deliver in broadcast, real-time experiences in form of multi-modal media with additional contextual information.

Moreover, any individual can access the content that is broadcasted on different devices with appropriate technical support. The retrieval

portal can vary from smart mobile phones to digital public screens, to home entertainment devices, to desktop computers. The aim is to propose a system architecture that provides consistent runtime environment for open browsing and standalone applications cross multiplicity of platforms.

The delivery of multiplicity of multi-modal media content along with their embedded contextual information is a challenge that demands serious consideration in terms of available connectivity technologies and maximum bandwidth that each of these can provide. Mobile Internet on 3G and beyond 3G networks could be considered as the network infrastructure for the proposed system since they allow both the delivery and acquisition of multi-modal media. In fact, the cellphone network is based on a bi-lateral connection and data dissemination and delivery happens through following steps: In Content viewing; the viewing party initiates a request for specific data package via user input in provided interface for a search engine; the request for content generated locally on the viewing terminal is sent via network to the central server; upon reception of the request package server side algorithms are invoked to query the database for requested content based on specified criteria; the customized result of the query is sent back to the requesting party in form of data packages pertaining to the search criteria. In content contribution, an application on the device establishes a connection with a central server via which real-time audio-visual stream along with contextual information is transmitted to the server to be managed, stored and made available for dissemination.

However, cellphone network-based data connectivity can result in unmanageable data traffic in the network. In fact, if multiple viewing agents try to access the content repository using the above over-simplified connectivity protocol awaiting the retrieval of multiplicity of high-volume content packages, the network will face serious traffic overload that will result in partial or over all crash of the network due to the generated data traffic. In contrast to the above scenario, imagine that the real-time delivery of the content is envisioned as channel-based continuous broadcasting of all available data packages in real-time using mobile digital TV connectivity protocol. Although digital TV supports multiple media and data channels, it offers a unidirectional transmission. Thus it only allows for purely local interactivity where viewers interact with downloaded applications to the terminal.

Therefore, we propose a hybrid architecture that makes use on one hand of the potentialities offered by mobile Internet platforms on the 3G networks to acquire content and on the other hand of the mobile digital TV technology for content delivery, by broadcasting the acquired content packages to unlimited number of recipients, whereas the content is filtered locally based on context of the recipient.
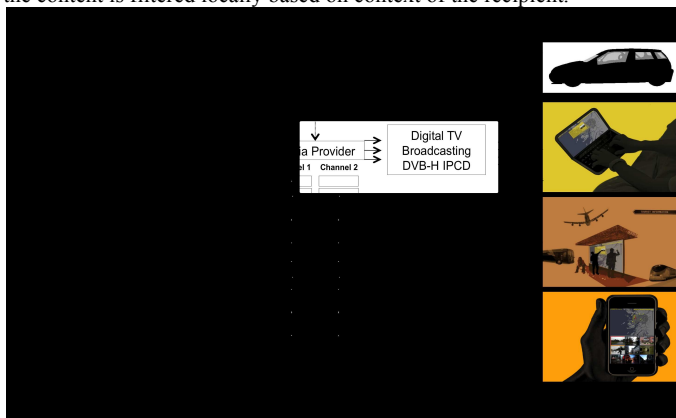

Figure 1. System architecture

Fig. 1 shows the high-level architecture of the system. Content contributions from different content sources are received by a central system via internet protocols. From there, a media provider packages

the information under multiplicity of channels depending on the service that the channel is associated to, i.e. city navigation or city events and festivities. Different channels are broadcasted via mobile digital TV broadcasting protocols. The broadcasted, integrated content will be available on plethora of recipients including cellphones, receivers embedded in digitally enhanced urban furniture like information displays and bus stops or smart navigation systems for cars. Since content dissemination happens via broadcasting as mentioned before there is no technical limitation in terms of data traffic on how many receiver units can access the content simultaneously.

Since the data connection is one-way meaning that the viewing agent is not able to initiate server-side query to retrieve desired portion of the content, our system controls what is to be viewed via a multiplicity of control mechanisms:

1. Data content is thematically categorized and channeled based on pre-defined criteria the broadcasting agents, i.e. based on geographical location, actual time and date, or thematically e.g. culture, entertainment, sports, city navigation, city events, etc.

2. Although the connectivity provided by mobile digital TV connectivity protocol is a unidirectional one meaning that it does not allow for filtering of information based on user input as server side received request, some level of control over navigation of the data can be provided locally. Applications can be implemented that allow for filtering of navigable content packets. Imagine while browsing the urban-scape in a city like Boston you are tuned in to a mobile digital TV channel that provides real-time feeds of all the cultural events of the city. Using a local navigation/filtering tool you can specify to turn on the information layer pertaining to all architectural lectures whereas you turn off the layer that includes performing arts or music festivals.

3. Local algorithms installed on the device allow for pattern recognition of user's likes and dislikes through time as well as determining user's context. Thus the applet can customize the navigation interface based on this acquired knowledge.

Fig. 2 shows different components on the receiving device. The integration Content Reception unit receives different packages of information in form of different channels. In this illustration we have included one channel with possible information packages integrated as such. Content management unit consist of different embedded sensors that allow the system to identify the context.
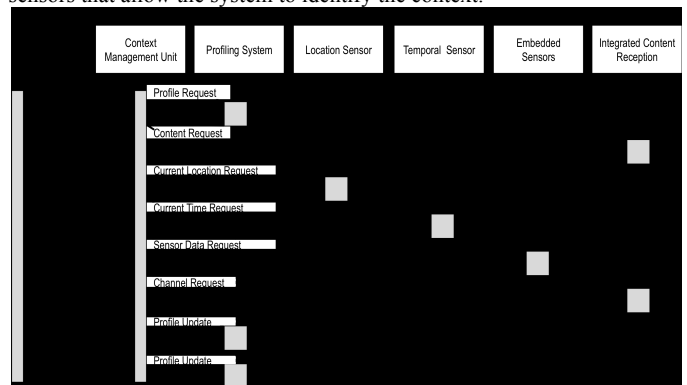

Figure 2. Interaction between components of the client application

As shown in Fig. 2, the system tries to retrieve context relevant content once the detected context is communicated with the content management unit. In this sequence diagram we describe interactions between the components of the content management unit. On start, the application asks for profile, which includes the specificities of the receiving device and user profile and use history as well as other locally stored information. In the next step, the system generates a request for available/received content via broadcast technology. The

list of available content is generated and provided to application. In the next step, the application request for relevant or context-based list. The context is identified by the system through sending requests and receiving the processed information from location sensor, temporal sensor and other embedded sensors. Based on the identified context, a list of relevant or context-based content is generated and provided to the application. The profile is updated by the system based on the list of relevant content and identified context to keep track of contextual patterns such as geo-spatial movement pattern of the user. At the application end, once the user selects a specific content from the generated list based on context and relevancy, the system will provide the selected service and meanwhile updates the profile to keep track of the content navigation behavior of the user through time which allows the system to improve its understanding of the user's preferences and likes and dislikes. The updated profile is going to be used by the system in future sessions.

As elaborated above, we look at possibility of customization of received/retrieved content packages locally on the receiving device as oppose to server-side customization or browser-based request/respond paradigm that requires bi-directional connectivity that is not provided in digital TV broadcasting network. Augmenting the potentials of Cellphone network-based connectivity protocols – two way connection that allows for user contribution – and digital TV broadcasting – one way broadband data connection that allows for delivering high-volume multimedia content packages to a theoretically infinite number of users - allows us to benefit from the potentials of both systems while negotiating the constrains and shortcoming of each.

5. A POSSIBLE SCENARIO

The following scenario explain how a set of content, broadcasted using a digital broadcasting platform, can be processed in different ways by different users. Here we assume that the receiving device is a mobile phone. We will call our personage Filippo. It is 6pm on a Friday night and Filippo is just leaving his office at MIT SENSEable City Lab after a long week of hard work and he would like to spot an event or activity in the City of Boston to spend his Friday afternoon. He uses the application running on his mobile phone to find out about what is happening in the city, where are the hot spots at this moment, and how he can get to one of the points-of-interest using public transport. Under such circumstances the context can include the following information: Filippo's current geographical location retrieved from embedded GPS receiver on the device; current time and date; Filippo's profile stored locally on the device that includes his specified preferences, e.g. he is interested in cultural events such as theatre, opera, live music performances, music festivals, etc.; Filippo's history of choices stored locally on the device, e.g. in his previous navigations he has chosen to check out user-generated videos about a Jazz Festival, and also he has searched for good deals and sales for books on history of Rap music; Filippo's input, i.e. in form of a semantic search for live performances; and Filippo's mode of transportation deduced from acceleration and speed data retrieved from corresponding embedded sensors on the device.

Tuning to the system, Filippo finds out that there is a considerable crowd in Harvard Square. Also navigating through the location-based advertisements placed on the system he finds out that the reason for it is a Folklore Music Festival organized by commercial entities of that neighborhood. He finds out that there are several people in the area that are streaming video of their experiences in real-time. The information layer populated with real-time video streams is filtered based on history of his choices stored locally on the device. Based on his history of navigation, videos that are semantically tagged in a way that seems being of interest show up in the interface. He chooses one of the video icons and based on his input, the chosen video is zoomed into. He likes what he sees and he decides to go there and check it out for himself. Choosing his destination and his preferred mode of

transportation, i.e. bus, the system will show him the real-time location of the buses and the bus routes that are relevant to the defined trip from the origin (Filippo's current location) to destination (Filippo's chosen destination). After taking the bus and getting to Harvard square, the device detects his location and will filter the information layer containing location-based advertisement locally based on his stated preferences on his profile and his current location. This information layer will be populated with advertisements that are relevant to his context. Once at location, in the midst of the offered urban experience, Filippo decides to share his experience of the event via real-time streaming from his 3G mobile phone. Filippo's contribution is added to the grid of user-generated real-time video content that will be available via broadcast to others who are tuning to the system.

6. CONCLUSIONS

In conclusion incorporating the potentials of two different data connectivity technologies - cellphone network-based protocols on one hand and digital broadcasting on the other hand - and enhancing the system with local processes for identifying the context and filtering the received content based on the real-time context, allows for envisioning different scenarios for collaborative real-time content generation/dissemination platforms. Using this approach, the use-base of the system will not be limited due to data traffic concerns since theoretically speaking unlimited number of receiving devices can hook up to a broadcasting network at any given time. Although the received content is the same for all the parties, how it is packaged locally on the device and filtered is based on context of individual devices and specificities exacted by users or connection session.

If such integrated system is implemented, it is safe to claim that our cities will become real-time wiki-cities, where as events are detected and reported in real-time by everybody, experiences (content with contextual information) are broadcasted and accessed by everybody. The physical infrastructure of the cities is augmented by a collaborative digital layer, pertaining to real-time processes of the city, which are acquired and shared by city officials, institutional or commercial entities as well as city denizens. Thus, we claim that the future of internet is real-time wiki-cities: cities augmented by collaboratively created digital layers of multi-modal media situ that is being accessed by mobile entities via mobile devices on-the-run and based on their context. Yet the potential of the proposed scenario is not just limited to retrieval of information on mobile phones; retrieval of information can also happen via other embedded receivers be it in digitally enhanced urban furniture providing relevant information to passer-bys such as smart bus stops or smart navigation systems providing context sensitive information to drivers, or even home entertainment systems.

7. REFERENCES

[1] Calabrese, F., Ratti, C. 2006. Real Time Rome. Networks and Communications Studies. 20(3-4), 247-258.

[2] Girardin, F., Calabrese, F., Dal Fiore, F., Ratti, C., Blat, J. 2008. Digital footprinting: Uncovering tourists with user-generated content. IEEE Pervasive Computing. 7(4), 36–43.

[3] Schatz, R. Jordan, N. Wagner, S. 2007. Beyond Broadcast- A hybrid Test bed for Mobile TV 2.0 Services. IEEE ICN.

[4] Ladebusch, U., Liss, C.A.. 2006. Terrestrial DVB (DVB-T): A Broadcast Technology for Stationary Portable and Mobile Use. Proceedings of the IEEE. 94(1), 183-193.

[5] DVB- IPDC fact sheet. 2009. www.dvb-h.org/PDF/DVB-DC%20Fact%20Sheet.0408.pdf

[6] Digital video broadcasting (DVB) transmission system for handheld terminals (DVB-H). 2004. European Telecommunications Standards Institute.

[7] Pereira, F. 2007. MPEG multimedia standards: evolution and future developments. In Proceedings of the 15th international Conference on Multimedia, New York, N.