UBIQUITOUS INFRASTRUCTURE FOR CONTEXTUALISED EXHIBITION SERVICES

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ABSTRACT

The ubiquitous computing field is evolving rapidly. Its applications are penetrating everyday situations. Furthermore, the increasing demand on personalisation and customisation is calling for new means of providing content and services to the users based on the user's own specific context. Museums and exhibitions, which form an integral part of the cultural heritage of society, are seeing increasing demands for contextualised exhibition services at every stage of the museum experience i.e. before, during and after a museum visit. Contextualisation aims to elicit a more engaging experience in order to enrich visitors' learning and enjoyment. Moreover, technological support for exploration, explanation, and communication are needed to support museums' essential functions, particularly, interpretation and exhibition.

In this research thesis, a novel infrastructure, called Medient Infrastructure is designed, implemented and evaluated. The main results, usage showcases and a demo scenario for the Holstentor museum in Lübeck, called "Holstentour", will be demonstrated to outline the infrastructure's design, which is realised based on Web Services, Service Oriented Architecture and an Event-driven approach. The design considers easy and flexible deployment in complex exhibition scenarios. Moreover, one of the main design goals is minimizing the required infrastructure and installation procedures, hence, visitors can use their personal mobile devices easily and effectively. Furthermore, museums are free to design their own mobile and stationary context-aware applications.

Basic, advanced and environmental context information is gathered to support a ubiquitous museum information environment to support multimedia content delivery on Bluetooth-enabled and AJAX supported mobile devices, whereby Ubiquitous Learning can be supported in museum environments. Finally, the system's approach is focusing on museums for the first pilot prototype. For future work, other environments such as the university campus, hospitals, etc will be tested against the proposed approach.

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1 CHAPTER ONE: INTRODUCTION

This chapter is a literature review of ubiquitous and media technology in museums. The aim is to show the main motivation for this research and the current trends in museums, by illustrating the link between the early development of museum exhibitions and the current needs, requirements and challenges. Moreover, it gives an outlook into multimedia and cutting-edge technology that has been used and likely will be used in the future in this field.

The chapter starts with a review of this research main motivations. After that, a review of the history of exhibitions in general and their development, as well as the role of multimedia in exhibitions is presented. Finally, the role of ubiquitous computing and its increasing adaptation in exhibitions is discussed.

1.1 Needs and Motivation

Technology is penetrating every part of our lives. It is getting more advanced, more powerful, always available, smaller and cheaper everyday [89]. Nowadays, every person is equipped with high-tech devices such as smart phones, mobile devices, digital cameras, handheld computers, positioning devices, and so on. As an indication of the vast demand on those devices, in Japan more than 90 million high performance mobiles are used, knowing that it has a total population of 127 million [65]. Actually, mobiles have high potential to be the future platform for personal museum guidance [12]. On the other hand, the cultural experience and the museum's visit are considered as very important parts of the cultural heritage and everyday leisure. As this research will illustrate, historically, technology has had an outstanding role in supporting the understanding and interpretation of cultural heritage especially in museums.

Making use of such available, daily-used, inexpensive and lightweight portable and stationary technology can support greatly people's activities in different environments. This research aims at enhancing the support for

museum visitors by maximising the museum's environment benefits from technology.

Museums carefully regard the visitor's experience [40], which is an important part of the museum visit and it cannot be in any case separated from the design of the museum exhibition. Therefore, visitor's context, which directly influences the perception of cultural artefacts [39], is given great attention and is assumed to be a cornerstone for the success or the failure of the visitor experience. Currently, automatic generation of context and context-awareness are becoming important features for most newborn applications. Moreover, context information such as location tracking, visitors' identities, time and data measures are becoming accessible anywhere and at anytime [51][73][25]. A detailed outlook about context awareness in relation to museums is considered an important element for this research whereby, clear illustration of its benefits on museums' visitors can be investigated.

From other side, Multimedia supported by new and novel science fields, such as ubiquitous and pervasive computing, may provide strong technological support for museums by considering their strong impact on the main museum functions. This research scope will be limited to the interpretation and exhibition functions of museums [38], with a little insight on other functions.

User generated content (UGC) is another part of the visitor experience in museums [79]. High social and educational discourse in any museum makes social abilities, such as exhibits ranking, annotating, implicit and explicit interaction between visitors, to play an effective role and add new possibilities in museums. Storymaker, as discussed in [43], is an example of many, illustrating some new possibilities of UGC.

Even though technology is giving solutions for people's daily life problems, it also creates challenges. Multimedia in the museum could cause interference with the exhibited artefacts. On the contrary, its absence results in losing very important communication and exploratory channels

with visitors [24]. Furthermore, ubiquitous computing [89] is a very promising concept to be applied, but it has a very limited success outside research labs because of its complexity. Moreover, ubiquitous computing applications are often complex to implement and hard to maintain [16]. Investigating an easy deployment approach of ubiquitous computing technology in museums is another issue in this research.

Museums' special needs and requirements are putting more challenges on any technology to be deployed in its protective environment. Social, educational, environmental and financial needs should be considered carefully.

In this research, a study about applying new technology in general, multimedia, ubiquitous computing and social software specifically, in the museum environment is investigated, whereby a novel infrastructure for providing contextualised exhibition services in museums is argued and designed. The proposed services are an enhancement of the museum needs to communicate, exhibit and interpret with the enforcement of having a ubiquitous media support for the physical environment to enhance the educational and enjoyable experience of the visitor. A working prototype of the suggested infrastructure is to be built as a proof of concept and reflection of the research results. The prototype will be called "Medient infrastructure: a Ubiquitous Infrastructure for Contextualised Exhibition Services". The name is constructed from words "ambient" and "media". In other words, it symbolises the infrastructure aiming at providing media accessibility in physical space.

1.2 Museums and Exhibitions

In this section, museums are defined and types of museums are outlined. Afterwards, an outlook into museums of the future is given.

1.2.1 Definition of museums

There is no unified and generally agreed definition of a museum. The International Council of Museums (COM) defines museums as "*A museum*

is a non-profit making, permanent institution in the service of society and of its development, and open to the public, which acquires, conserves, researches, communicates and exhibits, for purposes of study, education and enjoyment, material evidence of people and their environment." [45]

According to the Canadian Museums Association, museums are defined as follows*: "Museums are institutions created in the public interest. They engage their visitors, foster deeper understanding and promote the enjoyment and sharing of authentic cultural and natural heritage. Museums acquire, preserve, research, interpret and exhibit the tangible and intangible evidence of society and nature. As educational institutions, museums provide a physical forum for critical inquiry and investigation ..." [14, pp.1].* Their definition continues with further characteristics and classifications of museums. The importance of this definition comes from the inclusion of many terms, characteristics and elements that are used and referred to in this research.

Figure 1 The museum main functions as the hand's figures according to [38]

According to Joseph Veach Noble, the purpose of the museum is "*to collect, to conserve, to study, to interpret and to exhibit.*" [38, pp.75] Apparently, these five pillars or what he referred to as the hand's fingers are forming a unit to achieve a common purpose, but at the same time, each one of them is independent.

Under the first three fingers relies the definition of the classical past and the very early museums. The classical example of this definition shall be the earliest known museum, the "mousseion" of Alexandria three centuries before Christ as mentioned in [38], where the idea of collection was the dominating model of museums. Actually, that museum was rather a library than a museum in our current understanding.

Emphasizing the last two fingers highlights the modern form of museums, starting from the end of the 18th century [38]. Following the modern development movement of museums, the first public exhibition known as the "Ashmolean Museum" opened as the first public museum in 1683 [55]. In less than 150 years, this model has been rapidly spread not only in Europe but also all over the world. The Louvre, the Museum de l'Histoire Naturelle, and the Musée des Arts et Métiers were born as the first modern museums [38]. Later, the development process continued and as a result of international exhibitions, a number of museums have been established like the Palace of Discovery in Paris and the Technical Museum of Industry and Trade in Vienna [1]. Here, we can clearly notice some changing in role of the modern museums. By that time, museums have been looked at as a promotion to science, economy and industry, before the collection model was the dominating.

The 19th century was the scene of museums booming in Europe (e.g., 100 new museum in Britain and 50 in Germany), South America (e.g., new museums were founded both in the capital cities and in the provinces), and Asia (e.g., Indian Museum, Central Museum of Indonesian Culture, Tokyo National Museum, Sarawak Museum in Malaysia and many others in China and Thailand). In the late 19th century and early 20th century, large

number of museums has been established in Africa, including Zimbabwe's national museum, Mozambique's first museum, and many more [55].

1.2.2 Definition of exhibitions

As the definition of museums, the definition of the exhibitions is not unified either. Nevertheless, many exhibition designers agree to this definition "*An exhibition is a means of communication aiming at large groups of the public with the purpose of conveying information, ideas and emotions relating to the material evidence of man and his surroundings with the aid of chiefly visual and dimensional methods*". [39, pp.92]

Exhibitions in museums vary according to the size and the aim of the museum. Permanent exhibitions are more common in big museums. Long-term and short-term exhibitions are common in small and middle size museums. Nevertheless, those types share the same essential aims as explained in the definition. With the availability of new technology, questions regarding ways of enhancing the visual and dimensional methods are emerging. This research is taking part of this investigation.

1.2.3 Types of museums

A closer look at the way museums are classified is essential to understand the message and aim of museums. Besides, it is importance to deduce applicable and usable ideas for the development of any suggested approach by this research. Museums can be classified by different categories, including funding resources, the audience, the nature of their collection, etc. Museums can also be classified based on the role, they play in the society. A complete taxonomy of museum classification schemes is out of scope for this thesis and therefore, in accordance with [28][56], a classification based on their collection to distinguish between general and specialized museums will be exemplified. Five basic types can be identified: general museums, museums of history, museums of art, the natural history and natural science museums and finally museums of science and technology.

Considering and covering this classification scheme extensively will help to reveal important aspects for this research. The nature and the amount of needed content by museums can be inferred, each type's mission is clearly raised and the targeted audience can be inferred. Those three aspects are generally needed in the design process of any proposed solution for museums. They are strongly needed in this research, where the main interest is to provide contextualised services based on the museum's content, to enhance and support museums' certain elements and functionalities such as "to exhibit" and "to interpret" as mentioned before in the museum definition. Therefore it is important to understand the museum's content, audience and scope.

The general museums have mainly collections of more than one subject. They are also known as multidisciplinary or interdisciplinary museums. The primary task of those museums is to reflect the natural and human history, traditions, and creative spirit of the area, taking in account that many of the general museums are serving a region or locality [28][56]. Audience specialized museums take the general approach of collecting content that suits the targeted audience, like the children's museums. An example of such museum should be Kanazawa Bunko Museum, Yokohama, Japan [28].

The second, the most known and widely spread type are the museums of history. This type of museums evolved and shaped through different stages from the biblical history, moving to the Romantic Movement and industrialisation. The third stage was in the late 19th century, looking at history from different view. Rejecting the history of "great man" to the history of "ordinary people" was the main remarkable change. Later in the fourth stage as Heide Hagebölling [38] mentioned, is a step backward, were collecting and preserving all materials related to the past. For more details, under this type come the antiquities museum, the archaeology museum (historical evidence recovered from the ground) and the ethnography museum (museum of the cultures of other peoples). Many more museums are covered under this category [28]. In Mexico City

specifically in Chapultepec Castle, the National Museum of History is an example of this category.

The third type is the applied arts museums, which have a large visitor group. Actually, it is a huge repository of objects and pieces of art like paintings, sculptures, and the decorative arts. Those collection items are mainly accessible by elite [38, pp. 78]. A great attention is given to the ambient environment to create very strong visually appealing exhibits and to stress aesthetic value of the work. In addition, one of the main concerns of this type of museums is the preservation factor of the artwork, because of its sensitivity [53]. Examples of this type are the Museums of Modern Art in Stockholm and New York City.

The fourth category is the natural history and natural science museums. This type of museums is mainly concerned with the natural world. Collections from the nature are exhibited, such as specimens of mammals, birds, insects, plants, rocks, etc. Lately, the environmental issues and the issues about the natural conversion are strongly present [95]. The Natural History Museum in London and the Smithsonian Institution's National Museum of Natural History in Washington, D.C. are examples of this category.

The fifth category is the science and technology museums. Here, the preservation is for processes rather than objects. Meaning that, it focuses on preserving and exhibiting the technology and science development and their applications. An example of this type is The Ontario Science Centre in Toronto.

The different types of museums are considered as a key issue in defining the functional and non-functional requirement analysis of museums in chapter three. They also have a direct impact on the suggested usage scenarios in the same chapter.

1.3 Towards Ubiquitous Media in Museums

Multimedia is used in many different contexts and fields within museums. The International Council of Museums (ICOM) definition of multimedia: *"As multimedia is simply a combination of two or more different media, computerized multimedia systems form part of a long tradition of interpretive and explanatory technologies and techniques that grows from slide shows, text panels, and dioramas. Multimedia makes use of computers to store, combine, retrieve, and present information from a variety of media, and enables user-defined interactive navigation through these sources. A multimedia database of text, images, and sound can be searched quickly and effectively." [22, pp. 8-9]*

Following this definition, the importance of multimedia in museums, its services, its played role, and its relation to the visitor experience can be clearly deduced. Making use of the availability of different information channels provided by multimedia means within a museum will be tackled as a major part of this research. Attaching digital multimedia content to the museum exhibits exploratory and interpretive factor helps to realise parts of both museum and exhibition definitions and functions. Moreover, using new navigation scheme based on visitor's navigation in the physical space is integrated as part of this research. Following that, systems can deliver an enjoyable and aesthetic experience as well as an educational one as needed in museums [45][39].

Ubiquitous computing plays major role for supporting and delivering multimedia in museums. Mark Weiser defined the term ubiquitous computing in 1993 as: "*Ubiquitous computing is the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user.*" [89, pp.1] Another definition is the one from Marcia Riley in 1997: "*Ubiquitous computing, or calm technology, is a paradigm shift where technology becomes virtually invisible in our lives.*" [76, pp.1].

This section aims in investigating the possibilities that ubiquitous computing can provide in the museum environment to help in developing and enhancing the visitors experience during their visit. Hiding or making the computers invisible is the idea of the pervasive computing, furthermore, the computers should be smart to deal and to act within the environment. This leads to an intelligent environment [59]. On other hand, the main aim of ubiquitous computing is to integrate the pervasive computing functionalities within large-scale mobility [59]. Figure 2 shows the level of embeddedness and mobility of pervasive and ubiquitous computing according to Lyytinen and Yoo.

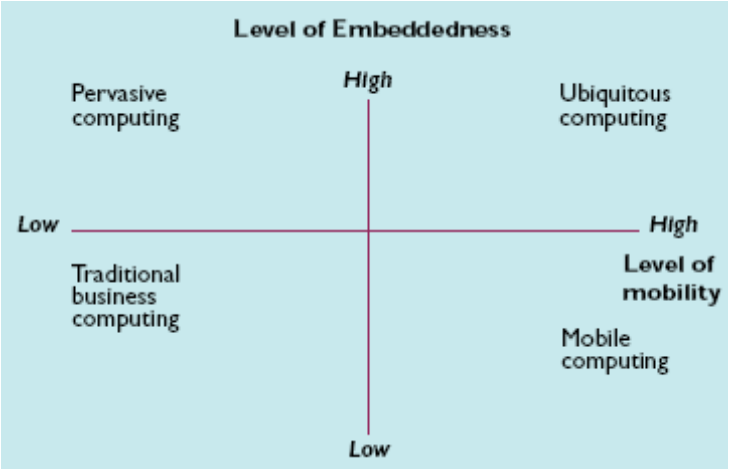


Figure 2 Ubiquitous computing and its level of embeddedness according to [59]

In fact, the main four principle of pervasive computing mentioned in [37] do fit to the museums exhibition needs. Here, the four principles are listed and projected in the exhibition environment:

- Decentralization: support the exhibition by distributing responsibilities among a number of devices, which have synchronized information. Mobile phones, PDA's (Personal Digital Assistance), laptops, kiosks and different type of currently available screens are all deployed in many exhibitions. More advanced services would become available with the existing information channels in the museums exhibition, if these devices were combined

in a ubiquitous manner in order to hide and distribute computation power.

- Diversification: it is not only the diversity of devices that meant to be in this concept, but also the diversity of content, services, ways and forms of accessing media. Managing this diversity is one of the main issues of ubiquitous computing. Previously, the diversity of exhibitions in forms of content, forms, and contexts are already tackled which of course enforces the needs of ubiquitous computing to be applied in museums.
- Connectivity: the seamlessly integration and connectivity among IT world's devices and the common standards, indeed is a great support to provide a connected objects in physical space. Ubiquitous computing allows for different exhibits and exhibitions to be connected together with a seamlessly bidirectional dataflow.
- Simplicity: the whole idea of ubiquitous computing in exhibitions is to provide a carefully designed system to provide convenient, intuitive and self-evident interaction modes for the visitor.

The ubiquitous computing is seen to be strongly relevant to education. Some believe that it is already affecting students' educational activities [13]. It will help to transfer learning to be everywhere in anytime and improves the communication abilities. Moreover, this will help the lifelong learning [50] and learning as becoming [63]. Hence, ubiquitous computing appears strongly in museums as one of the educational environments. Lately, Ubiquitous learning (U-Learning) [52][81][88], which enables people to leaning anywhere at anytime in a ubiquitous environment, and Ubiquitous museums (U-museums) [57] are new terms appear to get more attention in literature.

1.4 Museums in 21st Century

Usually, museums give great attention to their collections and buildings, to attract the visitors and to create a new visitor experience. Therefore, the way of exhibiting collections is a key of success for most museums. Many believe that this attention should also involve the visitors and their

behaviour, in order to integrate their expectations and their behaviour as factors of success for the museum.

In fact, many studies have been performed in this area, which show clearly the diversity of the needs and the behaviours of visitors. Hicks in his research about the modern museums, especially about the technological museum, concluded the importance for museums to learn from the experience of their visitors [40]. Of course, the availability of today's technology opens many doors to discover and cover those needs.

Certainly, design and design quality play a decisive role in exhibitions generally. Design is a primary pillar to determine the interpretation process between the exhibition visitor and the exhibit itself. It is obviously critical for museums, which can also be seen by the presence of "interpretation" and "exhibition" in Veach Nobles' definition of museums.

As mentioned earlier in this chapter, there are different models and types of museums. Many studies and theories in the 21st century are investigating different approaches and interests that museums might take. One of those studies concerned about the exhibition design [22] is suggesting a cultural approach, which is highly connected with the understanding of communication as social processes and symbols. Whereby suggesting new forms of awareness to give visitors different starting points for their visit in the same exhibition or the same museum. Apparently, exhibitions nowadays are broadening the scope of their interest to have better understanding of visitors and better exhibition services, which influence the continuity of museum exhibitions. Later in this chapter, the use of technology for supporting those demands will be investigated.

Lately, the idea of connecting exhibits together in small scale and museums together in larger scale is increasingly expanding. One example is the idea of having the regional and national museums in London as one dynamic museum [22]. Most likely, this model will be applied in the next few years or at least part of it for every existing museum. Connecting the

museums together will strengthen small museums like the regional ones by connecting them to other small museums or to bigger museums like the national ones. At the same time, the collection of the bigger museums will be for sure enhanced without losing each own identity. Actually, now the world is more connected as ever before. People are connected digitally through many communication channels like the World Wide Web. Furthermore, data is exchanged as never before and the travelling is much more dynamic and easy as well. Therefore, the idea of connecting museums around the world is greatly supported. Hence, providing means, of connecting exhibitions together, to give visitors broader sense of the museum and also connecting them with other museums should be considered during features' investigation of this research suggested infrastructure.

Such a need shows clearly that this field is still expanding, improving and taking a new shape. Although the development of museums already has a strong history, new ideas and concepts still evolve and the museum landscape will continue to be a dynamic and vivid place for experiments and development. Museums are a central part of human culture and as our civilization takes new shapes and moves from one stage to the other, museums will also evolve.

Again, this leads to the many questions regarding technology in general, its role, its effect, its influence on the museums. Issues regarding the ubiquitous computing impact and its role in the museum are important to be explored. Following that, sections in the next chapter will cover briefly and answer many issues regarding this role, starting from the discussion about multimedia in general and then diving to the level of mobile computing in relation to museum exhibitions.

2 CHAPTER TWO: STATE-OF-THE-ART AND RELATED WORK

In the previous chapter, themes related to museums, multimedia and ubiquitous computing were discussed. In this chapter, the current trends and usage of multimedia and ubiquitous computing in museums are addressed, in respect to technology and social aspects.

2.1 Multimedia and the Museum Exhibition Experience

In fact, the visit of a museum usually starts with the thinking and planning of the visit. At this stage, the visitor obtains information about the museum through different media channels by reading, listening, watching information about the museum. Nowadays, the Internet makes the planning process to visit a museum a very important step. Other sources of information might be brochures, guidebooks, radio, television, newspapers, etc. The role of multimedia in the preparation of the visit continues inside the museum. Description materials about the museum and some general guidance information are the first multimedia channels inside the museum. The usage of multimedia continues during the visit and later after the visit.

There is no doubt that multimedia is an important and relevant pillar in exhibitions. Indeed, this can be clearly inferred by going back again to the definition tasks of museums in Figure 1 in combination with the definition of multimedia at section 1.3. Multimedia supports diversity of channels for education [24][27][39], interpretation[24][27] and documentation [24][84]. Furthermore, we cannot detach it in any way from the social and cognitive functions of the museums [24].

Apparently, multimedia has a clear benefit in the collection function of the museum through the documentation and the curatorial research [84]. The multimedia databases make controlling and retrieving content much more effective than ever before. Multimedia also conserves the exhibit by storing databases of different media content (text, images, and videos) about the

object or the exhibit. Sharing and searching functions are provided to help in collecting and preserving exhibits and information about them. More clearly, the digital imaging is very important in the restoration and conservation process. For example, it enables for physical characteristic and composition analysis of the artefact [15]. This interpretation is also an important function of museums and is considerably enriched by multimedia. Multimedia proofed its effectiveness as an interpretive and explanatory tool [24] that influences the way people interpret the exhibited objects in the museums. One other major function of multimedia is presenting information in different forms and through different channels (multi-modality). This is exactly what museum needs for exhibiting objects to the visitors.

The power of interpretation and exhibition of the multimedia will be now discussed more extensively because of its great relevance to the thesis topic. The advantage of multimedia is the power of presenting and accessing media content in far different ways. It is not restricted to linearity, it rather allows for interactivity, whereby the user role is not passive any more. In contrast, he/she is actively interacting with the presentation in varying modes. The integration of multimedia in museums requires carefully reconsidering the audience, which includes normal visitors, researchers or staff as explained previously in this chapter. Those users can access the museum locally, nationally, or globally [24]. Furthermore, different usage behaviours can be observed: purposeful behaviour by hunting for specific things, exploratory behaviour by looking at exhibits randomly, and playing behaviour [48].

2.1.1 Usage scenarios of multimedia in museums

Looking at and discussing some examples might show the roles of multimedia in museums in a practical way. The International Council of Museums listed a number of multimedia usage scenarios in museum exhibitions in [24]. This list is neither decisive nor final. It can be expanded to cover more and more scenarios. This list consists of the multimedia as index (good understanding of the organization of the

exhibition), visitor guide, study collection (accessing material that can not be physically exhibited), explainer (including educational material and exhibition guide), examiner (engagement using question in the visit and pre/post the visit), and emotive trigger (effective sensory experiences, e.g. high quality graphics) [24].

A very interesting example of using multimedia in exhibition is given by an exhibition held in the Hunt museum in Ireland in June 2003. The main issue was to increase the engagement of the visitors to open wide opportunities for exploring the exhibited interactive artefacts. Hence, two rooms (study room & opinion room) were technologically equipped by a number of seamless installations to allow the visitor to explore mysterious objects and record their personal opinions of those objects. Recording stations, graphic displays and replica objects that can be handled by the visitors were deployed in the rooms [31]. Figure 3 and Figure 4 show two interactive multimedia installations, which were used by the exhibition visitors to access and retrieve content and to record their personal input as well.

Those two examples from the Hunt museum were chosen because both of them are explaining clearly how multimedia can effectively be used in museums. In the first example shown in Figure 3 we can see a very interesting shift, in the way, the visitor experience is dealt with very carefully. The visitor is standing in front of the recording station to record his experience, which can later be retrieved at the same station as well. The visitor experience became the subject of that part of the museum which increases engagement experience of the visitor. The recording of the experience is done through text, images and sound, to let the visitor to explore later his experience from a different prospective. Other recording experience examples in museums can be found in [44][48][32].

Figure 3 The recording station in [31], an example of multimedia usage in museums

The second example of the interactive desk in Figure 4 is different. The interactive desk is nothing more than a simple projection on a book, which was integrated smoothly with the antique furniture [31]. Different multimedia educating materials are projected on the book to give an illusion of the real book. The created atmosphere of the table combined with projecting different media helps the visitor in the interpretation process. Here, the interpretation and presentation of information via multimedia are the main aims and motivations for this idea.

Figure 4 The Interactive Desk in [31], an example of multimedia support for interactivity

2.1.2 Multimedia design in museums

For sure, it is important for the museum to exhibit objects in a way that can be correctly understood and interpreted by the visitor. Thinking about the introduced infrastructure leads to investigate the existing approaches for multimedia design in museums in relation to the navigation, used technology and most important multimedia design factors.

The issue of navigation is crucial in all multimedia applications and it is so in museums, mainly because of the differences between the hierarchical information structure and the hyperlink structure in structuring, accessing and navigating through the content. New possibilities are available today by the means of the cutting-edge technology that imposes abilities to access information by physical interaction with objects. Indeed, this can be seen as a new type or paradigm of navigation lead to a new type of contextualised media. In this research, an infrastructure that is adapting the contextualisation and the hyperlink information structure integrated with the physical interaction model is thought of. The issue of navigation is also considered in system design in chapter four.

Exhibitions use multimedia to broaden the visitor's capabilities to understand the work of art, exhibited object or material by giving information that cannot be predicted or implied from the visual appearance of the work. Thus, we see vast usage of kiosks in museums as information points. However, moving from narrow usage of such devices to a total integration of technology in exhibitions is the next step to be taken [24]. Widely, digital catalogues in museums have been one of the very simple and good examples of abilities that multimedia provides for museums. Basic information about the exhibition in combination with a background of context may not only provide a very strong support to the viewer but also different stories in different context can be generated [24].

Multimedia design in museums exhibitions can be viewed in two viewpoints: the structural and the contextual viewpoints, which will be covered in later sections.

The design of multimedia in exhibitions varies due to different reasons. It is influenced by five factors:

- the purpose (the aim of the exhibition),
- the structure (linear, not linear content accessibility),
- the content,
- the audience (local visitors, global visitors, children, etc.),
- and the communication approach [24].

Despite the importance of multimedia in museum exhibitions, some problems appear. The concept and design of multimedia has an important influence on the effects of those issues. Two of those problems are the costs of deploying multimedia, mainly the need of a number of portable devices that are normally carried by the visitors during the visit. Moreover, the unwanted iteration resulting from the deployed information stations within the exhibition [24]. Sometime it isolates visitors from their surroundings and distracts visitors from other exhibits [48]. Many researchers infer that some museums are misusing the computers in many ways, as described by Appleton: "to promote interactivity", "to recreate whole experience multimedia displays" and "to modernise" [22]. This research should take those issues in account while designing and modelling the proposed infrastructure.

2.1.3 Experimental results of using multimedia in museums

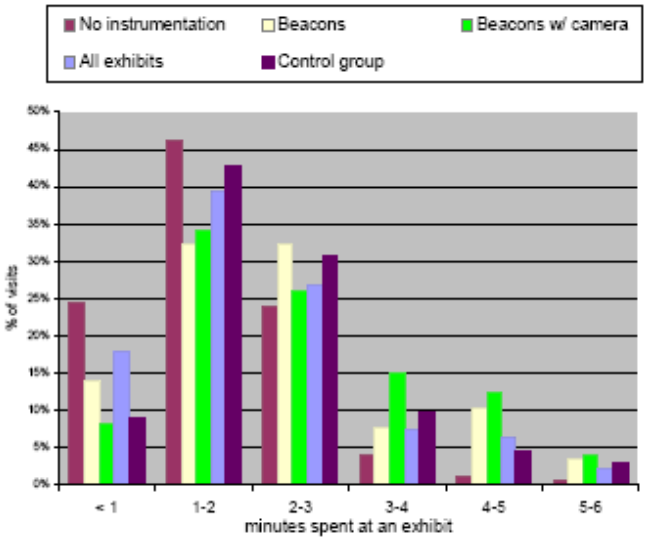
The discussed issues in the previous sections can be supported by considering some experimental results of established multimedia projects in museums. As already discussed, the popularity and the increasing use of computers can be seen to have great effect on current museum exhibitions and in the near future. In a literature review for the Australian Museum Audience Research Centre in 2000, a very interesting observation about the spent time in front of an exhibit has been published.

The good layout, novelty, and the ways to access content are increasing the spent time in front of the exhibited objects. On average, the spent time in

front of one exhibit equipped with multimedia is 3-4 minutes [48], which can reach 40 minutes in some cases. Actually, the spent time may vary according to the type of museums. In [32] for example, the average spent time on an exhibit is 1-2 minutes. In other situation, like in the Exploratorium museum, the average spent time is even shorter (30 sec) [41]. This time is decreasing when it comes to exhibits without multimedia and increasing by a factor of two or three in the case of multimedia and instrumental support.

In visitor surveys of Lacota in 1976 was noted that people "*wanted to see more specimens, but apparently they understood more, learned more and enjoyed it more when there was more to see*" [24, pp. 1538]. Indeed, the effect rather extended to encourage visitors to explore other parts of the exhibition [48].

In addition to that, some statistical results are available from the Rememberer project [32]. The results show a clear indication of the average spent time on different exhibits against the level of instrumentation in each exhibit. Their results concluded based on studying the spent time on objects and exhibits with the support of multimedia and technology instruments and some without.



Instr. level	Minutes at exhibit avg (stdev)
No instr.	1.2 (0.8)
Beacons	1.9 (1.2)
Beacons w/ camera	2.1 (1.3)
All exhibits	1.6 (1.1)
Control group	1.7 (1.1)

Figure 5 Times spent at exhibits against level of instrumentation in the Rememberer tool [32]

According to the findings in Figure 5 it is obvious, that time spent on exhibits with instrumentation is normally longer. It can be observed, that supported exhibits with instruments have a much higher percentage of visits with a high average spent time (4-5 minutes and more). This average time is not reached by unequipped exhibits. The exhibits without have on average less than three minutes spent time.

2.2 Ubiquitous Computing and Museum Exhibition Experience

Exhibitions do have many channels and presentation devices deployed in the environment such as wide varying resolution displays, smart tables [1], kiosks and even different projection styles, in addition to sound stations. Very often, mobile devices are used as the primary media channel to the visitor, since they are closest to the observer. In principle, providing a mobile user-centric computing environment by using pervasive devices is investigated by the topic of situated computing [74].

2.2.1 An outlook on ubiquitous computing technology

It has been a lot of progress in mobile device capabilities and mobile networking. The mobile processing power is continuously increasing and higher resolution and quality screens are being developed. Furthermore, wireless network and its protocols allow for higher data rate and more bandwidth. Universal Mobile Telecommunications System (UMTS) today provides up to 2Mbit/s instead of 171.2 kbps for General Packet Radio Service (GPRS). Nevertheless, there is no argument about the very limited mobile abilities to play existing media types efficiently. However, using the available situated devices with the mobile device can be a good model of integration of both for the benefit of visitors. Therefore, the author of this report will reflect this model into the proposed infrastructure.

As mentioned earlier, different media presentations are needed. Indeed, mobile devices are not the best medium for all of them, especially videos and high quality images. Therefore, the visitor's mobile device should communicate with the situated devices around to allow the visitor seamlessly to move the presentation from his mobile device to use more

suitable one if found, keeping his current session. At the same time, it allows for playing the same presentation differently in both the situated device as public device and the mobile device as personalized presentation. A TV-like presentation in the PEACH project (http://peach.itc.it, [86]) used the same concept. Personalized videos generated by personalized verbal presentations are played on the user's mobile device; more general and further materials are played on stationary screens distributed in the museum [78]. Multimedia/Video Department at Siemens Corporate Research proposed the Small Screen/Composite Device (SS/CD) architecture in 2000 [74]. According to the user's location and context added to the available devices around the most appropriate device is provided to play the multimedia content.

The technical resources and capabilities bring many questions about the adaptation. The design should cover most of the possible scenarios such as audio-only presentation because many users might have only audio capabilities available, taking in account that much information about the environment is already defined and given by the domain and space models, which have been discussed earlier in this chapter.

2.2.2 Ubiquitous computing usage categories in museums

By reviewing some of the ubiquitous computing projects related to the area of museums and exhibitions, categories can be inferred and distinguished by reviewing the functionality, goals and usage scenarios.

Experience recording and retrieving is one of those categories. In this category, the experience of the visitor is recorded by using different sensing technologies. The Rememberer tool [32] that is part of the CoolTown project is listed under this category. The idea of the project was to use the ubiquitous computing concept and its available technology to capture the visitor activities in the exhibition. It is considered as a nomadic tool of capturing records of a personal experience. This system was deployed in the Exploratorium science museum in San Francisco. The focus was to increase the visitor engagement and interaction with the

exhibits. Taking photographs of the visitor at different points as a record for his visit by number of distributed cameras, RFID (Radio Frequency Identification) transponders, and PDA's, connected by wireless 802.11 networks. The visitor himself triggers the capturing process. The user can simply retrieve his visit by accessing a dedicated webpage, later he/she can share this visit with others accordingly.

Although, the idea and the technology evolved in this nomadic tool were simple, the results were very promising. By looking at some of the study concluded results, it is very clear, that photography is a very good tool as record of experience. This tool was used by more than 80% of the visitor during the sampling period (151 out of 189 visitors). This is a clear indication of a high degree of technology acceptance among the visitors. Furthermore, statistics show that the time spent on the exhibits that were equipped with this technology was longer than without equipped exhibits as also mentioned in section 2.1.3.

From the other side, it has been recorded, that this technology caused an interference with the exhibit visits, which met some of the previously discussed general issues about the multimedia deployment in museums. By taking the example of Exploratorium museum, visitors were distracted by the used PDA's. According to them, the PDA was as large and fragile device [33]. In some cases, visitors had the feeling of isolation as one visitor described the handhelds "*It's like a car window that separates you from reality*" [41, pp. 5].

Nevertheless, the degree of interference might be reduced by hiding the computing devices (ubiquitous computing technology) and the usage of an easy-to-use user interface [24]. As explained earlier in this section, the main trend of pervasive computing is not only to hide the computing power but also to have a smart environment as well. This smartness will enable devices to learn automatically about the environment [59] in order to reduce the explicit interaction between the users and the devices themselves. In this paradigm, the user will be served by services smoothly without shifting attention or the need to think about the technology itself.

The smart environment allows museums' visitors to navigate physically in the museum, accordingly they are able to retrieve and interact with digital content or representation of exhibits. In this example, levels of explicit interactions are reduced by this sort of physical movements and actions of the visitor. Moreover, the smartness in museums might be realised in different ways such as simply by having an exhibit with abilities to sense environment and trigger actions accordingly.

Another related project called Experience Catalog System (ECS) was deployed and tested at the ATR Research Exposition in 2003 [67]. ECS takes number of photos, videos, and memos of the individuals and community as personal and community records. Later those records are rendered. The system is supported by a storytelling technique to create a story based on the individual visit combined with the community experience as a whole, which indeed helps the visitor to identify and recognize his visit more consciously. One more interesting aspect in this project is the ability to control the system by the exhibition administration to define general outlines of the story.

Museum guidance systems are another category of projects that got a lot success in the last few years. One of those projects is the nomadic exhibition guide Hippie [69]. Providing the visitor with the relevant information through the visit is this category's main issue. The information can be transferred to the visitor visually by showing dialog boxes or changes in visitor's mobile device graphical interface. It also can be transferred through sound. Audio descriptions about exhibits shall be played; additionally ambient sound can be played to indicate the movement from one exhibit or room to the other.

The examples discussed in this section are only few of many about ubiquitous technology and multimedia in museum exhibitions. Examples, such as ImogI [58], Sotto Voce [91], Points of Departure [82], Antwerp [36], C-Map project [60], etc., are deployed in museums to serve functions such as establishing connection with exhibits in the museum, giving details of objects in an old house, giving details about the used techniques in an

artefact, giving exhibits' details by capturing photographs and planning a tour and simulating users' locations, respectively.

2.3 Context Awareness in Museums

The museum exhibitions are full of different types of objects and exhibits. The visitor's perception of value and importance is directly influenced by their presentation. Therefore, it would not be smart to move the visitor's attention to anything else than the exhibit itself. In addition to that, exhibits and objects have different meanings for different visitors. They are also perceived differently [22]. Therefore, any proposed content should be minimized and concentrated as much as possible to meet the visitor's interest.

The issues related to the context and context awareness are important in all ubiquitous computing projects, simply because most decisions are made based on implicit interaction with the computing devices. Therefore, this section is covering the basic principles for context awareness generally and context awareness in relation to museums.

Principally, multimedia applications view the museum exhibition from structural and the contextual viewpoints as being complementary to each other. Following that, the structural viewpoint considers the application as an object, but contextual viewpoint analyses the museum as a whole [24].

The need of different context sensors relies on the application needs themselves. Simple context information like time, date and temperature can be easily detected by implementing simple sensors. Nevertheless, cutting-edge technology provides many technological solutions for sensing more advanced context like the user identity, locations, orientation, etc. The context awareness is considerably enriched by the competitive prices and availability of those technologies such as RFID, Bluetooth, Barcodes, camera sensors, WiFi, Global Positioning System (GPS) and many others. Some example of context awareness projects used in museum exhibitions are Electronic Guidebook [41], Hippie [69], and Rememberer [32].

There are many considerations regarding the environment and the individuals that should be taken in account. Oppermann and Specht in [69] discussed this issue as form of models, based on the following definitions "*A domain model describes and classifies the objects of the domain information are to be presented and processed about. A space model describes the physical space where the nomadic system is used and the location of the domain objects in the space. A user model describes the knowledge, the interests, the movement, and the personal preferences of the user.* "[69, pp. 2]

The domain model includes a clear structure "Taxonomy" of categories and it classifies exhibition objects, following that certain standards usually in use. Different location and orientation information are described in the space module such as possessory maps, user location and object location technologies (e.g. GPS as outdoor and RFID as indoor.) The user model involves identifying user's identity and monitoring his actions mainly against its location and its relation to time. Furthermore, dialogs shall be used for explicit user preferences setup such as language, presentation, and user interface setup. As more complicated and advanced pillar of the user module is the knowledge building process about the user, which monitors and interprets the user's interaction to conclude his interest.

Briefly, the user's interest is concluded easily from the positive and negative evidences, by gaining information about an exhibited object or by skipping an exhibit respectively. Actually, it is a question of attraction. The attraction exhibits in relation to the visitor attention. Thus, many psychology theories have been developed to study these issues in particular such as motivation theories, educational psychology, psychological perception and social psychology [69]. Actually, each model of the three can be static or dynamically changed. Although in many cases, the user model is considered to be dynamic. Indeed, considering those models will help in later design stages of the proposed infrastructure in chapter four, because they give a clear distinction between the possible technology, standards and design models for each model.

Issues discussed earlier in the first chapter such as the type of the museum and its size, type of visitors, type of message and aim of the museums and the exhibition design challenges should be considered during consideration of context in museums [25]. Moreover, a brief illustration of some design decisions regarding context in previous successful projects in museums, including the used context awareness technology, the functionality, information flow and the complementary devices, is done by [25] and shown in Figure 6.

	Awareness technology	Functionality distribution	Information flow	Complementary devices
Rememberer	RFID	Server based	Passive	Cameras
Sotto Voce		Locally stored info	Active	
ImogI	Bluetooth	Info stored in Bluetooth transmitters	Active, proximity manager	
Marble Museum	IrDA	Locally stored info, abstraction levels	Active, history of the visit	
PEACH project	IrDA	Server based	Passive, task migration	Screens
Points of departure		Locally stored info	Active	Screens
C-Map	IrDA	Server based	Active, exhibit recommendations	Active Badges, Screens
Lasar Segal Museum	IrDA	Server based	Passive	
"Antwerp project"	IrDA	Server based	Active	Cameras
Tour Guide System (Taiwan)	IrDA	Server based	Passive, subjective tour guides	
PDMA, Point it, Museum AR	IrDA	Server based	Active, by various means	laser pointer, glasses
Hippie	IrDA	Server based	Active, info presented based on the history of visit	

Figure 6 Design decisions regarding context according to [25]

3 CHAPTER THREE: REQUIREMENTS ANALYSIS

This chapter includes the results of the requirements analysis and the requirements specification derived. The requirements specification are used in the system design as will be explained in chapter four. The user needs are analysed in section 3.1. Section 3.2 will give a detailed software requirement specification of the suggested system.

3.1 User Needs

Firstly, this section describes the functionality of the infrastructure in terms of user interaction. Secondly, it identifies the functionality and goals of the system design. Thirdly, it analyses the museum environment, its stakeholders and actors.

3.1.1 Agreed goals

The main aim of this research, as indicated earlier, is to enhance the museum environment by providing visitors with personalised services based on the captured context in the museum environment. A design of an infrastructure followed by an implementation of a prototype, Medient infrastructure, will be concluded by the end of this research.

Yet, the required needs and services should be investigated. Nevertheless, one major goal of Medient infrastructure is the ability to provide those services, without the need to install special client on visitors' mobile phones. This is in order to avoid the complexity [16] and distraction that might occur due to the installation procedures. Furthermore, to avoid wasting the visitor's time in a very busy environment like the museum. Moreover, using platforms such as the web platform to achieve the eighth design pattern, software above the level of a single device [70], is a strong argument for the success of web 2.0 and a strong motivation to be applied in social software applications for museums.

Additionally, a model of information exchange and interaction, between the physical world (the museum's physical existence) and the virtual world

(the museum's digital information associated with each exhibit), should be concluded and reflected on the proposed solution.

The range of services, covered by this research, will be concentrated on the museum functions or museums' hand fingers as shown in Figure 1. The author will consider "to exhibit" and "to interpret" functions to support the visitor engagement, enjoyment and educational benefits based on the museum definitions, which have been reviewed in chapter one. In other words, the infrastructure should aim to provide good visitor services [47] by reducing the frustration, discomfort and fatigue levels. At the same time, it should help the visitor to enjoy the exhibition and to reach the exhibition aim to educate visitors.

3.1.2 The environment

The museums' environments vary from outdoor surrounding for Open Air museums, Working museums and Site museums to virtual environment for Virtual museum [56]. Nevertheless, the Medient infrastructure will target museums' indoor environment, where there is a need to link and support the physical surrounding (physical objects, spaces, zones, etc.) with digital service, e.g. a virtual representation of those objects. Moreover, an extended support for the visitor will be considered as pre/post stages of the museum visit as recommended by [33][41] to enhance and extend the learning experience of visitors because of the shortage of spent time in front of exhibits.

More specifically, one pilot prototype will be implemented. The testing phase will take place in a protective and partly controlled environment (the ISNM - International School of New Media[1]), whereby results can be captured for later evaluation and calibration. Later, the author aims to deploy the infrastructure in one of the museums in Lübeck city in Germany for real short-term evaluation.

[1] ISNM International School of New Media at the University of Lübeck, "Homepage", http://www.isnm.de/ (accessed August 08, 2007).

To specify the chosen scenarios, the infrastructure environment can be further split up in three different environmental perspectives as follows:

The infrastructure's business environment: the museum environment is a highly social and protective environment. Different people with heterogeneous age and education levels are expected to interact directly with the Medient infrastructure and its services. Besides, the knowledge and social exchange among users is relatively high. This applies on the five early discussed museum types in chapter one and relatively varies according to the audience that are targeted by the museum e.g. children museums.

The infrastructure's physical environment: The physical deployment of Medient infrastructure will cover the indoor parts of the museum building (ISNM building only for simulation purposes).

The museum space (rooms, halls, etc.) is usually divided into zones based on the exhibit value, subject, importance, story, etc. Commonly, visitors are moving freely in the visiting areas in the museum. Different visitors are taking different ways of exploring the museum [69][47]. Regardless the tour pattern which the visitor takes, certain artefacts are getting the visitor's attention. Therefore, the spent time among the exhibitions differs [32]. Furthermore, often a social interaction takes place between the visitors themselves as groups or individuals, which should be supported by the infrastructure [47].

In principle, each exhibit or artefact has some content to be shown to the visitor, differently according to the exhibition design. The content information is usually brief and often need to be more explained. The tour guide performs the explanation and interpretive role in many cases.

The infrastructure's technology environment: the technological deployment of any solution is vital and important issue in museums, considering their special needs and requirements. Popular wireless technologies such as Wireless Local Area Network (WLAN) and Bluetooth, which can be used as communication and context detection sensors at once, are relatively easy to be deployed in the museum. Additionally, their

integration in most popular daily used devices[2], such as mobile phones, makes them perfect match to this research needs.

Personal mobile devices are extensively available in museums. Mobiles are often Bluetooth-enabled and WiFi-enabled devices [19]. Furthermore, they are equipped with AJAX-enabled[3] web browsers such as Opera 9[4], Minimo 0.2[5], etc. Moreover, mobiles often equipped with a standard flash player such as Macromedia Flash Player 7[6]. In other words, their communication and media rendering capabilities qualify them to be used as personal media devices for museums' visitors. Moreover, this will also help to significantly reduce the system running and maintenance costs for museums [12].

Kiosks and other public displays that exist in museums will serve can serve as stationary media spots or stations. Combined with the usage of mobile devices, the public displays can also be personalised.

3.1.3 Stakeholders and actors

This section identifies the key needs and requirements for each group of prospected users of Medient infrastructure.

The stakeholders, sponsor, users, etc. are all influencing the needs, requirements and the way the museum functions. Indeed, the museum structure is not restricted; it is rather a generalisation. As mentioned earlier in chapter one, museums are categorized in categories based on different approaches or prospective. They also play different roles and serve in different levels. Precisely for these reasons, it is relatively difficult to have a strict structure that can be applied to all.

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[2] BBC news, "Bluetooth boom boosts CSR profits", http://news.bbc.co.uk/1/hi/business/4966118.stm (accessed August 11, 2007).
[3] W3Schools, "AJAX Tutorial", http://www.w3schools.com/ajax/ (accessed August 01, 2007).
[4] Opera Software, "Opera Mobile Homepage", http://www.opera.com/products/mobile/ (accessed August 05, 2007).
[5] The Minimo Project, "Minimo project page", http://www.mozilla.org/projects/minimo/ (accessed August 05, 2007).
[6] Adobe Systems Incorporated, "Macromedia Flash Player 7 For Pocket PC", http://www.adobe.com/products/flashplayer_pocketpc/ (accessed August 05, 2007).

Typical active players in the museum context are administration, management, sponsors and users (researchers, visitors, exhibitors, etc.) [29][53][47]. In the Figure 7 below, a generic organizational structure is shown.

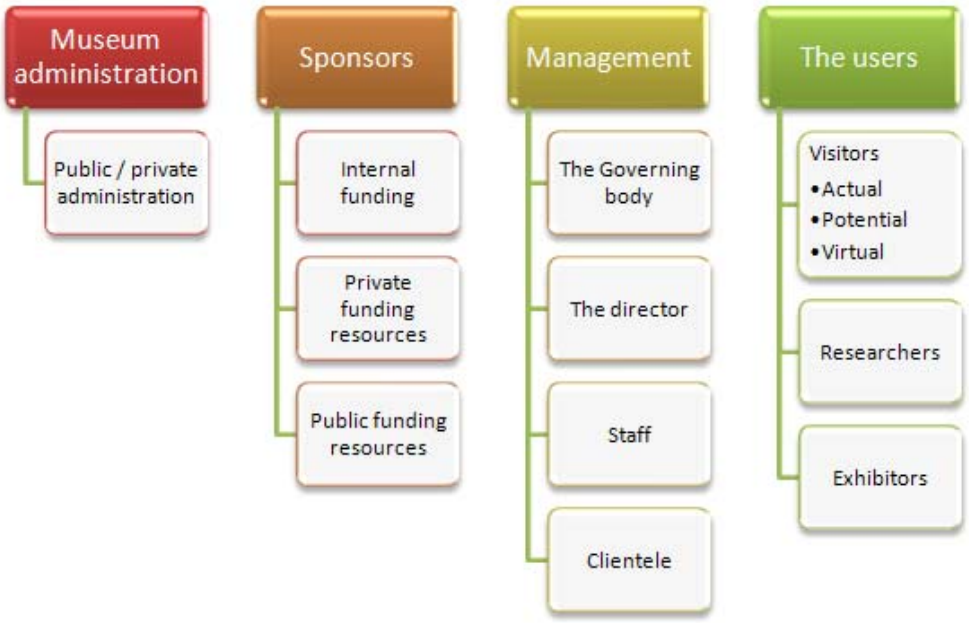

Figure 7 Museums organizational structure

The museum administration can be seen as publicly or privately administrated. Indeed, the situation varies from one country to the other, the degree of public legislation, state control, public and private sponsorship and the level of support. Traditionally, in France there is greater influence and control over museums by the state. Exactly the opposite is true the US, where the museum's administration is given greater autonomy [29]. Elsewhere, general legislation and regulations can be found such as the model of other countries like the UK and some other European countries.

Every museum has a governing body. This body decides the museum general policy, controls, and manages the museum resources. The director is responsible for running the institute. He/she is supposed to be the communication channel between the governing body, the staff and the clientele. The museum also requires a highly skilled and educated staff.

The staff usually consists of education specialists, communication specialists, interpretation specialists, designers, the security staff, marketing specialists and public relations personnel. Furthermore, it requires administrative personnel, maintenance personnel, and others [29][41].

Museums usually benefit from their internal and external funding. The internal funding consists of the entrance fees, services, commercial activities, etc [29]. Nevertheless, external sponsorship and funding from public and private sectors is also a major funding resource for museums. Actually, some museums even have their own supporting organizations like the organizations for museum's volunteers. An example of these organizations is the World Federation of Friends of Museums [29].

Users for sure have a leading role in the museums as well. Users' direct impact is seen by raising the staff morale, marketing impact, forming museums supporting groups, etc [47]. The researchers, for example, have very strong contribution for museums. In fact, museums often provide faculties for researcher [29], in order to support their research activities in the museum itself. The normal visitors are also assumed to be part of this organisation. As explained earlier in chapter one, some museums have more focus on the visitors themselves. In some cases, the user or the visitor becomes the core idea and sprit of the museum as shown in Figure 3. The exhibitors are also part of this structure. Often museums exhibit works for exhibitors like artists, etc. This research will focus on the museum visitors and the museum management in the first place and the proposed infrastructure is intended to serve their special needs.

Generally, some shared needs and expectation, which were inferred from some literature, among all users are:

- an equal access to information [47].
- equal participation possibilities in the system [70][43].
- an intuitive and easy interaction with the system [23].
- a reduced deployment complexity [16].

- and maximised usage benefits form available faculties, services, devices, etc. [92][70].

3.1.3.1 Museums' visitors

The museum visiting norms are group wise or individual wise. Consequently, the social, educational and enjoyment experience may differ [92]. Furthermore, visitors' motivation and expectation differ because of the diversity in age, interest and the aim of the visit, etc.

Generally and by observing the museum and exhibition definitions in chapter one, museums' visitors share the motivation to see and observe the exhibited artefacts and need to acquire certain knowledge about them [23][38][14][45].

To derive the key needs for museums' visitors, a little insight about tendency of different visitors is given. An individual visitor, independent learner, seems to be interested in particular exhibit or object to satisfy educational or personal needs. Often, detailed information is needed to reach their satisfaction. Independent adult groups usually are formed on social bases, having intensive social discourse within the visit. Therefore, those social needs should be met. Taking another group of visitor such as family groups shows the need to deal with heterogeneous and wide range of age interest at once. Of course, education groups also have different needs [92].

As shown in Figure 7, museums are aiming to serve three types of visitors: actual by supporting there visit, virtual by providing virtual tour and information about the museum and potential visitors by providing facilities and service that get their interest to visit the museum [92].

Following those needs, the research was imposed to cover two directions: the educational side and social side of visitors' needs. Whereby, the satisfaction, enjoyment and learning goals of the museum are obeyed.

Key needs:

- To enjoy the museum visit and to learn new things [38][45].
- Maximise the amount of relevant information retrieved about the artefact [78][25].
- To be notified of objects and exhibits of interest to the visitor.
- Cautious use of technology and multimedia to minimise the amount of interference that might be caused with the artefact [23][69].
- Allow for social interaction and provide feedback channels with the museum, e.g. the visitor opinion about an exhibit and sharing interest [92].

3.1.3.2 Museum's staff and exhibitors

The staff interacts directly with the environment. Education specialists, interpretation specialists, designers and marketing specialists are the most relevant and affected by the scope of this infrastructure. They are assumed to use and maintain the administration side of the infrastructure by selecting, preparing and maintaining the content which will be presented to the visitors.

Key needs:

- Incorporate technology to support the museum's mission to exhibit, to educate and to enjoy [67].
- Easy integration of the technology within the museum's environment and reduce the interference with their daily activities.
- Reduce the interference with the artefact or the exhibit itself. The digital representation should not be seen as replacement of the original one.
- The ability to create, edit and maintain the content effectively and easily.
- Supporting and complementary services to the museum's service team.
- The need for long standing system and the ability to be maintained easily.

3.1.4 User scenarios

Here, two of many possible usage scenarios to illustrate the main features of Medient infrastructure are considered. The first scenario illustrates the usage of the infrastructure by a prospective museum's visitor. The second one shows the administration usage of the infrastructure.

3.1.4.1 The visitor scenario

John and his friends are going to visit the national museum in the city. The group partly planned the visit, by reading some online information and brochures about the museum. At the entrance of the museum, they have been notified that they can use their available Bluetooth-enabled mobiles during the visit to take advantage of getting digital notification service, extra media content, personalised tour, etc.

John approaches a welcoming kiosk at the museum entrance. He switches on his mobile Bluetooth functionality and puts it in a marked place following the provided instructions by the kiosk. Meanwhile, he is able to browse the available exhibits and sites at the museum. Videos and additional materials could give him better outlook about the museum and shape his interest in that day. Optionally, he is asked by the kiosk to fill a short form to optimise the quality of service.

While browsing the content, John was able to add certain exhibits to his tour or his Exhibits of Interest list. As soon as he completes his selection, he receives a welcoming Bluetooth message on his mobile phone. This message indicates the success of his tour selection, Thereafter his actual tour is activated.

While walking in the museum, John is receiving notification signals on his mobile phone from different exhibits that match his interest.

Now, he moves to a second room, his mobile phone rings notifying him about a famous sculpture (saved in his tour) being present in this particular room. Furthermore, an explanatory webpage is pushed

automatically to his mobile browser. He is able to read further information and listen to some audio files about this sculpture.

Being interesting, John was happy to be able to rank and annotate some objects and exhibits. Hence, he can share his current experience with the others as well as it is a personal touch left in the museum.

After finishing his tour, John closed the browser and walked out of the museum with his friends. One week later, he was able to show his friends his favourite exhibits in his last tour by accessing his tour and his saved item from his “My-museum” online space.

The automatic detection of John and the content retrieval were based on his current context and aimed to help him focusing on the actual visit and his attention was kept on the original artefact. The notification was only a sign of interest of nearby objects or exhibits. It was only a sign of being able to get additional service at that spot. The decision for using the additional information is left to the user at all time.

3.1.4.2 The museum' staff scenario

The physical deployment of Medient infrastructure was performed by installing the Medient server at the museum. A set of Bluetooth receivers (media spots) equipped with the Medient sensor client are also installed in different spots at the museum. All receivers are connected to the museum’s wireless LAN. Moreover, a “welcoming kiosk” was installed at the entrance of the museum equipped with one Bluetooth sensor and Medient sensor client.

Marketing specialists together with content specialists at the national museum prepared digital representation of the main exhibits and artefacts in the museum by combining text, images and audio together as a separate webpage for each exhibit. Afterwards, the content was integrated into a lightweight design optimised for mobile devices. Once obtained, the webpages were assigned to the relevant exhibit by linking a unique exhibit number to a unique media spot.

The mobile webpages were easily prepared by adapting the text and images in the webpage template. The template contains the design, the logic and the notification add-ons needed by Medient infrastructure.

A special design and content were also made for the welcoming kiosk. Videos, text and images were added to a visually appealing presentation. Functionalities such as selecting a tour and exploring the museum are the main features for this application. The designer used there favourite multimedia media authoring tool to create the client. At the same time, they were able to access and communicate with the Medient services easily.

In the future, the staff members are able to add new exhibits by adding new media spots and assigning it to the exhibit. Staff members are able to use the Medient raw data as statistical data for further development and studies about the museum. User generated content might be very much of interest if it reaches the network effect where the quality and the value of the content are increasing by visitors' increasing usage and participation [83].

3.2 Software Requirements Specification

Functional and non functional requirements are clearly defined in this section derived from the previously discussed issues including: the goals, stakeholders' needs and expectations and the museum environment. Those requirements should be met at the Medient infrastructure design and implementation stages.

3.2.1 Functional requirements

In this section, the main functional requirements of Medient infrastructure will be discussed. Each requirement is handled according to the requirement purpose, input, process, output and priority. Each requirement is labelled and given a number, which will be referred to in the coming chapters.

Table 1 REQ1: Automatic mobile bootstrapping (Bootstrapping spot).

REQ1: Automatic mobile bootstrapping (Bootstrapping spot).	
Purpose	**The first media spot (Bootstrapping spot) should establish a bootstrapping connection, via Bluetooth messaging, with any new mobile devices.**
Input	• **The visitor located in the detection range of the Bootstrapping Spot at the museum entrance.** • **The visitor's tour selection.**
Process	**1. The detection sensors should be ready state.** **2. Bluetooth sensor scans and detects devices.** **3. Associate a unique ID for all new discovered devices.** **4. The visitor selects his tour.** **5. Send a Bluetooth message to launch the Medient web interface.**
Output	• **Creating a new session ID and announcing all new devices.** • **Pushing a Bluetooth message to the visitor.**
Priority	**High**

Table 2 REQ2: Detect the visitor identity by the exhibit (Media spot).

REQ2: Detect the visitor identity by the exhibit (Media spot).	
Purpose	The exhibit detects all nearby visitors' identities via Bluetooth sensor. Each exhibit and visitor has a uniquely identifiable ID. All information are retrieved and presented by the exhibit based on the exhibit and visitor identities.
Input	• The visitor is located in the detection range of the sensor, which is associated with the exhibit. • The mobile Bluetooth device address is associated with a valid session ID
Process	1. The detection sensors should be in ready state. 2. Bluetooth sensor scans and detects devices.
Output	• Bluetooth sensor announces the location of all detected devices associated with a valid session ID.
Priority	High

Table 3 REQ3: Push media content and events from the exhibit to all nearby mobile devices.

REQ3: Push media content and events from the exhibit to all nearby mobile devices.	
Purpose	The exhibit pushes content to the mobile device. Therefore, the mobile interface is updated according to the current location of the visitor.
Input	• The visitor is detected according to REQ2. • The current exhibit is listed in the visitor's tour selection.
Process	1. The server is updated with the current visitor's location and status. 2. The server retrieves the stored representation of the exhibit. 3. The server executes a notification event. 4. The server pushes the content to the mobile.
Output	• Notification event is executed. • A server pushes a stream to the mobile device browser.
Priority	High

Table 4 REQ4: Save an exhibited item (Remember me! service).

REQ4: Save an exhibited item (Remember me! service).	
Purpose	The visitor is able to mark certain content to be retrieved later after finishing the actual visit.
Input	• The content is shown to the visitor according to REQ3.
Process	1. The visitor takes the saving action (e.g. press save button on the browser.) 2. The request is sent to the server with the ID of the exhibit and the session as well.
Output	• Adding a new item in the visitor's saved item list. • Trigger the saving item call-back function.
Priority	Low

Table 5 REQ5: Retrieve all saved exhibited items.

REQ5: Retrieve all saved exhibited items.	
Purpose	The visitor is able to retrieve certain content, which has been saved during the museum visit.
Input	• The content is saved according to REQ4.
Process	1. The visitor takes the retrieving action (e.g. visit a special webpage assigned to the user.) 2. The request is sent to the server with the session ID. 3. Stored exhibits are retrieved for the system database.
Output	• The visitor's saved item list is retrieved as XML file.
Priority	Low.

Table 6 REQ6: Rank, comment and annotate objects and exhibits.

REQ6: Rank, comment and annotate objects and exhibits.	
Purpose	The visitor is able to rank and annotate exhibits, whereby it is accessed by the museum staff and other visitors as well.
Input	• The content is shown to the visitor according to REQ3.
Process	1. The visitor takes an action (ranking, annotating or commenting). 2. The request is sent to the server associated with the session ID and the exhibit ID.
Output	• The visitor's ranking is added to the other all ranking of the object of the exhibit. • The visitor's comment or annotation is associated with the exhibit.
Priority	Medium.

3.2.2 Non-functional requirement

The main four non-functional requirements are freedom in user interface design, usability of adding/retrieving content, performance and scalability requirements, and user privacy. Those requirements are prioritized and described below. Different aspects are covered including the purpose of the requirement, the expected input, the logical steps for executing the process and the expected output.

Table 7 Non-functional requirements of Medient Infrastructure

Name	Purpose	Priority
N-REQ1: Freedom user interface design	The interface designers can create there own interface design and application logic freely, without the infrastructure interference.	High
N-REQ2: Usability of adding/retrieving content	The infrastructure should allow the museums designer to integrate content easily and at the same time it should be effectively accessed by the mobile clients.	High
N-REQ3: Performance and scalability requirements	The infrastructure should perform in effective and scalable way. Different types of clients and number of client might be using the infrastructure.	Medium
N-REQ4: User privacy	The users' identities should be carefully dealt with and resolved.	Low
N-REQ5: Compatibility and adaptability	The infrastructure should allow for fast range of devices support (mobile and stationary devices).	Medium
N-REQ6: Reduce running and maintenance costs	Running and maintaining the system should be cost effective for museums.	Medium

4 CHAPTER FOUR: MEDIENT INFRASTRUCTURE ARCHITECTURE

This chapter will outline the Medient infrastructure conceptual model, general structure and detailed design issues.

4.1 Medient Conceptual Model

Figure 8 shows an illustration of the conceptual model. The left side of the model shows that context information (1) together with the user generated content (UGC) (2) is collected and stored in the system. In the middle part of the model, three levels of services categories (6,7,8) are shown. Those services perform different functions and can be accessed directly by any context-aware application. Moreover, the lower level services (to the left) are accessed by higher level services (on the right). As the results of a set of interviews with different user groups and categories (teachers, staff and visitors), an extensive list of services needed by museums was concluded by [41]. Services for exploring, remembering, explaining, communicating, etc [41] are considered by Medient infrastructure aiming to cover the needs and wants of museums and their visitors.

The main three service categories are the Context and Media Repository services (6), which provide direct accessibility to the context pool, media pool and UGC pool. The Access Services (7) provide accessibility to most available functions in the system such as feedback channels for enabling UGC (ranking, annotating, etc.), or accessing context information from the context pool. Moreover, the communication services are responsible of all communication and device discovery processes with the user's mobile phone. Finally, the Presentation Services (8) are responsible for accessing media information and notification functions such as playing sound files under certain events and actions.

The right side of the figure is showing the client side, where the visitor is equipped with a normal mobile device with a web-based application designed according to the exhibition purposes. This application does not require any special installation, and runs on any mobile device that hosts a

web browser with AJAX support. Furthermore, the museum is able to provide additional applications, which run on other devices to allow for advanced functionalities (5), which often exceed mobile phones' capabilities.

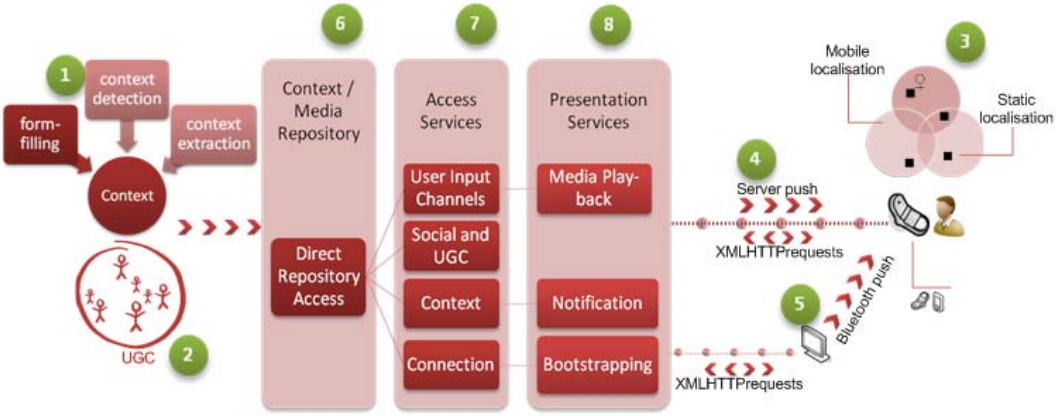

Figure 8 Medient's conceptual model

Out of the current context, such as user situation, history user interaction, available resources and others, different content is retrieved and shown by the context-aware application on the user's mobile phone. A general classification of context is shown in Table 8.

Table 8 general classification of context according to [93]

context	Contexts
User situation	User profile, location, users' physical condition, nearby people, current social state, etc.
Physical environment	Illumination, noise, traffic condition, temperature, weather, etc.
Computing system	Network connection status, communication cost, communication bandwidth, auxiliary devices, shared resources, etc.
History of computer & user interaction	Provided services, history of service uses, service recommendation, service failure, etc.
Available resources	Multimedia resources, portable device resources, power supply equipment, etc
Others	Time, date, transportation means, etc

The Medient architecture is adapting the service-oriented approach [94] and the event based approach [54][1] to provide and support context-aware applications. Medient allows for two types of context-aware applications. Firstly, mobile context-aware applications run on the visitors'

mobile phones, such as the visitor's PDA or mobile phone, and do not require any installation. Secondly, applications run on situated devices like kiosks.

The event-driven approach and architecture are tackled by a number of publications and used in a number of ubiquitous computing projects [54][1]. It can be explained as "*a notable thing happens inside or outside your business, which disseminates immediately to all interested parties (human or automated). The interested parties evaluate the event, and optionally take action. The event-driven action may include the invocation of a service, the triggering of a business process, and/or further information publication/syndication.*" [64, pp.3]

The Service Oriented Architecture (SOA) and web services showed their validity in ubiquitous computing and context-awareness applications [46][94]. Different projects have been developed in this direction such as CoWSAMI project [4]. Furthermore, the popularity of web services in pervasive computing is illustrated in [5].

Web services can be defined as the following: *"…Web Services, which is distributed component model, can access/use/reuse a remote web object by XML based standard protocol. Web Services is usually used to extending the functions of business domain applications."* [54, pp.1]. It is clear that ubiquitous computing, including this project, can benefit from this approach. The authors' in [54] argue that *"According to the characteristics of Web Services, it could support the diversity of terminal, network and user environment for ubiquitous computing environment."* [54, pp.1]. More extensively, web services for ubiquitous computing are given the term "Ubiquitous Web Services", which was introduced and characterised by seven characteristics: mobility, location awareness, interoperability, seamless, situation awareness, timely adaptation and finally pervasiveness [46].

Surely, due to the device usage, capabilities and design, the Medient infrastructure is giving certain capabilities for situated and mobile context-

aware applications. Applications that run on the situated devices like kiosks, are dealing directly with Medient web services interface. Hence, high degrees of freedom in the application design, programming and implementation style. The web service interface is separating completely Medient implementation from any application accessing and using the services. Therefore, minimum dependency and restrictions are required.

On the other hand, the infrastructure is giving a clear design model for context-aware mobile applications. It takes in account the limited capabilities of mobile phones. To avoid requiring client installation on the visitors' mobile phones the infrastructure is considering web-based implementation of Medient mobile clients. That imposes AJAX programming style [59], which is a combination of different web technologies to create a more interactive web-based user interface [63]. Therefore, context-aware mobile applications are limited in the programming and implementation style. Nevertheless, the application design and features are up to the designers to agree upon.

4.2 Medient Infrastructure General Model

The generic model of the infrastructure is elucidated in Figure 9. The visitor can interact with the infrastructure using the Mobile Context-aware Application running on the visitor personal mobile device (1). This application is an AJAX web client that is able to render multimedia content. The Active Range (2), called as well the Active Zone, presents the range of Bluetooth detection coverage for the exhibit. The detection and announcement of any new mobile device in range is done by the Media Spot (3), which actually runs a Medient discovery and services software. It is connected with the server via WLAN connection and with the mobile device via Bluetooth connections. The Media Spot is able to push Bluetooth messages with integrated multimedia content to any mobile device in range and registered to use Medient services.

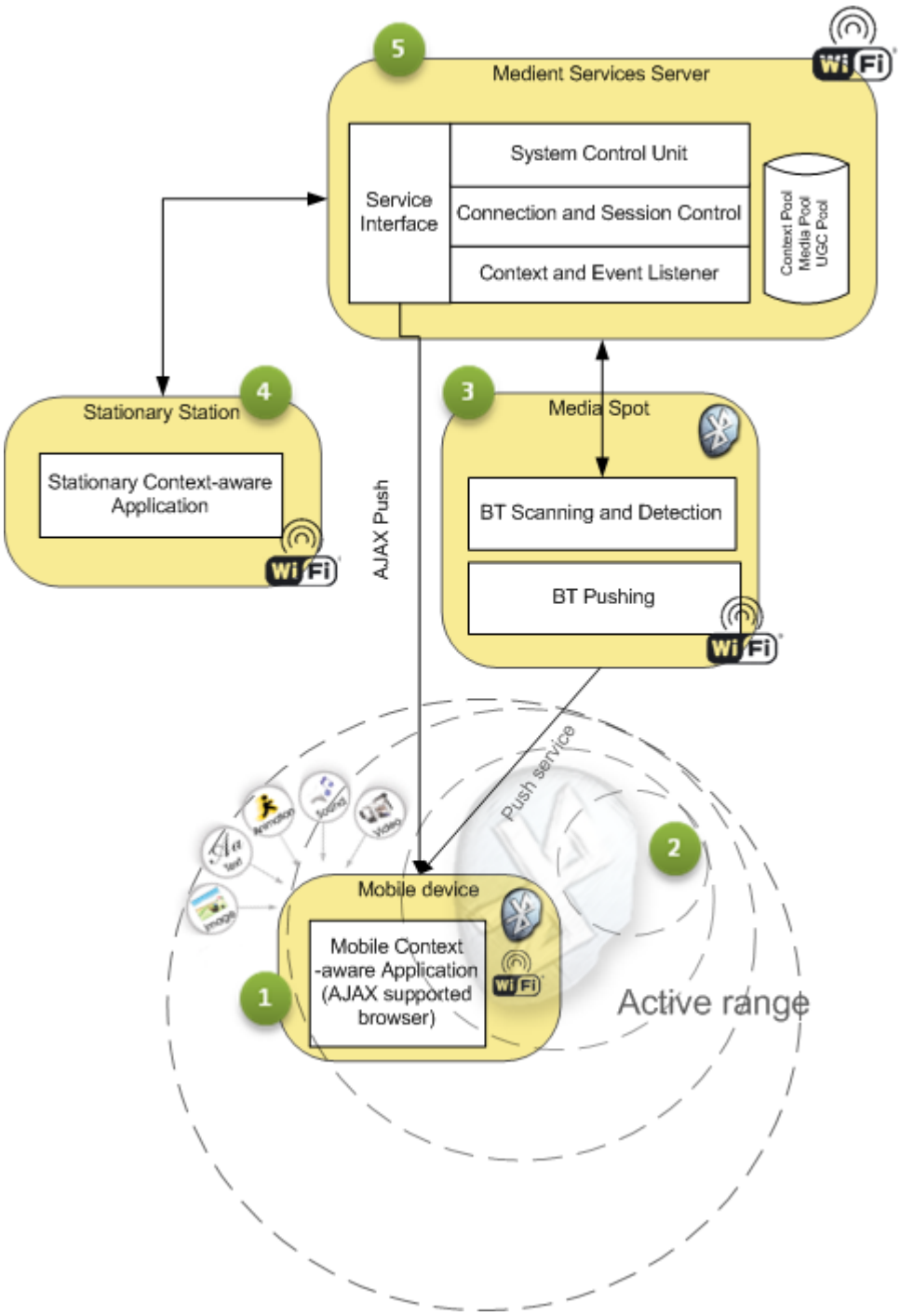

Figure 9 Medient generic model

Moreover, the visitor can use the Stationary Station at the exhibit (4), if available, for further services. Each station runs a context-aware application using the Medient provided service and being connected directly with Medient server via WLAN connection. It also provides a stationary localisation for each visitor using the station.

The Medient server (5) is responsible for controlling the whole environment and to keep track of all context information acquired. Furthermore, it establishes a wireless connection with each online mobile device registered in the system. Besides, it pushes content and events to the mobile client based on the visitor context.

At the entrance of the museum a Stationary Station with Medient Bootstrapping Spot should be installed, whereby the visitor is introduced to the provided mobile services and bootstrapping procedures are performed.

The bootstrapping is done by a real-time construction of a webpage that directs the mobile browser to the Medient AJAX web client. This step is performed via Bluetooth messaging. This process is free of charge, commonly used by visitors and it gives the visitor the choice to accept or reject the connection with Medient infrastructure. Therefore, there is no client needed to be installed on the mobile device and the bootstrapping process is done easily and in short time. The explosive growth of the Bluetooth usage [80] and messaging within the mobile user communities increases acceptance of this model. SMS, for instance, is used to enhance the learning experience inside and outside museums [77][87]. As indication of the increase popularity of SMS, the UK experienced 3.19 billion sent text messages in March 2006 [18].

Clearly, the communication with any mobile device is done combining WLAN and Bluetooth. WLAN allows for high bandwidth content channel and online streams. The Bluetooth radio signals are used for near-by devices detection and local Bluetooth data transfer and messaging using Object Exchange (OBEX) Protocol 10].

4.3 Detailed Model of Medient Infrastructure

A detailed block diagram of the Medient infrastructure is shown in Figure 10. It illustrates the main components of the system and communication scheme between them.

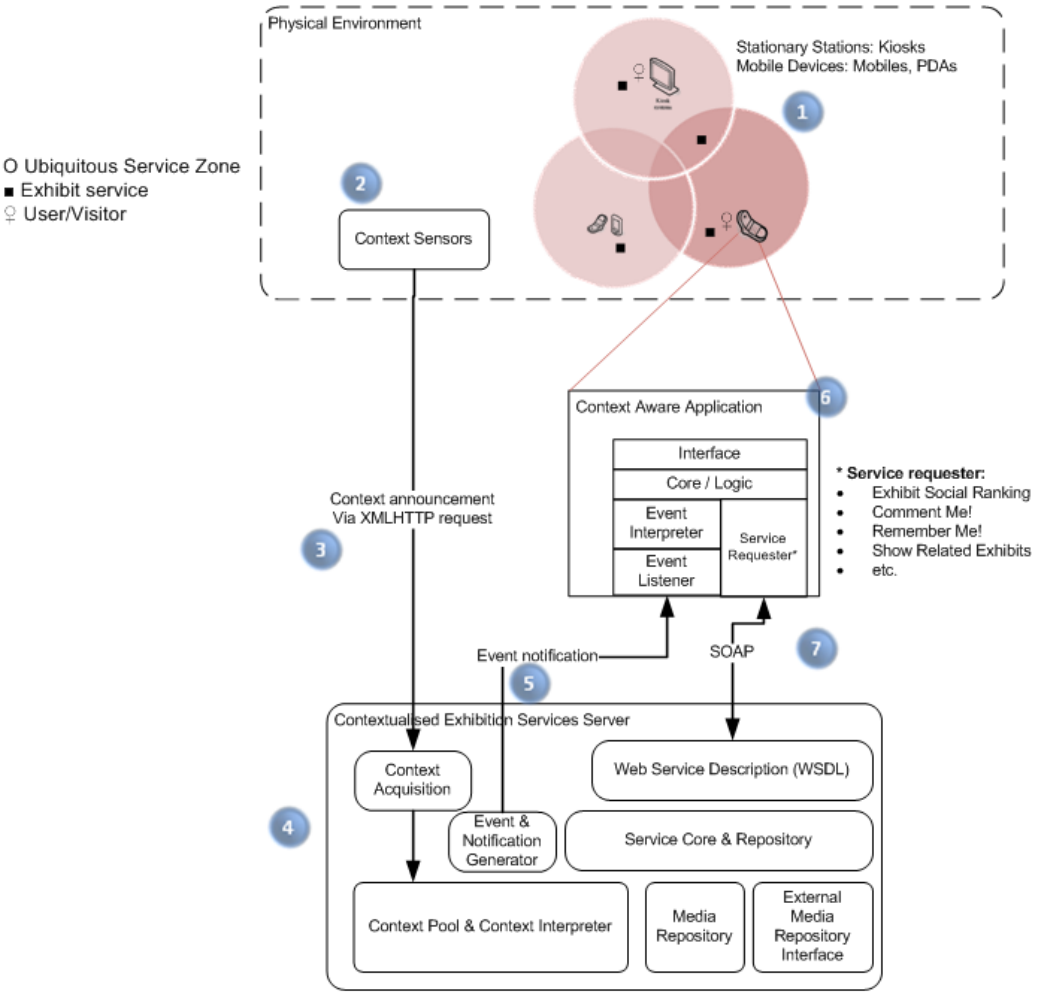

Figure 10 Block diagram of Medient infrastructure

In this model, ubiquitous service zones (1) are attached to the actual physical zones in the museum environment. Each zone covers one exhibit and can be zoomed in (to cover only one object) or out (more than one exhibit) according to the museum needs. In principle, the used hardware plays a roll in the detection accuracy. In Medient infrastructure, the main detection technology is Bluetooth which can be calibrated to cover different ranges according to the used Bluetooth class [8]. Class "1" can cover up to 100 meters and can be used to cover a number of exhibit rooms. On contrary, class "2" can cover only up to 10 meters, which can cover only one room. There are many other ways of limiting and extending the coverage of the Bluetooth sensors as well, which give some flexibility in deploying the infrastructure in different environments.

In other research projects, a combination of detection technologies are used alongside with Bluetooth in order to reach more accurate and scalable object detection Object visual recognition is one of those techniques, which uses the integrated mobile camera [12]. However, more processing and software requirements are needed on the visitor mobile phone, which are avoided in Medient model.

A number of stationary devices such as kiosks can be assigned to any ubiquitous computing zone. Furthermore, each zone is able to serve multiple visitors at the same time.

The Context Acquisition unit in Medient server (4) is keeping track of all visitors (location, identities, etc) and all other activities in the environment by receiving periodic announcements (3) from the Context Sensors integrated in the ubiquitous zones (2).

In the proposed model, all sensors are using XMLHTTP requests[7] to announce their current status to the server through the context announcement web service. This communication protocol allows the infrastructure to receive context information from different resources that use different standards, whereby the required interoperability in ubiquitous computing services [46] is met. In accordance with that, it becomes possible to add, remove or change sensors easily without major changes in the system. This kind of context detection approaches was discussed in [46].

The Context Acquisition unit is realized as a web service. Its main aim is to collect the announced data, which is gathered from three main resources: form-filling, context detection and context extraction. The first approach is used to construct the visitor personnel profile, preferences and social profile. The context detection detects and analyses runtime context information, like the visitor location along with information regarding the environment and devices profiles. The third approach combines the first

[7] Anne van Kesteren, "The XMLHttpRequest Object W3C Working Draft 18 June 2007", W3C liability, http://www.w3.org/TR/XMLHttpRequest/ (accessed July 31, 2007).

two approaches to extract more context information. Those three resources are extensively explained in [46].

The Context Pool and Context Interpreter are concerned with context information. In fact, Context Pool unit is a repository of raw context data, in form of database tables, which contains context information gained by previously mentioned approaches. The Context Interpreter interprets certain messages related to location detection, identity detection, and user profiles. Hence, this interpretation is used by the context-aware applications, which might also perform extra context processing to generate more advanced context out of the provided messages and interpretations from the infrastructure.

The Service Core and Repository unit is responsible for the presentation and context services that are provided by the infrastructure. Those services can be accessed by any application, which requires invoking services from stationary or mobile devices, able to communicate with the Web Services Description unit, which contains an XML-based service description (WSDL) for all running Web Services on the server. According the W3C, the WSDL is defined as "*A WSDL document defines services as collections of network endpoints, or ports. In WSDL, the abstract definition of endpoints and messages is separated from their concrete network deployment or data format bindings. This allows the reuse of abstract definitions: messages, which are abstract descriptions of the data being exchanged, and port types which are abstract collections of operations.*" [16, section 1].

All the services can be easily accessed after being published and their WSDL is constructed. Later, services on the server can be edited, updated and modified easily without changing the client side. Only if a new service is published then the application developer should update his application by accessing an updated WSDL.

This model is seen as a static model. In other words, there are no actual run-time changes or service discovery. On the other hand, a more dynamic

web services model is developed based on ECA (Event-Condition-Action), which also calls event-driven architectures based on Web Services [54]. Nevertheless, the adaptability of such a service model will be still applicable under certain changes, which might be applied in the service server and the application side.

In this model, as illustrated in Figure 10, events and notification messages are generated based on the context available in the system and its interpretation. Those events are sent to the mobile client (5), accordingly the client may ask for a service based on the event rules specified by the application developer. As argued before, the mobile context-aware application functions as a web client running in the mobile web browser, hence, the mere available option of implementing such events is the use of the Server Push mechanisms [17].

The context-aware application (6) presents any application (mobile or stationary) that uses the infrastructure. All events from the server are received and processed by the Event Listener and Interpreter unit. The Core, principally, is responsible for accessing the services provided by the server, through the full control over the Service Requester unit. In the same figure, a number of services were mentioned including: the Exhibit Social Ranking, Comment Me, Remember Me and Show Related Exhibits which all derived from the functional requirements REQ6, REQ6, REQ4 and REQ5 respectively. Simple Object Access Protocol (SOAP) is the communication protocol between the Service Requester and the server.

4.4 Medient Context-aware Applications

A more detailed generic model of the context-aware applications that use Medient infrastructure is illustrated in Figure 11. The proposed structure of those applications and their connection with Medient infrastructure are explained in this chapter.

Any context-aware application, in this model, consists of three abstract layers: Events and Service Acquisition, Application Core and User Interface. The application can be discrete or contentious. The discrete

application takes or triggers actions at fixed and known time. The continuous application updates some parts depending on context [94]. Both types can be found in this infrastructure contingent upon the usage scenarios.

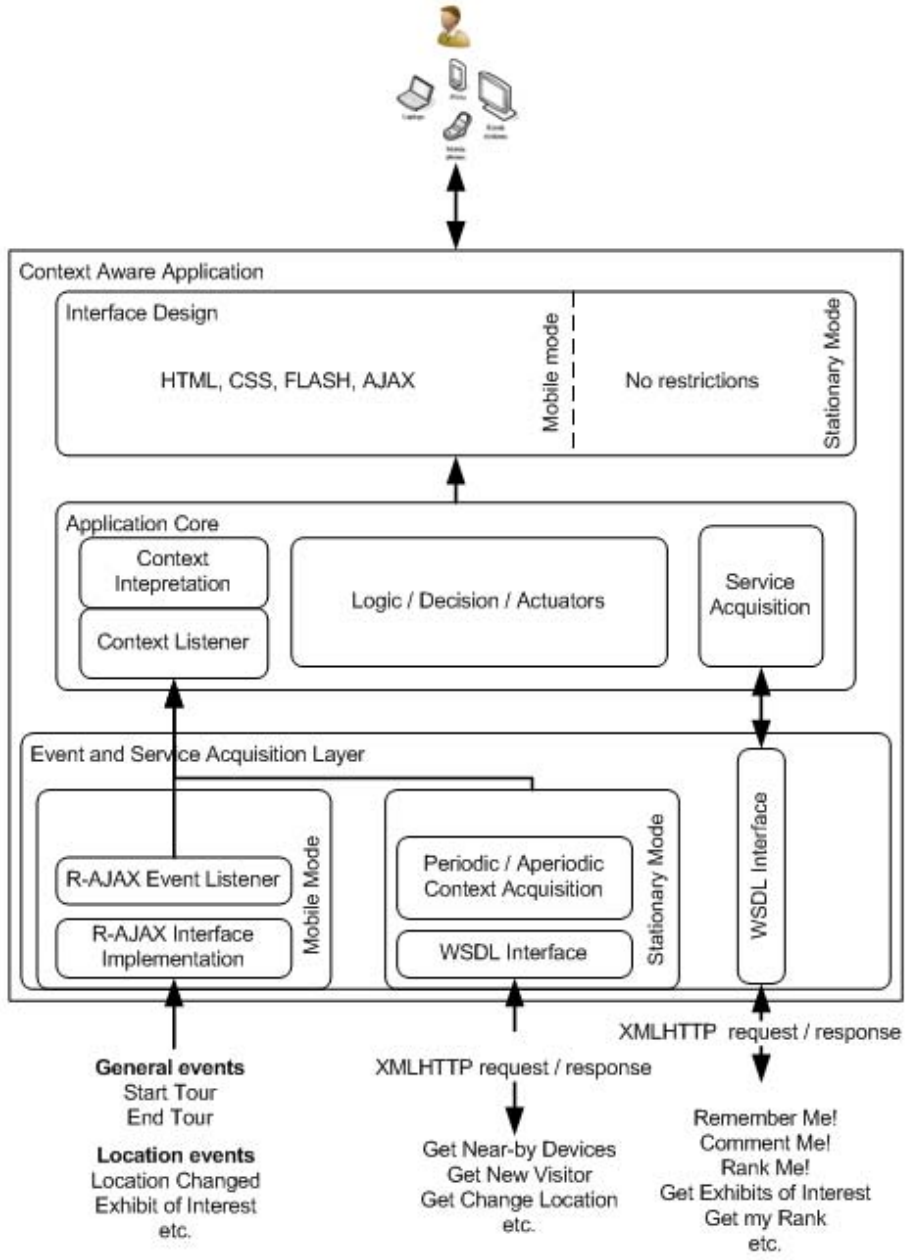

Figure 11 Context-aware application - generic model

As explained earlier, the whole architecture is based on functionalities that can be handled by mobile browsers. Hence, mobile applications can directly get advantage from the infrastructure by accessing the services

provided by the server and listening to the events generated by the server. Any client that runs in the Internet browser and supports Asynchronous JavaScript and XML (AJAX) technology[8] [59], is able to capture the context events. At the same time, it is able to use all provided services. Mobile context-aware applications should run under the Mobile Mode. This mode allows mobile applications to receive a set of general events to indicate the actual start and end of the visitor's tour. Moreover, it allows for notification events as indication of the visitor's current location and possible objects of interests near the visitor.

On the other side, context-aware applications for stationary media devices, such as content presentation, museum maps and directions etc, can benefit from the contextualised services. Those applications run under the Stationary Mode. This mode allows the application to perform periodic or aperiodic context queries, where they can be executed on the server and then the results are returned back to the application. This mode allows stationary applications without AJAX technology to use the stored context information, whereby a simulation of the event model can be accomplished.

For example, the stationary application can retrieve all mobile devices in the active range of the kiosk by calling the Get Near-by Devices service, accordingly the application executes an action such as displaying a personalised welcoming message to the visitor.

4.4.1 Event and Service Acquisition layer

In Figure 11, the lower level of the model consists of three required units for accessing services and capturing events. The Mobile Mode unit is capturing all events announced by the server though the Reverse AJAX [26] Interface Implementation unit. Reverse AJAX allows the server to push information and control the client remotely [26][30], whereby the

[8] W3Schools, "AJAX Tutorial", http://www.w3schools.com/ajax/ (accessed August 01, 2007).

infrastructure enlists this ability to send events to the client based on the gathered context by the system.

The R-AJAX Event Listener responds to those events and sends actions to the Context Listener unit. In Medient infrastructure there are three modes of running the Reverse AJAX events, those modes are: Polling (the browser requests the server in regular intervals), Comet (allows the server to start answering the browser's request very slowly) and PiggyBack (the server waits for the next browser's request and sends the update within the response) [26][30]. In Medient infrastructure, the events are easily handled by call-back functions, therefore application developers are not asked to worry about detailed technical issues concerning the reverse AJAX implementation.

The Stationary Mode requests the services, as explained in the previous section, through the WSDL interface unit and then sends the results to the Context Listener. In this case, the application itself is responsible to manage querying the service and handling the response.

In both the Mobile and Stationary modes, the client will request other presentation and streaming services from the server and this is done by the WDSL Interface unit via XMLHTTP requests based on SOAP.

4.4.2 Application Core

The middle layer presents the application core where all critical decisions, the flow of information and the application functionality and actuators are controlled.

As many event-driven ubiquitous computing applications, the context-aware application has to listen to all events and interpret the context information that comes from the lower layer, whereby the event handlers later perform actions.

The Service Acquisition unit is responsible for requesting all needed services from the server including context queries, play media, content

update, input user generated content, etc. This unit sends the requests directly to the server via an opened service socket on the server. It also receives the server response and delivers the results to the Core.

4.4.3 User Interface

The user interface is the upper and the last layer. Following the distinguishing between the “Mobile Mode” on mobile devices and the “Stationary Mode” on stationary devices, the interface restrictions, technologies and approaches are different. The “Mobile Mode” requires AJAX technology and approach to be used. Nevertheless, the interface appearance is up to the designer to decide about. The application developer is asked to integrate special scripts in his application to enable certain services such as the notification services. The audio notification functionality is activated by inserting notification module in any webpage that requires this functionality. The same applies on any webpage that needs to trigger other webpages under certain events (e.g. changing the physical location of the visitor).

In the “Stationary Mode” the graphic and interface designer should only consider limitations created by the technology used in building the application. Besides, in some cases the stationary device might use the Mobile Mode if the application runs in the browser.

5 CHAPTER FIVE: IMPLEMENTATION

The major outlines of Medient implementation are described in this chapter. Some sample codes, flowcharts and diagrams will be used to illustrate different implementation aspects regarding Medient Bootstrapping Spot, Medient Media Spot and its functions, the server implementation and the mobile context-aware application implementation.

5.1 Medient Bootstrapping Spot Implementation

This unit was implemented to insure a fast and reliable bootstrapping process for any new mobile phone, as a new visitor intends to use the exhibition services of Medient infrastructure. It is a realisation of REQ1 of the previously discussed functional requirements in chapter three.

Medient Bootstrapping client is an event-driven C# application that scans the environment and detects near-by Bluetooth enabled devices within certain range and time interval. Figure 12 shows the top-level structure of this Spot.

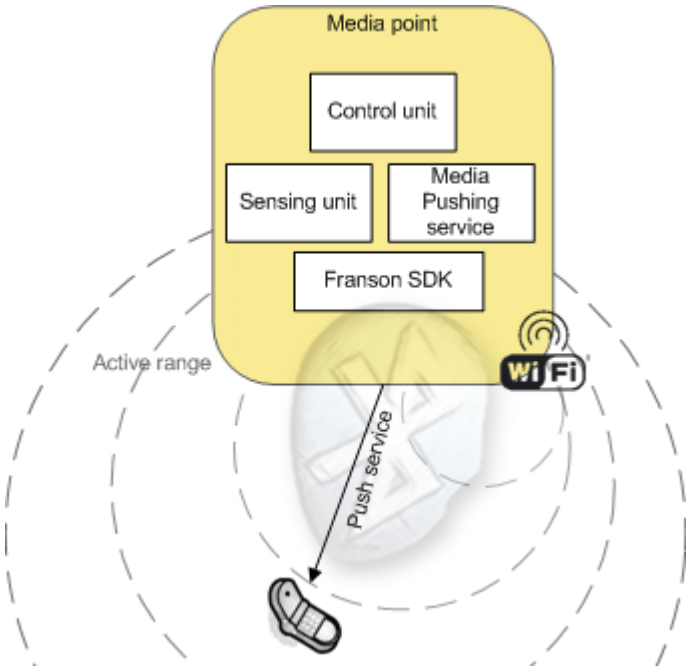

Figure 12 Medient Bootstrapping Spot - Client Structure

The application is constructed of a Widcomm Bluetooth Stack[9] layer, which is responsible for the control and access of the Bluetooth device drivers. On top, the system is using Franson .NET Bluetooth SDK [34] for a high level control over the hardware. The SDK allows for different discovery modes, Bluetooth events and event listeners, etc. Furthermore, the Discovery Unit performs all scanning and discovery processes. Moreover, it uses events to announce any update in hardware status. Events such as "OnServiceDiscoveryStarted", "OnServiceDiscoveryCompleted", "OnDeviceDiscovered", "OnDeviceLost" and "OnDeviceDiscoveryStarted" are used in the application effectively and for different purposes.

In the case of "OnDeviceDiscovered" event, the detected device is stored as a device object and given a session number. Thereafter, the device object is announced through an HTTP request to the server as shown in the sample code below.

```
string url = "";
url = "http://" + MpointSetup["mediaServer"].ToString() +
":8080/CES_proxy/proxyCESServlet?serviceName=announceDeviceDisc
overy&deviceAddress=" + deviceAddress + "&loginDate=" +
loginDate + "&mediaPointNumber=" + mediaPointNumbr +
"&deviceStatus=" + deviceStatus;
String temp = dbService_req(url);
```

Moreover, the Media Pushing Service unit is responsible for run-time generation of a bootstrapping object, which contains session parameters for the current visitor, to be pushed to the mobile client via the OBEX Object Push service as shown in the code below.

```
private void deviceList_bootStrap(RemoteDevice sd){
…
// detect Object Push service (OPP) on this device
selectedDevice.DiscoverServicesAsync(ServiceType.OBEXObjectPush
);
…
}
```

[9] Broadcom Corporation, "Bluetooth", http://www.broadcom.com/products/Bluetooth (accessed June 28, 2007).

This object is sent as a Bluetooth message in HTML format. As soon as it is received by the mobile device, it will be automatically launched by the browser. Thereafter, the browser will be directed to Medient Mobile client on the server to start the tour. Finally, the Control Unit performs centralised control over all layers.

From the technological point of view, Medient is currently using ANYCOM 250 Bluetooth USB adapters which are using Bluetooth 2.0+EDR specification (Full technical specifications can be found in Appendix 1). This allows for a range of advantages over older Bluetooth specifications including better discovery speed and the transmission time [9]. Furthermore, some experimental performance parameters are illustrated and explained in Table 9.

Table 9 Medient Bootstrapping Spot - Performance measures

Measures	Values	Notes
Discovery Time	7-12 Sec	Depends on the number and distance of the available devices.
Discovery Mode	DiscoverDevicesAsync Mode	Device discovery is done in the background (CPU friendly).
Max No. of Discovered Devices	Unlimited	-
Max No. of Handled Devices	1	Limited due to Franson implementation of OBEX and Medient Bootstrapping structure.
Establish Connection	~2 Sec	Relative to the mobile device and its distance from the antenna.
Sending Bootstrapping object.	< 1 Sec	-
Coverage Range	< 20 cm	The device's antenna was shortened to limit the range.

In order to have easy deployment and configuration of the system, Medient is using an xml configuration file, where through all settings can

be specified and changed including the database server address, Medient server address, the preferred name and number of the spot, etc. The XML file with more description about its content can be found in Appendix 2.

5.2 The Media Spot Implementation

The Media Spot unit should be attached to each exhibit or ubiquitous service zone in the museums. The hardware part of this unit is the previously discussed Bluetooth hardware. The software part is a C# client called Medient Media Spot application.

The application's main aim is detecting near-by devices and announcing those devices to Medient server. It operates in two detection modes: the Scanning Mode, where the discovery is done by periodic device scanning, and the Pinging Mode, where a direct Bluetooth connection to a certain mobile device is established to verify the existence of this device in the range of the Media Spot.

Accordingly, the server keeps track with exact locations of all mobile devices in the museum. Therefore, it gives the advantage to direct personalised services to each visitor according to his current location combined with other contextualised information. Some performance measures of Medient Media Spot client are handled in Table 10. The measures are split according to the used detection mode.

Table 10 Medient Media Spot - Performance measures

	Discovery Mode	**Pinging Mode**
Measures	**Values**	**Values**
Discovery Time	7-12 Sec	< 1 Sec – detecting a new device <8 Sec – detecting losing a device
Max No. of Discovered Devices	Unlimited	Number of device registered the exhibit as of their interest
Max No. of Handled Devices	Up to 7 *	3
Coverage range	< 6 m **	< 6 m
Efficiency	CPU friendly	Not CPU friendly

* Limited because of the speed of handling http requests and invoking the announcing service.
** The Bluetooth antenna was manipulated.

The number of media spots in the museums varies according to the number of exhibited items in the museums. The covered zone also varies according to the range of the ubiquitous zone (from the coverage of one exhibition item to the whole room). Each Media Spot is configured by an XML file as discussed in the previous section and as explained in Appendix 2.

5.3 The Contextualised Exhibition Services Server Implementation

The Medient architecture is a Service-oriented and Even-driven Architecture. All system components are supported by a centralised server called Medient Contextualised Exhibition Services Server. The server receives regular context information from all deployed sensors in the museum based on SOA and delivers content to mobile devices based on the event model. The detailed design of the server is illustrated in Figure 13.

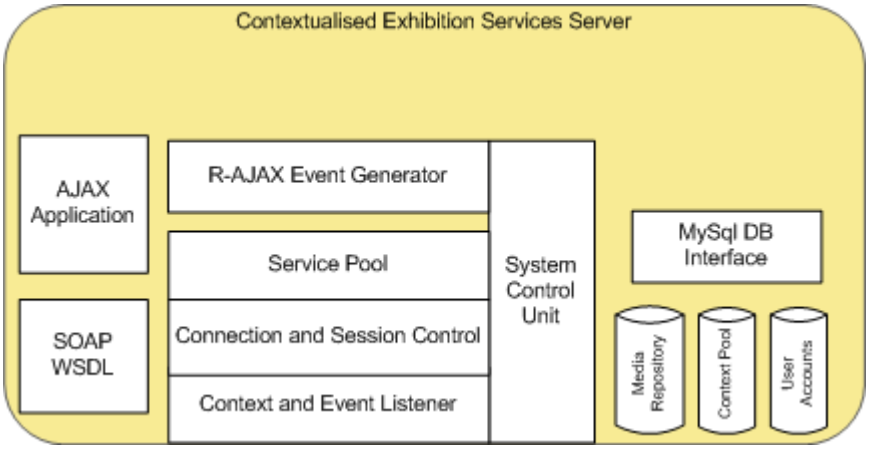

Figure 13 Contextualised Exhibition Services Server

The server is using MySQL database[10] management system to store and manage media content, context and user account information by implementing six database tables called: "devices", "sessions", "devicetracking", "tourselection" and "savedexhibits". More detailed

[10] MySQL official website, "MySQL AB :: The world's most popular open source database ", http://www.mysql.com/ (accessed August 23, 2007).

information about the tables and their structure is explained in Appendix 3.

5.3.1 Context and Event Listener layer

This layer is responsible for listening to all context sensors in the environment. Actually, it consists of web service ports and operations, which are used by the Bluetooth sensors to announce information such as location information, visitors' identities and so on.

Principally, Media and Bootstrapping Spots are invoking this layer frequently by using HTTP requests. For future extension, the layer is designed to be used by any sensors with abilities to perform HTTP requests.

5.3.2 Connection and Session Control layer

On a higher level, Connection and Session Control layer is responsible to establish, maintain and manage connection with the available mobile clients. This layer assigns a unique session identification code for each visitor in sequential manner.

The system is designed to associate the Bluetooth adapter address, which is a unique address for each Bluetooth device, with a session ID generated each time the visitor is approaching the Bootstrapping Spot. At the same time, one session is active per visitor in side the museum. Moreover, the inactive sessions can be used, for example, to study the visitor behaviour.

5.3.3 The Service Pool layer

The Service Pool is a layer with Java implemented web services. Currently, the most important web service operations are already implemented. Service operation names, parameters and associated ports are shown in Figure 14. The full WSDL description for those services can be found in the "Medient Resources" DVD under folder "[drive]\Medient Software Resources\CES server\WSDL\ CES_SERVICES.wsdl". A detailed model of web service realisation is shown in Appendix 5.

Table 11 illustrates the main service and their description. The supported services can be classified to a number of categories. Firstly, context announcement services, which are used by all context sensors to announce the visitors' locations. Secondly, visitors' tours and selections services, which are used by context-aware applications to display certain maps and content based on the visitor selection and current context.

Under the same service category, new marketing services can be designed and integrated such as e-posters and e-brochures that can be attached to the exhibits, whereby visitors can actually pick up and store those materials by using their mobile phones.

Figure 14 Medient WSDL Realisation diagram

Furthermore, stationary devices are often acquiring localisation services to provide a personalised content based on the nearby devices. Often, mobile applications are using both tour and selection services combined with localisation services for real-time location mapping and content delivery. Under the fourth category the social activity services are handled, where exhibit's annotation and ranking operations are provided.

Table 11 Medient Implemented Services

Service Name	Parameters	Description
announceDeviceDiscovery	deviceAddress, loginDate, mediaPointNumber, deviceStatus.	To announce a new device discovery in a Media Spot zone. A new entry of the detected device will be stored in the database.
announceDeviceUpdate	deviceAddress, logoutDate, mediaPointNumber, deviceStatus.	To announce losing a device from the range of a Media Spot zone. The corresponding entry of the device in the database will be updated.
getCurrentLoc	sessionID	Return the current known location associated with the provided session ID.
getInterestedDevices	mediaPointNumber	Return an XML file* with a list of all interested devices in a Media Spot. Usually, the interested devices are the ones having the Spot registered in their favourite list or in their saved tour.
GetExhibitsOfInterest	sessionID	An XML file** is retrieved, which contains all objects or exhibits stored in the visitor tour. It can be used to draw maps on mobile context-aware application.
SetExhibitsOfInterest	sessionID, ExhibitsOfInterestList	Saving the visitor's tour selection in the database, whereby it can be used to determine the visitor interest. Usually, it is used to draw personalised maps, etc.
GetSessionIDs	mediaPointNumber	It can be used by other Media Spot to know exactly which sessions are active in other Media Spots. This can be very useful for any stationary application to keep track of activities outside its scope. The retrieved list is an XML file***.
getSavedExhibits	sessionID	The visitor is able to retrieve all saved content or exhibits in his "Remember Me!" basket.

saveExhibit	sessionID, currentLocation	This service is called "Remember Me!" whereby the visitor is able to save any exhibit or content of favour to be retrieved later according to his needs.
setRanking	sessionID, exhibitRank	This service is called "Rank Me!" whereby the visitor is able to rank any exhibit or content. The given rank is a scale of [0-10].
getRanking	mediaPointNumber	Applications are able to retrieve the current ranking of the needed exhibit or spot
setComment	sessionID, exhibitComment	The visitor is able to attach a comment to any exhibit or content. This service is called "Comment Me!"
getComments	mediaPointNumber	Applications are able to retrieve all attached comments to an exhibit.
	* More to be found in Appendix 4 - A ** More to be found in Appendix 4 - B *** More to be found in Appendix 4 - C	

Full documentation of functions and classes of Medient Services Server can be found in "[drive]\Medient Software Resources\ CES server\CES Javadocs\index.html".

5.3.4 R-AJAX Event Generator

Medient mobile context-aware application is a web client that runs in the visitor's mobile phone browser. The implementation of this client is done by using the reverse AJAX approach as discussed in the fourth chapter, whereby an event-driven approach of communication between the context-aware application and the Medient server is realised. The R-AJAX server side of Medient is actually a bridge between AJAX clients and the Medient contextualised services, where through the services can be provided on event driven bases.

Here, a number of implementation issues will be discussed. Firstly, as Medient server is build based on Java, an open source implementation of reverse AJAX, called Direct Web Remoting (DWR), is used [26] to ensure compatibility and to maximise the performance.

Medient AJAX application as other AJAX applications [35][85] uses: XHTML and CSS as basic presentation standards, the Document Object Model (DOM) for dynamic display and interaction, XML for data interchange and manipulation, XMLHttpRequest for Asynchronous data retrieval and JavaScript to join all elements together.

Medient R-AJAX web application is designed and implemented to host events and some services for mobile applications. Therefore, it actually, performs all functions on the server side. The mobile client has to request services, receive and process the returned results and render the interface.

In basic cases, Medient mobile application can be designed by using Medient AJAX template, a ready to use AJAX application, combined with a simple website that is hosted on Medient server. A number of webpages should be numbered according to the exhibit's number, e.g. "1.html" associated with exhibit number "1" and so on. Content and functionality are decided according to the museum needs.

In more advanced cases, scripting and web programming is needed to create more advanced applications. Nevertheless, web scripting is relatively easy and popular, which reduces the needed complexity while dealing with Medient mobile application.

The diagram below, Figure 15, illustrates the flow of data and processes of Medient AJAX application against the Medient R-AJAX server side. It is necessarily important to understand that this model is an event-driven model. Therefore there is no sequential flow of data or processes.

The server side is implemented to be called by different functions from the AJAX client and as soon as any results are ready to be returned to the client an event is generated and the listener on the client side is taking the results and upon certain call-back function is called.

Simply Medient AJAX client starts by including a set of Java libraries such DWR libraries and Medient R-AJAX library. On the page load the client should call Medient start-up function, which is called "startMedient". This

function will trigger the Reverse AJAX server to start periodic invoking of the “getCurrentLoc” service, as covered in Table 11. As soon as a new location for the visitor is recorded the server will send a changing location event to the client. Thereafter, the client performs a call-back function. Usually, a changing in the interface should take place, for example updating part of a displayed tour map or triggering a content related to the current location.

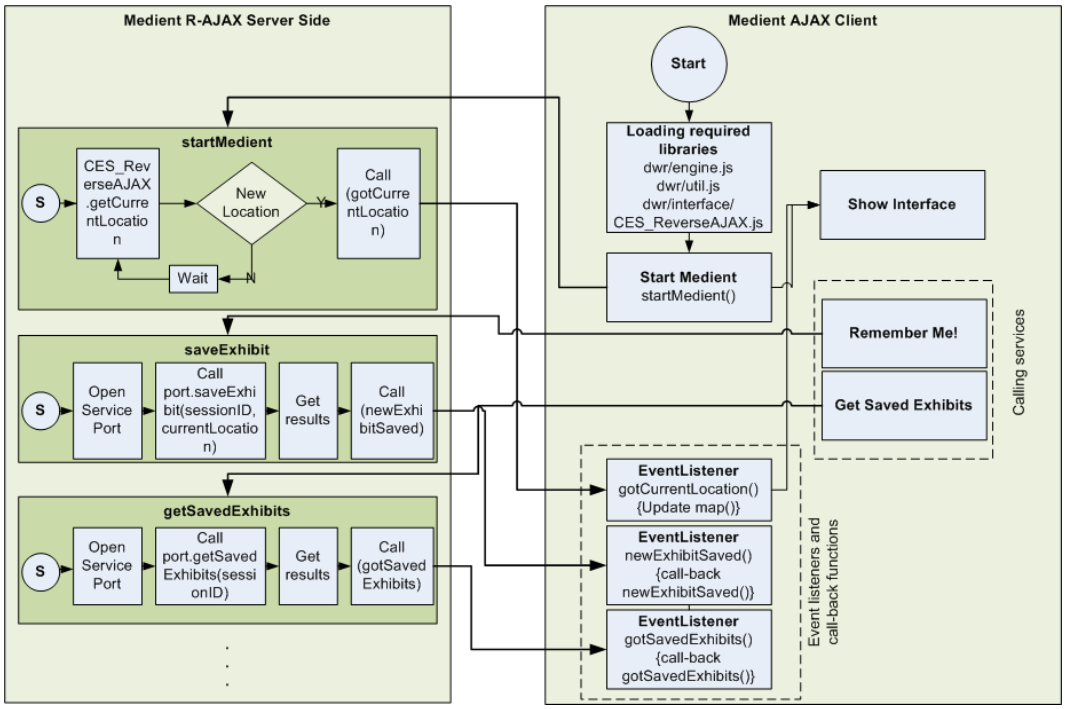

Figure 15 Flowchart - R-AJAX Server Side & Medient AJAX Client

In this case, the client is only indicating its desire to listen to the server events. There is no load created on the client by having a periodic pooling or update. As shown also in the figure, the client is able to call any other service such as “Remember Me!”, “Comment Me!”, “GetSavedExhibits”, etc. by calling the correspondent function on the server. The application is not necessarily waiting for response. The client will get the results back form the server in form of an event which upon the client performs a call-back function. In this case the event will be done by calling “gotSavedExihbits” function on the client.

Full documentation of functions and classes of Medient R-AJAX Server implementation can be found in “[drive]\Medient Software Resources\CES R-AJAX Server Side\CES R-AJAX Server javadoc\index.html”.

6 CHAPTER SIX: EXAMPLE INSTALLATIONS

In this section, a usage scenario of the proposed infrastructure is introduced. The HolstenTour project[11] was developed within the course "Ubiquitous Computing" of Prof. A. Schrader at the ISNM - International School of New Media[12] in Germany. The HolstenTour project is a prototype for one of the famous museums in Lübeck, Germany, called the "Holstentor Museum"[13]. This museum is located at one of the most important sites in the city, called the Holstentor[14]. The project is a combined effort from different teams[15].

6.1 The Concept and the Usage Scenario

The project team described the project as following: "*Mobile HolstenTour is an interactive ubiquitous solution for the Holstentor museum in Lübeck. The idea behind Mobile HolstenTour is providing personalized context-aware mobile tours to museum visitors.*" [42, pp.1]. The project was realized in very short time and demonstrated on July 9th, 2007. The final prototype will be shown in combined with the prototype presentation of this project.

The main idea behind this project is to develop a personalized tour in the museum based on the user selection and objects of interest. Different media files (text, video and audio) are meant to be attached to different rooms in the museum. The media can be accessed though kiosk systems as stationary devices and PDA's as mobile devices. A kiosk, called the welcoming kiosk as shown in Figure 16, at the entrance of the museum is used by the visitor to set her tour by selecting her objects of interest. Videos and explanatory materials are played to help the visitor to take

[11] Mobile HolstenTour, "HolstenTour", http://www.isnm.de/projects/holstentour/ (accessed August 01, 2007).
[12] ISNM International School of New Media at the University of Lübeck, "Homepage", http://www.isnm.de/ (accessed August 03, 2007).
13 LYNET Kommunikation AG, "Museum Holstentor Die Macht des Handels", http://www.luebeck.de/tourismus/kultur/museen/holstentor/index.html (accessed July 20, 2007).
[14] Arno Weiste, Boris Mahnke, Sönke Ebert, "Die Geschichte der Hansestadt Lübeck", http://www.holstentor.info/english_version/index.html (accessed July 20,2007).
[15] Mobile HolstenTour, "Teams", http://www.isnm.de/projects/holstentour/teams.htm (accessed July 20, 2007).

better selection. The visitor's mobile phone should be placed in a dedicated place on the kiosk as shown in the same figure.

Figure 16 HolstenTour project - Welcoming kiosk

Figure 17 HolstenTour project - Tour selection and interactive map

The visitor can interact with the map on the kiosk and can select her tour, read more information about the available objects and watch a set videos attached to each exhibit or object, as shown in Figure 17. The kiosk application was build using Flash 8[16]. As soon as the visitor picks up her tour, it is automatically uploaded to her mobile phone via Bluetooth. As soon as she leaves the kiosk the tour will start automatically. At any time during the selection process, the interactive map shows the visitor navigation and selection information in clear and easy way.

By moving from room to room, the content response to each room in the tour will be played on the Bluetooth-enabled mobile device in form of a set of web pages with text and sound integrated. In Figure 18, the context-aware client that is running on two different clients, Dell Axim 50v and Nokia N95, is shown.

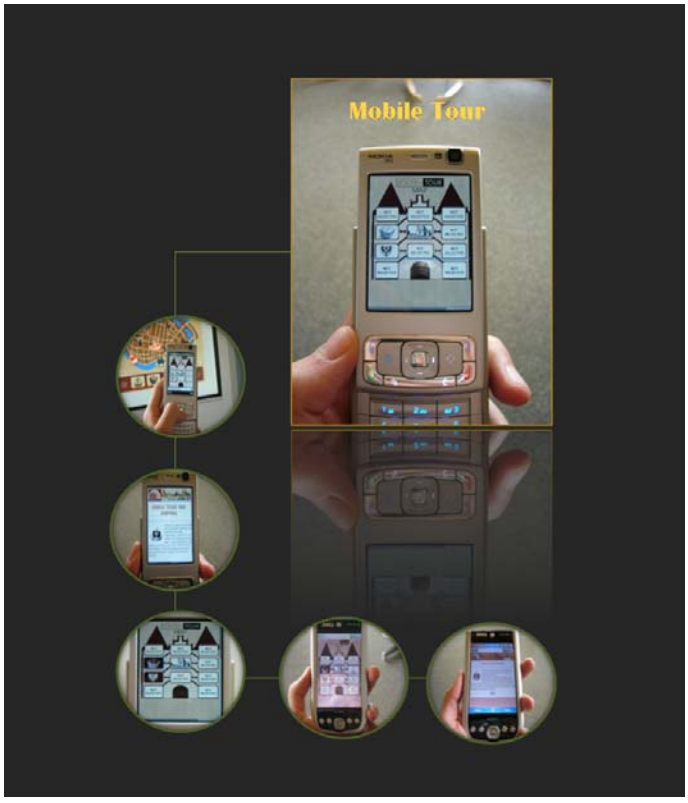

Figure 18 HolstenTour project - Mobile Tour.

16 Adobe Systems Incorporated, "Flash 8 LiveDocs", http://livedocs.adobe.com/flash/8/ (accessed July 15, 2007).

6.2 The Interface Design

The graphical design team did the graphical design for the kiosk and the mobile client. The graphical design for the mobiles was implemented using the standard VGA resolution (640 x 480). Samples of the graphical design are shown in Figure 16, Figure 17 and Figure 18.

6.3 Usability Evaluation

This section is reviewing some usability issues regarding Medient based on the researcher observations in the case of the HostenTour project. An extended usability study is not available due to time and resource limitation.

6.3.1 Medient usability evaluation – Application development

The application developers and designers in the HolstenTour project were able to build their museum tour applications (mobile version and stationary version) by means of Medient infrastructure.

Regarding the stationary unit, no need for instructions or guidance was required. The web service model was easy to work with, using interactive content creation tools such as Flash 8 which provide modules for accessing and communicating with web services through the WSDL description.

The HolstenTour mobile unit was created based on AJAX and PHP scripting. One developer and one designer were able to build the client in approximately fifteen working hours each. The developers were not asked to know the internal details about location and identity detection technologies. The automation of the discovery and bootstrapping processes in Medient reduced the complexities of dealing with low level drivers, detection modules and so forth. Nevertheless, the developers were able to understand the logic of the system and the approach behind.

For more simplification, an intermediary proxy was implemented to hide any complexity of dealing with the service server directly. It has been

recorded that the usage of this proxy made the usage of the service much easier.

6.3.2 Medient usability evaluation – Visitor usage

During the first trails of Medient, the usage of mobile device features such as Bluetooth and Bluetooth messaging is familiar. Moreover, the use of mobile browsers and internet navigation in general is also common. Therefore, there is no need for additional information to illustrate the usage of those features. Instructions about the overall usage of the system and the provided service could be given directly.

The need for more synchronised communication and information flow between the welcoming kiosk and the Bootstrapping point is raised. Currently, a fully automated bootstrapping process is realised and the visitor is only noticed by the completion of this process as a form of normal Bluetooth message.

Using the physical location and proximity as a navigation metaphor was also accepted by the users. Nevertheless, a slow detection speed was recorded as stated in Table 10, which caused some confusion at some cases. Furthermore, varying in discovery time is noticed according to the device and the surrounding environment which indicated in other research with more details [20]. Furthermore, having physical signs indicating the coverage of the ubiquitous service zones may also help the visitor for better navigation.

6.4 Further Installations

To elaborate further strengths and benefits of Medient Infrastructure two installation examples are discussed in this section. Those examples are titled as “Free2Move tool” and “MyLibrary system” as an International fairs personal guide and organizer and context-aware library application respectively. Those examples are not actually implemented but both are proposed based on the extensively discussed Medient services in Table 11 and Figure 10.

6.4.1 Free2Move tool - International fares personal organizer

In many international exhibitions and fairs the visitors usually find themselves in pool of huge exhibiting halls and areas containing hundreds or thousands of different exhibitions.

Free2Move tool is a personal mobile guide and organizer. It helps the visitor to manage and arrange his tour in such environments. As shown in the HolstenTour example Free2Move tool is provided to the visitor at the entrance of the exhibition area by a simple Bluetooth message. The idea behind this tool is to make the visitors become more aware of all surrounding activities from both the exhibitors and the visitors perspectives.

The Free2Move application is AJAX based client implementing different services based on Medient infrastructure. Guidance and localization services such as “announceDeviceDiscovery”, “announceDeviceUpdate” and “getCurrentLoc” are used to create an activity and guidance maps of the visitor. Those maps help the visitor to be aware of his pervious and current activities.

A media point is installed in each exhibition. Each exhibition is providing contact information and advertising materials through the installed media points. The “Remember Me!” service as described Figure 10 is implemented to give visitors the ability to collect contact information and advertising materials as provided by the exhibitors. Hence, the visitor is able to organise and retrieve his selection without the need to carry and handle a lot of printed brochures and materials.

One of the interesting functionalities provided by this tool is the ability to connect the visitor with similar exhibitions. This is done by implementing the “Show Related Exhibits” service whereby the visitor is able to get an extend view about the other available possibilities.

Moreover, the exhibitors can inform the visitors about their products and offers in more personalised fashion through the accessibility of the context

information. Each media point is implementing the "getInterestedDevices" services. Therefore, exhibitors can target visitors more effectively to establish the first contact.

The visitor is also benefiting from the social services provided such as ranking and annotating services in Table 11 and Figure 10. "Comment Me!" and "Rank Me!" services give a shared view of the other visitors which can be very helpful in taking decisions during the tour. Moreover, favourite and highly ranked exhibitions are shown on the map on the visitor mobile phone.

As in the HolstenTour project most of the work load and effort should be directed toward the usage scenario and the interface design. In principle, Medient infrastructure is providing the entire physical infrastructure and all mentioned services for this application are already implemented and ready to be used.

6.4.2 MyLibrary - context-aware application for library services

MyLibrary context-aware application provides the library visitors with ability to receive digital services in side the library building. This example illustrates the validity of the Medient infrastructure in such an environment. This application is considering two main Medient services. Firstly, it is implementing the localisation services. MyLibrary application allows the user to receive a notification on his mobile phone about publications and collections newly added to the certain library sections according to the user interest.

Secondly, it is implementing ranking and commenting services to allow the users to share their own view about certain publications with the others. Moreover, simply by adding Amazon API[17] MyLibrary application enables the users to view global comments and reviews about those publications.

[17] Amazon.com, Inc.,"Amazon Web Services", http://www.amazon.com/gp/browse.html?node=3435361 (accessed October 21, 2007).

Thirdly, the library provides simple searching engine that is linked to the library database which allows the visitor to query the database for information on their mobile phones, as complementary to other information access points such as kiosk systems. This service is an example of using external web services combined with Medient services to fulfil special user needs.

Fourthly, MyLibrary application is also implementing “Remember Me!” services. This services is combined with the community board were different ads and media materials are posted simply by installing a media point at that location. The users can save the posted materials on their mobile phones for later use by means of using this service.

As seen in this example, even though the characteristics of the library setup and environment are different from the museum setup, the ability to use medient system and medient approach is still valid.

7 CHAPTER SEVEN: EVALUATION

This chapter presents an evaluation of the Medient infrastructure based on the implemented prototype. It is an outlook into Medient implementation against the functional requirements, non-functional requirements, features and expectations.

7.1 Technical Review and Observations

The built prototype reflects the validity of the design approach that was presented in chapter four. All system components are able to perform individual tasks and cover the required collaborative goals as well.

The Medient Service server is able to serve and handle parallel requests from a Bootstrapping Spot, a number of Media Spots and mobile clients. No limitation or performance problems were recorded in this regard. All context services, exposed in Table 11, were implemented and tested. Those services cover the functional requirements REQ4, REQ5 and REQ6.

The Bootstrapping Spot is able to perform all functions assigned to this component. This part of the system fulfils REQ1. The robustness of this component is relatively high. On other hand, it is CPU friendly. Nevertheless, during the testing phase a long Bluetooth discovery time was recorded as exposed in Table 10. As mentioned in [71][72], the discovery time is affected and influenced by multiple inquiry devices, even though the discovery device inquiry time is well characterised. Therefore, some technical complexities have been encountered during the deployment of the Bluetooth adapters. Moreover, it is noticed that calibrating the Bluetooth antenna helps to reduce the discovery time. It also prevents accidental discovery of random nearby Bluetooth devices.

The Media Spot is able to detect and announce mobile devices locations and identities to the server as REQ 2 requires. During the trials, no problem was recorded regarding the device discovery under the Discovery Mode. Nevertheless, performance problems were recorded in the Pinging Mode. Operating under this mode requires very high CPU resources and

sometime causes a breakdown in the system, whereby the Media Spot needs to be restarted. The reason for that can be returned to the operation way and speed of the Bluetooth stack and driver. Moreover, this can also be returned to exceeding the maximum number of allowed connections by trying to establish a new connection before ending the previous one.

Medient reverse AJAX server is able to provide context events for multiple mobiles at once. This component is fulfilling REQ3. Some performance problems were recorded mainly in the memory usage. The problem is formulated because the system is creating a new thread for each new connection. Nevertheless, this problem can be technically subdued by using techniques such as continuations as extensively discussed in [90].

7.2 Evaluating Medient Mobile Client on Mobile Devices

The testing of the Medient mobile client took place on DELL AXIM 50v[18] with WM5[19]. Different mobile browsers have been tested in order to evaluate the supported features against the required ones to operate Medient AJAX client. This compression is handled in Appendix 6. Opera Mobile Browser was chosen because of its support for AJAX technology on mobile devices and because of it is support for different Symbian and Windows Mobile handsets[20].

The limited and restricted capabilities to play media on mobile devices that are equipped by the selected browser were one of the major encountered problems during the implementation phase. Therefore different technical difficulties had to be solved such as playing sound streams in the browser, which is needed for the audio notification feature in Medient. More discussion about this problem, trials and a proposed solution are discussed in Appendix 7.

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[18] Dell, "Introducing the Dell Axim X50v and X50 Handhelds", http://www.dell.com/content/topics/segtopic.aspx/brand/axim_x50?c=us&l=en&s=gen (accessed August 11, 2007).

[19] Microsoft Corporation, "Microsoft Windows Mobile - Smartphone and Pocket PC Software with ActiveSync", http://www.microsoft.com/windowsmobile/default.mspx (accessed August 12, 2007).

[20] Opera Software, "Opera Mobile", http://www.opera.com/products/mobile/ (accessed July 03, 2007).

From the performance point of view, it was possible to run Medient with a full feature set including AJAX, R-AJAX, audio notification, text and sound streaming on an Opera 8.65 mobile browser. Theoretically, any mobile client with AJAX support should be able to render Medient mobile client. Medient Mobile client is causing no performance problems or side effects. The client is running in robust and outstanding manner.

7.3 Evaluating Medient Adaptability and Compatibility

Building Medient based on SOA and even-driven architecture combined with web-based mobile clients allows for fast range of computability and adaptability.

As indicated previously, Medient Mobile Client is taking advantage of the fast support and features of the mobile browsers. Most of the hardware complexities and adaptability issues are handled by the browsers themselves. Currently, browsers support advance webpage rendering that improves the navigation experience and adaptive graphical appearance of web clients. Tools such as zooming and enabling and disabling visual elements, etc, make different devices with different preferences, screen sizes and media capabilities able to render web clients effectively. Theoretically, Medient Mobile client is able to run under any AJAX supporting browser. It was possible to test the client fully on Opera 8.65 browser and NetFront 3.4 Browser[21]. The client is also running on Nokia N95[22] with Opera mobile Symbian browser 8.65, which opens the door for vast compatibility with Symbian devices.

The usage of XML-based configuration files for Media and Bootstrapping Spots proofed its effectiveness for fast deployment of the system. Furthermore, location announcement and reporting, from the deployed spots based the XMLHTTP requests, allows the system for adapting other context sensors.

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[21]ACCESS CO., LTD , " NetFront™ Browser v3.4", http://www.access-company.com/products/netfrontmobile/browser/index.html (accessed August 17, 2008).
[22] Symbian - Press release, "Symbian welcomes new Nokia Nseries devices", September 27, 2006, http://www.symbian.com/news/pr/2006/pr20068425.html (accessed August 24, 2007).

8 CHAPTER EIGHT: CONCLUSION AND FUTURE WORK

This chapter is divided into two sections illustrating the main results and outcomes of this research. Moreover, it gives an outlook of possible future work and recommendations for further research in this area.

8.1 Conclusion

An extensive study of museums, their primary functions and their stakeholders in conjunction with the historical development of the role of technology on the cultural heritage especially in museums have been presented. Moreover, a large number of ubiquitous computing and multimedia projects, empirical concepts, usage scenarios, statistical findings, experiments, etc, in the area of museums has been reviewed and analysed carefully. Thereafter, sets of usage, environmental and managing needs and requirements toward ubiquitous media in museums have been concluded and analysed.

Furthermore, a novel infrastructure, called Medient Infrastructure, to provide context-aware services in context-rich environments is investigated, designed and implemented, with deep insight and focus on the museum environment. The infrastructure's design provides tools and possibilities for application designers and developers to create context-aware applications. Medient hides the complexity of context acquisition, localisation and content delivery, whereby the development and deployment of context-aware applications become easier, effective and scalable. Medient supports mobile context-aware clients that run on Bluetooth-enabled mobile devices such as smart phones, PDA's, mobiles, etc. Moreover, it supports stationary context-aware clients that run on stations such as kiosks, public screens, etc.

Minimising deployment, maintenance, and requirements costs are the main features in Medient. Therefore, the infrastructure does not require the installation of dedicated software or drivers on designated mobile devices. Hence, visitors can simply access the provided services through an event-driven AJAX client with no need for special configurations.

A working prototype implementation based on the proposed design model and demo scenario for the Holstentor museum in Lübeck, called "Holstentour" was tested against the intended infrastructure capabilities and features.

Technically, many challenges have been encountered. Combining different technologies in one solution may cause incompatibility or synchronization problems. Moreover, those problems increase due to the lose connection between different ubiquitous computing technologies and the absence of standards in this regard. Furthermore, dealing with multiple devices with different features and setups arises adaptability issues. Nevertheless, using new web technology can reduce this issue dramatically. In general the presented work can be considered as a proof of concept for the potential of ubiquitous technologies for building flexible low cost infrastructures for contextualized media.

Finally, this research is considered as one step towards a ubiquitous computing world. Infrastructures such as Medient, which are using mobile phones and web technology, can be seen as available and powerful tools to support learning, enjoying and engaging experience especially in dense information environments.

8.2 Future Work

This research was mainly concerned about the museum environment. Nevertheless, the system design considers and can be applied in other context-rich environment such as Hospitals, university campus, companies' buildings, etc. The provided services can be customised based on the needs and requirements of the environment and the users. Therefore, more usage scenarios can be defined and tested.

More analysis about the performance of the design and the approach can be explored and researched in more details. Issues such as the usability and acceptability of the infrastructure can be investigated extensively.

During the development of this research, the author noted a lot of experiences in terms of the availability of different standards and different implementation of standards. Even though the research tackled issues regarding web technology on mobile phones, such as AJAX on mobile phones and reverse AJAX, more extensive evaluation of web technology could lead designers for researching new approaches of providing content on mobile devices. Questions regarding the adaptability and usability may arise.

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ABBREVIATIONS AND ACRONYMS

AJAX	-	Asynchronous JavaScript and XML
CSS	-	Cascading Style Sheet
DOM	-	Document Object Model
GPRS	-	General Packet Radio Service
HTTP	-	Hypertext Transfer Protocol
Mbit/s	-	Megabit per second
OBEX	-	Object Exchange (OBEX) Protocol
PDA	-	Personal Digital Assistant
SOA	-	Service Oriented Architecture
SOAP	-	Simple Object Access Protocol
SS/CD	-	Small Screen/Composite Device
UGC	-	User Generated Content
UMTS	-	Universal Mobile Telecommunications System
WiFi		Wireless Fidelity
WLAN	-	wireless local area network
WSDL	-	Web Services Description language
XHTML	-	Extensible HyperText Markup Language
XML	-	Extensible Markup Language
XMLHTTP	-	Extensible Markup Language Hypertext Transfer Protocol

Appendix 1 ANYCOM USB-250 adapter technical specifications

[Source:http://files.anycom.com/documents/datasheets/cc3036-datasheet-en.pdf, accessed September 03, 2007].

The ANYCOM USB-250 adapter is one of the first Bluetooth adapter world-wide to follow the new Bluetooth 2.0 + Enhanced Data Rate (EDR) standard. Bluetooth 2.0 + EDR offers a three times higher data transmission rate with up to 2.5 MB/s, has an improved performance with several simultaneous connections and is fully backward compatible to previous Bluetooth versions. Even with Bluetooth devices not based on the current Bluetooth standard you will see a performance improvement, as the ANYCOM USB-250 optimizes each connection. The ANYCOM USB-250 allows you to easily add latest Bluetooth technology to your Desktop, Notebook oder Media Center PC. You can use your Bluetooth adapter for many different wireless applications like

- Synchronisation PDA/Mobile phone and PC
- Network/DSL entrance via Access Points
- Transmission of pictures and blade tones
- file transfer
- Wireless printing and printer sharing
- VoIP applications (e.g. Skype)
- Mouse and keyboard binding
- High-quality audio transmission in MP3 quality

ANYCOM USB-250 Bluetooth adapter have a range of up to 120 meters and supports up to seven connections at the same time allowing a user to run upto seven devices through a single adapter. The adapter ships with the latest Widcomm Bluetooth Software (BTW) 4.0 which includes support for a wide range of Bluetooth profiles. The Bluetooth security features PIN code authorization and 128-bit encryption will ensure a secure communication between all your Bluetooth enabled devices.the scope of supply. The integrated safety functions with pin authorizing for each connection and the 128-bit coding ensure maximum security of the data transmitted by you.

Specification Bluetooth:	Bluetooth 2.0 + EDR (Enhanced Data Rate)
Frequency Range:	2.4 - 2.4835 GHz
Approvals:	World wide standards adhered including USA and Canada FCC and European CE
Chip set:	Broadcom BCM 2045
Radio Class:	Class 1
RF Output Power:	20 dBm
Sensitivity:	<0.1% BER at -86dB
Range:	up to 120 meters (400 feet)
Dimensions (HxBxT)	50 x 19 x 8 mm (1.96" x 0.75" x 0.3")
USB Version:	2.0
Supported profiles:	GAP, SDP, SPP, DUN, LAP, FAX, ObexFT, ObjectPush, HCRP, PAN, HID, Handsfree, Headset, Sync, Audio gateway, BIP, BIP Camera, A2DP, AVRCP
Security:	Safe entrance with password and pin code, data communication with up to 128-bit in accordance with Bluetooth specifications codes
Antenna:	Integrated antenna
Power Consumption:	5 V over USB
LED:	one for Link and Pairing Status
Warranty:	2 years
Box content:	Bluetooth USB adapter, Quick start Guide, Application software BTW 4.0 , Installation software and user Guide on CD
Part. Number:	CC3036

Appendix 2 Bootstrapping Spot / Media Spot configuration (XML schema and a sample file).

The XML file should be named as “setup.xml” and should be placed along with client exe file. In the sample XML file, the spot is named as “Media Point 0” and give the serial number “0” as indication that this is the first spot the visitor will encounter. Other server configuration parameters are also set in this file.

The figure bellow shows the XML schema of the configuration file.

```
<?xml version="1.0" encoding="UTF-8" ?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
  <xs:element name="bootStrap">
    <xs:complexType mixed="true" />
  </xs:element>
  <xs:element name="dbName">
    <xs:complexType mixed="true" />
  </xs:element>
  <xs:element name="dbPassword" type="xs:string" />
  <xs:element name="dbServer">
    <xs:complexType mixed="true" />
  </xs:element>
  <xs:element name="dbUser">
    <xs:complexType mixed="true" />
  </xs:element>
  <xs:element name="mediaPointNumber">
    <xs:complexType mixed="true" />
  </xs:element>
  <xs:element name="mediaServer">
    <xs:complexType mixed="true" />
  </xs:element>
  <xs:element name="MpointSetup">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="pointName" />
        <xs:element ref="mediaPointNumber" />
        <xs:element ref="bootStrap" />
        <xs:element ref="dbServer" />
        <xs:element ref="dbName" />
        <xs:element ref="dbUser" />
        <xs:element ref="dbPassword" />
        <xs:element ref="mediaServer" />
      </xs:sequence>
    </xs:complexType>
  </xs:element>
  <xs:element name="pointName">
    <xs:complexType mixed="true" />
  </xs:element>
</xs:schema>
```

The figure bellow shows a sample of the configuration file.

```
<?xml version="1.0"?>
<MpointSetup>
        <pointName>Media Point 0</pointName>
        <mediaPointNumber>0</mediaPointNumber>
        <bootStrap>C:/MediaPoint/external/mytour</bootStrap>
        <dbServer>141.83.78.173</dbServer>
        <dbName>ces</dbName>
        <dbUser>root</dbUser>
        <dbPassword></dbPassword>
        <mediaServer>141.83.78.173</mediaServer>
</MpointSetup>
```

Appendix 3 CES database structure and Apache web server.

The used web server is Apache/2.2.4 and MySQL 5.0.41. the installed package is XAMPP for Windows Version 1.6.2 [http://www.apachefriends.org/en/xampp.html]

The webserver can be accessed by: http://localhost/

The web server directory is : [local drive]\ xampp\htdocs

The database is called CES and stored in medient database directory. Here some important information needed to setup and work with the database.

It can be accessed by: http://localhost/phpmyadmin

It is locally stored in [local drive]\xampp\mysql\data\

Username: "root" / Password:"".

Link: http://localhost/

The "devices" table: this table contains all information related to all registered mobile devices in the system. The structure and one example are shown bellow.

Field	Type
deviceID	int(11)
deviceAddress	varchar(40)
deviceName	varchar(20)
registerDate	varchar(30)
deviceStatus	varchar(10)

deviceID	deviceAddress	deviceName	registerDate	deviceStatus
1	(00:12:37:06:B4:9D)	WM_StarkMann	19/08/2007 12:44:50	Active

The "devicetracking" table: this table contains the localised information for all devices including the registration dates, the current status and the media spot (point) number. The structure and one example are shown bellow.

Field	Type
No	int(11)
sessionID	varchar(30)
mediaPointNumber	mediumint(11)
loginDate	varchar(30)
logoutDate	varchar(30)
Status	varchar(10)

No	sessionID	mediaPointNumber	loginDate	logoutDate	Status
2	1	2	22/08/2007 23:27:45	22/08/2007 23:28:15	Inactive

The "exhibits" table: this table contains the all registered exhibits in the system including there names, descriptions, etc. The structure and one example are shown bellow.

Field	Type
exhibitNo	int(20)
exhibitName	varchar(30)
exhibitDescription	varchar(150)
exhibitMetadata	text

exhibitNo	exhibitName	exhibitDescription	exhibitMetadata
1	Rathaus	Rathaus (outside with the coat of arms of Hansa ci...	Rathaus
2	Lübeck market place	Lübeck market place	Lübeck market place

The "savedexhibits" table: this table contains all stored objects or exhibits for the current session. This information is used to retrieve the content related to the visitor on demand. (Usually, after finishing the visit.) The structure and one example are shown bellow.

Field	Type
sessionID	int(11)
savedExhibit	int(20)

sessionID	savedExhibit
3	1

The "sessions" table: this table contains all information about all sessions (active / passive). Al session can be tracked easily and context information can be concluded. Session usually are unique and connected with a unique device ID. The current status of the session and current location are also listed. The structure and one example are shown bellow.

Field	Type
sessionID	int(11)
deviceID	varchar(10)
sessionDate	varchar(30)
sessionStatus	varchar(10)
mediaPointNumber	int(11)

sessionID	deviceID	sessionDate	sessionStatus	mediaPointNumber
1	1	22/08/2007 23:16:45	Active	0

The "tourselection" table: this table contains the tour information for the visitor. Each tour is attached to the session ID of the visitor. The structure and one example are shown bellow.

Note: at the Media Bootstrapping Spot the myTour field should be filled in order to send the bootstrapping webpage to the mobile client.

Field	Type
tourNo	int(20)
sessionID	int(11)
myTour	text
Notes	varchar(100)

tourNo	sessionID	myTour	Notes
3	2	1,2,3,4	

Appendix 4 Medient services return XML structure.

getInterestedDevices XML return file: by calling the "getInterestedDevices" service the following XML file will returned back to the service invoker.

```
<?xml version='1.0'?>
<DevicesAddresses>
<DeviceAddresse>(00:12:37:06:B4:9D)</DeviceAddresse>
<DeviceAddresse> . . . </DeviceAddresse>
</DevicesAddresses>
```

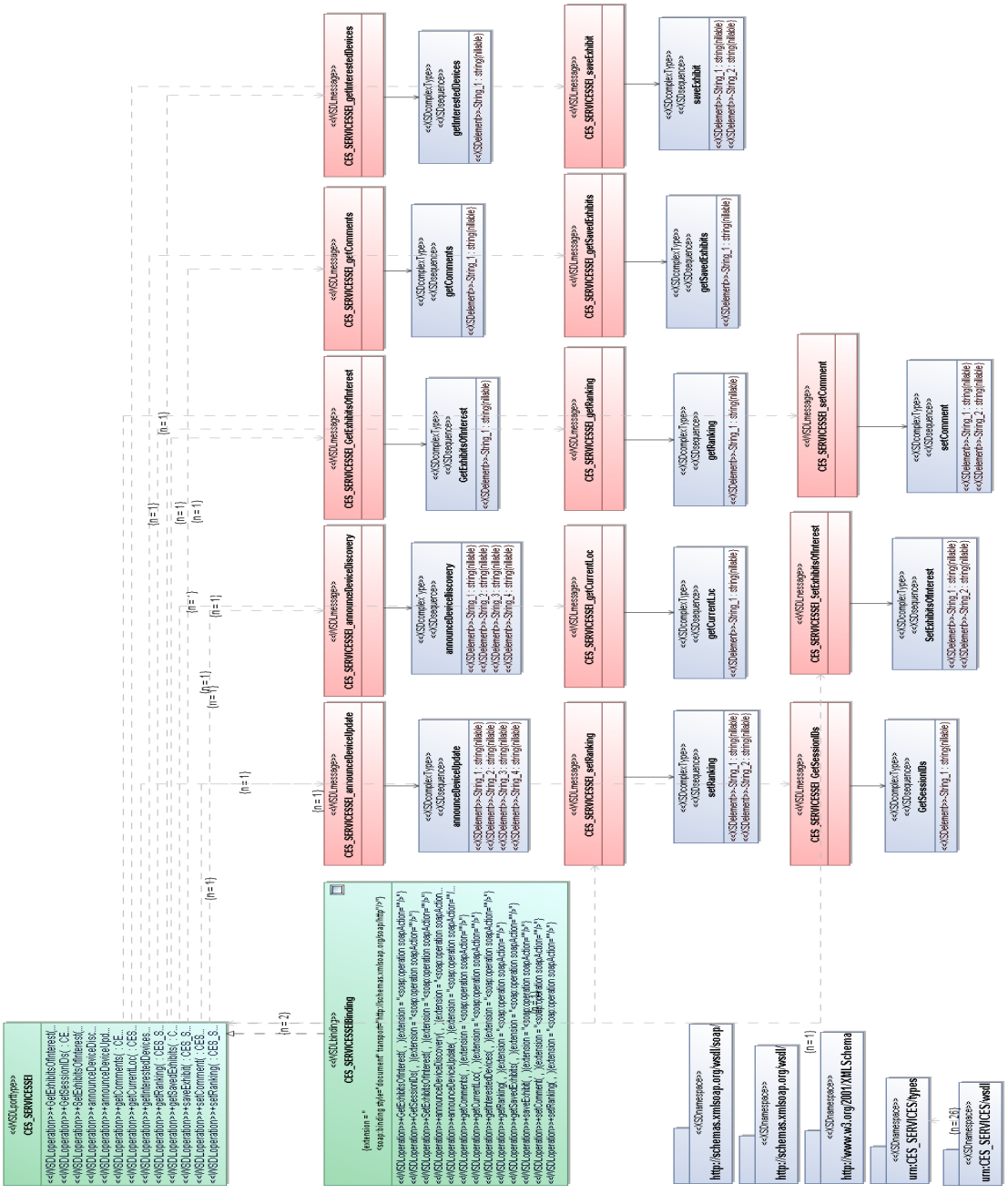
GetExhibitsOfInterest XML return file: by calling the "GetExhibitsOfInterest" service the following XML file will returned back to the service invoker.

```
<?xml version='1.0'?>
<tourSelection>
<exhibitID> 1 </exhibitID>
<exhibitID> 2 </exhibitID>
. . .
</tourSelection>
```

GetSessionIDs XML return file: by calling the "GetSessionIDs" service the following XML file will returned back to the service invoker.

```
<?xml version='1.0'?>
<ActiveSessions>
<sessionID> 20 </sessionID>
<sessionID> 34 </sessionID>
. . .
</ActiveSessions>
```

Appendix 5 Realization diagram of Medient services – Detailed



Appendix 6 Mobile Browsers - Brief evaluation

[Posted by Bashar Al Takrouri, On 28.06.2007, http://isnm.de/~takrouri/blog/?p=9]

Due to some problems in the sound streaming, this is a brief evaluation for the most popular mobile browsers have been performed.

Before couple of weeks opera announce its new BETA version of opera mobile browser. Opera mobile 8.65 supports AJAX, JavaScript, web 2.0 and so on. All those features are needed for our prototype implementation for the HolsenTour project at ISNM. Nevertheless, sound playback appeared as very important problem to solve. Unfortunately, I have not been able to play sound using opera mobile 8.65. therefore an evaluation have been performed trying to extract the current features that the available and popular mobile browsers support. The aim is to find a that dose and supports the following: JavaScript, AJAX, HTML Embedded sound and reversed AJAX.
My testing was as the following:

	JavaScript	AJAX	Reversed AJAX	Embedded sound	Embedded sound (MP*)	Flash support
Opera Mobile 8.65	Yes	Yes	Yes	No	No	Yes**
MS mobile browser (WM2003, WM2005)	NO	NO	NO	No	No	Yes***
Minimo 0.2	Yes	Yes	Yes	No	No	No
NetFront 3.3	Yes	No	No	No	No	Yes***

* Media player
** It dose not support controlling flash from JavaScript and it dose not support controlling the parameters of the EMBED object. It dose support fly streams e.g youtube.com
*** Simple flash and JavaScript to flash supported. Flash streaming dose not work e.g youtube.com

So far I do not have any clue about the solution of this problem. As you can notice from the table if I can control flash over JavaScript then Opera mobile 8.65 would be the best choice. So far I could not find any related topic on the internet. Conclusion the issues of embedding sound in HTML and play it on windows mobile 2003 using opera mobile 8.65 still open are not resolved .

Here I provide some links for useful examples I used in my test:
http://www.dart.com/pwlc_LiveSound.aspx [Sound example based on LiveSound ASP.NET Server Control]

http://www.permadi.com/tutorial/flashjscommand/ [A Flash movie, and a JavaScript controller. The controller buttons are all standard html Top of Form element. The buttons are associated with JavaScript function calls. When a button is clicked, it

“connects” to the Flash movie.]
http://www.jeroenwijering.com/extras/javascript.html [Controlling flash video with JavaScript]
http://www.javascripter.net/faq/sound/play.htm [play sound with JavaScript]

More about AJAX and reversed AJAX covered in pervious posts.
http://isnm.de/~takrouri/blog/?p=8 [Popular libraries for reversed AJAX]
http://isnm.de/~takrouri/blog/?p=5 [AJAX is supported on mobile phones.]

Appendix 7 Media Playback on Mobiles (Browser-based)

[Posted by Bashar Al Takrouri, On 03.07.2007, http://isnm.de/~takrouri/blog/?p=10]

I am reporting here about my investigation about the media playback support in mobile devices using mobile browsers. This part of sound notification component I am developing for my thesis.
Actually, when it comes to play media in mobile devices (Pocket PCs and smart phones) it is far difficult to have a strong control over the environment. This is not because we do not have standards but may be we have too many! This is strongly true for multimedia support in mobile devices as well as in other devices.

In my master thesis I insist to use already available solutions in my infrastructure to provide context awareness services for museums. But this option requires a lot of really hard work to figure how things work individually and within the system. And in the first place to select which tool for what and dose it fit or not! If I wanted to develop a new tool myself then it might be easier.

Well, I spent the last week on developing the notification player component. The aim basically is to notify the user by playing dedicated sounds when he/ she moves from one exhibit to another, or when there is an exhibit of interest for the user. I started with the very good news from Carlos "THERE IS NO STREAMED SOUND PLAYING ON OPERA". Thinking about the problem seemed easy but when it cames to the practical implementation I encountered problems much more than expected.

I am working with Opera 8.65 mobile browser installed on DELL AXIM 50v with windows mobile 2005, not to forget the Flash player 7. Apparently, Opera is supporting media player and flash (ActiveX blugins), but accorrding to this post from ISMAIL this support is also limited for some reasons discussed in his post. Anyway, when I started testing, the embedded audio sounds in the web page could not be played by the media player on the DELL. I tried different encoding for the sound but none worked, even though the same sound file can be played in the player but not embedded in the page itself.
So my next choice was to try different browsers like the MS browser, NetFront™ Browser v3.3 for Pocket PC and other versions of opera mobile. But I encountered the same problem.

So I tried to use flash to play media (streamed mp3) but I had many controlling problems from outside flash. The idea was to use JavaScript to control flash played content and timing. But unfortunately, all standards

methods of communication between JavaScript and Flash like the External interface, FlashJavascriptGateway, fscommand, getURL() function are not supported by the flash player. All of these methods were working with flash player 8 but not 7. I did tried flash lite 2.0 player as well but it plays flash content so it did not make any difference.

My other choice was to use normal media playback, based on flash and http requests from the flash itself. These calls with invoke a page that will send back controlling parameters to flash. But this is also did not work on the mobile browsers (opera 8.65 and Microsoft built-in browser). Neither loading xml file using LoadVars() not XML() worked. Of course they work fine with flash 8 player but not with them mobile version of flash 7 player. My last option was to use very simple technique to control the flash using JavaAsctipt and the embed object parameters in the html (more can be founded here).

Of course this is not the best technique but I think by have a new flash player that works with external interface my life would be much easier. Flash with opera will be very nice solution to do more complex application in the mobile browser.
Now the notification component is working. Nevertheless, mobile browsers and media support should be given more attention. I think the model of browser-based application will be highly valued in the next few years. The example of AJAX technology is evidence. So let us see what next.