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Locawe – Developing Platform for Mobile Ubiquitous Services

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Abstract

Development of new advanced mobile ubiquitous multimedia services presents number of challenges which needs to be addressed in service platform design. We have been developing our Locawe platform for this goal in several research projects using systematic develop-evaluate design cycle as a research approach. During the development we have build an adaptive architecture, which we have learned to be a key requirement for a usable and sustainable service platform. The result of a number of field studies, including various field experiments and industrial pilots, have verified our solutions and proven our approach to be successful. Our Locawe platform has shown to be applicable and useful for developing different types of mobile ubiquitous services that utilise the latest technological possibilities.

Key words: *Mobile services, Location-aware systems, Architectures, Ubiquitous computing, Service platforms*

1. INTRODUCTION

Mobile information and communication technology has revolutionized our lives in many ways during the last couple of decades. What feels like revolution to us has actually been more of an evolution, though extremely rapid. And, naturally, it is not over yet.

This evolution has its roots in advancement of computing technology. Miniaturization of technology has increased mobility. Present day mobile phones are multimedia computers, which have more computing power that the desktop computers just a couple of years ago. The networks have grown gradually more fast and more wireless, and Internet is developing as median content and computing platform.

During the last decade of mobile ICT evolution, location awareness has been one of the most significant driving forces. Location awareness is immanent potential in mobility; mobility means change in location. By now, the majority of the high end mobile phones have a GPS positioning capability and map access, as well as navigation applications pre-installed. With those mobile phones, you can send, access and share also other location-based multimedia content easily, for example by sending the photo you just take with your phone to Flickr service just with a couple of clicks.

The evolution of mobile ICT and multimedia is still going on. The next step can bee seen in emerging ubiquitous technologies. Utilisation of ubiquitous technologies, such as sensors integrated to the mobile devices and environment, will open new possibilities. The mobile devices include already some sensors, such as camera, GPS and accelerometer, but more sensors, for example RFID readers, are coming. In the near future, the era of ubiquitous multimedia services will be emerging, and available for public at large.

In order to be able to produce new advanced mobile ubiquitous services, you need a flexible and adaptable development platform. We have developed this kind of platform, which is called Locawe. Locawe has been developed in CENTRIA Research and Development, Ylivieska in several research projects during the last 3-4 years. Locawe has been designed the future technological and service innovations in mind, paying attention to adaptable architecture. The main goal of the research and development has been a platform that can be used for building different types of location-aware mobile and ubiquitous services for both outdoor and indoor environments with current and emerging new technologies.

In the development, we have used a research approach based on develop–evaluate design cycles. Evaluation of the designed and implemented services with multiple field studies has given us rigorous validation of the solutions we have made. In addition, it has allowed us to pay attention to the advancement in technology and business environment in this application area, as well as and include topical business needs and relevant new scientific knowledge in the design process. In this way, we have been able to respond to the challenges of mobile ubiquitous multimedia platform development.

In this paper, we present you the Locawe platform and its development approach and principles. At first, we outline the major challenges of mobile ubiquitous multimedia service development and tell about our research approach. Then we present the Locawe architecture and describe its main components. This is followed by some of the field studies we have carried out. In conclusion we will summarise our work and what we have learned, as well as outline the future of Locawe.

2. CHALLENGES OF MOBILE UBIQUITOUS SERVICE DEVELOPMENT

As we noted in the introduction above, mobile ubiquitous multimedia services systems are closely linked to the general evolution of mobile ICT technology. When we focus our attention on the special characteristics of mobile and ubiquitous services, they are based on location-aware, location and context-based services. The background can be found then from Geographic Information Systems (GIS), which history goes back to 1960's. The merge of GIS with mobile communication technology and mobile positioning, at the end of the last millennium, led to the birth of Location-Based Services (LBS) [1].

The potential of LBS is still present in mobile ubiquitous multimedia services, but also some of the challenges are also inherited. Traditional information systems, also GIS, have been designed around central servers and desktop computers as clients. They have typically relatively high computational and bandwidth requirements. During the recent years, the capabilities of mobile devices and wireless communication networks have increased to the level where they can be efficiently used for advanced location-aware multimedia services. Their computational power, displays, memory and data transmission speed allows to use them as active parts of mobile ubiquitous service systems. However, they are still not at the level of desktop and wireline solutions in many respects.

Mobile wireless devices as a part of information systems present significant challenges. There is considerable difference in using mobile devices as clients and wireless connections in data transmission as they are more dependent on the user and usage context, location and time. Advanced mobile ubiquitous services are also highly distributed systems, affected significantly by the solutions made concerning the distribution of computation and data storing with respect to data transmission.

One major challenge for mobile ubiquitous service systems using geographic information is presented by the geographic data. Management and calculations of geographic data, consisting of spatial data and attribute data components, is often computationally highly demanding, as well as presentation of the data as maps. Geographic data is usually managed and manipulated by map engines running on servers. However, this is not always possible, or the best, solution for mobile services. Mobile ubiquitous services use often map user interfaces, when the map should fit to the limited screen of the mobile devices. Zooming, panning and rotating as well as adding of other information, can be seen as basic requirements for the map presentation in mobile devices [2]. Spatial data is typically stored in GIS databases as vector format. The use of a standardized format, for example widely used Geographical Markup Language (GML) is recommended [2]. For advanced management and visual presentation of geographic information, the data is required to be stored in the mobile device. The optimisation methods for spatial data management and map presentation within the limitation of mobile devices are one of the major research problems with respect to location-aware mobile systems.

Mobile ubiquitous services should also be able to utilise and combine different geographic data sources, such as marine maps, road networks, and building registers as well as various forms of geocoded attribute data sets. In additoon, mobile devices and ubiquitous technologies have significant potential and innovation possibilities in collecting mobile data [3]. This potential can be used for example in maintenance work and mobile learning applications. A good example of mobile learning solutions is the Ambient Wood project [4], where the students have gathered measurement and observational data about ecological processes in the nature. The system consists of mobile devices with an access to a wireless network, different sensors, short distance radio transmitters, positioning equipment, and audiovisual applications.

Challenges to data management by the new ubiquitous technologies are also introduced when a part of geographic data is gathered from sensor networks. For practical and optimisation reasons, smart solutions for distribution of data between local mobile device and remote server are needed. Potentially massive amounts of sensor data that can be gathered from the environment require new kinds of data selection methods. Data can be selected in for example automatically based on GPS positioning. New methods, like for example physical selection with RFID integrated to mobile devices, offer also promising possibilities [5].

Even if GPS solution is available and widely used in mobile ubiquitous services, positioning still presents serious challenges. GPS can be used in outdoor conditions, but it is not viable option in indoor environments. There are no existing global indoor positioning systems available. Typically indoor positioning requires an additional infrastructure in the particular user environment.

Indoor environments have many applications and much potential for mobile and ubiquitous services. When a system consists of mobile and ubiquitous technologies, too complex architecture is quite a risk. In the western countries, population is aging rapidly. A need for smart environment research to support the quality of life will be tremendous [6]. Thus, an ambient assisted living with ubiquitous technologies will be a significant research area in the near future. On the other hand to avoid such problems the possible alternatives in the implementation phase has to be considered carefully.

Considering the development of mobile ubiquitous service platforms from the system point of view, the major challenges lie on the architectural solutions. Traditional web based service architectures are designed to be used in desktop conditions with web browsers. As a consequence, all the intelligence is in server side, especially if the system is designed without any web plug-ins. These plug-ins will improve functionalities in client side but they have also weaknesses. The main problems are in usability with extra download processes, and security issues. In any case, all the spatial data is stored in server side. There are certain basic problem in this web based service architecture if the focus is in mobile and ubiquitous features. Because the main processes are typically implemented on server side, and in addition web browsers have not been designed for ubiquitous computing, all sensor, positioning or identification data has to be read in a more complicated way. As a consequence, this kind of architecture increases communication between the server and the clients. In case of mobile ubiquitous services, for practical reasons, it is often required that the main part of spatial data is store locally in the mobile devices.

3. RESEARCH APPROACH IN LOCAWE DEVELOPMENT

Locawe platform has been developed taking into account the challenges of current and future mobile and ubiquitous multimedia services. In order to aswer to the challenges, special attention has been given to an adaptive architecture that can incorporate multiple technological solutions, including also the future technologies and new service innovations.

In the development process of the Locawe platform, we have utilised develop-evaluate design cycle, presented in Figure 1, which corresponds largerly the principles of design science presented by Hevner et al. [7]. In development, the business needs, requirements and ideas from the particular case have been used for driving the design and addition of new features. In addition, the knowledge and experiences gained from the earlier field experiments and industrial pilots have been utilised in the design, together with the recent scientific knowledge available from other sources.

The evaluation has been done with multiple filed studies during several years. The field studies consist of field experiments and industrial pilots. In these evaluations we have considered what software and hardware alternatives are feasible and appropriate for improving the newly developed features of the platform. These features have been evaluated also from usability, visualization and communication techniques perspective.

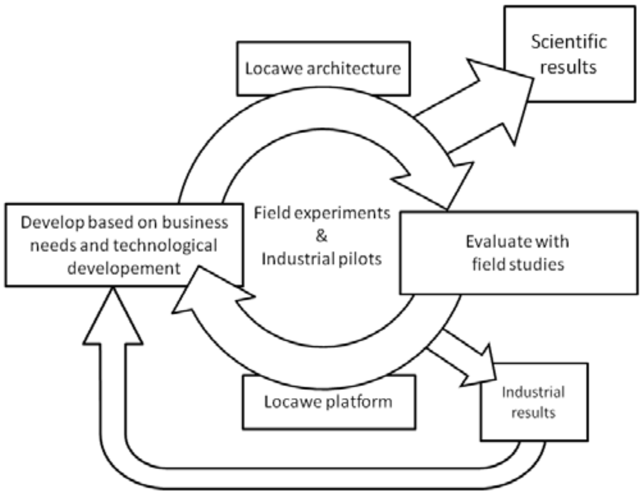

Figure 1. Research approach used in the development of Locawe architecture and platform

4. LOCAWE ARCHITECTURE

The Locawe platform has been designed according the web-based client-server architecture. It is a client-server solution, which consists of mobile units and servers for services, such as tracking and communication. Communication between the mobile units is typically implemented as Internet sockets. It is possible to create user interfaces, which include video, location and identification information on the map or on the floor plan [8]. Mobile devices can be mobile phones, PDAs or Panel PCs with GPRS or WiFi connection. For implementing mobile ubiquitous service systems using Locawe, it is possible to use different combinations of sensors, telecommunication channels, and positioning technologies. More specifically, there is support for sensors like temperature and accelerometer sensors, several telecommunication channels, such as GPRS, WiFi, ZigBee, 6LoWPAN and Bluetooth, and positioning technologies including GPS, WiFi and RFID positioning.

In order to answer to the challenges of advanced mobile ubiquitous multimedia platforms, we have used approach that differs from the traditional web-based client-server architecture design. The main difference of our approach in Locawe architecture, presented in Figure 2., is the client side functionality. The mobile client contains map engine, but also other components for the management of sensor, positioning and identification data. Thus, Locawe architecture consists of a client software, which manages spatial data locally, renders maps, listens sensors, communicates with server only when it is reasonable.

We have used our Locawe architecture mainly for service systems which are using mobile terminals. However, we have tested the platform also with other kind of applications, for example in the case of remote controlling of a mobile robot. This experiment extended and widened the Locawe platform possibilities for covering also new and considerably different application domain. In this case, the application context was more challenging, due to the requirements of indoor positioning and implementation of data transmission with Locawe server [8].

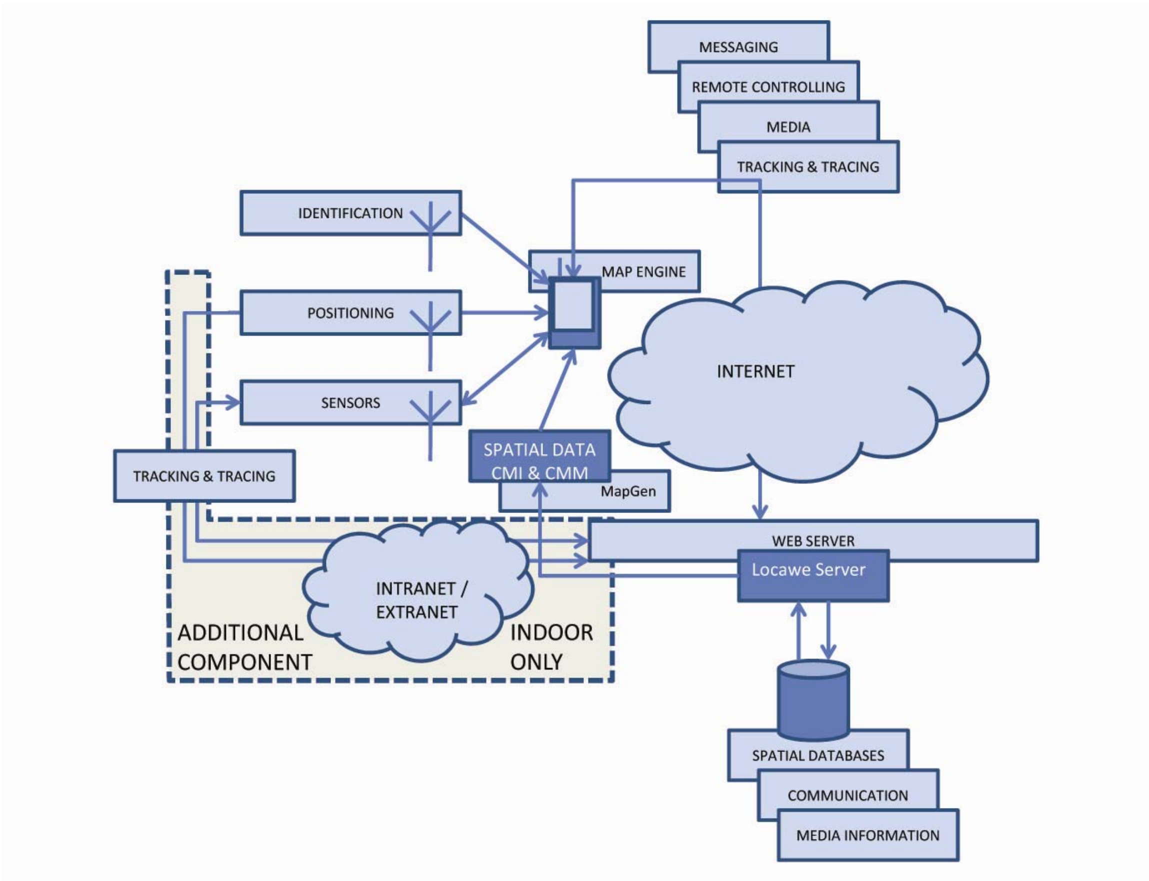

Figure 2. Locawe architecture for mobile and ubiquitous multimedia service systems.

5. LOCAWE COMPONENTS

Our Locawe platform architecture consists of a number of main components which provides its functionality. The key components and their relevant characteristics are presented here for giving and understaning of Locawe features.

1) Map generator: Locawe platform supports any kind of geographic data, which is a combination of spatial data and attribute data. Thus it is possible to implement location-aware services combining several different types of geographic data source, for example, marine maps, road networks, and building registers. The format can be any textual and unencrypted format such as GML or or other global well known data format. Locawe includes a map generator module called MapGen, which can be used or adjust for different kind of data structure. Typically spatial data consists of georeferenced points, lines, and polygons which presents the spatial features.

MapGen has also features for optimizing maps. One of the optimization fearures is progressive vector data transmission based on hierachical priority of the data segments. With this feature, for example, only the main roads are downloaded if there is no need for more detailed maps. The used hierarchy levels can be changed in MapGen dynamically. Another important feature for the map optimization in MapGen is spatial data generalized, implemented with Douglas-Peucker algorithm, for the use of maps in different scales. The map generalization feature is useful for simplifying massive objects, such as water areas as big polygons, especially when used in mobile devices with minimal resources. At the end of the optimization process, all spatial data will be converted to a binary format in an approppriate geographic coordinate system. There are several reasons for the use of binary files. Binary files need less storage space in mobile devices and the drawing is more efficient than in case of using text-based format. Furthermore, spatial data can contain also confidential information and binary files are more security in thar respect.

The structure of spatial data in Locawe platform consists of three different types of files. Settings for the map and layers as well as the list of map areas are included in XML file. The second file, called CMI file, includes boundaries of map areas, layer information, boundaries of layers, and the addresses for data in CMM file. Correspondingly, the material file, called CMM file, stores all boundaries and coordinates of map objects.

2) Map engine: Map Engine, as a part of Locawe platform, is the central facility in the creation of new location-aware services. New applications can be constructed with C++, C# or Visual Basic programming. In the case of C++, there are two components available for the software development. One of the components contains functions, which are designed for handling spatial data.

This component loads all the map areas, which will be rendered and visualized on the map user interface. These map areas can be loaded from spatial data files described earlier in this chapter. This object contains several layers for different types of spatial data. There are methods for creating and deleting vertices, polylines, and polygons. Visibilities of these layers can be handled dynamically. For the developers this component contains also other visualization methods, such as changing of the styles of pens, brushes, and colors. Because rendering maps in mobile devices is a time consuming process, this component optimizes drawing area with so called bounding boxes.

All the drawing routines are included in another component. This component checks hierarchically based on bounding boxes and drawing orders, whether this data is visible and in the drawing area. In this rendering process, it is possible to use routines, which can handle for example angles, zooms, pans, and center points of the current map. This component can also be replaced by other rendering components, such as DirectX or OpenGL. In fact these components have already been tested in our 3D version of map engine. In our own previous studies, a part of these features have been evaluated. We have done, for example, an in-traffic experiment on automatic rotation and zooming with mobile roadmaps [9].

Locawe can be used also in indoor conditions. In this case floor plans are used as spatial data. Typically floor plans are made by architectures with CAD software. For example AutoCAD files can be used in map engine if spatial data has been converted to its' exchange format called dxf. This textual format has a structure which can be read with parsers. For the developers the use of floor plan is a challenge, because of their typically unique designs. Thus, the structure of textual CAD information can be varied a lot and these floor plans are not processable automatically like topographical maps.

3) Positioning technologies: In Locawe, it is possible to use different positioning technologies, in outdoor case typically GPS. GPS receivers are nowadays usually integrated in mobile devices. So the use of this sensor is relatively easy without any extra components. GPS receivers provide positioning information in WGS84 coordinate system. This has to be converted like all spatial data before the rendering process. Typically there are available national transformations, which will fit best in the current region. On the other hand for example Helmert transformation is available in international projects and is commonly used in GIS to transform maps between geographic coordinate systems.

Locawe supports also indoor positioning, and it has been tested with both WiFi and ZigBee positioning [8]. WiFi positioning information provided by Ekahau's [10] Positioning Engine (EPE) can be integrated to our platform. This means that it is possible to visualize tracked or traced objects like persons and vehicles on the floor plan. The accuracy of WiFi positioning varies a lot, and it is depended on the environment itself. Due to the influence of metal surfaces and continuous changes in the environment, it is typically not possible to achieve high level accuracy in industrial conditions. Thus it has to be taken into account in the software development whether an accuracy of 3-8 meters is sufficient. On the other hand, this kind of accuracy can be sufficient in many location-aware services. In many cases, it is enough to know about the moving objects in which part of the building the objects are. In our field experiments, the accuracy of ZigBee positioning with Chipcon's CC2430 nodes has also been about 3-8 meters. In this case, the positioning algorithm is an in-house solution based on signal strength measurements. Thus, the application possibilities are quite the same as with the WiFi positioning.

These both technologies have their advantages. WiFi is already available in many environments, and has also the advantage of a wider bandwidth. ZigBee network allows sending only short textual information. On the other hand, in the future ZigBee will be relatively cost-effective. Furthermore, ZigBee technology as a Wireless Sensor Network (WSN) can also be used for data gathering at the same time.

4) Ubiquitous technologies: In Locawe, ubiquitous technologies consists of positioning, identification, and sensor network technologies. Mainly RFID identification technologies have been tested with Locawe. Identification can be implemented also with WiFi or ZigBee nodes because all the nodes have their unique identification number. Accordingly the GPS units can be identified as well, as every tracked object has an unique identification number in Locawe platform. In Locawe, we have tested both mobile devices with RFID adapters [11, see Fig. 3 left side], and bigger UHF readers [8, see Fig. 3 right side].

As these examples show, Locawe can be used flexibly in different kind of environments with different kind ow ubiquitous technologies. When a location-aware system is designed for mobile devices and mobile users, the typical combination is a mobile device with RFID-reader integrated in the device itself. Another option is to use RFID adapters like in our previous tests [11].

If the RFID reader is attached to moving vehicle or robot, the size is not a critical part of the process. Furthermore, in this case the reading distance can be relatively longer. One another option is an environment containing readers itself. This is also supported in Locawe platform.

Figure 3. Examples of Locawe extensions. Left: a mobile map and RFID reader used in an experiment as an example of Locawe mobile GIS extension; right: a mobile robot used in our research as an example of Locawe ubiquitous extension.

With respect to wireless sensor networks, Locawe is designed for the use of ZigBee or nowadays use of 6lowpan (IPv6 Packets over IEEE 802.15.4) technology. In the first place, ZigBee nodes have been used in Locawe as a part of infrastructure. Thus, all the communication has been between wireless sensors and servers. Recently, we have started to use 6lowpan technology and mobile devices have been integrated as a part of wireless sensor network.

6. EVALUATION WITH FIELD STUDIES

According our reseach approach, we have developed and evaluated the Locawe platfom in several field studies, including number of field experiments and industrial pilots in various application contexts.

We started the Locawe development in CENTRIA based on experiences and knowledge gained from our first location-aware system industry pilots, namely from a mobile service for fire inspectors and a tracking service for fire operations. The service is currently in daily use of Jokilaakso municipality fire department, which proofs its usability. These systems and practical knowledge were then used to develop the first version of a location-aware mobile multimedia learning platform. This initial mobile multimedia platform was the foundation of mobile ubiquitous multimedia platform Locawe, which we developed by adding support to new ubiquitous technologies and extending features required by other applications.

The research on Locawe platform has been conducted in number of research projects during several years, based on our design-evaluate approach. Large part of our field experiments have been conducted based on our location-aware mobile multimedia learning platform. However, also the industrial applications have been strongly present and we have carried out a number of industrial pilots. The results gained in educational applications can also be applied in the industry and vice versa. Wider selection of field study application contexts provide more innovations for development and give stronger validation of the implemented solutions.

One of the early educational field experiments we carried out, in which the Locawe platform was gaining its form, was a parallel collaborative learning evaluation between students in the classroom using a desktop computer and students in the field using a mobile device [12]. The original idea for this experiment was got from the technical department of the municipality of Ylivieska. In their visions high school students could be used as assistant in an early phase of field planning processes. These visions were analyzed and used as a basis in this experiment in which our platform was extended with location-aware multimedia communication techniques such as route tracking, chat messaging, photo transmission, information points and a drawing tool.

The gathering and analysis of the experiences of first industrial pilots and field experiments provided us valuable results. It lead us developing the map engine further, to more efficient and usable design for location-aware service development. The pilot verified also that new evaluated features can be applied in mobile field work.

Figure 4. High school students gathering information about telephone poles together with a representative from Pohjanmaan PPO Ltd.

Utilizing the gained knowledge, we did an other field experiment by implementing a maintenance service of telephone poles for the telecommunications operator Pohjanmaan PPO Ltd. The service was implemented with a map-based user interface with forms for gathering pole attributes on mobile devices with GPS receivers. The data input was designed with predictive features, i.e. the previous input attributes were used as a default values for the next ones. In this field experiment, 8 high school students working for PPO, gathered location-based information of approximately 1200 telephone poles (Figure 4).

Other component included in our Locave platform architecture has been WSAN (Wireless Sensor and Actuator Networks) technologies. In the beginning of component development phase, we integrated the mobile devices as a part of WSAN with an additional Bluetooth node. This node worked as a Bluetooth bridge between a 6LoWPAN network and a mobile device and the communication from the mobile device to the first 6LoWPAN node was achieved over Bluetooth communication (see Fig. 5 right side). With this solution, we were able to read sensor information, such as temperature or light, from the wireless sensor nodes. In addition, we could now use this information locally or we could transfer this sensor information over internet to the Locawe server for the further use.

Our next step of this platform component development was an industrial pilot with Sensinode Ltd and Kitworks Ltd (see Fig. 5 left side). As a result our research group in CENTRIA, in cooperation with the mentioned companies, implemented the world's first 6LoWPAN integrated handheld device [13]. This implementation provides now a direct communication from mobile devices to WSAN nodes in the Locawe platform. Following our research approach that we have used successfully in developing Locawe platform with mobile ubiquitous learning and maintenance service development, our research group (in CENTRIA) is now focusing on design the first industrial pilots in which WSAN sensors will be used with map-based user interfaces in location-aware maintenance services.

Figure 5. In-situ monitoring with mobile devices in Locawe platform.
Left: directly over 6LoWPAN communication with a handheld device;
Right: over a Bluetooth bridge (LM-048 module from LM Technologies and RadioCraft's RC2301AT module).

This information was containing 21 attributes of every poles. Based on this information, the poles with problems can be identified and reported on a map for further maintenance work. During the development of the Locawe, we have designed the architecture so that it can be adapted to new technologies. Different mobile terminals and wireless networks have been used in consecutive field studies.

7. CONCLUSION

Current and future mobile ubiquitous multimedia services present various challenges for the developers. Innovative advanced solutions for new application domains require flexible platform for their development. In this paper, we presented the results of several years research work towards the goal of designing a platform which can coop with those challenges.

Our Locawe platform has been developed during several years in a number of projects using systematic develop-evaluate design cycle as a research approach. In the course of this cycle, we have carried out rigorous many filed studies, some of them presented her, which have given validation to the solutions and provided new imput for the development. The field studies have included field experiments and industrial pilots. Many of the developed and evaluated solutions have been used in high school geography education. The first industrial pilot was a map module of a mobile service for fire inspectors. Prototypes have been implemented also for a maintenance work and agriculture. In the maintenance work, Locawe was used for gathering maintenance data from telecommunication poles. In agriculture, Locawe has been applied in tractors for collecting cultivation information from the field. Ubiquitous elements have been experimented in a mine and in a cow house. In both of the cases, WiFi and ZigBee positioning was tested with map user interface in harsh conditions [14.] The Locawe platform with developed adaptive architecture has been tested also in several other field experiments with respect to the features of automatic zooming, and rotating, techniques for selecting locations, route visualizations, collaborative communication techniques, and techniques for remote controlling mobile robot [8, 9, 11, 12, 15].

The main challenges in the development process have been the use of different kinds of ubiquitous technologies. Based on this, we have found out that the key issue in building mobile ubiquitous service system platform is an adaptive architecture. Adaptive flexible architecture allows easy addition and integration of multiple current and future technologies for devices, networks and computing. It gives also possibilities to utilize the platform for various services in different application domains. Therefore we have paid special attention to the architectural solution in Locawe. The adaptive Locawe architecture, which can be used in different types of application environments both in indoor and outdoor conditions, enables also to use and store geographic data in mobile devices as well as manage information coming from local sensors.

The results of our field experiments and industrial pilots have given evidence that our research approach is successful and our architectural approach is suitable for developing differen types of new advanced mobile ubiquitous multimedia services.

In the future, we will continue both the development of architecture and conductiong of field experiments. For example the use of 3D maps is already in testing and evaluation phase. Another future direction will be experiments with wireless sensors in mobile or ubiquitous learning, where we have already got the first experiences. We believe that in the near future sensors will be used extensively in natural sciences for collecting measurements from the field.

As the Locawe architecture will be used in the future more extensively for various new services, the main challenges in applying this architecture efficiently will be in interoperability issues. Therefore the next research activities will be focused on searching for the most suitable standards related to the Locawe platform especially from geosensor network development perspective [16].

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