The Fourth IEEE Symposium on Computers and Communications, **ISCC'99**, Red Sea, Egypt, July 6-8, 1999

A Modular Location-Aware Service and Application Platform

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Abstract

Location-Aware applications for supporting the mobile user as well as logistics of movable objects have proven significant relevance for future telecommunication and computing. Based on the state-of-the-art analysis, the paper evaluates the outcome of the labs and the requirements of commercial usage.

A system architecture is proposed from the technical perspective for localisation, information, communication, and management. The required support of heterogeneous resources leads to the necessity of an adequate middleware platform. The Location-Aware Service and Application Platform provides modular, unified access to various services, which are commonly and overlappingly used by multiple applications. Service request trading assigns the appropriate in-house services or third-party providers to the requirements of the applications. Merging data from different sources and constraints in the transmission and presentation capabilities of the mobile side require sophisticated media scaling and conversion capabilities. The envisaged service architecture leads finally to the discussion of a number of prototype applications developed and being developed on our test-bed.

1. Introduction

The revolutionary progress in the convergence of computing and telecommunication technologies is set to globally transform the fundamentals of commerce, politics, and culture – redefining the way we all live, work, learn, and play. New application scenarios are enabled within shorter and shorter periods of time. Mobile voice and data communication, localisation and positioning systems, portable devices have not only become available for everybody, they have even reached a degree of miniaturisation that enables even further integration of complex systems to hand-held devices.

Advanced communication technology comprises proposed systems such as UMTS [1], currently developing technology as wireless ATM, as well as already established structures such as GSM, DCS1800, DECT. Positioning and localisation, scaling from global to in-house systems, is provided by miniature Global Positioning System (GPS) receivers as well as infrared tracking devices. Personal Digital Assistants (PDAs) are produced for various dedicated purposes and for general use with increased processing power, memory, presentation capabilities, and extendability by standardized expansion cards.

From the content point of view, platforms for electronic commerce and information currently establish themselves in the Internet. Future scenarios could be considered as virtual electronic marketplaces, where providers of services and consumers communicate and trade. However, most applications are designed for mainstream stationary office use; only very few content providers will maintain dedicated tailored content considering the specific requirements of mobile usage.

Further, the majority of potential users demand to be supported in the way they are used to live and to do things. So, even in the new world of Electronic Commerce and Cyberspace, the old habits of the users need to be mapped to the capabilities of technology.

Within this context, GMD FOKUS and TU Berlin / OKS have established the creation of a modular location aware service and application platform, focusing on the integration of state of the art mobile and localization technology with special consideration of content handling and adaptation. The project is based on sound experience within the institutes regarding electronic tracking, Personal Communication Support, filtering and dynamic conversion of communication media [23], middleware platforms [20], and Mobile Agents [18].

The resulting platform supports a wide range of applications with support for information, navigation, localisation and communication in different scenarios. In addition, the platform is designed to integrate services from third party vendors in these areas with components for service brokerage and electronic commerce. The basis for these services is represented by the information already available through internet services like WWW on the one hand, or databases inside a provider domain, which are filtered, converted, and/or combined in accord to the desired added value.

The following section provides a review of the state of the art in related technologies, regarding location awareness, mobile communication, distributed processing, and mobile computing technology. Based on a short discussion of the business view, we look at the proposed platform from an architectural-technical point of view. Following, the essential service components are introduced. The fourth section provides an overview of the applications already ported to the platform and new applications currently developed.

2. Analysis

2.1. Related Work in Location Awareness

The expanding interest in location-aware, mobile computing has brought up several experimental platforms within the recent years, since the early 90s. Very active pools of research are grouped around Xerox PARC and Cambridge University, UK.

For location derivation, Olivetti Research and Cambridge University, UK, provided the nowadays classical approach of the Active Badge [4] infrared sensor system, sufficiently published, currently supported by the weight-measuring Active Floor [5], and the ORL ultrasonic location system [6]. While the floor measures the movement of people and carried objects, analysed by Markov Chains, the latter employs hardware attached to objects, transmitting ultrasonic pulses in specific directions, detected by a matrix of receivers mounted on the ceiling. It obtains a resolution of 10..15 cm. While the commercial exploitation of Active Badges by Olivetti industries was less successful, the idea has been used within systems of other manufacturers at the cutting edge of infrared technology [7].

B.N. Schilit and R. Want described experiments with PARCTab PDAs [8] and infrared communication. They pioneered the Ubiquitous Computing Experiment at Xerox [9], where they discussed philosophical and design aspects of hand-held computing interfaces. They provided basic definitions and categorizations of context-aware applications [10], like proximate selection, automatic contextual reconfiguration, contextual information and commands, and context-triggered actions. With the Active Map Service [11], they proposed a hierarchical structure for the description of objects in relation to locations, such as rooms, floors, buildings, regions, and areas. They already discussed the effects of bandwidth limitations in wireless scenarios.

S. Long discusses various aspects of context-aware applications [15] and describes an electronic guidebook experiment, employing GPS. She receives dedicated information, previously tailored to the requirements of the PDA, such as maps and routing facilities. The approach suffers from the bulkiness of the GPS receiver these days. She discusses the relationship of positioning and communication: PARCTab and Active Badge are found relying on the very close coupling of positioning and communication, as the beacon of mobile communication is used for location. If, on the other hand, positioning comes from GPS as a provider of pure location data, a separate communication link is required if the stationary entity needs this knowledge for selection and preparation of content.

P.J. Brown uses prototype systems in Kent [14], based on the PARCTab PDA [8] and the HP Palmtop for local infrared communication, deriving location information from Active Badges and separate GPS receivers. He describes the context-aware application of "stick-e" notes, mapping the metaphor of PostIt notes into the electronic domain. The retrieval of previously produced notes is triggered by entering the same context by the same or a different person.

2.2. Location-awareness in Commercial Applications

Today's commercial applications in the context of location awareness are usually limited to a dedicated purpose and scenario. Examples are navigation systems, combining GPS positioning data with motion sensors of the vehicle, traced within an electronic map. Traffic jam warning systems with GSM-based information delivery already utilize location information from the GSM cellular structure. In-house localization technology provides knowledge about the vicinity where staff or equipment is located.

As these examples show, the scenarios are spread over separate, sometimes dedicated, devices due to lack of general integration and a unifying platform.

2.3. Mobile Communication

Various ongoing activities ensure that the user in the 21st century will have access to mobile broadband networking facilities, at any time and in any place [1]. Figure 1 provides a comparison of existing and proposed wireless communication technology. Hereby, UMTS will provide a generic core network comprising various radio access networks, either already existing (GSM, DECT), or specifically designed for UMTS, either terrestrial, or satellite based. N. Negroponte [17] speculates that, in future, everything which comes now over the air will come by wire, while all that now arrives by wire will come over the air.

The solutions already in use still have strong limitations regarding bandwidth and QoS. Although the situation will improve with technology like wireless

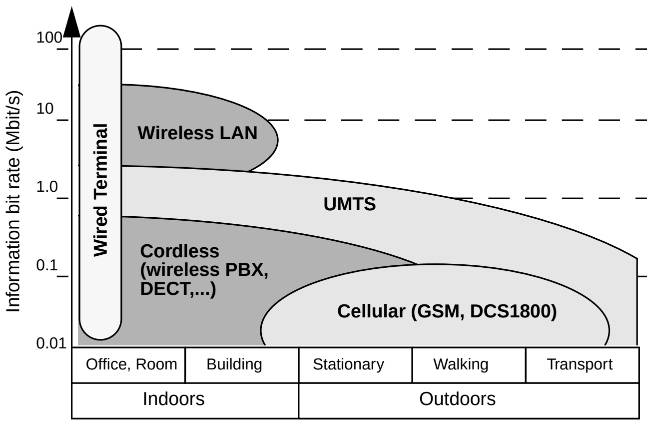

Figure 1 Comparison of Wireless Transmission Capabilities (after [1])

ATM, also in future the bandwidth will be magnitudes smaller than in wired networks. As a consequence, mobile information systems have to consider the necessity to receive content specifically tailored for this kind of application, or to adapt and scale the commonly used content for the specific limitations, i.e., to tailor it 'on the fly'.

2.4. Distributed Objects, Platforms, Mobile Agents

The necessity of object oriented middleware platforms as a basis for future telecommunication, defining sets of principles and components supporting openness, flexibility, and programmability, has gained general acceptance within the recent years. The Common Object Request Broker Architecture (CORBA) has been established as standard which enhances Remote Procedure Call based architectures by free and transparent distribution of service functionality.

Promising CORBA based technologies, like the Telecommunication Information Network Architecture (TINA) [19], have been developed for the domain of fixed access networks and succeed their migration into mobile communication networks [3]. In the latter case, special consideration is dedicated to problems distinguishing radio access from fixed networks, such as seamless hand-over.

The TANGRAM platform [20] prototypes and evaluates an environment supporting the object-oriented development of distributed multimedia applications based on the architecture developed by TINA-C. This platform suggests how to structure software for information networking. Its strength is the applicability for a wide range of telecommunication services and the independence of system and network technology. To enforce the approach taken in TINA-C, the concepts of abstract object-oriented frameworks are introduced and applied.

The technology of Mobile Agents (MA) is currently overcoming the threshold from laboratory to its application within the telecommunication industry, providing an important enhancement of distributed object technology. M. Breugst [18] discusses their influence on mobile communication and illustrates how they can be used for the implementation of service control and mobility management functionalities. He describes an agent platform, Grasshopper, entirely implemented in Java on top of CORBA, developed in compliance to the OMG Mobile Agent System Interoperability Facility (MASIF) [16].

2.5. Device Technology for Mobile Usage

In the context of location aware applications the usage of mobile devices especially in the area of navigation, information and communication systems will be one of the main target scenarios for the Location-aware Service and Application platform (LASAP).

One of the limiting factors of previous experiments, the bulkiness of the mobile hardware, has now been eliminated. PDAs provide nearly the same processing power as modern notebook computers. Communication and localization devices are either integrated or delivered as a small PC card. The modularity and easy exchangeability of these devices is regarded as a feature, allowing the scalability of location-aware scenarios from global or metropolitan to in-house applications.

The variety of hand held computers on the market is currently exploding [12]. A large scale of sizes, processors, memory, open or proprietary operating environments is now supported.

Integrated GSM communication is now available in lots of devices, and so is a variety of more or less proprietary radio communication facilities. Combined modem adaptors for GSM and plain old telephony are available as PC card for the connection to a mobile telephone, or as a card with integrated transmitter and antenna. For in-house connectivity, infrared transmission (IrDA), a DECT device, or a WaveLAN card provide access to the (wireless) LAN.

With the necessity of one PC card slot for exchangeable communication, a second one needs to be occupied with the localization equipment, which might be a GPS receiver. Today, it differs from a standard card just by the hunchback of the antenna. As an alternative within buildings, this card could easily be replaced by an infrared transmitter compliant to the Active Badge system.

Operating environments range from proprietary solutions limiting the applications to the choice of the hardware manufacturers to more or less open systems supporting Java, Win-CE, and UNIX.

We believe that it is only a question of very short time in industrial development to have very compact devices for dedicated purposes.

3. System Architecture

3.1. Business View

The case studies evaluated in section 2 were focused on laboratory experiments, where content and adaptation services were concentrated on the same party, playing different roles. Today's situation in the Internet, on the other hand, is characterized by many parties involved, which lack classification into their roles. Approaches in Electronic Commerce now consider the division of labour between specialized parties. Our Business Role Model follows the ideas in UMTS [2], while it brings stronger focus to the variety of providers in a contract relationship to the customer, and third party providers distinguished for services and content.

Network operators provide mobile access networks as well as fixed network connections, interconnected by core and backbone networks. The various service providers in direct relation to the customer are subdivided in contractors for network services, information retailers, and parties providing commercial services. These service providers retail their own applications, additionally, they may add value to services and content from third party providers, e.g. by adapting public domain (or licensed) information and common services for the specific requirements of the mobile user. While the users and the subscribers may be identical (e.g. individual user), our model covers also the case that e.g. a company subscribes services used by their employees.

An important commercial aspect of the modular location-aware platform is the protection of the investments on the customers side, also called the "total cost of ownership". Once he has installed an expensive location-aware system, e.g. an infrared based tracking system in the buildings for a particular reason, more value-added services/modules can be offered to him, avoiding additional installation cost.

3.2. General Architecture Overview

The goal of designing a Location-Aware Service and Application Platform (LASAP) is to provide a modular system for a variety of applications. The advantage will be the reusability of already implemented services for other applications, and the joint use of services commonly required for different scenarios. To give an example, an information system providing location aware data about employees can then employ the location aware communication support to contact the employee found somewhere.

As shown in Figure 2, all components for localization only employ the interfaces of the LASAP, and so do all applications. By these means, the applications have access to all services and location information in a unified way. The LASAP provides a view to the system on a location-aware application level. All other underlying technology, such as middleware or legacy services are transparent.

The main feature of employing a Distributed Processing Environment (DPE) is the provision of an abstraction from the complexity of the underlying structure of heterogeneous hardware platforms, operating systems, and the difficult networking functionality (various telecommunication as well as data networks, including all kinds of fixed and mobile access). The DPE should span all potential end user systems and provider systems (exceptions are discussed below). Having in mind the openness and heterogeneity of target environments, e.g. as envisaged in UMTS, the usage of a standardized platform is mandatory for interoperability between different providers, vendors and users.

The middleware platform we have applied to our system design is CORBA. The LASAP itself is implemented mostly in CORBA too and provides IDL interfaces towards the applications.

Inherently, the LASAP provides the full range of internet based information and service towards its applications, while specific needs for tailoring and adaptation can be realized in the service part of the core architecture. To support the full scope of telecommunication services, also legacy services have to be considered, e.g. parts of the 'plain old telephone services' (POTS). They are symbolized as an specific

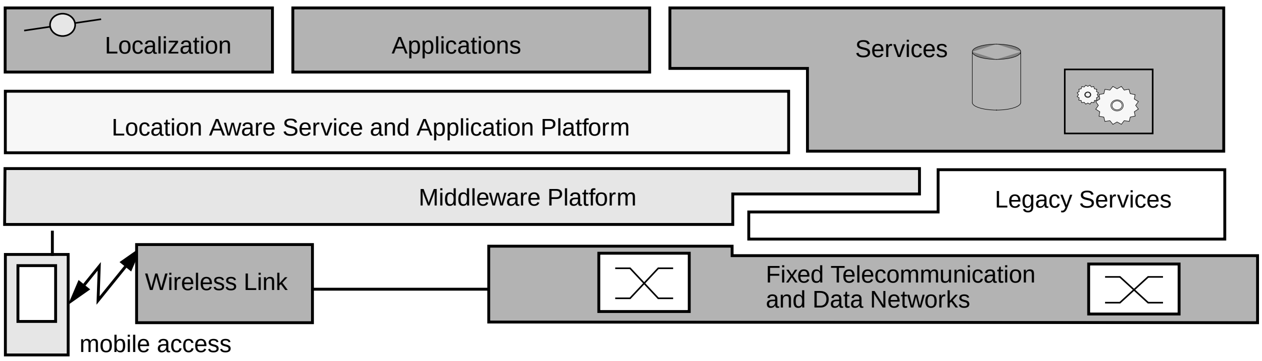

Figure 2 Architecture overview for the Location-Aware Service and Application Platform

layer in Figure 2. As they cannot completely covered by middleware, separate service specific gateways in the service part cover these aspects. The overlap with the middleware describes the possibility that some parts of legacy services can be already handled by middleware, e.g. the signalling and connection management of telephony could be handled by the middleware, while the stream is connected directly to the respective service unit.

3.3. Functional Overview

Abstracting from the underlying middleware layer and network layer, Figure 3 provides the functional overview from the perspective of application and services. The interfaces to the LASAP are subdivided for services and applications, where the interfaces for localization information are considered as specialized service interfaces.

A Service Request Trader implemented within the LASAP decides whether services required by an application could be delivered by which internal or external service. Internal services, for example covering the scope of a CPE environment, can comprise enterprise databases, multimedia stores, localization data of persons and objects, proxy services for remote locations, and, in particular, adaptation services for static information data as well as for dynamic communication, asynchronous as well as synchronous.

The concept of the Service Request Trader allows an adjustable degree of freedom for the application about the source of received information. If necessary, it may contact third parties directly for location independent purposes. When it needs the location awareness, and/or wants the data adapted to specific needs, it contacts the integrated retailer. The latter may provide service from internal databases, or collect information from the third parties.

Generic use of location-aware technology has to consider all degrees of coupling between localization and communication, i.e. the use of independently received position data (GPS), transmitted IDs (Active Badge), as well as beacon derived data (in-house infrared). In consequence, the position data have to be transmitted from the mobile user to the retailer, hence making the latter role mandatory. Positioning methods employing data from cellular structures (e.g. GSM) are not discussed separately here, as the granularity of the cells is too coarse for the applications in mind. If the low precision of cellular structures is sufficient for a specific application (e.g. localized road traffic delay warning), it can of course employ the localization interfaces of LASAP.

The localization data are stored within a hierarchical data structure in the internal databases. Objects may have a geographical location, expressed as lati-

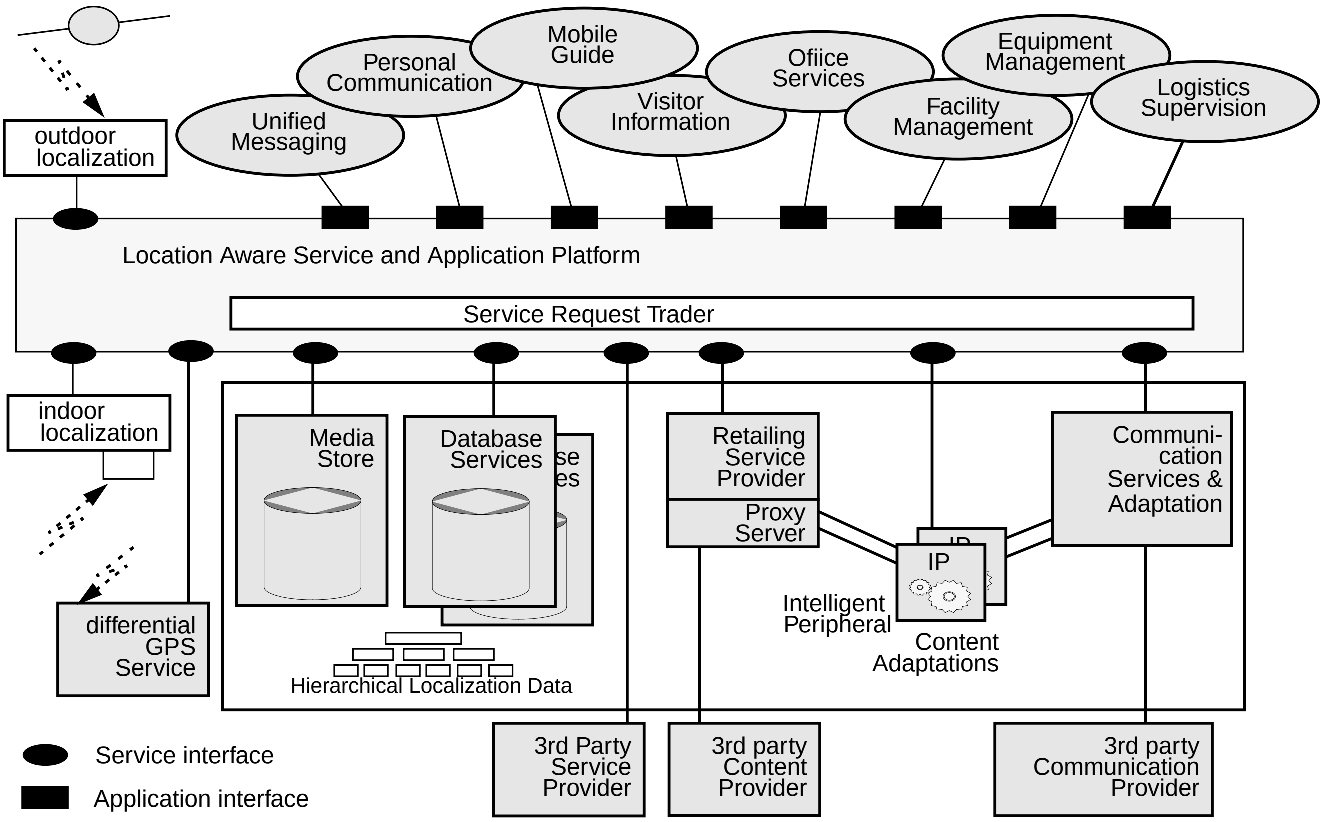

Figure 3 Functional Overview of the Location-Aware Service and Application Platform

tude and longitude. While a building has exactly one geographical location, pointing to the entrance, it has additional in-house locations, pointing to rooms or sections of rooms. Considering the varying precision of localization tools, the data contain a tolerance value, and time and frequency patterns of sightings.

3.4. Localization Services

The localization services are implemented for in-house and outdoor localization. Beyond the technical solutions chosen for our prototype, the LASAP interfaces are open for many localization and registration technology, automatic and manual, such as smart cards, transponders, the Java Ring (www.ibutton.com), cellular phone location, etc.

Outdoors, we use GPS positioning, obtaining the geographical data from a card within a mobile device, and sent to the LASAP interface. Specific attention has been given to the precision problem of GPS. Developed as a military system, the centimetre-precise positioning signals are encrypted. Civil users have access to the "Selected Availability" level, purposely randomised to a radius of approx. 100 meters. Within non-military areas, a legal approach to enhance the precision is "differential GPS" (dGPS). Here, a stationary GPS receiver (with therefore known precise location) analyses the difference of signals received from the satellites compared to its own location. This difference is transmitted via earthbound radio channels. A mobile GPS receiver, which receives information from the same satellites (i.e. is not too far from the stationary one), can employ this difference information for correcting its position. Lot of nautical dGPS stations exist for free along the US coast, some as commercial services within the country, only few stations exist in Europe. Civil aviation plans to use dGPS and will increase the number of terrestrial stations.

The mobile applications based on LASAP utilize some form of wireless communication channel. Hence, this can be also used to transmit the differential signals for the mobile devices, avoiding the necessity of a separate receiver for this purpose. We are currently setting up such a station, providing dGPS information for Berlin, as a Web-based service. It will also provide timing and satellite constellation (almanac) information, which can initialize cold-started mobile receivers and reduce the "Time to First Fix" from 15 minutes to 30 seconds.

In-house, two different systems are employed, namely the EIRIS IR-system by ELPAS [7], based on a Echelon LON and the Active Badge System [4] (by Olivetti) based on a serial RS-422 bus. The datagram computing is realized in Java to provide a maximum flexibility and platform independency.

From both areas of location, the data are delivered to database services, where they are stored in the hierarchical structures discussed in the previous section.

3.5. Database Services

As the basis for various applications in the area of information retrieval and communication management, the LASAP provides different kinds of databases as a core service. These databases are structured in several areas related close to the main services of the platform: information, localisation/navigation and communication.

On the one hand an infrastructure database stores all relevant information for localisation (see above) and communication purposes. This includes information about in-house and outdoor locations like maps, rooms, as well as the infrastructure of these areas like terminals, inventory, telecommunication facilities and localisation data of persons and equipment. On the other hand there is a database handling the content information, which may contain data about specific topics (e. g. offers of a department store or restaurant) as well as personal data of employees of an organisation, enterprise data covering a whole company, a media store for multimedia information, etc. A third class of database inside the LASAP provides meta information about the offered services of the platform and the services offered by third party content and service providers. The incorporated service trader of the platform use these data for combining services according to the requests of different applications.

As all the information stored in different databases are related to each other (e. g. a person is located in a room, a room has several communication devices, these are accessible through a couple of services by different service providers), all these databases are realised through a relational database management system (RDBMS), provides different views on the same information objects for different applications.

In our prototype scenario we developed a data and information model covering the needs for the applications discussed at the end of this article. The database was first realized on a large scale Oracle 8 enterprise database, also been ported to lightweight Adabas SQL database. The access to the different databases is transparently covered by a unified Data Access Layer, which is accessible to the applications either as a CORBA service or as platform independent Java-API.

3.6. Dynamic Content Adaptation by Media Conversion

Adaptation, scaling and conversion of data may be performed at different places in the scenario. Technical adaptations, such as simple stream format conversions, may be performed at the network level, in particular at the interface between fixed network and the radio access provider. More sophisticated conversion should be performed by the system services, which know the device profile of the user in detail, or through a specialized third party. For the unit executing the conversion, the term of an Intelligent Peripheral (IP) [21] has been adopted from advanced concepts of Intelligent Networks (IN).

To restrict the scope of available information to previously tailored data limits the freedom of choice of the user and builds dependencies on specific content providers. Therefore, the goal of our research is the usage of content not specifically designed for the purpose of PDA technology and mobility. On the other hand, we cannot ignore the mobile bandwidth limitations and the restricted presentation capabilities of hand-held devices for multimedia data.

We need capabilities to convert information from one carrying medium into another while maintaining the semantic; or to scale and adapt the information to the displayable resolution or transmittable volume. Within the context of the peer-to-peer oriented PCS, we have achieved this goal by providing a system for dynamic selection and allocation of suitable media converters from a large set of available modules, followed by their automatic configuration and chaining [23]. Our approach (Figure 4) goes far beyond the classical provision of pre-wired converters for dedicated purposes, as it allows flexible access to data of previously unknown type and characteristics.

It has been found also valuable for tailoring web-based and other database information for the needs of location-aware PDA applications. This technology provides therefore a platform for easy definition and upload of filters for personal preferences, and common and personalized content filters.

While simple adaptations might be performed within the limited resources of a PDA, the more complex scenario of adaptation happens either within a proxy server in the provider environment, or as a third party service, or in case of format adaptation in the network layer. The mobile entity might have unfiltered access to common resources like the WWW or various Electronic Commerce servers, and additionally the possibility to connect themselves to the personalized interface at the proxy provider.

In Figure 4, the mobile terminal delivers its location data as well as its wishes to the retailing provider system, which searches the relevant information. It selects the content from third parties and finds that the data do not match the capabilities of the mobile user. Therefore, it sends the media requirements to the media adaptation service, where the Intelligent Resource Selector evaluates the conversion capabilities for the incoming media, selects the appropriate converters, configures a converter chain, and starts the Job and Stream Control (Converter Framework) with the dynamically configured chain. The raw data from the content provider are finally converted and delivered to the mobile user.

3.7. Retailing Services

The access to a huge amount of location dependent and location independent information by the stationary user as well as the remote mobile user requires various services and technologies. On the one hand,

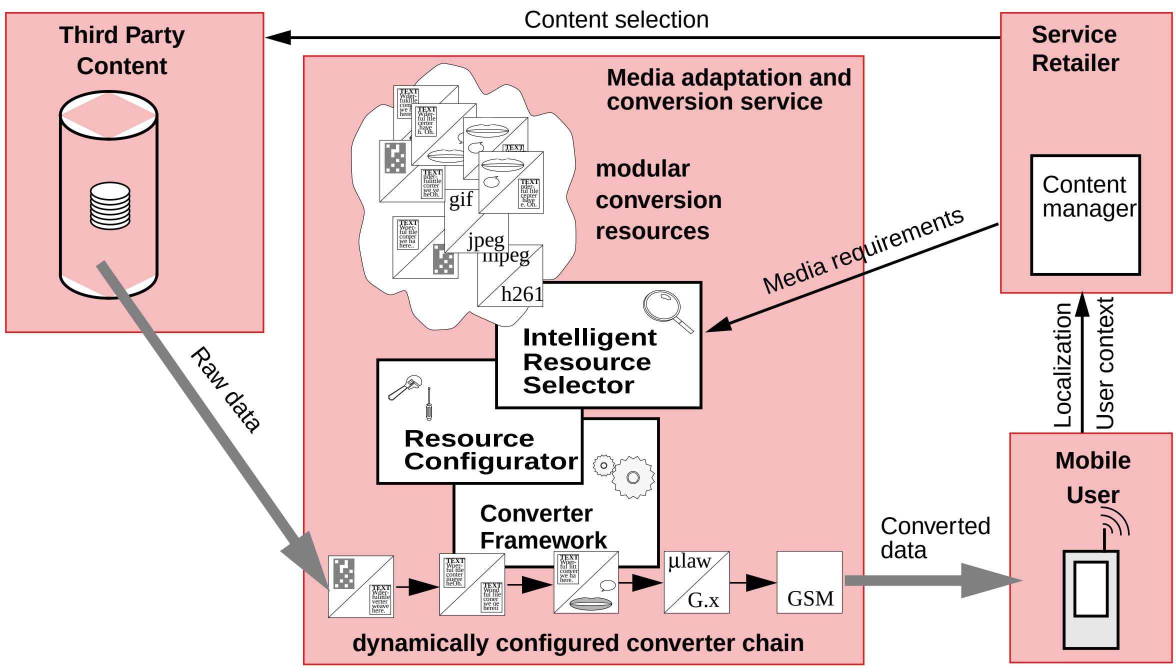

Figure 4 Dynamic Media Adaptation and Conversion Service

content has to be tailored to the specific requirements of the mobile terminals. The location data have to be mapped to local and remote databases, e.g. for retrieving the part of a map from a Geographic Information Systems (GIS) relative to the location of the user.

3.8. Communication Service Gateways

Service Gateways connect the system to the whole world of communication outside, synchronous as well as asynchronous. They realize the access to legacy services (phone, fax, e-mail) and future telecommunication and data communication services (multimedia conferences, joint document editing, etc.).

Towards the LASAP, the gateways provide a generic interface, while they are service specific to the kind of telecommunication they support, providing exactly one specific communication service (e.g. telephony service), but that for all users (user generic). They can process messages for multiple users at the same time.

Remote Access Gateways allow the user to access the system services, e.g. stored multimedia messages, remotely from nearly any kind of terminal. These special types of gateways are realized e.g. for Java applet access (via the WWW), for access with Mobile Agents, and as telephony gateway (access controlled by touch-tones or interactive voice response). Other forms of remote access are possible, such as fax polling or automated e-mail response.

These gateways had already been implemented for the former stand-alone PCS system, and have been ported towards the usage of the platform. E.g., three variations of telephony gateways have been implemented, which are the support of an ISDN device within a workstation, the CSTA based control of a small ISDN-PABX system subordinated to any large company PABX, and the direct CSTA based control of a dedicated large PABX (Siemens HiCom).

3.9. Mobile Agent Service

Within the LASAP, cf. Figure 5, an Mobile Agent Service has been installed, opening various interesting applications in electronic commerce and service brokerage scenarios. As depicted, a commercially available Distributed Agent Environment (DAE), namely Grasshopper [18], has been used for specific services, while applications can also avoid the agents and employ the LASAP directly.

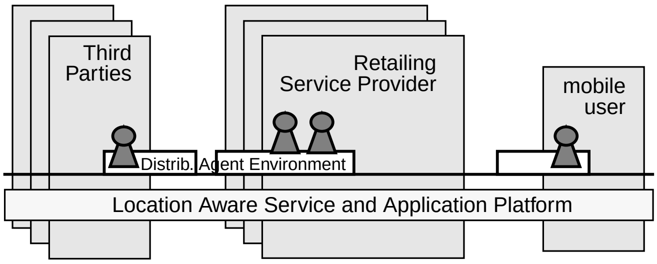

Figure 5 Middleware architecture for distributed processing and agent support

Grasshopper is an agent platform entirely implemented in Java, running on platforms supporting JDK 1.1. and above. The suitability for LASAP results on its usage of CORBA. Agents are transferred via CORBA IIOP or Java RMI, further transport mechanisms are planned. Apart from its distributed agent runtime environment, various plug-ins enhance the core functionality, such as agent creation environments and graphical agent management interfaces.

4. Applications

This section describes applications already implemented on top of the LASAP, as well as parts being currently developed. The former are derived and reimplemented from individual location aware projects already performed, and usually bring a bundle of services with them. They are described in detail below, before the other applications are drafted.

4.1. Media Flexibel Unified Messaging

The concept of Unified Messaging (UMS) has recently emerged from the research of Personal Communication Support (PCS). With strong industrial coverage, it addresses the task of overcoming the multiple-mailbox approach of today's communication scenarios, with separated facilities for e-mail, voice storage, fax reception, etc. This coincides with the vision for future communication, to deliver *information any time, any place, in any form*, as it is described in the Virtual Home Environment (VHE) concept within the (UMTS) standards [2].

Enhancements consider that global reachability is today realized by mobile equipment, so now the user wants to manage and to control this accessibility in order to maximize or to filter it – independent of his location, the used communication service medium, and the applied human communication interaction. Additionally, he wants access to his asynchronous message store from everywhere and in any form (i.e. using the available equipment). In this context the concept of PCS [23] provides people with a new

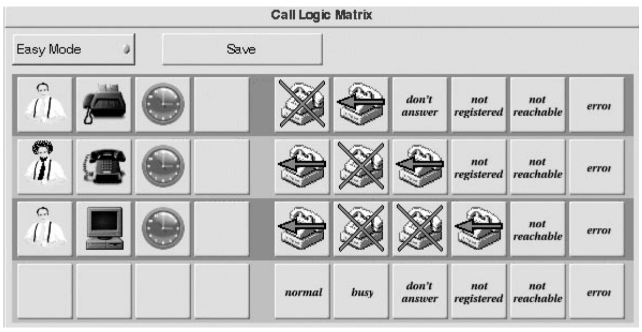

Figure 6 Personal Call Logic for Unified Messaging

dimension in communication. It allows users to establish their own personalized communication environment by addressing three important aspects, namely:

- *Personal Mobility*, i.e. the mobility of the user in fixed and wireless networks, allowing him to use available communication capabilities at different locations, i.e. at *any place and any time*;
- *Service Personalization*, for communication/ reachability management, according to the user's specific individual needs, i.e. *if, when, where, for whom, and for what content* he will be reachable;
- *Service Interoperability* in distributed multimedia environments between different types of communication services and terminals. Maximizing the user's reachability requires capabilities that enable dynamic/intelligent content handling and conversion of different media types and media format: to deliver information in *any form*.

The UMS components are derived from our implementation of the *intelligent Personal Communication Support System* (iPCSS) [22]. Overcoming the static approach of fixed, 'pre-wired' media conversion for converting fax, e-mail, and voice into each other, we implemented a system considering a set of user preferences (Figure 6) for the dynamic selection of appropriate media converters, applying the evaluation of the *quality of the conversion* outcome for the final selection of the most appropriate chain of converters.

This approach of dynamic content adaptation has been re-used for the respective service component described within the previous section.

4.2. Mobile information and communication system

A mobile information and communication system named *Mobile Guide* [25] system is designed for scenarios, where location dependent up-to-date information is needed to satisfy the individual needs of a potential user in an easy and intuitive way.

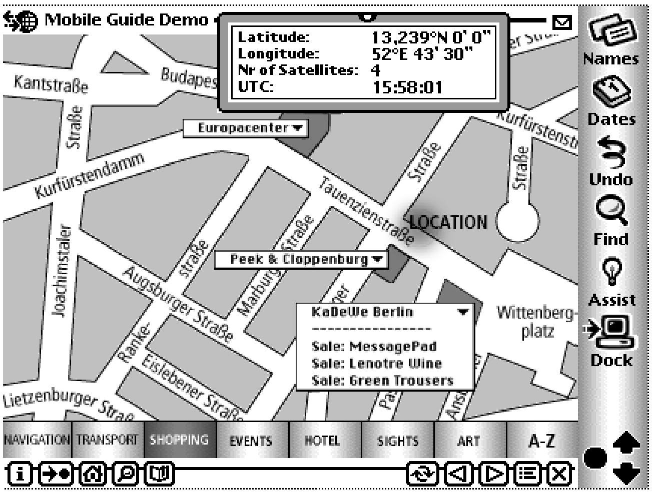

Figure 7 Mobile Guide: Ku'damm application

The system is especially useful to visitors, foreigners and tourists inside the following scenarios:

- *Points of interest*, *shopping* possibilities, public *traffic*, etc.: Each topic is enriched with additional services, like reserving cinema or theatre tickets, hotel reservation, booking sightseeing tours, or simply browsing through the daily offers of a restaurant or department store;
- *Museum* or *exhibition* area: providing guided tours, object specific information (by standing in front of one), links to related topics, etc.; here an interactive intelligent route planner, communication capabilities for visitor groups and a recorded tour are additional services;
- *Fair* or *conference* area: schedules, theme and location specific information, etc.; also useful for this scenario is the personalised handling of communication (e-mail, fax, messaging, incorporating services provided by the UMS Service upon the LASAP), a personal time planner with reminder functions and offers for evening events incl. restaurant reservation, etc.;
- *Airport* or *railway* station: presenting actual timetables, booking/reservation possibilities, shopping facilities, daily offers of shops and restaurants, etc.

The integration of existing services inside the LASAP, like enterprise in-house information databases, communication and access control systems allows additional scenarios for the Mobile Guide system, like an interactive shopping assistant inside a department store, or a guide to persons, events and locations inside an organisation. The mobile terminal is realised as an easy-to-use intelligent hand-held PDA equipped with internal storage (for information caching) and exchangeable devices (Figure 8) for wireless communication and localisation. Localisation information are retrieved via GPS, infrared data or cellular tracking, according to the facilities available at the current location (in-house/outdoor usage). The wireless communication as part of the LASAP is transparently accessed by the mobile terminal via the provided services and hardware devices.

Within the open and object oriented system design, all these components are exchangeable, and can be combined according to the specific requirements of the mobile device, the customer and the service provider. This architecture makes it possible to exchange several components of the system (e.g. localisation techniques) or to use different types of terminals without the need to change major parts of the whole system.

The front-end application inside the mobile terminal is realized as a HTTP-client. The application running on the mobile terminal needs to provide a generic access to a localized context of information depending on the users current position. It provides user-selectable contexts related to the current location, e.g. shopping facilities, traffic information, points of interest. Among the information related to the special context of the location of the user, the Mobile Guide system also offers a couple of location independent, generic services provided by the LASAP as local or third party services. These services enable a user to access personal communication services like fax, e-mail, etc., which are partly controlled by other LASAP based applications like UMS, and generic services like a yellow page service or a search for topics and keywords. Also an intelligent route planning service (e. g. fastest way to airport, way to next letter box, next metro link to the Zoo) is available as a basic service.

The information request containing the location information and the selected context is wirelessly transmitted to a dedicated service and content provider running the Location-Aware Service and Application Platform (LASAP). This platform combines different sources of information and communication services according to the requests of the mobile user, and transmits this information (e.g. a bitmapped image containing visual information, a list of choices, etc.) back to the mobile terminal.

Based on this mobile terminal and the underlying LASAP we have established a small test-bed for an dedicated outdoor-scenario covering parts of the Berlin city area around the Kurfürstendamm and Wittenbergplatz (Figure 7). Inside the platform we realized a couple of services by example. One service provides shopping information of different department stores, which resides in a local database. The underlying map information is provided by an external CORBA-based Geographical Information Service (GIS) of Berlin's public transportation company (BVG) as a third party provider, which uses the same data also for tracking their GPS-equipped vehicle park.

This way, the latter example maps the location-aware systems of two providers together, considering the location of the user in relation to the location of the approaching bus.

Another service uses the databases of the Berlin City Train (S-Bahn) for up-to-date information about the public transport around the user's current location. An alphabetical overview about currently available services is another service developed inside the prototype scenario.

For the integration of intelligent agent services for electronic commerce the DAE services of the system are employed, as described in section 3.9.

For our prototype test-bed (Figure 8), we use an Apple Newton MessagePad 2100 (160 MHz RISC processor, 8 MB RAM, 480x320 pixel greyscale pen-sensitive display).

To support a broader platform of mobile devices, the applications are currently ported to a Win-CE environment on a Toshiba Libretto. For the purpose of localisation, one of the PC-slots is used by a Centennial GPS-card. As an alternative within buildings, this

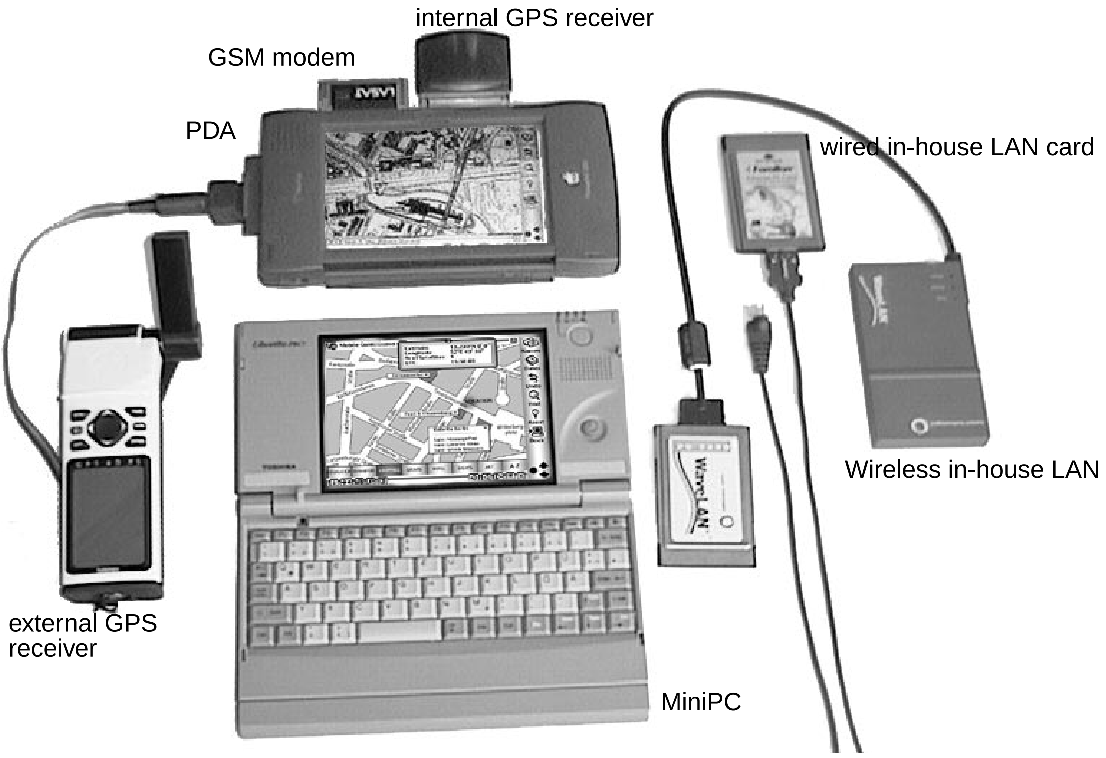

Figure 8 Compact PDA with integrated, exchangeable positioning and communication technology

card could easily be replaced by an infrared transmitter compliant to the Active Badge system. In future, the infrared capabilities (IrDA) of the PDA itself could be used for this purpose, currently the heterogeneity of the infrared bearing layer hinders the immediate integration. The wireless communication located in the other slot is currently based on GSM-technology for outdoor use or on a PC-Card based WaveLAN interface for indoor scenarios.

4.3. Visitor Information System (VISIT)

The interactive kiosk system has been designed for visitors of an organisation or company and performs the role of an electronic receptionist. The information system provides a visitor with multimedia information about the organisation itself (e.g. departments, projects, products), information about the building (maps for orientation/navigation), and finally information about the employees of the organisation.

The kiosk system leads a visitor inside the company by an interactive search to a specific individual. During the search process the user has the possibility to follow links to related topics, alternate persons, or get actual information about current events or the surroundings of the building. In addition to the multimedia information to a person, the visitor has the possibility to communicate directly with the currently selected person via voice telephony or video-conferencing. For localisation, the employees are equipped with an infrared Active Badge system. The LASAP provides the VISIT application with the following services:

- *database access*: unified access to personal, multimedia and infrastructure information,
- *communication* facilities: access to in-house communication provided by the services by LASAP,
- *localisation*: identifying the current location of employees (Active Badge infrared infrastructure),
- *media and type conversion*: adapting communication requests to the communication facilities at a specific location.

Beneath the kiosk terminals, a couple of related applications access the LASAP. Administration tools allow the maintenance of the database content. An office version of the information application enables the employees to access the information from their desktop. All front-end applications are realized in Java for a platform independent usage. The applications communicate to the platform through standard IP-based protocols like IIOP, HTTP, FTP, and Java RMI.

The multimedia and infrastructure information is provided by the Oracle database service integrated into the platform. Telephony is provided by the communication services (the service gateways).

VISIT profits from the enhanced communication services provided by the UMS project as well as the UMS application uses the personal and infrastructure databases provided by the VISIT scenario.

4.4. Facility and equipment management

The Vista-Tracker is a typical application made possible by recombining services, which other projects delivered to the LASAP architecture. It is part of a project in the area of smart home / smart office environments. The Tracker realizes a visualisation tool of a localisation system, and keeps track of equipment and people inside an in-house scenario.

The idea behind this application is to get actual information about the current location of a person and additional information about the available communication infrastructure (e. g. telephone, workstation). Another task of the application keeps track of special equipment (e. g. expensive devices). The Vista-Tracker allows the monitoring of these devices (e. g. giving an alert when leaving a specific area) or a search for a device within the company. The applica-

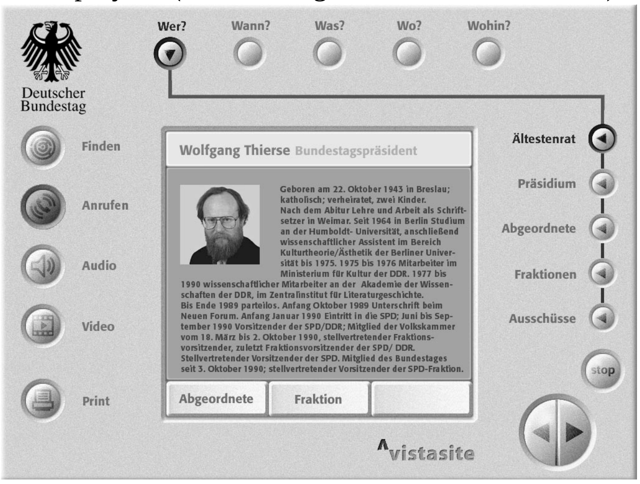

Figure 9 Visitor Information touch terminal

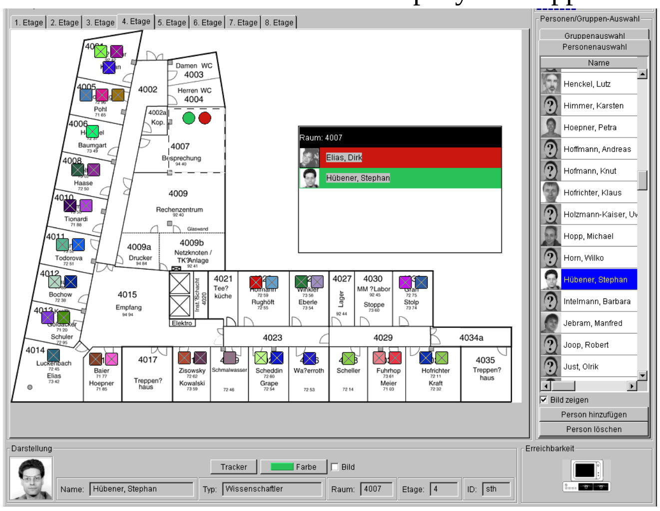

Figure 10 Vista-Tracker Application

tion visualizes an object on a graphical map (Figure 10) with colour coded dots (here: square for people, round for equipment), and provides additional information by selecting an object or region.

The LASAP provides the Vista-Tracker with the following services:

- *localisation*: identifying the current location of persons and equipment using an Active Badge infrared infrastructure
- *database access*: access to organisational, personal and infrastructure information

4.5. Further Applications

The example above is currently expanded into a full facility management scenario. The information about presence of people within the building is utilized to control the heating system, the lighting of common places, to provide security enforcement and access control, maintenance cycle statistics, to allow remote control of office and home equipment.

A customization of the system is under way for a medical institution, providing the location-aware information as described above about medical personnel (wearing Active Badges) on one hand in conjunction with reachability and access control, one the other hand continuously collecting bio-metrical data from patients (transmitted via IR by wearable sensor devices) for long-term diagnosis, monitoring and alerting purposes.

A logistics supervision application is under preparation for an outdoor scenario of an port of transshipment for tracking standardised containers within a designated area.

5. Summary

Within this paper, we have discussed the state-of-the-art in location-aware mobile applications. We have proposed a system architecture fulfilling the requirements of upcoming Electronic Commerce scenarios, by introducing a middleware platform for distributed processing, enabling the 'plug-in' of modular services. Some of them can be based on Mobile Agents, currently under implementation. The prototype installation is already implemented on top of a CORBA environment and provides the communication with third party services as well as media adaptation by dynamically generated converter chains for several different applications.

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