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Mobile Guide – Location-Aware Applications from the Lab to the Market

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Abstract: Location-Aware applications for supporting the mobile user have proven significant relevance for future telecommunication and computing. The paper evaluates the outcome of the labs and the requirements of commercial usage. Based on the state-of-the-art analysis and the business view, a system architecture is proposed from the technical perspective. The required support of heterogeneous resources leads to the necessity of an adequate middleware platform. 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 the prototype developed on our Mobile Guide test-bed.

Keywords: Location-Awareness, Mobility, Multimedia communication in distributed, heterogeneous networking and computing environments, Media Conversion, Multimedia Databases, Electronic Commerce.

1. Introduction

The rapid progress in the melting computing and telecommunication technologies enables new application scenarios 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.

Communication technology comprises available systems such as GSM, DCS1800, DECT, as well as proposed systems such as wireless ATM and UMTS [1]. Positioning and localisation, scaling from global to in-house systems, is provided by miniature Global Positioning System (GPS) receivers as well as infrared tracking. 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, applications are designed for mainstream stationary office use; only very few content providers will maintain dedicated tailored content considering the special requirements of mobile usage.

On the other hand, 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 Mobile Guide Project, 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 [19], middleware platforms [16], and Mobile Agents [14].

The experiments consider as the business case for Mobile Guide the support of travelling business men and tourists visiting foreign cities and having the need to be guided and to communicate, to book commercial services as car rentals, local travel, accommodation, to inform themselves about leisure entertainment, etc. Therefore, the system supports the major domains of location-aware, mobile computing, which are Navigation, Communication Services, Information services, and Electronic Commerce.

The basis for these services represent 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. Obviously navigation support and directory services are also offered by Mobile Guide. In addition Mobile Guide features location independent information services access as well as personalizable communication services (e.g. fax, email, (internet) telephony, etc.), access to service brokerage and electronic commerce.

This paper describes the Mobile Guide architecture, the potential application cases and the design of a prototype. In the following section, the paper 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 discuss the system architecture in general technical terms, the requirements of middleware platforms, the media adaptation, and the service architecture. Finally, the Mobile Guide system is introduced with descriptions of the hardware test-bed, the currently supported scenario, and the prototype implementation.

2. State of the Art

2.1. Related Work in Location Awareness

The emerging 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.

B.N. Schilit and R. Want described experiments with PARCTab [7] PDAs and infrared communication and pioneered the Ubiquitous Computing Experiment at Xerox

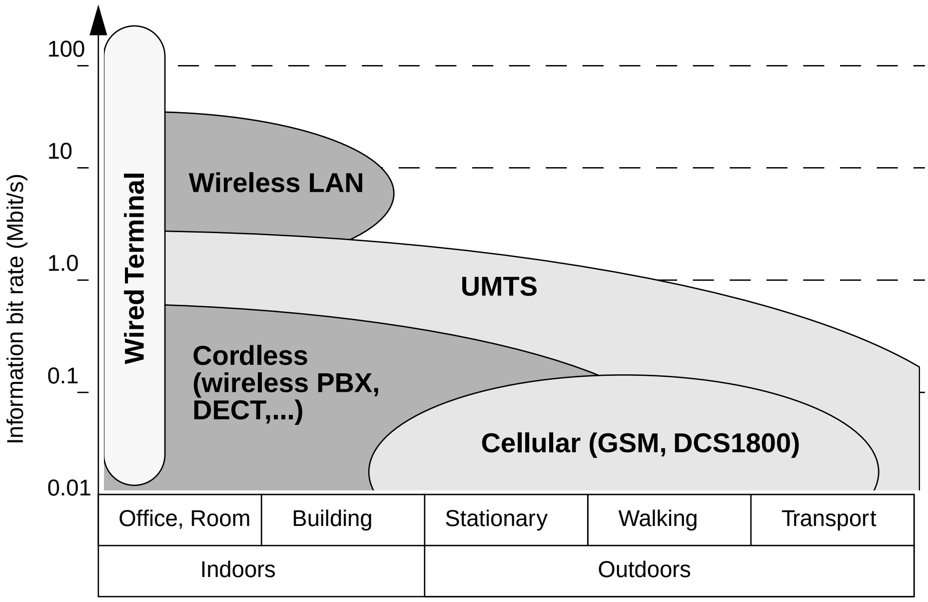

Fig. 1. **Comparison of Wireless Transmission Capabilities (after [1])**

[8], where they discussed philosophical and design aspects of hand-held computing interfaces. They provided basic definitions and categorizations of context-aware applications [9], like proximate selection, automatic contextual reconfiguration, contextual information and commands, and context-triggered actions. With the Active Map Service (AMS) [10], they propose a hierarchical structure for the description of objects in relation to locations, such as rooms, floors, buildings, regions, and areas. They discuss the effects of bandwidth limitations in wireless scenarios.

S. Long discusses various aspects of context-aware applications [13] 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 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 [12], based on the PARCTab PDA [7] 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. 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

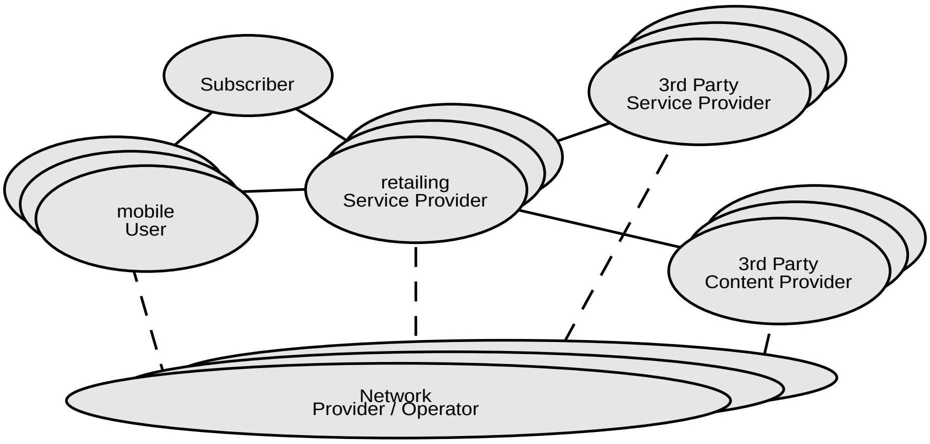

Fig. 2. Business Role model of mobile services

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.

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

2.3. Distributed Object Technology, 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 RPC based architectures by free and transparent distribution of service functionality.

Promising CORBA based technologies like the Telecommunication Information Network Architecture (TINA) [15], have been developed for the domain of fixed access networks and succeed their current evaluation for migration into mobile communication networks [3]. In the latter case, special consideration is dedicated to specific problems, which distinguish radio access from fixed networks, such as seamless handover.

The TANGRAM platform [16] prototypes and evaluates an environment supporting the object-oriented development of distributed multimedia applications based on the architectures developed by TINA-C. This platform suggest 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. Such frameworks can be a means to support the

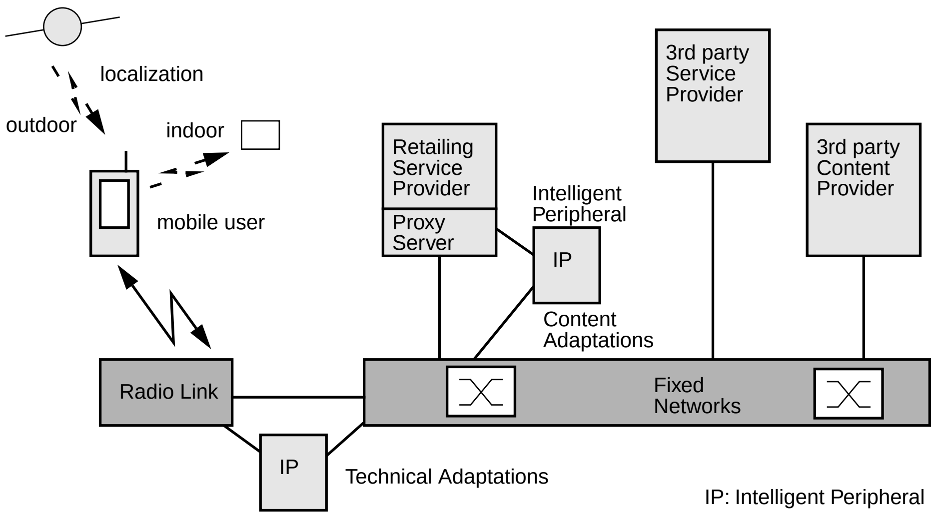

Fig. 3. Technical System Architecture

design and development of software sharing the advantages of object-orientation like reusability, scalability, and customizability.

The technology of Mobile Agents (MA) is currently overcoming the threshold from laboratory to its application within the telecommunication industry. It is today's current understanding that MA provide an important enhancement of distributed object technology. M. Breugst [14] 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).

2.4. Terminal Device Technology

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. This 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.

Some PDAs, such as the Nokia 9000i Communicator, already integrate GSM communication, so we expect to see this approach within other devices sooner or later. On the other hand, the Nokia concept is completely proprietary, not flexible like the open concept of the Apple Newton, regarding the operating system and the hardware support for two PC cards.

For communication, combined modem adaptors for GSM and plain old telephony are available as PC card for the connection to a mobile telephone. Nokia and Ericsson have announced a card with integrated transmitter and antenna for spring 1998, in form of a slim Nokia Wireless Data PC card (type II), and a thick PC card (type III) from Ericsson. For in-house connectivity, a WaveLAN card provides access to the wireless

LAN. Alternatively, a DECT compliant communication device or infrared data transmission can be used for this purpose.

The other PC card slot is occupied with the localization equipment, which might be a GPS receiver. 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.

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, as illustrated in the Business Role Model in Figure 2.

Our model follows the ideas in UMTS [2], while it brings stronger focus to the variety of providers in a contract relationship to the user, and third party providers distinguished for services and content.

As depicted, the 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 user 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 information and common services for the specific requirements of the mobile user.

While the user and the subscriber may be identical (e.g. individual user), this model covers also the case that e.g. a company subscribes services used by their employees.

3.2. General Technical Overview

When describing the system architecture, the business model from the previous section has to be mapped into more technical terms, which leads to Figure 3. 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). 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. In consequence, the position data have to be transmitted from the mobile user to the retailer, hence making the latter role mandatory.

The mobile user is free to decide about the source of the received information. He may contact third parties directly for location independent purposes. When he needs the location awareness, and/or wants the data adapted to the specific needs, he contacts his retailer. The latter may provide service from his own databases, or collect information from the third parties.

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

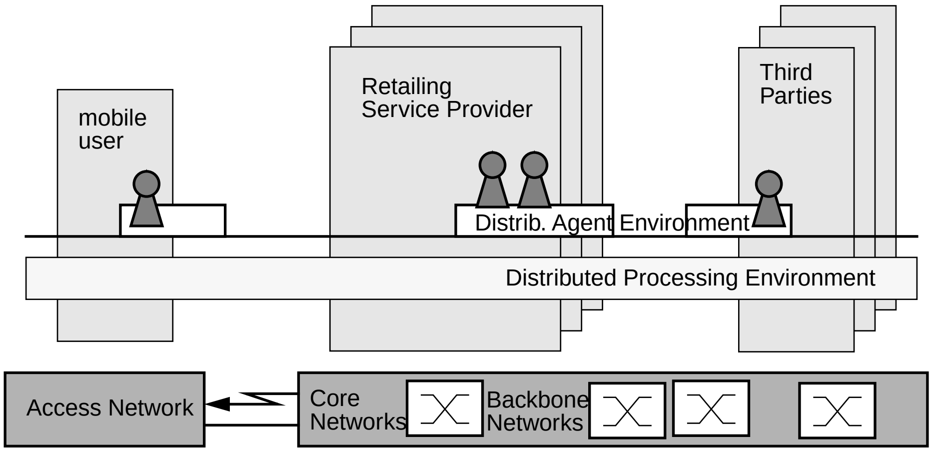

Fig. 4. **Middleware architecture for distributed processing and agent support**

performed at the network level, in particular at the interface between fixed network and the radio access provider. More sophisticated conversion may be performed by the retailer, who knows the terminal profile of its customer in detail, or through a fourth party, specialized in this specific service. For the unit executing the conversion, the term of an Intelligent Peripheral (IP) [17] has been adopted from advanced concepts of Intelligent Networks (IN).

3.3. Distributed Processing Architecture

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 and the difficult networking functionality. The DPE spans all potential end user systems and provider systems. Having in mind the openness and heterogeneity of target environments, e.g. as envisaged in UMTS, the usage of a standardized platform, such as CORBA, is mandatory for interoperability between different providers and vendors.

On top of the DPE, cf. Figure 4, dedicated environments may be installed. As depicted, a Distributed Agent Environment (DAE) can be used for specific services, while other applications can avoid the agents and employ the DPE directly. Details of the DAE usage and functionality can be found in [14]. The usage of agents itself opens various interesting applications in electronic commerce and service brokerage.

3.4. Dynamic Content Adaptation by Media Conversion

Approaches discussed in the section of related work rely on data specifically tailored for the needs of location-aware PDA applications. The applications itself are either proprietarily designed, or employ the WWW browsing technology built into the PDA.

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

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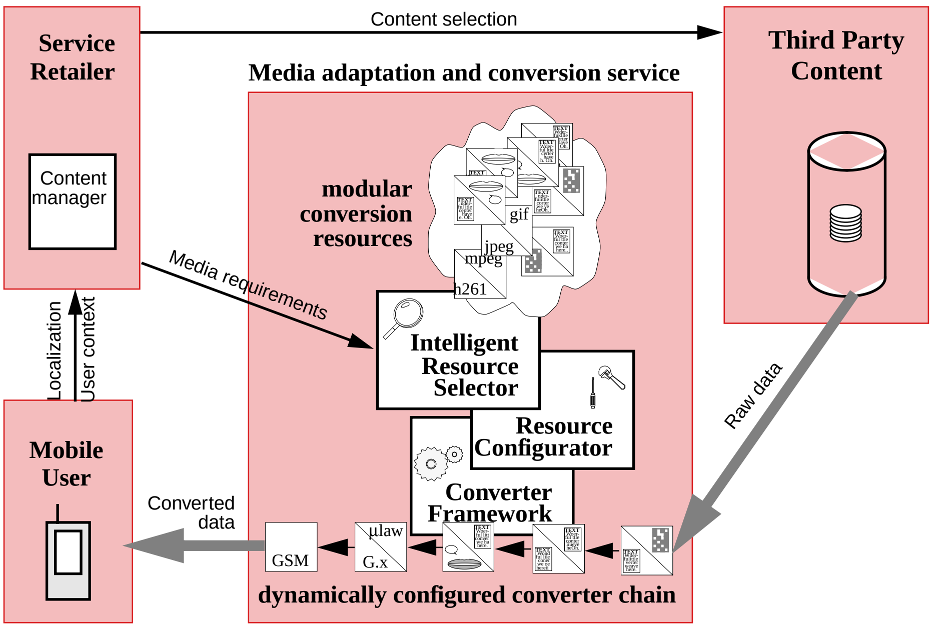

Fig. 5. **Media Adaptation and Conversion Service**

bandwidth limitations currently existing in mobile communication 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 Personal Communication Support, 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 [19]. Our approach (Figure 5) 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.

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 the 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. As depicted in Figure 3, 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 5, the mobile terminal delivers its location data as well as its wishes to the retailing provider, who searches the relevant information. He selects the content from third parties and finds that the data do not match the capabilities of the mobile user. Therefore, he 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

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chain. The raw data from the content provider are finally converted and delivered to the mobile user.

3.5. Service Architecture

While the previous sub-sections discussed the technical preconditions, we will now classify the services that can be provided within the described environment. The possible scenarios share the basic capabilities of the system architecture. The services comprise

- navigation support,
- location dependent and location independent information access with user specific context selection,
- communication support,
- electronic commerce.

However, these list of services is open to any future extension by plugging components into the modular platform. The four "slices" in Figure 6 build the service architecture of our prototype Mobile Guide system, which each contains a number of exchangeable and expandible services and components for specific tasks. In combining currently available key technologies for mobile communication and distributed information processing the Mobile Guide system realizes a couple of value added services beneath a wireless internet access and an intelligent mobile computing device.

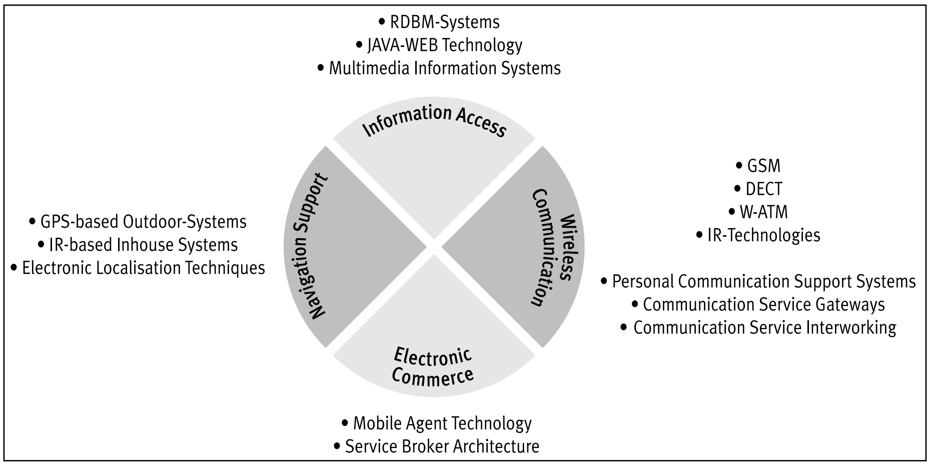

Fig. 6. Service Architecture

The slice of navigation support realises distinct components for localisation techniques and route planning services. The localisation includes components for outdoor localisation like GPS, cellular tracking, as well as components for in-house localisation using infrared systems. Specialized service providers for navigation support are part of the Mobile Guide infrastructure and feed the mobile terminals with location information. Also the components for route planning are provided by external service providers and are accessible to the user on the mobile terminal.

The second slice represents the access to a huge amount of location dependent and location independent information by the remote mobile user. Various services and technologies are necessary to realise the complex information structure behind the Mobile Guide system. The use of web technology in combination with state-of-the-art

Java and CORBA components enables the composition of content tailored to the specific requirements of the mobile terminals. The data are retrieved from various information services like web contents, remote databases, Geographic Information Systems (GIS), or input from different commercial content providers like Pointcast or Marimba. The filtering, conversion, and processing of these information is the task of the Content Provider of the Mobile Guide system.

Realized inside the communication support of the Mobile Guide service architecture, there is a transparent access to various transport media for the mobile device as well as the access to a broad number of personal communication services for a single user. Therefore different wireless communication services for the data transmission between the mobile terminal and the content provider of the Mobile Guide system like GSM-Data, DECT, wATM, and UMTS communication are currently part of this service architecture block.

The personal communication services will be realized as embedded services inside the Mobile Guide service architecture. Depending on the type of the required service the communication will be transmitted via GSM/DECT-voice or will be routed through several gateways at the Mobile Guide service provider domain. These gateways include access to Internet Protocol services like e-mail, www, ftp as well as access to networks of third party service and network providers like ISDN, POTS, local PABX, paging and messaging services, etc. Also more enhanced services like internet telephony, video and audio conferencing will be integrated via appropriate gateways into the Mobile Guide service architecture [19].

The last section of the Mobile Guide service architecture represents the supported services for electronic commerce. This enables a user to participate from the possibilities of the upcoming electronic market, including services for electronic cash, accounting for enhanced communication services, booking and reservation services, electronic shopping, the subscription of mobile agent based services, etc.

4. Mobile Guide System Overview

The Mobile Guide system is designed upon the state-of-the-art technologies (as discussed above) in the area of mobile computing devices, localisation techniques, wireless communication and information, and communication platforms realized through internet technologies like WWW, Java, CORBA, etc. The integration of these technologies and the open system architecture makes the Mobile Guide system flexible for future trends and developments in this area.

The distinct components of the Mobile Guide system combine these different technologies to enable the access to information sources and communication facilities in various scenarios. The mobile terminal is realised by an easy-to-use intelligent handheld PDA equipped with internal storage (for information caching) and exchangeable devices for wireless communication and localisation. Localisation information will be retrieved via GPS, infrared data or cellular tracking, according to the facilities available at the current location (in-house/outdoor usage). The wireless communication is currently realized through the access to GSM and will be extended to upcoming services like DECT, WATM, etc. Within the project, the development of UMTS is followed closely.

The application running on the mobile terminal needs to provide a generic access to a localized context of information depending on the user's current position. It will provide user selectable contexts related to the current location, e.g. shopping facilities, traffic information, points of interest. Among the information related to the special

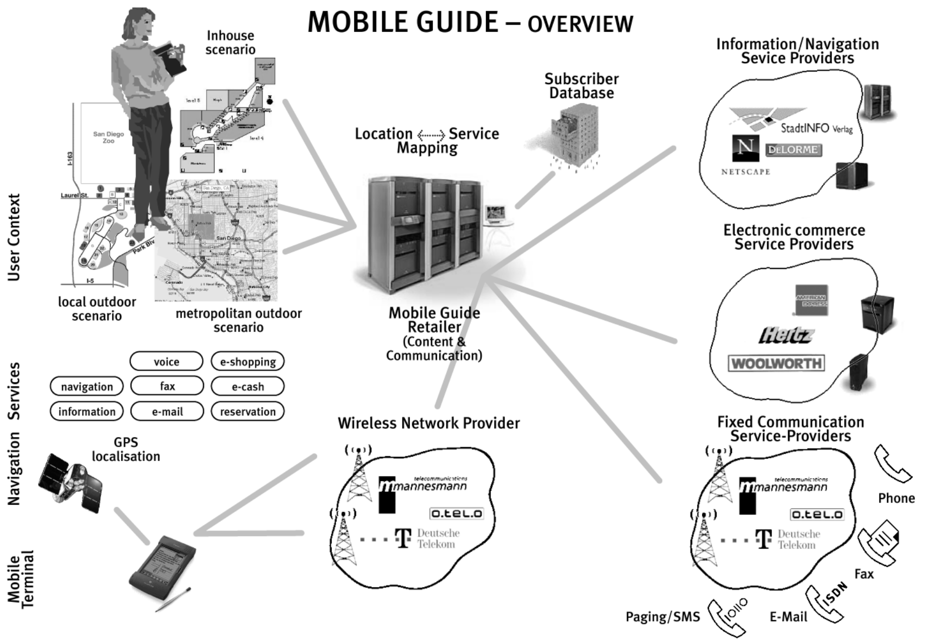

Fig. 7. Mobile Guide system overview

context of the location of the user the Mobile Guide system also offers a couple of location independent, generic services. These services enable a user to access personal communication services like fax, e-mail, etc. 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) will be available as a basic service.

The information request containing the location information and the selected context is transmitted wireless to a dedicated service and content provider. This service 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.

4.1. Scenarios

A mobile information and communication system like the proposed Mobile Guide 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. The system will be especially useful to visitors, foreigners and tourists inside one of the following scenarios:

- a city area:
  offering points of interest, shopping possibilities, public traffic, etc.,
  each topic may be 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;
- a 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 will be additional services for this type of scenario;

- a fair or conference area:
  accessing schedules, theme and location specific information, etc.,
  also useful for this scenario will be the personalised handling of communication (e-mail, fax, messaging), a personal time planner with reminder functions and offers for evening events incl. restaurant reservation, etc.;
- an airport or railway station:
  presenting actual timetables, booking & reservation possibilities.
  This scenario may also contain similar services of the above scenarios, like shopping facilities, daily offers of shops and restaurants, etc.

Also an integration with existing enterprise in-house information, communication and access control systems will be a possible scenario 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.

4.2. Prototype

The Mobile Guide system architecture is divided into three major domains which are embedded into the underlying DPE Middleware Platform discussed before (Figure 4). These domains are represented through the mobile terminal, the communication and content server, and a variety of third party service and content providers**.**

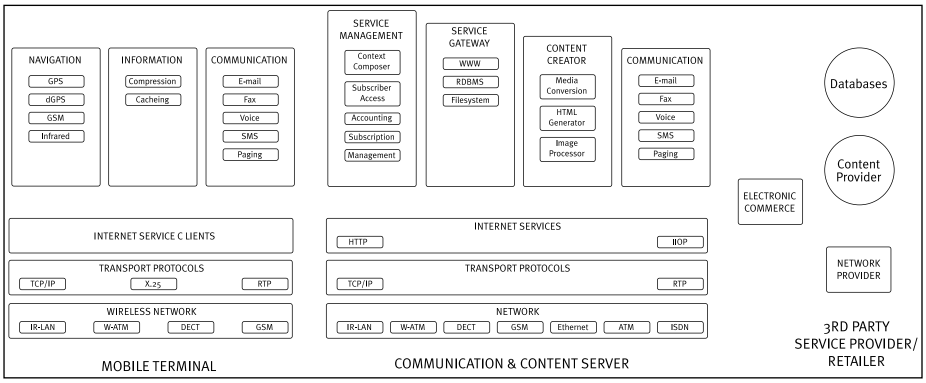

Fig. 8. Mobile Guide system architecture

Each of these domains follows a layering of components (Figure 8). In the bottom, the network access layer needs to support all involved wired and wireless networks permanently on the communication server domain for supporting multiple terminals. On the mobile side, these networks are used in a modular way, one at a time. The transport layer provides the unified access to the heterogeneous network components.

While the communication & content server domain needs Internet client services for collecting and combination of information, it also provides server services (HTTP, FTP, CORBA-layers, etc.) for the mobile terminals. Appropriate gateways forward the communication, or adapt them to the mobile requirements. The Service Management components handles subscription and accounting for a personalized use of the system. The Content Composer retrieves the demanded location-dependent information from

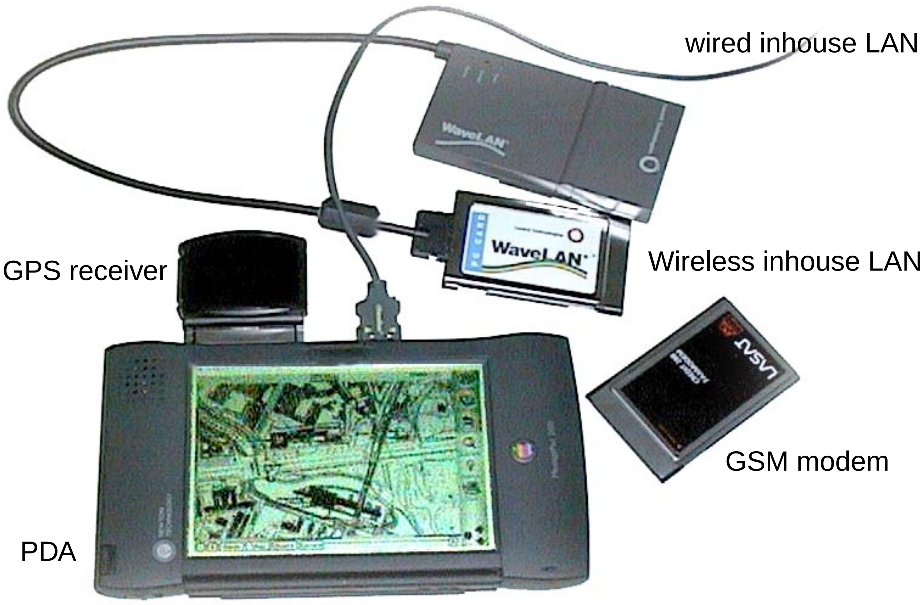

Fig. 9. Compact PDA with integrated, exchangeable positioning and communication technology

different sources according to subscribed services. The service gateways provide access to information requests in local and remote databases and file systems as well as from the WWW and other internet based information systems. Inside the component of the Context Creator, the retrieved information is converted to the capabilities of the mobile device. This information processing includes dynamic media conversion and type conversion as well as dynamic page generation.

Based on the communication layers mentioned above the mobile terminal provides components for navigation support, information access, personal and data communication and a component for management of the terminal itself (e.g. software upgrade by download).

Inside the open and object oriented system design, all these components are realized as interchangeable modules, which 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.

4.3. Test-bed

For our prototype test-bed (Figure 9), we use an Apple Newton MessagePad 2100 with 160 MHz RISC processing power, 8 MB RAM memory, and a 480x320 pixel greyscale pen-sensitive display. As one of the most important features, this device provides two PC cards slots for flexible expansion.

For the purpose of localisation one of these slots is used by a Centennial GPS card, which differs from a standard PC card just by the hunchback of the antenna. As an alternative within buildings, this card could easily be replaced by an infrared transmit-

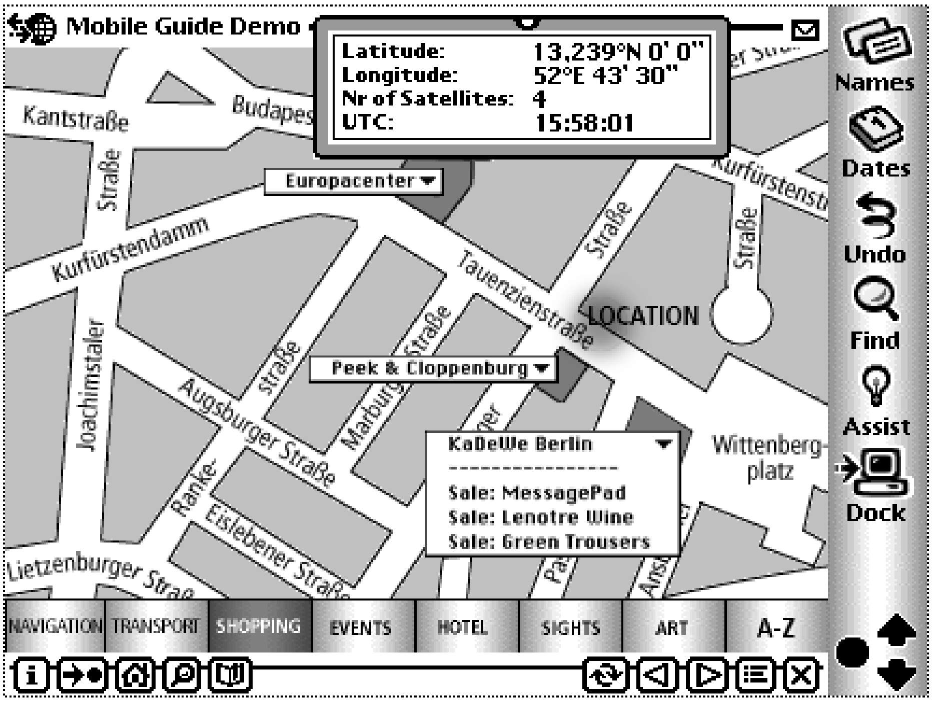

Fig. 10. Snapshot of the Kudamm application

ter compliant to the Active Badge system, which is currently under development in our hardware department. In future, the infrared capabilities 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.

Based on this mobile terminal and the DPE environment described above 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 10). Inside the DPE middleware platform we realized a couple of services by example. One service provides shopping information of different department stores, which resides in a local database maintained by the Content Server environment. 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.

The adaptation of the Grasshopper agent platform [14] is in progress for the integration of intelligent agent services for electronic commerce. Another service uses the databases of the BVG for up-to-date information about the public transport around the users current location. An alphabetical overview about currently available services is another service developed inside the prototype scenario.

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 in CORBA and provides the communication with third party services as well as media adaptation by dynamically generated converter chains.

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