A COMMUNICATION GATEWAY FOR INFRASTRUCTURE INDEPENDENT WIRELESS ACCESS

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Abstract

Wireless Communication Infrastructure is characterized by an increasing multitude of heterogeneous systems. To provide an infrastructure independent access to services and applications for highly mobile users (e.g. in cars) we present a communication gateway architecture as an important component of wireless personal communication systems beyond 3G. We especially emphasize the role of digital broadcast networks for future mobile networking.

Keywords: *Smart Mobile End Systems, Wireless Systems beyond 3rd Generation, System Survey*

Introduction

The wireless communication infrastructure is and in future will also be characterized by a heterogeneous multitude of systems. The plethora of wireless communication systems is not limited to telecommunications systems like GSM, IS-95, DECT. Moreover non-cellular systems like DVB, DAB and Wireless LAN increase the variety.

To adaptively use the right communication system in the right situation, systems are missing that provide selective access to all currently available wireless communication systems. In this paper we present our server architecture that solves this problem in mobile end systems and is intended to be a part of wireless personal communication systems beyond the third generation.

The Limits of Universal Integrated Networks

The IMT2000 family in general and its European member system UMTS in particular specifies the third generation of wireless personal communication systems. It is expected that UMTS will greatly improve the current situation of heterogeneous standards of wireless communication and allow new applications through an increased bandwidth. This is like what was thought ISDN should be for the wireline world. But has ISDN really fulfilled all requirements? Has not the heterogeneity of wireline systems even increased since the introduction of ISDN? In addition, future systems will still be heterogeneous because current systems do not fit with all the new requirements arising through new applications like e-commerce, information retrieval, enhanced data transmission, ASPs and customized multimedia telecommunication services. Furthermore there are many communication systems like CATV, data networks, and even powerline that contribute their bearer services to enable value added applications. For a detailed discussion of future telecommunications networking refer to [1].

What happened in the wireline world is expected to happen also in the wireless world since both are tending to converge on a service level. It is not that UMTS/IMT2000 would not be able to fulfill most requirements, but there are wireless communication systems in the field that may serve some needs of the customers much better or are available at a better reception in certain areas. In fact UMTS/IMT2000 complements the existing wireless systems and does not replace them. UMTS/IMT2000 will open up additional bandwidth from the scarce radio frequency spectrum. Advanced future systems have to combine all infrastructures to provide a seamlessly accessible wireless communication infrastructure for application services. Wireless infrastructure in this way not only means cellular systems, but also broadcast systems or ad-hoc networking. Therefore we aim at enhancing third generation wireless communication end systems in this paper to cope with the heterogeneity.

The remainder of this paper is structured as follows. First we describe some application scenarios and their relation to the automobile environment. In the next section we discuss some related research projects. After that we give a short overview over third generation mobile communication systems and beyond. The main part of this paper describes the concept of a communication gateway architecture to deal with the wireless system heterogeneity. We outline the main functionality and illustrate the main components. A summary followed by a discussion of some open points for further research concludes our paper.

Application Scenarios

Multi-Service Multi-Media Mobility

Application scenarios can be easily envisaged illustrating the need for access to high–bandwidth communication services for highly mobile users.

Imagine having subscribed an advanced broadband application service like an electronic newspaper with an "always-on" style of delivery. Your system provides you not only with the latest information in a multimedia presentation style including broadband audio and video but also allows you to request further information. In addition the access to your email, fax and voice mail and even telecommunication services are possible through this single system. Moreover your applications are accessible everywhere and at any time via some wireless communication infrastructure.

Such scenario cannot be realized today in the wireless world, in its full implementation. Not only the infrastructure is not capable enough for such a service today, but also a worldwide existence of one uniform infrastructure is questionable in future.

Vehicular Environment

Especially the automotive industry would greatly benefit from such solutions, since the car is becoming more and more part of a global network.

Today, business people but not only those, who spend lots of time driving between customer appointments, rely on cellular communication systems like GSM for communication as well as for information services. But the bandwidth (9,6 kbit/s) is far too low for most of the services. The scenario sketched above will be especially beneficiary in a car environment. The customers will need (multimedia) information related to their job as well as information to assist driving, e.g. route and traffic information, not considered in the above scenario.

On the road one will pass different areas with different communication services on air. This will be OK for local information services e.g. traffic jam reports but not for services supporting ubiquitous personal communication, like phone or email.

Furthermore, the availability of communication services will not only vary with the location but also with the time. We have a great discrepancy between the life cycle of an automobile (approx. 10 years and growing) and of communication systems (less than 3 years). This emphasizes the demand for intelligent end system solutions that are extensible to cope with upcoming standards.

Related Work

The importance of and the global interest in a spectrum efficient provision of mobile applications combining heterogeneous infrastructure has gained importance in several research bodies recently. For example, two European IST projects have started in 2000 addressing interactive IP-based services on a combined wireless infrastructure. The primary focus of IST DRiVE (Dynamic Radio for IP Services in Vehicular Environments) [2] is radio resource management and transport network architecture. IST MCP (Multimedia Car Platform) [3] investigates an IP based platform in the car based on DVB-T and GSM/GPRS.

Our approach laid out in the following concentrates on the end system e.g. car and the architecture of a gateway bridging client application requests in the end system to the heterogeneous networks.

Third Generation Mobile Communication Systems and Beyond

While the step from first to second generation mainly brought the transition from analog to digital, the approach towards third generation systems is mainly driven by the fast rise of the Internet and the ever increasing need for fast data transmission capabilities while on the move. In a first step, second generation systems will be upgraded and enhanced by packet radio services like GPRS and newer air interface technologies like EDGE for a more efficient access to the Internet. In fact, it is the enormous importance of the Internet that is the main driver for all packet oriented enhancements. The ultimate goal lies in the allocation of additional radio spectrum and the development of a third generation system called UMTS/IMT2000 [4]. UMTS/IMT2000 will be offering data rates up to 384 kbit/s for mobile users. It is harmonized on a worldwide basis and offers integrated services from formerly separate mobile systems.

This will be complemented by high–capacity/high–bandwidth systems like wireless LAN (IEEE 802.11, HIPERLAN, HIPERLAN2) or Wireless/Mobile ATM. They already today offer significantly higher data rates than UMTS/IMT2000 will be providing (up to 10 Mbit/s). For certain limited service areas, these systems will offer the capacity and bandwidth requested by users and make them a valuable complement. This even more so, as the spectrum allocated for 2nd and 3rd generation systems never seems to be enough and serious doubts already arise, whether any such thing as mobile multimedia can be accomplished with UMTS/IMT2000 alone. A common strategy is to make these high bandwidth systems an optional air interface access technology for a future UMTS/IMT2000 service and transport backbone. This will enable personal and personalized communication services to be used independent of time and place, but with significantly better performance in certain areas providing the more advanced access technology.

Moreover, especially Wireless LAN access technologies take the current networking paradigm one step further by providing communication services without requiring any fixed infrastructure to be installed. These ad–hoc communication networks can be easily set up between peer end systems in a zero–configuration fashion (plug and play). This flexibility is also being introduced to body area networks for easily networking personal communication gadgets like organizers, mobile phones and portable/wearable computers. A possible radio technology for this kind of digital short-range radio communication is currently being developed within the Bluetooth initiative [5], an industry consortium. A similar system is being standardized by the IEEE (IEEE 802.15).

Broadcast Networks

Besides these current and future personal mobile communication systems, another wave of digitalization opens up a plethora of new services: digital broadcasting. Analog FM radio and TV will soon be replaced by their digital counterparts, Digital Audio Broadcast DAB [6] and Digital Video Broadcast DVB [7]. While these systems will continue to offer mass media services of the current style, they also have the capability to transport any kind of digital information. Their ability to efficiently reach large groups of subscribers and providing them with a high–rate, though one–way data stream will make these digital broadcasting systems an interesting complement to 2nd and 3rd generation mobile communication systems.

A set of multimedia information units (web pages, digital audio or video clips, personal electronic newspapers, regional information systems) can be composed and transmitted via these distribution networks. The push of information and periodic transmission cycles will enhance the availability of the transported application services [8].

In general, multimedia data casting [9] provides a very well suited possibility to bring advanced services to the users, even, when we have to rely on an unidirectional though broadband transmission system. Especially Internet application services are by no means all interactive, e.g. streaming services. The asymmetric fashion of many applications, like the concurrent access of users to popular web pages or the download of information, videos etc., enables the usage of broadcast networks combined with a narrowband return channel that complements the distribution networks and enhances the variety of supported services.

A hybrid system for IP based data casting has been realized in the university lab (LKN) using DVB-T and GSM. In the work described in this paper we profit from the experiences made there. More on our prototype can be found in [8].

Communication Gateway: Server Architecture

To enable a communication service independent wireless access to services and applications from wireless end systems we propose a new server architecture. This server architecture resides within the end systems between the user end terminals and the different wireless networks providing their communication services. In this way our system realizes a *gateway* functionality bridging between client/terminal requests and the communication services of the networks. In the following we refer to our system simply as the 'server'.

Our architecture is designed with respect to automobile end systems e.g. cars, buses, etc., because we see the most interesting business case herein. But it could in general be applied to all kinds of mobile end systems.

Network Independent Service Platforms

Several existing approaches show the importance for network independent service provisioning not only for mobile networks. These concepts provide solutions to support the network independent provisioning of multimedia information and communication services either in dedicated intelligent servers residing in the networks, e.g. [10], or using a programmable network approach, e.g. [11] affecting all network and terminal components.

For the mobile users themselves it would be more advantageous to have a convergence layer close to the mobile terminals on the receiver side. The intelligence for service assistance (service access, proxy caching, profiling, network selection, location awareness, security) should reside at the network edge rather than in the network core for mobile users, since it is the current user equipment and its current location that determines the availability of network services.

An approach for adaptive service access, controlled within wireless end systems independent of both, user terminals and networks, is missing so far.

Server Concept

Our server architecture is designed to support different service classes like information casting, information push, data retrieval, access to data networks/Internet, and telecommunication services. To summarize the requirements, the server architecture fulfills the following tasks.

- Provide access for different client communication equipment on one uniform, open interface (client adaptivity, in-car middleware).
- Mapping of the communication and information services requested by the clients onto wireless network communication services currently available through the communication modules of the server (network adaptivity).
- Combination of communication modules to provide the possibility to realize new services and applications also spanning several networks (service control).

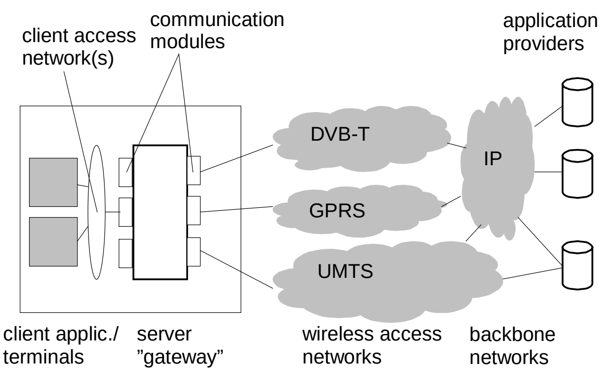

Fig. 1: Overall System View

This means the server system allows its clients the transparent usage of application services, where the clients do not have to cope with the specific characteristics and configurations of the communication modules. The server provides an open interface for the convergent use of application services over heterogeneous transmission systems. With the adaptive (e.g. based on availability) selection of currently matching wireless communication systems, a maximum of quality of service can be gained.

This general concept is illustrated in Figure 1, which shows the server system in a sample environment. The server acts as a kind of intelligent, multi-functional communication gateway between the client / end system network and the heterogeneous wireless infrastructure to connect client applications with the appropriate service providers.

Main Functionality

Figure 2 illustrates the functionality of the server architecture and its main system components.

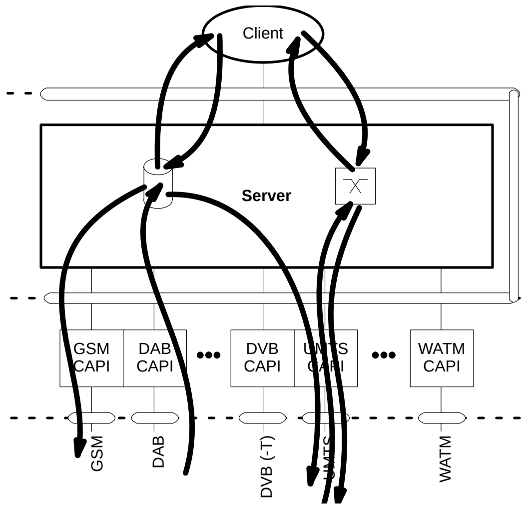

Fig. 2: Server Architecture

The client represents the customer’s equipment that is either a terminal that is fixed in the automobile (e.g. display, hands free dialog system, radio, TV, vehicle platform) or that can be brought by the customer (e.g. laptop, mobile phone, personal organizer, play station, mp3-player). Whereas the former systems may have a wireline connection to the server, for the latter a wireless connection would be advantageous. Independent of the physical connection we provide an open interface between the client and the server architecture for all application services.

The server itself consists of a central unit for the adaptive mapping of requests and therefore uses two main components. For distribution-oriented services a storage component realizes a proxy cache in order to support local interaction functionality. Real-time conversation applications and services are handled by a switching unit that supports packet switching as well as connection switching.

Finally the server components address the different communication modules via another, open interface. That means it is the communication modules that do the adaptation of the server architecture requests to the different protocol stacks of the connected wireless networks. The interfaces of the communication modules to their networks are of course network dependent. The interface also allows new communication modules to be integrated flexibly to the server architecture in a plug and play fashion.

In principle the following communication paths controlled by the server are supported. The client can request communication services either from the proxy unit or from the switching unit. The proxy unit receives data via broadcast or multicast. For client requests an additional upstream channel can be used, e.g. GSM. These bi-directional communication modules are also used by the switching module to map conversation style services on appropriate networks.

In addition the client can request other services from in-car equipment, e.g. GPS, that are not addressed here.

Decomposition

According to the main tasks of the server summarized in the server concept, and the general architecture depicted in Figure 2, several functional units have been identified in the server. Figure 3 shows details about these server components.

All requests coming from the client side or from the network side are maintained by the central control unit, which selects all components for further processing (mapping). The control unit only rules the mapping between different communication access technologies. This includes the combination of access systems where necessary, e.g. DVB-T and GPRS.

As we already have described above, telecommunication services as well as dialog oriented data services are supported by the server by mapping of client requests to modules providing bi-directional communication. The appropriate modules are selected dynamically according to the requirements of the request. Since the server selects not only between networks of the same functionality but from different providers, the selection is also according to quality issues, e.g. bandwidth or delay. The communication relationships can be packet oriented (data networks, e.g. GPRS) or connection oriented (traditional telecommunication networks, e.g. GSM). The switching unit dynamically maps the connection signaling onto available networks that can fulfill the requirements. For an ease of handling the server contains a table with the general service capabilities of common applications. Varying attributes like availability, bandwidth, and even prices are handled dynamically using service discovery mechanisms e.g. by a 'join manager' in JINI [12].

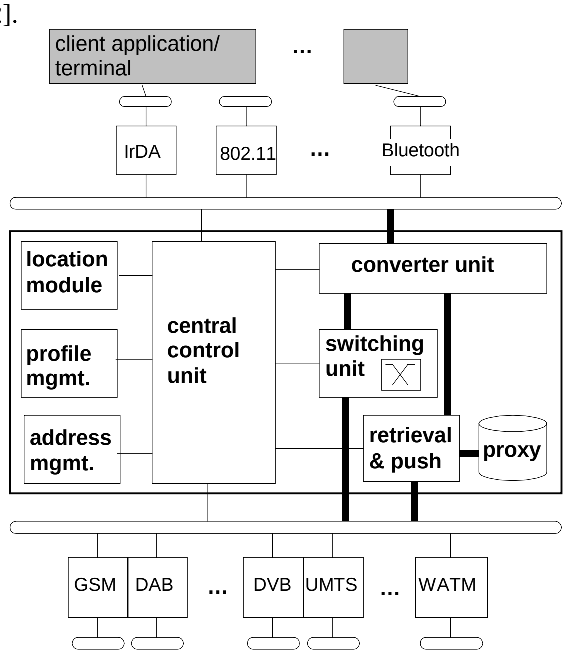

Fig. 3: Server Components

Also switching functionality is provided by the switching unit, if more than one communication module are involved or, if more than one client are connected to the server.

For broadcast based services (retrieval and push control) a local caching is realized in a proxy component. The traditional store and forward concept (e.g. email) is enhanced to forward and store. The original message box of the user will be maintained within the core network. All messages are transmitted to the server message box immediately when they arrive. To ensure proper reception a narrowband return channel e.g. GPRS synchronizes the network and the server based message box.

For conversion of data or display formats the storage units use conversion components (converters). This allows e.g. the conversion of a fax to the gif format or even the conversion of an email to speech.

To enable location based services we include a GPS based location module within the server.

Beneath common service capabilities the server also contains a data base for a user's personal profile. The profile can be set up manually or can be stored by clients, e.g. for their organizers that are connected to the server. The latter is especially useful for environments with frequently changing customers, e.g. rental cars. The control unit of the server configures the communication control units according to the personal user profile. This allows for example the automatic retrieval of information the user has configured in his profile [13].

Another feature to be integrated in our server architecture in addition to communication units to conventional network infrastructure are ad hoc networking communication modules. They allow an infrastructure independent information exchange between passing-by systems. In the automobile environment these systems include fixed "info stations" e.g. highway gates and also other cars.

It has to be noted, that not all information transmitted to the end system has to be intended to be consumed by the user her/himself, but also can be dedicated to e.g. clients in the automobile system for telematics services.

Conclusions

We have shown that the wireless communication infrastructure is and will be characterized by heterogeneity. In addition the availability of wireless network services varies with the location of a mobile user. This problem is especially important for automobile users having a high mobility spanning many countries with different standards.

In addition to the traditional wireless infrastructure, wireless broadcast networks like DVB-T or DAB provide possibilities for data casting to enhance broadband mobile services.

In order to cope with the heterogeneity of network services and standards intelligence in the end systems / at the network edge is required to map the user/client requests onto network services that are currently available. We have defined a server architecture to realize this functionality.

Whereas our architecture is designed for an automobile environment it can be applied to other fields as well. In general our approach describes a "mobile communication gateway", which can be used in any situation where an intelligent solution is required for the interconnection of different clients to networked applications over heterogeneous wireless networks. For example mobile offices could be set up easily with our system. Today such systems have to rely only on GSM, e.g. laptop connected to your mobile phone. Our adaptive selection mechanism guarantees availability of services independent of the location. Currently, we are working on an implementation of our concept based on integrating WLAN, GSM/GPRS, and DVB-T.

Nevertheless, the presented concept implies some questions that require further study. One problem is how to solve billing for varying networks and changing users. Problems like the realization of a virtual SIM card are not solved yet. Another open question is addressing, which is strongly related to the availability of IP addresses for end systems e.g. in-car systems and end user equipment. Whereas our concept works fine for the adaptive selection of wireless networks for an application, the problem of vertical handover, i.e. maintaining an application across alternating networks, remains for further study.

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