

Virtual City Portal – A Multi-Network Personal Information System for Automobile Users¹

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Abstract

This paper describes the Virtual City Portal prototype that is developed within the SOFTNET project. The system allows automobile users to request information or communication services using different wireless access systems. We integrate, broadcast networks like DVB-T for area-wide broadband delivery of general information, Wireless LAN for hot spot access and ad-hoc communication between vehicles, cellular systems for personal requests and Bluetooth for the interaction of mobile in-car devices. Channel selection is based on availability, network characteristics, application requirements and user preferences. Delivered content is automatically adapted to the user device according to a user profile.

1. Introduction

The success of upcoming generations of mobile communication systems will largely depend on the migration of existing, heterogeneous wireless access technologies. This is especially true for the vehicular environment, which is characterized by high mobility and a demand for advanced communication services [1,3].

The special setting of information and entertainment services in an automobile environment poses certain requirements on system design and service behavior. Initiative action of information services must support the driver with relevant information taking into account the driving situation. Reactive system behavior on the other hand also needs to be situation aware. Static menu structures would lead to unnecessarily complex interaction sequences to receive the desired functionality. More intelligent system support reduces the effort to achieve the user's goals. We are therefore designing the system to be context-aware with respect to different system characteristics. We are planning to do real-world experiments considering the usability of a situation adaptive user interface and query response.

Service and information provisioning can as well be tailored to the situation. For example, while driving to work in the morning, the driver might be more interested in emails, news or calendar information. In the evening, content may be chosen to be more appropriate for evening plans, like theater trailers, opera recommendations or restaurant suggestions.

The current focus is on the integration of heterogeneous wireless communication technologies. We want to achieve seamless roaming, choosing the best suited of the available networks for the case at hand. The access and switching algorithm needs to adapt both to changing network conditions and

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varying application requirements during the trip. The set up of a prototype system for automobile-based communication integrating multiple networks enables the test and evaluation of solutions for a seamless usage of heterogeneous mobile communication networks in a real-life scenario. In order to gain experience regarding the different system aspects, the implementation of a “Virtual City Portal” (VCP) serves as an example application (see Figure 1).

This scenario involves users that are new to a city, e.g., as tourists or for business. As they cross the borders of the city they can receive general interest data about the city via various wireless access networks. In addition to interactive information retrieval via cellular networks, users get information, e.g., up-to-date traffic, parking- and tourist information, from Digital Video Broadcast senders or as they drive past Wireless LAN (WLAN) information points [6]. WLAN information points offer the advantage to transfer up-to-date information at high data rates. The received information is locally integrated with the car’s navigation and entertainment system.

The remainder of the paper is structured as follows. First, we show the overall concept of the Virtual City Portal system by describing its requirements. Section 3 provides details about the realization of the VCP prototype regarding applications, network selection, component structure and client implementation. An outlook on the further system evolution concludes the paper.

2. Concept

The main idea behind the Virtual City Portal is to combine the provision of city related general interest information over a broadcast medium with bi-directional data requests and transactions. As a target user group we see visitors to foreign cities. Our main scenario exemplifies this:

1. John and Bob are entering Munich for their first time in a car they rented at Munich airport.
2. At the outskirts of the city they come into reach of a VCP Server. The VCP Server broadcasts a local information program via Digital Video Broadcast (DVB). The received data is cached locally and the VCP client in the car gets an announcement that new data of a local VCP Server has been received.
3. The VCP client announces the now available Virtual City Portal’s services to the driver. John and Bob are here for the first time. They would like to see a music concert and before that, they plan to visit some famous sites of Munich. But first they are hungry and seek a good restaurant via the VCP client. Regarding the personal preferences of John and Bob, the VCP client pre-selects a list of restaurants along their sightseeing trip. They choose the restaurant at the “Olympiaturm” and ask their navigation system for the way. The navigation system can retrieve the most current data that is an encrypted part of the VCP application. Here, the key and related payment is provided by the rental station.
4. The VCP client gets information about a nearby parking facility. Luckily there is some space left at the facility next to the “Olympiapark”. The in-car VCP client proposes to leave the car there. John accepts and parks the car.
5. After lunch John and Bob want to make a guided tour. There are several provided by the VCP application but some of them are also encrypted. John decides to buy a tour. Payment and keys are exchanged via GSM.
6. During the tour they receive information about interesting spots from local information points and also up to date information about the traffic condition from local access points at traffic lights and from other cars. The navigation system updates the sightseeing tour accordingly and finds the smoothest route. This feature turned out to be very practical for them as once during the tour they receive information about an accident that caused a traffic jam. Crossing cars sent a warning to their car that recommended an alternative route.
7. After the sightseeing tour they drive to the local concert hall and enjoy the concert.

From the described scenario, some important system requirements can be derived [2]:

- **Service focus:** The design of the whole system has to be focused on the envisioned services. The success of the architecture will depend largely on the support of service implementation and deployment and on the usability of the system. Technical and capability characteristics of the architecture have to be evaluated on how good they support the envisioned services. We thus have a strong focus on the services and applications that should be provided by our system already in the development of our prototype.
- **Seamless and transparent access:** The mobility of the vehicle makes seamless access to services difficult, because network coverage changes while driving. As service interruption is very disturbing for users, the system has to enable seamless usage of different networks depending on the particular availability. The different characteristics of the networks like bandwidth, delay, cost, etc. have to be considered while selecting the appropriate network. The choice of a network should be transparent for the service. Therefore an appropriate API must enable services and applications to use generic network services without having to deal with specific network characteristics. The actual network selection is done comparing the available networks and their characteristics with the requirements of the service.
- **Context awareness:** To make the provided services attractive for mobile users, the way to discover, select and execute the appropriate service needs to be straightforward with a minimum of interaction. The service offerings have to be adapted to the actual context of the user including location, speed, destination, etc. On the highway, traffic information is more important than information about local hotels and should be easy to select. Once the final destination is reached, detailed local information might become more important than traffic information.
- **Personalization:** In addition to context awareness, personal preferences of the user should be considered to facilitate service selection and usage. To some extent, the system can behave proactively and make a preselection of provided information based on the stored personal preferences of the user, e.g. instead of browsing through a (long) list of hotels, the traveller could make his choice within a (short) preselected list of hotels, based on his personal preferences of price, category, etc. In our system, the main portal pages of the VCP can be adapted to individual users, e.g., the content of the page "Tourist Information for Munich" (Figure 2) can be re-arranged regarding personal user preferences. The personal profile of the user has to be stored on a globally available server, in order to enable the user to access their personal environment in different vehicles.
- **Multi channel access:** Even if our prototype focuses on the vehicular environment and the in-car client is the prime demonstrator for our scenario, the VCP-services should also be reachable through other terminals and devices such as mobile phones (e.g. WAP or i-mode), PDAs and standard Web browsers.

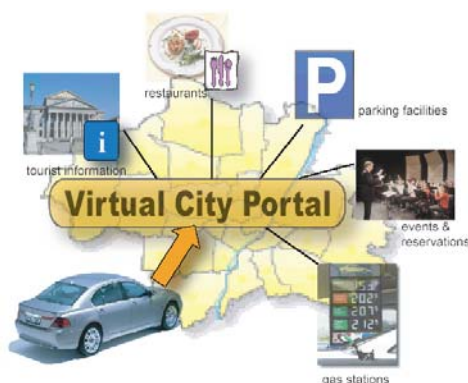


Figure 1: Virtual City Portal scenario



Figure 2: Example of the GUI

3. System Realization

For the realization of the Virtual City Portal we use a web-based approach. The Virtual City Portal server itself is a web application server that can be accessed from outside via HTTP. For the first prototype of the client-side we employ a web-browser for the GUI. Instead of direct access to the Virtual City Portal server we use an intermediary application server on the client side that pre-processes the user requests. This decision allows a rapid prototyping approach while leaving the opportunity to exchange the end user interface technique, for example we could switch to the Java ME platform.

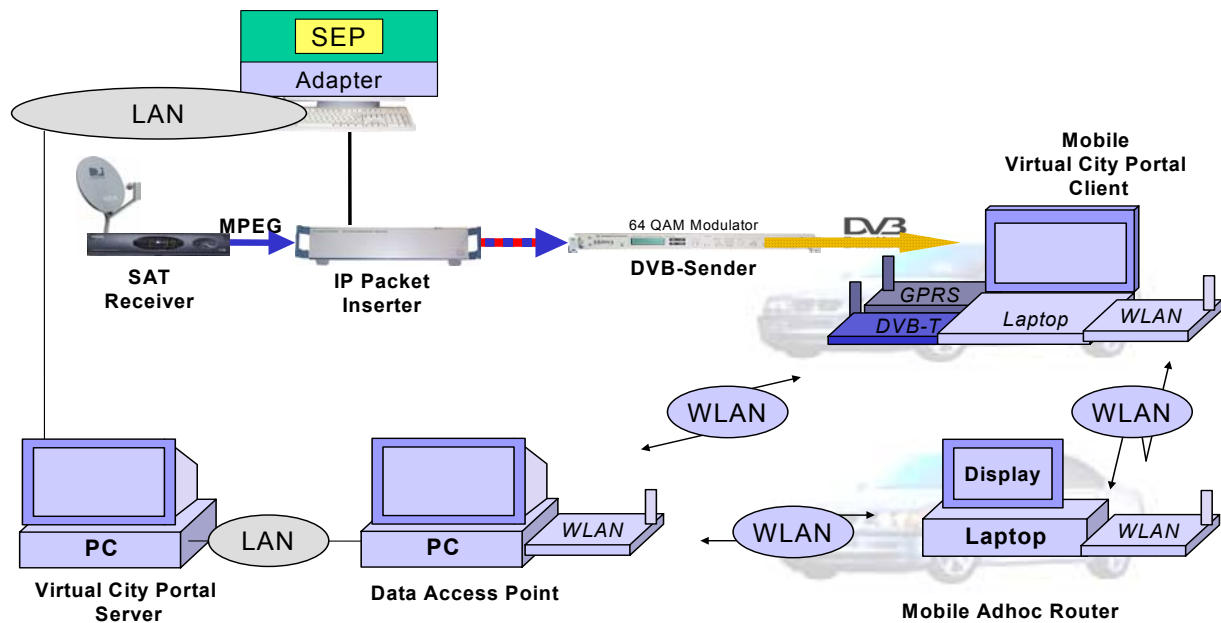


Figure 3: The Virtual City Portal in the SOFTNET testbed

3.1 Applications

To implement the desired scenarios we have selected the following applications and services for the Virtual City Portal:

- Find parking facility: helps drivers to find near parking garages relative to their current position. Also information about prices, opening times and current capacity can be accessed.
- Provide tourist information: gives information about sights in a city. This includes: location, historical background, opening times, tips and prices. This service could be extended with guided tours, where a driver is guided with the help of the navigation system and the VCP Client along a given route through a city.
- Find restaurant: lets a driver find an appropriate restaurant due to her/his personal taste and reserve a table.
- Event calendar: informs about city events. All information about events can be accessed here: date, time, prices, location, program description, etc. Also reservations for events can be made.
- Find gas stations: shows where the next fuelling facility is available or can give an overview of gas stations of a certain urban area.

For each of these applications a separate service has to be provided on the server, which is realized as a Java Servlet.

3.2 System

Figure 3 shows the setup of our prototype within the SOFTNET testbed [4]. We use a Wireless LAN (WLAN) network, a DVB-T network, and a GPRS network. The VCP Server on the left is located at some place in the Internet. It is accessible from any place in the world, using mobile devices particularly via a GPRS gateway and a WLAN Internet gateway. Additionally, the Virtual City Portal server can push general interest information over DVB-T. Technically a Data Access Router receives the data via Internet and forwards it to a Package Inserter component that inserts IP packets into the digital video stream. We have two types of clients. The fully equipped client, Car 1 in the upper right part of the figure, can use several networks. Push data is received by a DVB-T receiver; requests are done either via WLAN or GPRS. The low equipped car, Car 2, on the lower right, can only use WLAN and needs other cars for hop-by-hop data routing. We employ the AODV routing protocol with some enhancements for this purpose [5].

3.2.1 Server

For the Virtual City Portal server we apply a web-service approach (see Figure 4). The VCP server is a portal that hosts application sub-services for the VCP applications and uses other web-services for support, such as media broadcast. This approach allows the development of thin servers that only host application specific services and outsource the rest. For example, user localization in a cellular network will be done by the network provider. The application developer accesses this service over a web API.

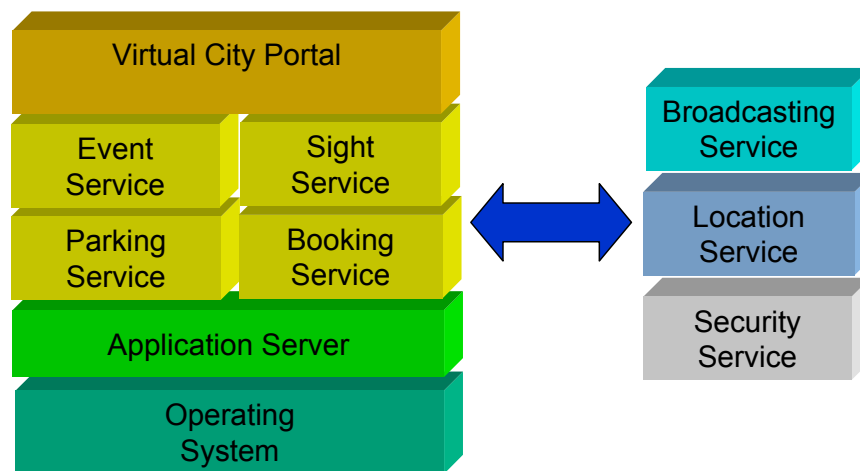


Figure 4: Server-side structure

3.2.2 Client

The Virtual City Portal client is structured into three layers: an application layer, a multi-media layer, and a vehicle platform layer. With this structure we follow the idea of an application platform for mobile multi-media services that support the development of clients for such services [1]. This platform in turn is based on a vehicle platform that extends the underlying operating system with specific enhancements for mobile systems and heterogeneous networks. Figure 5 illustrates this structure with the application layer on top, the multimedia-layer below and the vehicle platform encompassing the components on the level of the operating system at the bottom. Section 3.4 describes the vehicle platform layer in more detail. The application layer consists of clients for the Virtual City Portal services, actually web pages sent by the server. The most complex layer is the multi-media layer, which contains components for filtering and adapting information from the server, for caching them, for security and context management.

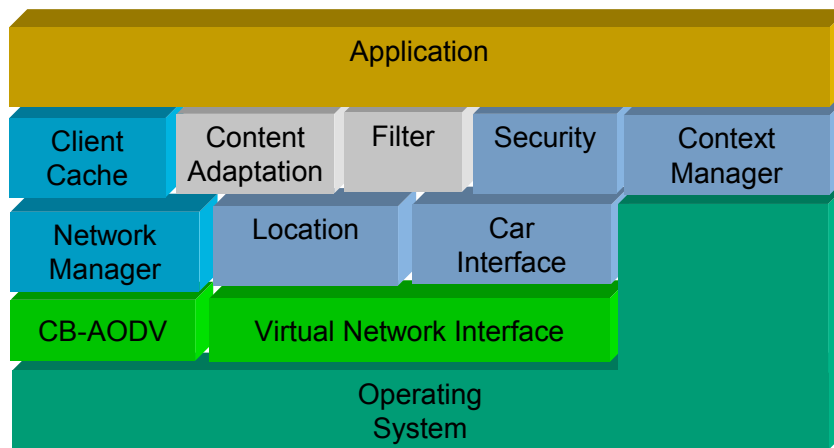


Figure 5: Client-side structure

3.3 Heterogeneous Access

As mentioned before, the Virtual City Portal is used as a demonstrator and tested for our concepts on content driven data access. So the following requirements have to be fulfilled:

- Use of heterogeneous networks on the content provider and the content consumer side
- Adaptation of network usage to content and context
- Adoption of decision rules for network selection

Each available network has different advantages and disadvantages. We analyzed different types of networks and compared them on the basis of features important for end-user applications: network coverage, available bandwidth, communication direction, and running costs for the user. For our first prototype we analyzed DVB-T, WLAN, GPRS and Bluetooth (Table 1).

We are using DVB-T to transmit IP data. For the transmission of IP packets either a dedicated DVB channel or the unused stuffing packets, which fill the varying data rate of the video or audio streams in one channel to the fixed data rate of the transport stream, can be used. However, in any case we can say that DVB-T or similar broadcasting techniques provide the capability to efficiently distribute information that is interesting for a large number of users in a quite large area. However, differing from the other techniques in Table 1, DVB-T is not bi-directional.

WLAN comes with a short-to-medium radio range of about 250m. With its bandwidth of up to 11 Mbit/s for the IEEE 802.11b standard and 54 Mbit/s for the IEEE 802.11a standard it is a technique well suited for the exchange of information between vehicles or between vehicles and local information points. Compared with the costs for GPRS and the anticipated costs for UMTS, the costs for WLAN transmissions are supposedly considerably lower. In addition, if WLAN is used for a direct (single- or multi-hop) connection among the participants, no money has to be paid to a network provider.

Despite the advantages of WLAN solutions with respect to bandwidth and cost, we see cellular networks like GPRS and UMTS as a necessary complement to our system. Cellular networks are usually available countrywide and support very high mobility. Other than Wireless LAN, these techniques can be used to submit important data immediately (i.e., we don't have to wait until a Local Information Point comes into range). Continuous connectivity even during phases of very high mobility is another advantage of cellular systems over WLANs.

Finally, Bluetooth becomes more and more important. Its characteristics (especially the relatively low power consumption) are suited very well for short-range data transmission between battery-powered, mobile devices. Depending on whether we use Bluetooth to connect to the Internet via a Local Information Point or to connect directly to other Bluetooth devices, the communication costs will be low to zero.

We classify the content that should be transmitted into several classes according to [1] and allocate an appropriate network interface on the basis of the respective features (see Figure 6).

	DVB-T	Wireless LAN	GPRS	Bluetooth
Coverage	High, 1 to several 100 km	Low, <300m	Very high, country wide	Very Low, < 10m resp. < 100m
Bandwidth	Up to 24 Mbit/s	11 -54 Mbit/s	Up to 115 kbit/s	Up to 1 Mbit/s
Communication Direction	Uni-directional	Bi-directional	Bi-directional	Bi-directional
Costs for the user	Low	Low/None	Comparably high	Low/None

Table 1: Network comparison

For the assignment of content to network interface, various rules and strategies can be used. Generally, the development of such strategies can be done separately for the content provider and for the content user, e.g., the VCP operator and the VCP client system in the car. The available network on the server side is relatively constant, while it is changing constantly for the mobile client. In our first prototype we only distinguish between static, general interest data and user specific requests. We use DVB-T broadcast for the former and wireless network access via Wave LAN or cellular network for the latter.

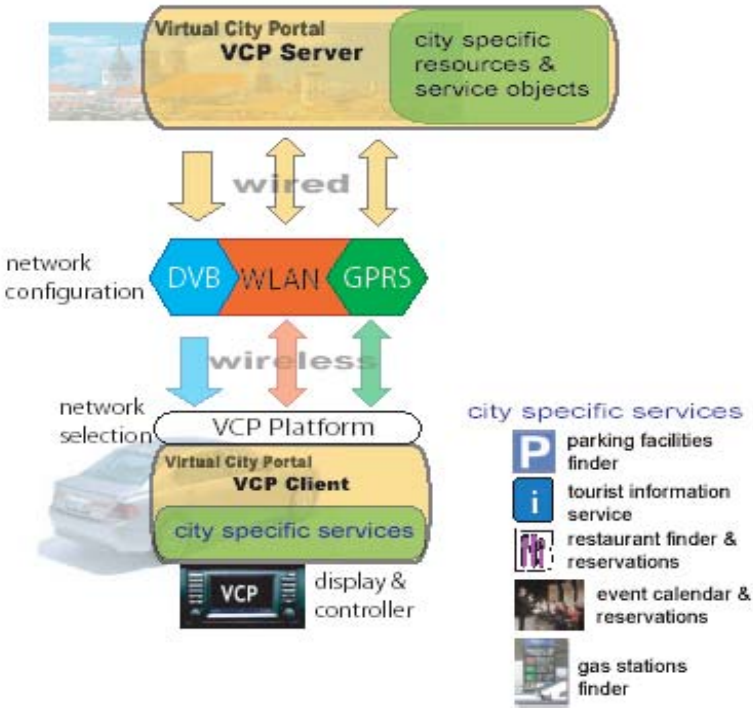


Figure 6: Network setup

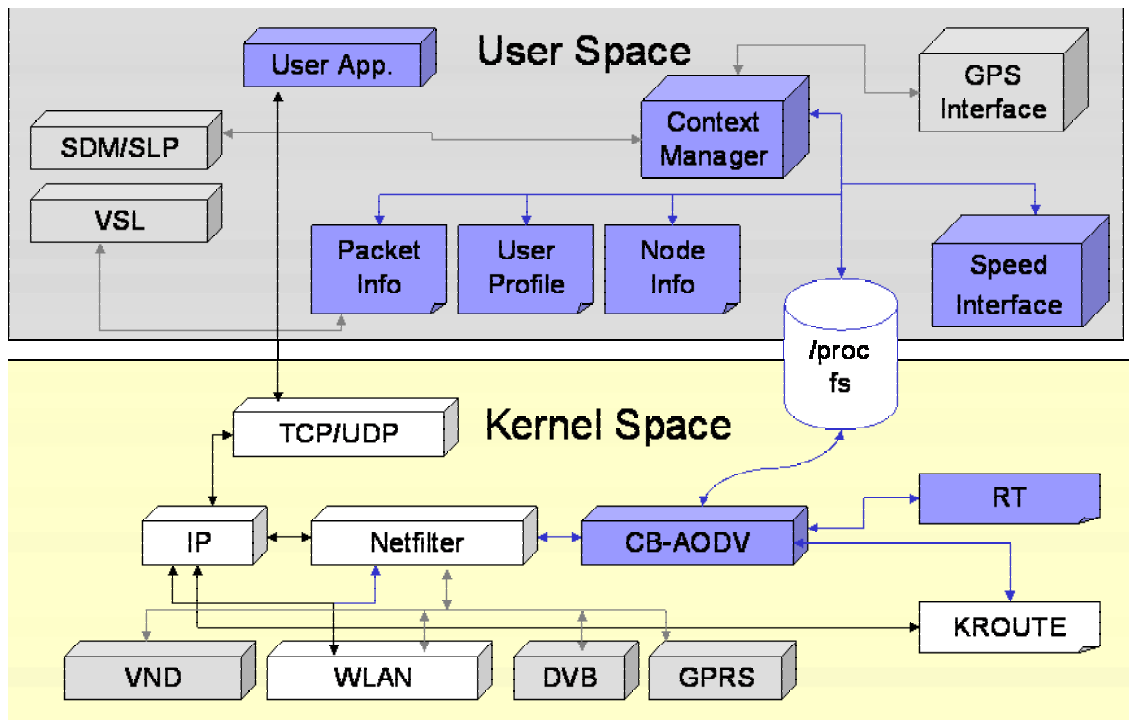


Figure 7: The vehicle system

3.4 Vehicle Platform

Figure 7 shows how the underlying communication system is implemented in the vehicles (clients). Due to its accessibility and modularity, Linux is used as operating system.

All information (except network availability) concerning context and location is collected from applications running in user space. You can see the user profile that is stored in user space, the GPS interface for collecting location information, a speed interface to the vehicle bus and a context manager. The context manager is, among other things, responsible to add some interpretation to the pure location information from the GPS interface. For example, information from the digital map in the navigation system concerning restaurants or famous places and buildings is merged with the current location in the context manager.

Using the Linux /proc file system, all the information collected in user space can be communicated to modules running in kernel space. E.g., the virtual network driver (VND) can select the appropriate network interface using information about network availability and the user profile. Another main component in kernel space is the CB-AODV (context-based AODV) module. We modified the NIST-AODV implementation to integrate mechanisms for geocast routing and the interpretation of context data [5].

3.5 Current Status

The envisioned system we describe here is developed in accordance with the current state of the art in information-centric systems. An implementation following the standards in this field sometimes leads to an overhead for a research project. For example, for the broadcasting of documents via DVB, the ATVEF specifies the UHTTP transport protocol [7]. Instead of implementing it completely, we chose to implement a simpler version, that uses the same principles, but is not compliant with the standard. Generally, we chose to use an architecture that fits into these standards but implemented only the necessary parts.

The implementation of the VCP server is still in an early stage. We tested a set of enhancements for web application servers, but the implementation is still quite monolithic and needs some restructuring efforts. But as the principal design follows the common architecture for web applications we do not expect problems in the transition.

On the client-side, we have concentrated on the network-related issues. In a first step, we have adapted the Java 1.4 network API to heterogeneous networks. The application system does not yet use the advanced features of the vehicle platform such as context-based AODV or the virtual network driver. Instead we use a feature of the Java 1.4 platform that allows to select a network interface on the application layer. The consequence is that we are not able to do network handover on the IP layer and have a Java only solution. But once we make the step to the vehicle platform we only have to adapt the Network Manager, which means that it will become simpler because the platform does most of the work for it. One part of that API is a Cache component. In a next step we want to refine the Cache component to implement filtering and content adaptation.

The vehicle platform will play a key role for adaptation of the user-car interaction because it must provide the needed car and traffic related information to generate context-information. With this context-information the system can take control over the presented information. Currently, this kind of information is only used for the routing but not on the application layer. Generally, the user-car interaction, particularly to focus the user's attention to important information, is still in an early stage.

4. Conclusion

In this paper, we presented the "Virtual City Portal" prototype that is developed within the SOFTNET project. This prototype combines different networks in order to provide automobile users with a variety of information and communication services. These services include broadcast information services, like traffic and tourist information, as well as individual communication services.

Field trials of the system have already been achieved and will be extended in the future. Especially the seamless interworking between the different kinds of networks will continue to be the main focus of our ongoing work. In the prototype we see a clear need for mobile information systems that adapt the presented information to the current driving situation. Such an adaptation must be done by the underlying platform. While we only implement some basic context-aware service behavior, we believe it is a key success factor in a vehicle platform such as we propose. Prototype based research will be needed to evaluate the usefulness of such service adaptation.

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