IN-CAR COMMUNICATION USING WIRELESS TECHNOLOGY

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ABSTRACT

The evolution in mobile and wireless communication technology allows passengers and drivers in vehicles to use the Internet while they are on the road. Built-in equipment in cars or trucks can easily access traveling-related dynamic information, such as the current situation on the roads, weather forecasts, or information on local points of interests. However, personal information of the vehicle's passengers – which could be also very useful for their travel – is usually distributed over various different devices, such as PDAs, PTAs, cellular phones, or laptops. Thus, this information is not easily accessible by the driver or the built-in equipment. In this paper, we envision future scenarios that might come up if those devices within a vehicle are able to communicate and interact with each other. Therefore, we discuss the characteristics of wireless infrastructure-based and ad-hoc networks for communication between mobile devices in vehicles in order to establish a local and integrated information system. Wireless communication systems are very interesting for communication in vehicles as the heterogeneity of devices bring a plethora of different plugs and interfaces for wired communication. We describe the Bluetooth de-facto standard in detail, which is one encouraging technology for those future scenarios. Bluetooth is a communication technology that is basically optimized for communication between small devices in mobile and wireless ad-hoc networks.

MOTIVATION

In the near future, vehicles will become mobile information centers that are integrated in large information systems. Cars or trucks will have a permanent connection to the Internet and will be provided with various kinds of information necessary and useful for traveling. The information might be the current road situation, weather conditions, or the parking situation at the destination. Access to the Internet is possible by using wireless wide-area communication technologies that are available in almost every European country, such as GSM, GPRS, EDGE, or the upcoming UMTS technology [1]. Alternatives might be the use of DECT [1] or IEEE 802.11 [2] in regional limited areas, like in cities or on motorway service areas, as those technologies can only be used from vehicles driving slowly. The information itself is sent to the car using common Internet protocols (such TCP/IP and HTTP) or the WAP technology (Wireless Application Protocol [4]). Additionally, traffic information may be received via DAB (Digital Audio Broadcasting [1]) and the current position is received from satellites using GPS. Future vehicles will also be able to form (local) clusters of vehicles for exchanging information in an ad-hoc fashion, such as floating car data (FCD) or warnings of accidents in front of a car so that the following vehicles are able to slow down in time (c.f., Figure 1). Meanwhile, car manufacturers and vehicle equipment suppliers realized this trend and are very interested in telematics devices and services as this is a growing – and thus profitable – market segment. According to a forecast by the International Data Corp. (Framingham, Mass.) the worldwide market in telematics hardware and services will escalate to US $42 billion by 2010 from just $1 billion in 1998 [5].

However, in vehicles the information useful for traveling is usually not located at one device – it is distributed over various mobile and handheld devices:

- The mobile phones of the car passengers contain their phone books (with names and phone numbers).
- The PDAs (Personal Digital Assistants) manage the passengers' time schedules.
- The navigation unit has the current information of the road situation and is able to specify the route with the estimated time the driver reaches the specified destination.
- The DAB car radio receives periodically the current weather conditions which are also needed for an exact estimation of the traveling time.
- A laptop that lies in the boot of a car might contain e-mails or documents that should be sent.

This distributed information has to be exchanged between the various devices in order to exhaust the capabilities of the resulting information center. Thus, those devices have to rely on appropriate communication technologies for their interaction. Before we discuss possible alternatives, we take a closer look at future scenarios which might come up with the interaction of the different equipment technologies.

APPLICATIONS AND SCENARIOS

Within vehicles, we currently see the trend that several devices work together in an integrated fashion, resulting in new services as demonstrated by the following three examples:

- With the combined usage of the navigation unit and a RDS/TMC or DAB car radio supporting traffic information, the driver can be guided to the desired destination by avoiding congested roads.
- Combining car radio and cellular phone, the car radio mutes the loudness and can be used for hands-free telephony. Note that this is a necessary and important feature for cars as drivers are not allowed to use their cellular phone while driving in most European countries.
- Together with the vehicle's positioning system, a cellular phone can be used for on-demand emergency assistance. The system sends the position of a car having an accident (and other information such as impact speed, airbag and engine status, etc.) to a service center which organizes help for the driver.

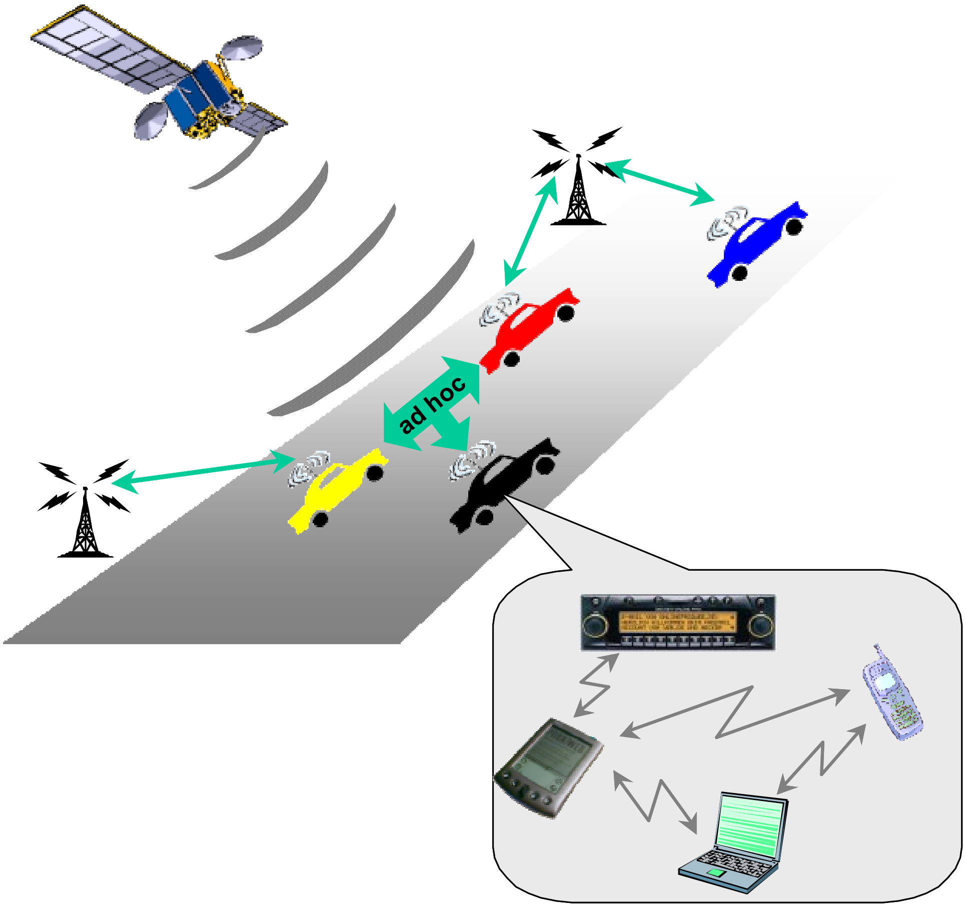


Figure 1: Future Interaction between IT and Vehicles

However, consumers will take applications and mobile devices from their homes and offices and integrate them seamlessly into their cars. Those applications comprise, e.g., online banking, online brokerage, e-mail, maybe video conferencing, telephony, or further Internet services. Thus, the new generation of equipment for vehicles offers additional services to the passengers like access to the World Wide Web (WWW) using Internet or WAP technologies, or e-mail services. Combined with speech control for this equipment, distractions will be minimal and drivers can keep their hands on the steering wheel and their eyes devoted to the road. The combined use of the new equipment for vehicles and the passengers' mobile devices such as laptops, cellular phones or PDAs allow several new scenarios in the (near) future. However, it is supposed that all those devices are able to communicate with each other.

When the driver comes to her car, a security card, her PDA or cellular phone unlocks the car. With the personal settings of the driver's preferences (stored, e.g., on her PDA), the seats and mirrors are brought in the desired position and the volume of the radio will be automatically adjusted. When the passengers enter the car, the vehicle already has cached the current road and weather conditions, while the driver's PDA uploads the new destination to the car's on-board navigation system. A Personal Travel Assistant (PTA, which might be integrated in the navigation unit) supports the driver planning her trip. While on the road, traffic conditions on the motorways will be sent periodically to the car, the car forwards the selected information to the PTA, which calculates a new route if there is a congestion on the motorway. The information is also sent to the passengers' PDAs, which automatically rearrange their schedules for meetings. Additionally, the laptop in the driver's bag informs the other participants of the meeting about the predicted delay so that they can synchronize it with their schedules. If one of the passengers needs to send an urgent time-critical memo, the e-mail address of the recipient is stored on his PDA, lying somewhere in the car. The passenger speaks to the cell phone via a microphone integrated the car radio system and requests the number. The phone retrieves the number of the ISP (Internet Service Provider) and, on request, dials it. It then mutes the car's stereo system that plays the driver's favor MP3 songs coming from her laptop in the boot of the car. The passenger gets the needed e-mail address via the car radio and enters the message orally into the PDA using the (local) connection via the cellular phone. The same connection is used from the passenger to address the e-mail, attach the memo and send it from his PDA using the dialed connection from the cellular phone.

Additionally, the combined use of different devices enables many other services, such as the following scenarios:

- On motorway service areas, the laptop could download new music files or movies the passengers can listen or watch later via the in-built multimedia equipment.
- Using the personal information on PDAs, the charge for using roads or for fuelling the car can be debited "on the fly" without any interaction.
- If technical car components are also equipped with communication technologies, their status can be sent to a computer in the repair shop, which allows for remote vehicle diagnostics.
- An electronic logbook application running on the Laptop of a business man can be automatically updated when the car is used for business trips.

Of course, similar scenarios are conceivable for air or railroad traffic. Additionally, we will see several novel and promising communication protocols enabling new services and applications (such as WAP 2.0 or iMode), which must be integrated seamlessly in this communication system. However, this plethora of new capabilities and services requires the interaction between the different mobile devices. Appropriate communication technologies should be powerful, easy to use, integrated in many mobile devices and, thus, very cheap.

COMMUNICATION TECHNOLOGIES

In general, two alternatives are conceivable for realizing wireless communication between mobile devices: infrastructure-based networks and ad-hoc networks. In order to deploy an infrastructure-based network, an access point (AP) must be set up within the car. The AP is usually integrated in the communication platform, which is the gateway to the Internet. Each device is connected to the AP and is able to exchange data with other mobile devices only via the AP. At the moment, there are several technologies for infrastructure-based wireless networks, e.g. IEEE 802.11 or DECT. However, this kind of network is not well adapted for communication between the devices in vehicles. First, the network must be configured, i.e. each device must receive a valid IP-Address. This could be achieved by manually configuring the network settings of each device, or by using the dynamic host configuration protocol DHCP). Note that in the case of using DHCP, each networking device must be registered in the DHCP server which also results in manual administrative work. Second, infrastructure-based technologies are mainly optimized for local area networks with high bandwidths (e.g., up to 11 Mbit/s for IEEE 802.11) and, thus, waste the scarce energy resources of small devices. Additionally, the logic for controlling the hardware needs much space for the integrated circuit. Third, the hardware of current technologies is rather expensive or not available for many different types of mobile devices such as PDAs or mobile phones.

Alternatively, ad-hoc networks seem to be well suited for communication within vehicles. Those networks do not rely on an infrastructure and can be set up quickly, as the mobile devices are able to organize the network themselves. Thus, ad-hoc networks provide the high flexibility that is needed for the scenarios described above. Communication can be realized via infrared light (using IrDA [6]) or via radio technology. Although IrDA is a very cheap and wide-spread technology, infrared light has several disadvantages: it allows only an establishment of peer-to-peer connections, it requires a line of sight between each device, and the communication characteristics depend mainly on the environmental situation. In contrast, radio communication does not have those limitations. Especially on lower frequencies, a direct line-of-sight is not needed for communication by providing relatively high data rates (up to 11 Mbit/s using, e.g., IEEE 802.11). An upcoming technology for radio communication is Bluetooth [7], which addresses the specific requirements of mobile devices: it should be cheap (when available, about $5 per transmitter) and built-in in almost every electronic device, it is very robust against environmental influences, and it supports various kinds of communication scenarios, e.g., asynchronous data transfer or synchronous links for multimedia data. Currently, the first Bluetooth-enabled products are available, and lots of new products and services are announced by industry.

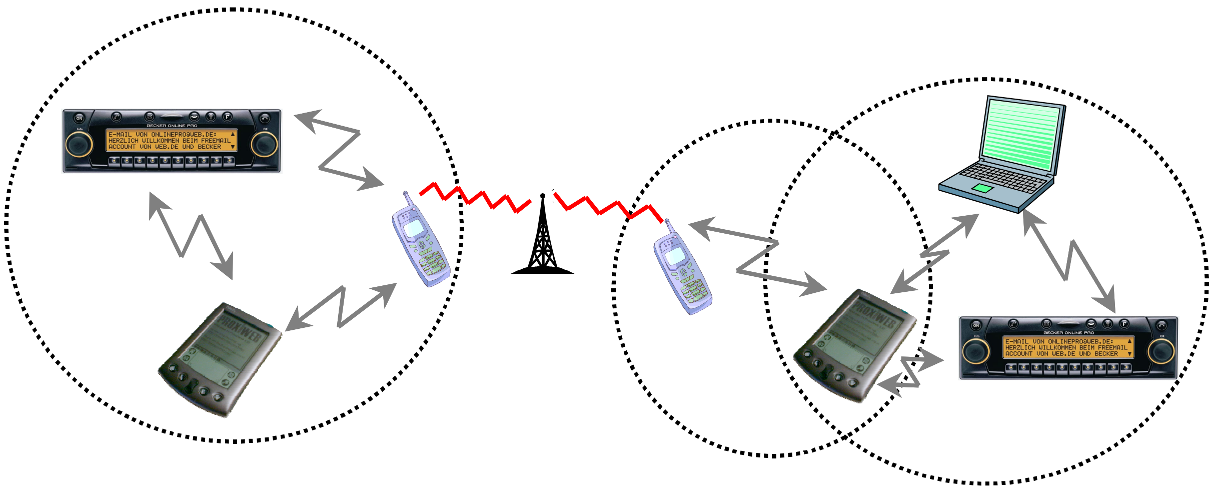
BLUETOOTH

Starting in spring 1998, five companies (Ericsson, Intel, IBM, Nokia, Toshiba) founded the Bluetooth Consortium [7]. The name is derived from Blåtand, the surname of the Danish king of the Vikings Harald "Blåtand" af Danmark who ruled in the early mid age. The Bluetooth Consortium grew rapidly and has currently 2491 members (in June 2001). The basic idea was to develop a single-chip, low-cost, radio-based wireless networking technology in order to avoid expensive wiring or the need for a wireless infrastructure. However, Bluetooth is not a standard like IEEE 802.11, but it is currently on the way to become a de-facto standard, established by the industry and promoted by the Bluetooth Consortium. The first version (version 1.0) of Bluetooth was released in July 1999, version 1.1 – which is the basis for the following description – followed in February 2001.

Using Bluetooth technology, many different scenarios can be imagined (as described above). Figure 2 (a) shows a simplified example using a wireless pico net in a vehicle, where a cellular phone (with an integrated Bluetooth chip) is connected to a PDA and a navigation unit in a simple way. In this example, the cellular phone is able to act as a bridge between the pico net and, e.g., a GSM network. Thus, it is able to receive updated traffic information an forward it to the navigation unit.

Bluetooth uses the ISM frequency band (Industrial, Scientific, and Medical) at 2.4 GHz, which is globally available and can be used without the need of a specific license. A frequency-hopping scheme is used for transmission with a hopping rate of 1,600 hops per second over 79 hop carriers equally spaced with 1 MHz (in Japan, France and Spain only 23 hop carriers due to national restrictions). The transmission power of Bluetooth devices can be up to

100 mW, resulting in a communication range of up to 10 m (or even up to 100 m with special transceivers). As mobile devices typically rely on battery power, Bluetooth supports several low-power states: Devices that do not participate on communication are in standby mode and listen periodically for paging messages (every 1.28 s). When activated, three low-power states are defined to save battery power if no data should be transmitted. A park state where the device has its lowest duty cycle and releases its address (but remains synchronized with the pico net), a hold state where the device does not release its address, and a sniff state where the device listens to the pico net at a reduced rate.



(a) **(b)**

Figure 2: Pico Net (a) and Scatter Net (b)

All devices participating in a Bluetooth pico net must be synchronized, which is realized by using the same hopping sequence. Connections (and thus pico nets) can be initiated by an arbitrary device which then becomes automatically the master in this pico net. All other devices (up to seven) act as workers. The master device determines the hopping sequence, which is derived from its unique device identifier and its internal hardware clock. It also controls the access on the medium. Two different pico nets are separated via CDMA (Code Division Multiple Access [3]). This means that all Bluetooth devices are able to act in master or worker mode. However, the restricted number of devices within one pico net seems to be not applicable. This led to the idea of forming groups of up to eight pico nets with overlapping coverage. This scenario is called a scatter net, which is illustrated in Figure 2 (b). In this example, two pico nets form the scatter net, in which one devices participates in two different pico nets. As CDMA is used to separate different pico nets, it is obvious that the master of one pico net can only act as a worker in other pico nets, as the hopping sequence is given by the master.

Bluetooth offers two basic service types: a synchronous connection-oriented link and an asynchronous connectionless link:

- **SCO (Synchronous Connection-Oriented Link):** SCOs are symmetrical, circuit-switched point-to-point connections with a data rate of 64 kbit/s, which is achieved by reserving timeslots at fixed intervals. For reliability, no forward error correction (FEC), 2/3 FEC, or 1/3 FEC can be dynamically selected (the 1/3 FEC is as strong as the FEC for the packet header and triples the amount of data). This type of connection can be used for, e.g., telephony services.

- **ACL (Asynchronous Connectionless Link):** Data applications typically require asymmetrical packet-switched point-to-multipoint links. Data rates in this mode are either up to 432.6 kbit/s for symmetrical links or up to 721.0 kbit/s (57.6 kbit/s in the other direction) for asymmetrical links. Bluetooth can support either a single ACL, three SCOs, or one ACL and one SCO at the same time.

APPLICATION PROFILES

Although the core standard of Bluetooth covers the technical aspects of communication, the Bluetooth Consortium thought about typical user scenarios for deploying Bluetooth technology. Their work is published in a separate document and comprises 13 application profiles.[1]

- **Generic Access Profile:** This profile defines generic procedures for discovering Bluetooth devices and link management aspects of the connection to other Bluetooth devices. It also defines procedures for different security levels. Thus, this profile is needed for forming and organizing pico nets and scatter nets by finding other Bluetooth devices within the communication range.
- **Service Discovery Application Profile:** This profile defines the features and procedures to discover services provided from (other) Bluetooth devices and retrieve any desired available information pertinent to these services. Using this profile, a Bluetooth device can expose its capabilities to other devices, such as a dial-up networking functionality.
- **Cordless Telephony Profile:** The so-called 3-in-1 phone use case is supported by this profile. It covers the features and procedures that are required for interoperability between different units active for those devices. 3-in-1 phones provide a solution for three modes of operation to cellular phones: First, Bluetooth can be used as a short-range bearer for accessing telephony services in fixed networks via a base station, i.e., the user can use the cheaper fixed network for telephony instead of the expensive cellular infrastructure. Second, Bluetooth can be also applied to set up calls between two terminals (e.g., for wireless telephony) in small office environments. Third, Bluetooth enabled devices can access supplementary services provided by the external network.
- **Intercom Profile:** The Intercom Profile defines the requirements for Bluetooth devices necessary for supporting the intercommunication functionality within 3-in-1 phones.
- **Serial Port Profile:** This profile defines the requirements for Bluetooth devices necessary for setting up emulated serial cable connections between two peer devices.
- **Headset Profile:** In order to support headsets, this profile defines the requirements for Bluetooth devices that are necessary for this scenario.
- **Dial-up Networking Profile:** This profile defines the requirements for Bluetooth devices necessary for the support of dial-up networking functionality. This allows mobile users to connect to a modem of their Internet Service Providers (ISPs).
- **Object Push Profile:** This profile specifies the application requirements for Bluetooth devices necessary for pushing objects (e.g., vCards) to other devices.

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[1] Note that other institutions are currently trying to form parts of Bluetooth into international standards. In the 802.15 WPAN (Wireless Personal Area Networks) working group, the IEEE [2] cares for the lower (communication-based) layers, whereas ETSI [1] tries to standardize and integrate the higher layers of Bluetooth.

- **Fax Profile:** Fax functionality of Bluetooth devices is covered by this profile.
- **LAN Access Profile:** Devices supporting this profile will be able to access local area networks. First, the LAN access Profile defines how Bluetooth-enabled devices can access the services of a LAN using PPP. Second, it shows how the same PPP mechanisms are used to form a network consisting of two Bluetooth-enabled devices.
- **Generic Object Exchange Profile:** This profile defines the requirements for Bluetooth devices necessary for exchanging various types of objects, such as vCards (business cards objects) or vCal (calendar objects).
- **File Transfer Profile:** This application-level profile defines the application requirements for Bluetooth devices necessary for transferring files from one device to other devices.
- **Synchronization Profile:** This profile defines the requirements for Bluetooth devices necessary supporting the synchronization of applications, such as PIM data (Personal Information Manager, e.g. schedules, phone books, address lists, memos, task lists, etc.).

Recalling the scenario for the use of wireless communication between devices within vehicles, we see that several Bluetooth profiles are very important and promising for realizing the new types of services we described above. For example, the Generic Access Profile and the Service Discovery Application Profile are basically needed for the organization and configuration of the ad-hoc network between the mobile devices and the built-in equipment. Thus, all devices are able to find a gateway to the Internet (Dial-up Networking Profile) or devices offering telephony services (Cordless Telephony Services Profile). However, improving the provision of traveling-related services in vehicles supposes the integration of both, mobile devices and on-board equipment into the vehicle's information system. This might be achieved by a definition of additional profiles for the on-board services to facilitate their discovery for the mobile devices.

CONCLUSION

The trend of integrating new services in vehicles increases rapidly. Meanwhile, car radios have evolved to small communication centers, offering dynamic route guidance, access to Internet services, or on-board emergency assistance. As mobile devices become more and more popular, users wish to integrate them into their vehicles, as those devices also contain information useful for traveling. In order to enable those devices to communicate with each other, we showed that ad-hoc networks based on wireless technology are very interesting, as they are organize and configure themselves. Bluetooth is one of the emerging communication technologies for realizing ad-hoc networks – not only within vehicles – and it will help that the vision of mobile information centers on the road will become true.

[1] ETSI (2001) *European Telecommunications Standards Institute.* (http://www.etsi.org)
[2] IEEE (2001) *Institute of Electrical and Electronics Engineers.* (http://www.ieee.org)
[3] Schiller J. (2000) *Mobile Communications*. 450p. (Addison-Wesley, London/New York)
[4] Bechler M. and Schiller J. (2000) The Need for the Wireless Application Protocol (WAP) in Cars. *Proceedings of the 7th World Congress on ITS, Turin.*
[5] IDC (2001) *International Data Corp.* (http://www.idc.com)
[6] IrDA (2001) *Infrared Data Association.* (http://www.irda.org)
[7] Bluetooth (2001) *Bluetooth Consortium.* (http://www.bluetooth.com)