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"Adaptive and Cooperative Technologies for Intelligent Traffic – Cooperative Cars"

CoCar Feasibility Study

Technology, Business and Dissemination

Public Report by the CoCar Consortium

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Abstract

As a result of a structured assessment, **Cellular Hazard Warning (CHW)** has been chosen as the most challenging and valuable application to be investigated within the Cooperative Cars (CoCar) feasibility study. CoCar CHWs are safety-critical warnings exchanged in high speed and with low latency in cellular communication systems. CoCar CHW provides drivers with the opportunity to adapt vehicle speed and inter-vehicle distance in a timely manner, leading to a higher situational awareness of unforeseen danger or, in other words, extending the telematics horizon. This report summarizes key findings from a technical and a commercial point of view.

Final Conclusions and Outlook

From a technical point of view, CoCar CHW has been identified as a feasible application in today's Universal Mobile Telecommunications System (UMTS) networks with their latency well below one second and with the necessary capacity available to exchange CoCar CHWs.[1] For a full rollout, the utilization of a broadcast mechanism would be beneficial. Here, Multimedia Broadcast Multicast Service (MBMS) has been identified as the technology of choice.

From a commercial point of view, it was satisfactorily shown that CoCar CHW can provide valuable benefits for individual drivers, business and governmental customers and society in general. Due to the critical mass phenomenon and direct network effects, the development, introduction and deployment of CoCar CHW will require the combined effort of all market participants. Two footprints for cooperative Value Creation Architectures (VCAs) have been developed and discussed in detail.

Cooperative telematics services like CoCar CHW should be introduced as service bundles together with standalone services like eCall to exploit functional, technical and cost synergies. CoCar CHW could become operational in 2014 following a two-year equipment rollout phase. The equipment rate will reach 15 % by the end of 2014, the first year of operations, and 93 % in 2023, the 10th year. The corresponding business case identifies relatively high investment barriers on one hand, but extraordinary opportunities on the other.

In summary, the continuation of the CoCar CHW development and introduction is recommended unconditionally. Future research should cover more specific Benefit Cost Ratio (BCR) analyses, more in-depth user requirements and the preparation of valid business cases for various actors and stakeholders. From a technical point of view, the performance of evolved cellular technologies, such as the emerging radio access technology Long Term Evolution (LTE) and the service management platform IP Multimedia Subsystem (IMS), should be further investigated.

In the following, the key findings of the technical and the commercial feasibility study are presented in more detail.

[1] Both the functional set up and the simulation performance results could also be verified in a CoCar live demonstration on May 14th 2009 in Munich.

Technical Feasibility – Key Findings
Technically the CoCar system comprises in-vehicle systems that send and receive warnings via a mobile cellular network. These warnings are processed by the CoCar Information System, which consists of three central logical components: Reflector, Geocast Manager and Aggregator.

The Reflector re-directs CoCar CHWs into the vicinity of the hazard so that vehicles close by are warned immediately of time-critical and hazardous situations. This can be achieved within a vehicle-to-vehicle transmission delay of a few hundred milliseconds. The precise value depends on network parameters, e.g. the chosen physical channel. The Reflector also sends a copy of each CHW to the Aggregator.

The Aggregator consolidates the CHWs with external information and evaluates, whether or not an incident is relevant to an extended geographical area. Thus, by correlating incidents by time, location and type of warning, it is possible to derive a holistic picture of the road traffic with a higher level of information. An intelligent reasoning algorithm would combine individual warnings classified by type into consolidated events. In a third step, the Aggregator determines the area where a CoCar CHW should be distributed and uses the Geocast Manager to set up the dissemination.

The CoCar project developed dedicated protocols for both reflected and aggregated data. The service basically comprises two use cases: the upload from the vehicle to the CoCar Information System and the CoCar CHW distribution to the receivers. The Fast Traffic Alert Protocol (FTAP) utilizes small messages of less than 100 byte to realize fast data transmission. For aggregated data, the Transport Protocol Expert Group (TPEG) protocol adds flexibility and extensibility. The regular upload of less time critical traffic probe data is implemented using the Traffic Probe Data Protocol (TPDP) defined by CoCar.

All developed application layer protocols are based on the Internet Protocol (IP) and can thus operate generically on various access systems. An overview of candidate cellular technologies as bearer for CHW is given within the report. The technology in focus of the technical feasibility study was UMTS and its enhancement High Speed Packet Access (HSPA). In detailed performance studies, the upload of binary and XML coded CHW messages was studied, using either the common Random Access Channel (RACH) or the Dedicated Channel (DCH). Furthermore, the distribution of CoCar CHWs via the network to the receiving vehicles via unicast and broadcast mechanisms was investigated.

It was shown that, in general, the mean delay for a CoCar CHW from source to sink can be well below or at least on the order of 500 ms making it attractive for a variety of telematics services spanning safety, comfort and information services. To realize CHW with today's UMTS and HSPA networks, the use of common channels is recommended. Dedicated and shared channels make sense for downloads and uploads or peer-to-peer applications exchanging larger volumes of data. For higher service penetration rates, i.e. a full deployment scenario, a resource efficient broadcast channel – as offered by MBMS – is recommended for CHWs distribution.

Commercial Feasibility – Key Findings
CoCar CHW clearly contributes to socio-economic goals with significant safety and traffic impacts that result in monetary benefits of nearly half a billion € per year in Germany in its fully rolled out version. The BCR is estimated at 2 for the total system benefits and costs, respectively at more than 10 for the ratio of safety impacts and state-run subsidies. This implies that every spent € leads to societal benefits of 2 € respectively of more than 10 €, if only the state-run subsidies are considered as costs. Not yet included in this assessment are other positive effects such as employment and environmental effects, tax revenues and innovation capabilities.

In order to design stable value creation architectures for the broad range of possible actors in each value creation step, the pros and cons of different VCAs are discussed in detail. Depending on who is shaping the market, setting the rules and is willing and able to take risks, the outlined VCAs are: (1) an Original Equipment Manufacturer (OEM) driven model, (2) a Personal Navigation Device (PND) manufacturer driven model, (3) an Automobile Association driven model, (4) a Mobile Network Operator (MNO) driven model and (5) two cooperative models.

A crucial disadvantage of models 1 to 4 is the fact, that one market shaper alone will be neither able nor willing to invest in the necessary critical mass of CoCar CHW terminals and to contribute sufficiently to positive direct network effects. Mainly for these reasons, market participants will have to cooperate with each other to increase the service value and the single benefit of each partner conjointly. Within the Telematics Platform Provider (TPP) model (Figure 1), a TPP plays an active market shaper role and acts as the central contact point for all customers.

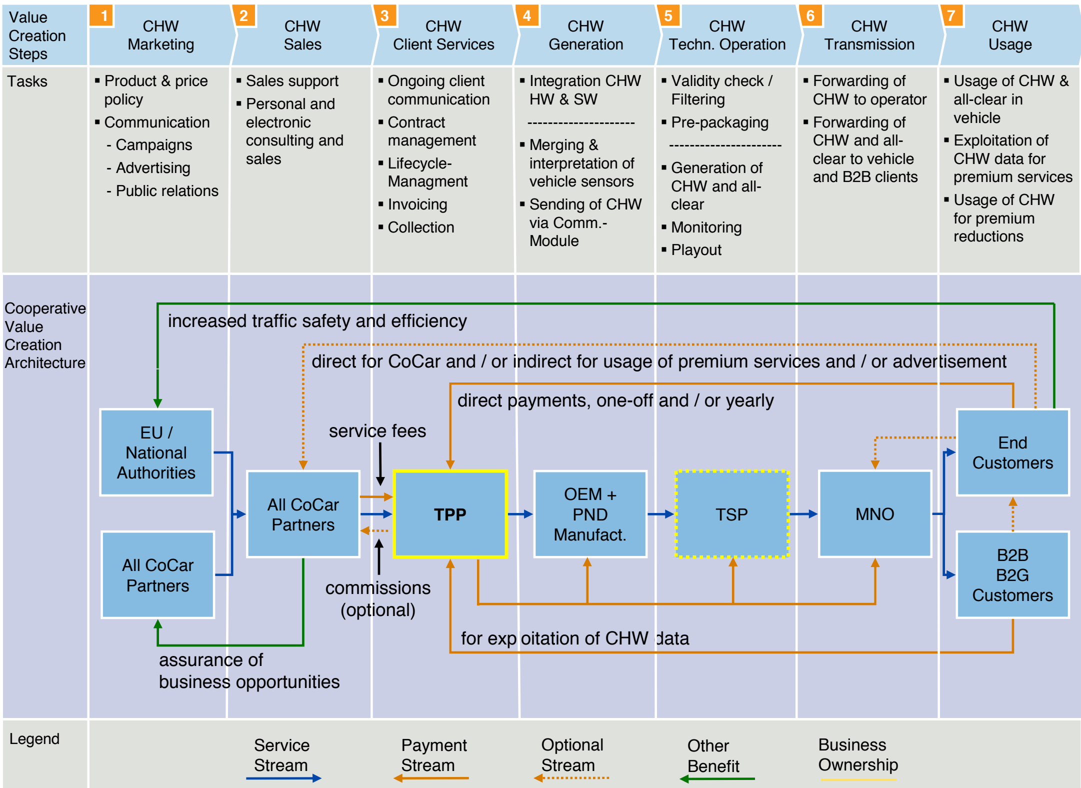


Figure 1: Cooperative CoCar CHW value creation architecture - TPP model

The TPP provides comprehensive processes that may comprise first and second-level support, contract management, billing and lifecycle management. Additionally, the TPP could act as a payment clearance platform, controlling and allocating the revenue streams from the vendors to the service providers and, in return, from customers to vendors. The technical operations of CoCar CHW could also be provided by the TPP.

From an organizational point of view, the TPP could be an industry-independent start up or be partially or completely owned by one or more of the market participants (e.g. OEMs and / or MNOs). OEMs will provide PND manufacturers and possibly other after-sales market players with a bundle of defined sensor data that will be exchanged via a dedicated data exchange interface. In return, OEMs will receive higher customer value for their own line-fitted solutions, an increased customer satisfaction and a wider scope in pricing. Such a flexible value creation architecture based on a market shaping TPP will allow all market participants to play CoCar CHW according to their competitive strategy (differentiation or cost leadership).

The implementation and deployment of such a promising VCA is threatened by a number of risks. OEMs in particular will carefully consider their risks regarding the return on investment, product liability, and the costs of potential recall campaigns. It is assumed that OEMs are willing and able to take these risks and moreover support a cooperative VCA for two reasons. Firstly, a conjoint CoCar CHW approach can achieve promising business outlooks (see CoCar CHW business case). Secondly, value-added services like Customer Relationship Management (CRM) and Vehicle Relationship Management (VRM) can be made possible or improved significantly, resulting in high business benefits and additional refinancing sources for the units' installation costs. The product liability risk remains a serious potential show stopper whose impact must be kept as small as possible by legal measures.

It is recommended that CoCar CHW will be offered in a bundle with standalone services like eCall and dynamic route navigation. Such a service bundle would make sense from a functional, technical and commercial point of view:

Functionally, CoCar CHWs very well amend existing traffic information services with real-time data, and can therefore become an additional source of information for dynamic route navigation. Furthermore, CoCar CHWs might become an input source for in-vehicle Advanced Driver Assistance Systems (ADASs). *Technically*, the service bundle will make use of the cellular communication interface, which allows the realization of synergies. Additional services like remote software management, bCall and other value-added services can be easily included. *Commercially*, the bundle will provide an attractive added value for potential customers. This added value might be a crucial purchase driver for those customers that have been indecisive in buying a standalone service.

The service could become operational in 2014 following a two-year equipment rollout phase. Such a rollout phase in advance of the service operations is necessary because a minimum equipment rate estimated at 10 % has to be reached before the users will perceive sufficient benefits from the service core value proposition.

Regarding the CoCar CHW equipment rate, it is assumed that 50 % of all new vehicles as of 2012 will be equipped with CoCar CHW with a subsequent annual growth of 5 % in the equipment rate. Additionally, retrofitted vehicles will contribute to the overall penetration rate as of 2014 with 5 % of all unequipped vehicles and an annual increase of another 5 %. The resulting equipment rate will reach 15 % by the end of 2014, the first year of operations, and 93 % in 2023, the 10th year of operations.

CoCar CHW business case calculations for Germany result in a Net Present Value (NPV) of more than 4 billion € at a Weighted Average Cost of Capital (WACC) rate of 8 % for the period of 2012 to 2023. Assuming that state-run subsidies will be granted, the Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA) won't be negative at any time.

Nevertheless, this positive result can not hide the fact that about half a billion € have to be invested before the operational start of the service. Break-even will not be reached until 2016, the third year of operation. The discounted cumulative cash flow will not turn positive before 2017. These facts result in a business case with relatively high investment barriers on one hand and extraordinary opportunities on the other. A sensitivity analysis shows that both Capital Expenditures (CAPEX) and Operational Expenditures (OPEX) are clearly dominated by vehicle related costs.

Contents

Chapter 1

Introduction

1.1 Background and Research Questions

The Cooperative Cars (CoCar) feasibility study addresses both, the technical and the commercial feasibility to realize vehicle communication in general and especially Cellular Hazard Warning (CHW) on cellular networks.

Chapter 2, *Technical Feasibility*, examines the technical realization of vehicle communication with existing and upcoming mobile network technologies. The following research questions will be answered:

1. Which mobile communication technologies are available today or will be in the future?
2. Can these technologies meet the latency requirements of typical Car-to-Car (C2C) applications? Which applications are feasible?
3. Is the system capacity sufficient to connect all vehicles? Which applications can be realized with today's networks and which need network enhancements?

Chapter 3 covers the *Commercial Feasibility* of CoCar CHW. Objective is to answer the following research questions and to elaborate valid solutions for them:

1. Service related questions: which CoCar service will this work package focus on according to which criteria? Which socio-economic and individual benefits does the service provide? What are the most important influence factors for service creators within the relevant market environment?
2. Value creation related questions: who are the service's stakeholders and what are their main interests and capabilities? How could and should the service value be created in the future? Which value creation architectures and business models for the main actors can be recommended?
3. Market launch related questions: which are the main risks, opportunities and critical success factors of a market introduction? How can the service be launched successfully in the vehicle telematics market?
4. Business case related questions: will the business case pay off? Under what conditions will it pay off and which are the most important cost drivers and revenue drivers? Will the service spur any other services?

1.2 Structure of the Report

The technical feasibility part is structured into three main sections. First, section 2.1 explains the CoCar system architecture and the developed CoCar protocols for different kinds of vehicle applications. Next, section 2.2 introduces the various mobile network technologies that play a key role in Intelligent Transport Systems (ITS) setups today or that will play such a role in the future. Finally, section 2.3 summarizes the performance results and concludes the technical feasibility of CoCar pilot applications with Universal Mobile Telecommunications System (UMTS) and, as an outlook, with Long Term Evolution (LTE).

The commercial feasibility study is structured into four main sections. In a first step, the relevant services will be identified and described in detail in section 3.1. In particular, the individual and socio-economic benefits and the current market environment, including the political and regulatory environment, will be elaborated. In section 3.2 possible value creation architectures and business models for the service configuration will be analyzed, designed and evaluated. Based on this rather generic groundwork, appropriate market launch scenarios will be discussed in section 3.3, among those opportunities and risks, critical success factors, market diffusion scenarios, and marketing and sales strategies. Finally, in section 3.4, all assumptions made in the chapters before will be assessed monetarily and calculated in a comprehensive business case, covering the period from 2012 to 2023.

Chapter 2

Technical Feasibility

This chapter concludes the feasibility of the CoCar Cellular Hazard Warning (CHW) service from a technical and network point of view. The performance, in terms of network latency, capacity and scalability, for the CoCar protocols and system components is the most prominent criteria for technical feasibility.

The technical feasibility part is structured into three main sections. First, section 2.1 gives an overview on the CoCar system architecture and CoCar protocols. Next, section 2.2 introduces the various mobile network technologies that play a key role in ITS setups today or that will play such a role in the future. Finally, section 2.3 summarizes the CoCar performance results derived during the project and concludes the technical feasibility of CoCar applications with UMTS and LTE.

2.1 System Overview

C2C communication refers to all kinds of communication patterns where information is exchanged between cars. However, the transmission path has not necessarily to be a direct communication link between cars, as it is assumed for Wireless Access in Vehicular Environments (WAVE) / IEEE 802.11p setups. It is also possible and – due to a specific network topology – sometimes advantageous to introduce intermediate nodes, like other cars or infrastructure nodes. Using today's and future cellular communication systems for C2C applications, the communication path always comprises central infrastructure nodes like base stations or the core network. Dependent on the corresponding layer in the OSI Reference Model, these nodes are usually named repeater (physical layer), relays (medium access layer), routers (network layer) or gateways (application layer).

2.1.1 CoCar System Architecture

The C2C communication system investigated in the CoCar project is based on a cellular network architecture (see Figure 2.1). Due to the hierarchical concept of cellular systems, the communication path between cars always passes infrastructure nodes. In CoCar, the C2C communication mechanism is named Cellular Car-to-Car Communication (CC2CC), since it is facilitated by a cellular network. The mechanism is enabled by the introduction of an application gateway, called Reflector, that re-distributes road traffic incident messages back to vehicles based on their location and without modifying the content of the messages. The Reflector constitutes a functional component, rather than a physical network element. As a result the

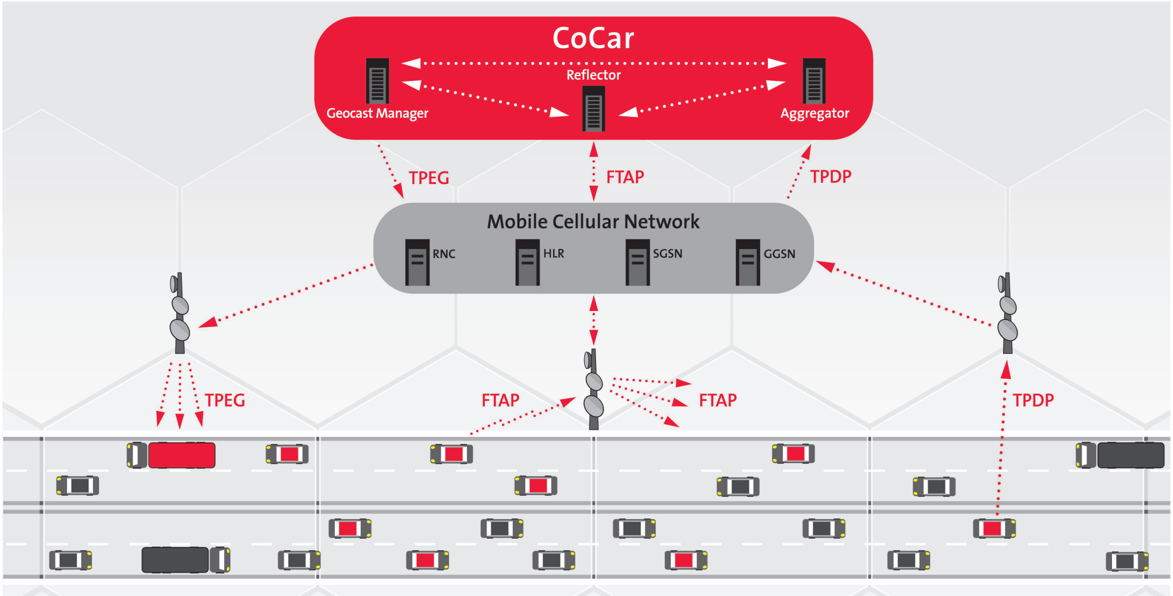


Figure 2.1: Overview of the CoCar system architecture

Reflector sends specific messages from vehicles back to other vehicles in the proximity. The location-based re-distribution method could be based on cellular or GPS positioning and unicast or broadcast transmission. The used embodiment is dependent on available technologies and scalability requirements.

Figure 2.1 gives a high-level overview on the CoCar system architecture as developed and defined within the CoCar project.

Three novel functional components are introduced: the already mentioned Reflector, a Geocast Manager, and an Aggregator. These three components represent the core of CC2CC services like the thoroughly analyzed CoCar CHW.

Besides the location-based re-distribution of road traffic incident messages by the Reflector, the Aggregator may consolidate messages it receives from Reflectors with other incident messages and even external information. By correlating incidents on time, location and type of warning, it is possible to derive a holistic picture of the road traffic with a higher level of information. An example may be a massive freeway pileup, where several different incident warnings arrive from nearly the same location and time. Based on the type of warnings, an intelligent reasoning algorithm may be able to classify all warnings to a single consolidated event. In a third step, if incidents are considered relevant for a larger geographical area, the information is repackaged and sent to all users in the larger area using the Geocast Manager.

The size of the distribution area of the CHWs should be adapted to the message type, the road traffic density. Furthermore, the road topology could be taken into account to optimize the distribution area layout, e.g. the regions could follow the run of major roads. Two different addressing schemes are supported, unicast and broadcast. In case of unicast distribution, each vehicle within a specific region receives the CHW message through an individual communication channel. Transmissions using broadcast channels are more efficient for a large number of recipients. For both distribution cases, the vehicle system has to select only relevant warnings that will be indicated to the driver. This filter process interprets the location, time stamp and heading field of the CHW message and compares them with the current vehicle conditions.

2.1.2 CoCar Protocol Architecture

The CoCar project developed several application layer protocols that cover most use cases identified in the CoCar project. The proposed protocol stack depicted in Figure 2.2 takes specific requirements of certain CoCar applications into account.

The instant CHW upload from a vehicle via the cellular network to the CoCar system is handled by the use of the Fast Traffic Alert Protocol (FTAP). The messages are binary coded to allow a small message size of below 100 byte and thus fast data transmission. These optimized messages can be transmitted on a UMTS common channel, i.e. the Random Access Channel (RACH) in uplink direction. The RACH provides fast and resource efficient upload capabilities for small amounts of data.

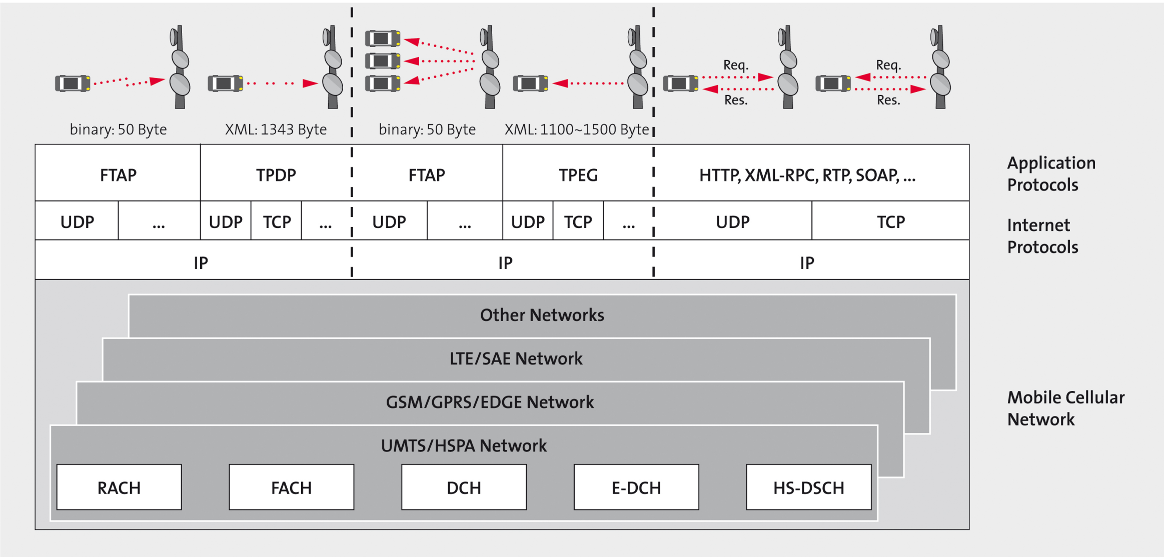


Figure 2.2: Overall CoCar protocol architecture

The regular upload of less time critical traffic probe data is realized using the Traffic Probe Data Protocol (TPDP). This protocol allows the regular upload of road traffic probe data similar to Extended Floating Car Data (XFCD), generally using dedicated UMTS channels (DCHs). The protocol is able to adapt to the penetration rate and vehicle density within a specific region to avoid unnecessary network load.

In downlink, again, the small FTAP messages allow fast and efficient message dissemination. In UMTS, the FTAP messages can be transmitted via the common Forward Access Channel (FACH). In addition, messages may be coded as Transport Protocol Expert Group (TPEG) messages. TPEG provides flexibility and extensibility and is a world wide accepted standard for the representation of traffic messages. CoCar developed a TPEG message type to capture all requirements of the CoCar pilot applications. It is mainly used in downlink for message dissemination for the less time critical messages.

The mentioned protocols are specially adapted to the needs of CC2CC applications. However, a large amount of vehicle-related applications like remote diagnostics, file downloads, etc. can also be realized using well-known application layer protocols like HTTP, RTP, etc.

Within the first years of service introduction, unicast (point-to-point) mechanisms will most likely be chosen to make CHWs available to vehicles. If the number of equipped vehicles increases year-by-year, it will at some point become more efficient from a network resource point of view, to use a single broadcast (point-to-multi point) mechanism instead of numerous unicast transmissions in parallel. Cellular broadcast is for example standardized for UMTS and LTE, namely Multimedia Broadcast Multicast Service (MBMS).

2.2 Mobile Network Technologies

The following section introduces the various mobile network technologies that play a key role in ITS setups today or that will play such a role in the future. Figure 2.3 gives an overview on the network evolution over time, containing the technologies described below. The figure indicates that the continuous network evolution enables both, increase in data throughput and the decrease in system latency.

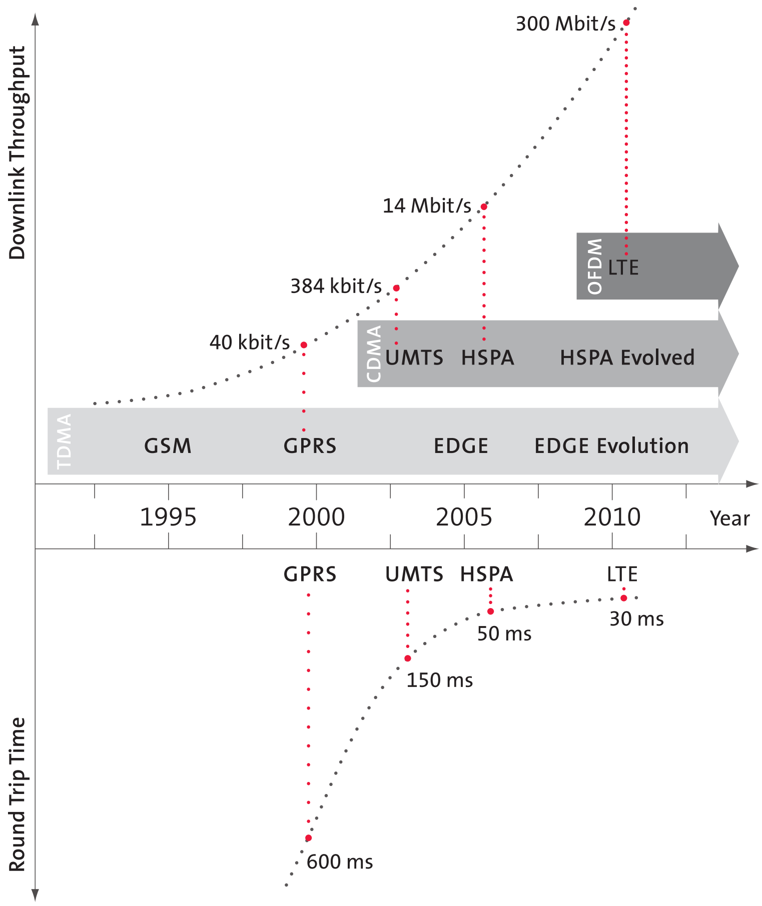


Figure 2.3: Evolution of cellular network technology

2.2.1 GSM/GPRS

GSM

With the experience of over thirty years of analogue wireless voice telephony networks across Europe, incumbent European operators like Deutsche Bundespost (now Deutsche Telekom), France Telecom, British Telecom started discussions the early 1980s, to create a single European cellular network standard. In 1982, the European Conference of Postal and Telecommunications Administrations (ECPT) created the Groupe Spécial Mobile (GSM) to start standardization of a new mobile communications system. After several proposals were made, in 1987 the group chose to proceed with a narrow band Time Division Multiple Access (TDMA)/Frequency Division

Multiple Access (FDMA) system. This standard was seen to finally abandon wireless analogue communication, introduce simplified roaming and to manifold the number of customers being served. A Memorandum of Understanding (MoU) was signed by 13 countries to introduce the new system from 1991/92 on. [1]

In 1989, the responsibility for the GSM standardization was transferred to the newly formed European Telecommunications Standards Institute (ETSI), commissioned by the European Union to overlook standardization in the telecommunication sectors. The first GSM specifications were frozen in 1990 – at that time GSM was renamed to Global System for Mobile Communication.

In Europe, GSM operates in the 900 MHz and 1800 MHz band. In the USA and Canada, where this spectrum is used for other purpose, 850 MHz and 1900 MHz are used. Other countries use somehow a combination of these bands to operate GSM networks. Typically, the bands are divided in two 25 MHz carriers, the lower one for uplink and the upper one for downlink transmission. For example the 900 MHz band is divided into 880 MHz – 915 MHz for uplink and 925 MHz – 960 MHz for downlink. In Germany the 900 MHz and 1800 MHz spectrum is shared among all four operators.

The 25 MHz carriers are again divided in 124 FDMA channels with 8 time slots per carrier, which then form the speech channels. This means that in total up to 992 speech channels are available and any speech channel offers a gross bit rate of 22.8 kbit/s. The full rate traffic channel carries 13 kbit/s coded speech or data with an actual user data rate of 9.6, 4.8 or 2.4 kbit/s. Half rate channels were introduced to increase the system capacity, with the user data rates being reduced accordingly. [2, p.71], [3, p.143]

GSM also standardizes the circuit switched based Short Message Service (SMS). [4] GSM is called a system of the second generation (2G).[1] In fact more than 80 % of the world's mobile connections are handled by second generation GSM systems (i.e., GSM and GPRS) and by the end of the year 2008, more then 3 billion users were using GSM. In total more than 89 % of all mobile connections are handled by systems of the GSM familiy. In addition, UMTS accounts for 300 million (8 %) additional connections. [5]

CSD

The first data services were realized based on circuit switched GSM connections and hence were called Circuit Switched Data (CSD). GSM CSD supports data rates from 1.2 to 9.6 kbit/s, as already stated in the GSM chapter above. For instance, the mobile facsimile service is realized on CSD.

HSCSD

High-Speed Circuit-Switched Data (HSCSD) is an enhancement of CSD. It gives a single user simultaneous access to multiple channels (up to four) at the same time. Furthermore, the ability to use different coding methods increases the maximum data throughput per channel. Assuming a standard CSD transmission rate of 14.4 kbit/s and using four time slots, HSCSD allows theoretical speeds of up to 57.6 kbit/s. HSCSD became commercially available end of 1998. [3, p. 256]

CSD and HSCSD represent circuit switched data connections, as the underlying connections

[1] The evolution of mobile communication is always described in generations, whereas the first generation (1G) is the first wireless analogue systems and 2G is the digital systems like GSM and GPRS. A typical 3G technology is UMTS.

are essentially voice calls transporting packet data instead of voice data. This should not be confused with packet switched connections as used in GPRS, as these circuit switched connections are kept open even if no data is transported and are billed on time instead of volume. That is why CSD and HSCSD are regarded inefficient, both from an economical and a technical point of view. But they allow the exclusive use of a connection, provide a quite low latency and a predictable throughput.

GPRS

Within the framework of the continuing development of GSM Phase 2+, ETSI worked on a packet-oriented service concept for the transfer of data to overcome the difficulties of CSD. Essentially, General Packet Radio Service (GPRS) introduces a way to allocate unused GSM voice channel capacity for packet switched communication. Therefore, a scheduler assigns free resources to transport packet data.

GPRS introduces two new network nodes for the IP-based traffic: the Gateway GPRS Support Node (GGSN) and the Serving GPRS Support Node (SGSN) are the entry points into the cellular network and all packet switched network traffic is routed through these nodes.

The GPRS technology allows a theoretical downlink throughput per cell of 160 kbit/s, i.e. using 8 timeslots in parallel. [6] However, commercial handsets only support up to 4 voice channels. This way, the terminals can be realized using the same Radio Frequency (RF) equipment for up- and downlink. However, many GPRS networks today only offer data rates of about 40 kbit/s.

The GPRS Round Trip Time (RTT) is in the range of 600 ms. [7] GPRS belongs to the 2G technologies. However, to emphasize that it is an evolution of GSM it is sometimes referred to be a 2.5th generation (2.5 G) system. GPRS became commercially available in 2000 and first roll outs took place in Germany in 2001.

EDGE

After GPRS, the next step in the GSM evolution was taken with the introduction of Enhanced Data Rates for GSM Evolution (EDGE). After standardization was finalized by 3GPP in 2000, first networks were deployed in 2003.

EDGE carries a peak data rate of 384 kbit/s in downlink and the average data rate in commercially operated networks is in the range of 200 kbit/s. The RTTs of today's advanced EDGE networks lies around 150 ms. [7]

Predominately, EDGE is used in conjunction with GPRS. These services are designated Enhanced GPRS (EGPRS), which is a superset expression comprising EDGE and GPRS. It thus improves the performance of packet switched data traffic. Since EDGE fulfills the IMT-2000 requirements, it belongs to the group of 3G systems[2]. [8]

EDGE Evolution

EDGE Evolution is a quite new and presumably the last enhancement developed for GSM-based systems. It was standardized in 3GPP Release 7, i.e. together with HSPA Evolution. The primary motivation for enhancing EDGE is to ensure the future competitiveness of the dominant

[2] Typically the term 3G is very much connected to UMTS, since it uses a different radio interface than the 2G GSM/GPRS technology. However, EDGE is also accepted as a 3G system, because it fulfills the IMT-2000 requirements for 3G networks.

GSM/GPRS technology and filling the service gap between GPRS and UMTS/HSPA.

EDGE Evolution systems allow downlink peak bit-rates of up to 1 Mbit/s per cell and typical bit-rates of 400 kbit/s. This is achieved by the introduction of dual carriers, which double the available bandwidth to 400 kHz, shorter Transmission Time Intervals (TTIs) and by utilizing higher order modulation (see [7] for details). The latency (RTT) is reduced to below 100 ms.

With these characteristics, Evolved EDGE surpasses the speed of the first generation of UMTS networks. EDGE Evolution has been developed with the objective of minimising the impact of existing GSM/EDGE network infrastructure in order to help operators leverage their existing investments. Therefore, the different enhancements could be done gradually and most of them as software upgrades. The network architecture remains unchanged.

2.2.2 UMTS/HSPA

UMTS

UMTS Release 99 was standardized by 3rd Generation Partnership Project (3GPP)[3]in 1999. UMTS fulfills the IMT-2000 requirements and is thus a 3G standard.[4] Out of different radio interfaces, the Wideband Code Division Multiple Access (W-CDMA) technology is the one rolled out across Europe. W-CDMA is based on Direct Sequence Code Division Multiple Access (DS-CDMA), which means that every signal of a physical channel is spread over the whole carrier bandwidth by multiplying it with a certain channelization code, the Orthogonal Variable Spreading Factor (OVSF, short: SF) code. Thus, with the W-CDMA technology, a unique code identifies each physical channel, and the SF of the code determines the bit rate. The new technology requires the operators to obtain new spectrum allocations. Although the UMTS radio interface is completely different from the GSM/EDGE one, a lot of architectural concepts and procedures have been inherited from GSM and typically terminals are backwards compatible.

UMTS is operated as a Frequency Division Duplex (FDD) system by using a pair of 5 MHz carriers – one for uplink and one for downlink. Release 99 networks provided downlink speeds up to 384 kbit/s and uplink speeds up to 128 kbit/s, when it was finally introduced to the market. First commercial systems were available in 2001. In Germany, first UMTS deployments started in 2004.

UMTS Release 99 introduced Dedicated Channels (DCH) to exchange data between the base station (called NodeB in UMTS) and the terminal (called User Equipment, short UE in UMTS). These channels achieved a RTT of around 100-200 ms, [10, p.397] whereas the RTT is the latency from the mobile through the UMTS network to an application server and return.

For Germany the frequency bands 1920 MHz – 1980 MHz are allocated for UMTS uplink and 2110 MHz – 2170 MHz for the downlink. These frequencies, awarded in auctions in 2000, are significantly higher than the GSM 900 MHz bands. This results in a different propagation environment and leads to smaller coverage areas per cell. In fact, UMTS needs up to 30 % more base stations compared to GSM at 900 MHz to cover a given area.

[3] 3GPP is a standards developing body that specifies UMTS and GSM systems. Formed in 1998, the scope of 3GPP was to produce global specifications for a 3G mobile system based on an evolved GSM network. The task to maintain and develop the GSM/EDGE specifications was added to 3GPP in a later stage. [9, p. 10]

[4] Within the International Telecommunication Union (ITU), the members outlined the International Mobile Telecommunications 2000 (IMT-2000) concept as the basis for the third generation (3G) wireless communications. All systems that fulfill the IMT-2000 requirements are after this definition a 3G technology, e.g. UMTS and EDGE. [8] IMT has already IMT-Advanced requirements for 4G, which will probably be met by LTE Release 10 and WiMAX II.

In addition to W-CDMA, UMTS also includes a Time Division-CDMA (TD-CDMA) radio interface. However, the major technology used across Europe is W-CDMA. Germany actioned unpaired spectrum, but no services have been deployed yet.

In parallel to the European W-CDMA deployment, other 3G systems have been rolled out in other parts of the world. E.g. the USA deployed the cdma2000 family and China also uses a special technology called Time Division-Synchronous Code Division Multiple Access (TD-SCDMA).

HSDPA

The first enhancement to UMTS was introduced with High Speed Downlink Packet Access (HSDPA) in 3GPP Release 5. HPDPA increases the downlink data rates up to 14.4 Mbit/s and the RTT can be pushed below 70 ms. [10, p.397] Work on this standard enhancement started in 2003 and the technology was finally commercially available in late 2005. [11, p. 7]

Besides other features, HSDPA introduces a shared downlink channel, the High Speed Downlink Shared Channel (HS-DSCH). In HSDPA a certain amount of channelization codes in downlink are reserved for this channel. The resources are then assigned by a scheduler. This means that only users that requested downlink resources will get them, and they will receive much higher peak data rates. This increases the efficiency as the new shared channel allows to use the resources more efficiently. The scheduler may prefer those UEs with the best radio conditions or with tighter delay constraints. By employing this mechanism, the network performance can be improved both in terms of throughput and latency.

HSUPA

High Speed Uplink Packet Access (HSUPA) was introduced to UMTS Release 6, improved uplink data rates up to 5.7 Mbit/s are possible. It can be seen as the counterpart to HSDPA. With first HSUPA deployments the RTT could be pushed below 50 ms. [10, p.397] First networks have been rolled out using this Release 6 technology in 2007.

HSUPA actually implements the same sort of techniques already used by HSDPA. However, unlike HSDPA, HSUPA is not based on a complete shared channel transmission scheme. The new uplink transport channel Enhanced Dedicated Channel (E-DCH) is actually a dedicated channel with its own physical resources. The actual resource sharing is provided by the NodeB, which allocates transmission power for uplink transmission based on resource requests sent by terminals.

HSPA

High Speed Packet Access (HSPA) is referred to as the combination of HSDPA and HSUPA as introduced in Release 5 and 6.

HSPA Evolution/ HSPA+

UMTS Release 7 and 8 standardize an improved version of HSPA called HSPA Plus or HSPA Evolution. Essentially, HSPA Evolution targets the performance characteristics of LTE in a 5 MHz deployment while being backwards compatible.

Release 7 introduces higher-order modulations that increase the peak data bit rate by 50% to 21 Mbit/s. Likewise, in uplink the peak data bit rate is doubled to 11 Mbit/s. Applying multiple antennas, i.e., using the Multiple Input Multiple Output (MIMO) defined in Release 7, the peak data bit rate can be improved to 28 Mbit/s. In Release 8 even 42 Mbit/s are possible in downlink, and 11 Mbit/s in uplink. [12] These data rates are valid for the typical 5 MHz W-CDMA carrier. If multi-carrier operation is used, these data rates can be multiplied. This means that e.g. for dual-carrier operation peak rates of 84 Mbit/s are possible. Furthermore, in HSPA Evolution the performance of common channels was improved significantly, with Release 7 focussing on the downlink and Release 8 on the uplink improvements. This allows for reduced setup and state transition delays and therefore reducing latency for bursty traffic. 3GPP Release 7 networks are expected to be rolled out during 2009.

2.2.3 WiMAX

Worldwide Interoperability for Microwave Access (WiMAX) is based on the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard. Standardization started in 1999. The name WiMAX was created later on by the WiMAX Forum[5], which was formed in June 2001 to promote and certify conformity and interoperability of the standard. IEEE 802.16d provides support for non-line of sight (NLOS) end-user terminals for fixed wireless broadband, i.e. as an alternative to wired access. The technology uses Orthogonal Frequency Division Multiplex (OFDM) in uplink and downlink.

In 2005, the standard was amended (IEEE 802.16e) adding – amongst other improvements – support for mobility. Therefore it is also known as Mobile WiMAX. Mobile WiMAX based upon 802.16e has been accepted for inclusion as the sixth wireless link system under IMT-2000 and is thus understood as a 3G technology. State-of-the-art networks offer data rates up do 9 Mbit/s using a 10 MHz Time Division Duplex (TDD) carrier. [13]

Because IEEE 802.16 standardization only covers basic connectivity up to the media access (MAC) level, the WiMAX Forum also addresses network architecture issues for Mobile WiMAX networks. The focus of the first network architecture specification (Release 1.0) is on delivering a wireless Internet service with mobility.

The evolution of WiMAX to WiMAX II or IEEE 802.16m is currently under standardization. It will probably be proposed for IMT-Advanced as a potential 4G technology.

WiMAX is a pure mobile broadband technology focusing on providing plain IP connectivity to its customers. Backing for WiMAX comes primarily from large IT companies like Intel. Traditional operators favor the evolution of their already existing 3GPP networks to ensure smooth migration, interoperability and backward compatibility. Therefore it is doubtful that Mobile WiMAX will be used to provide cellular voice and data services.[6] However, it is likely that some regions, especially in the US, will soon be connected using WiMAX at least for fixed connections.

2.2.4 LTE/SAE

Long Term Evolution (LTE) and Service Architecture Evolution (SAE) are two complementing work items handled by 3GPP. It is often referred to be the fourth generation (4G) of mobile networks. However, the first LTE Release that will probably fulfill the IMT-Advanced requirements is Release 10.[7] With the lessons learned from the “slower-than-expected” introduction of

[5] www.wimaxforum.org

[6] Because CoCar focusses on widely spread communication technologies and their evolution, WiMAX is not in the focus of the CoCar performance studies.

[7] 4G is defined as systems that fulfill the IMT-Advanced requirements. LTE Release 10, as well as Mobile WiMAX II are expected to fulfill these requirements. However, the term 4G is often used as synonym for LTE and Mobile

3G, the development of a successor to 3G begun quite early. Furthermore, in parallel to the standardization activities, the Next Generation Mobile Networks (NGMN)[8] was founded to drive the 4G development from the operator side.

LTE describes the new radio access technology. SAE is the name of the 3GPP work item on the core network development and evolution. The work on LTE/SAE started with a 3GPP Radio Access Network (RAN) Evolution workshop in 2004. [9] A set of high level requirements on the system – now listed in Technical Report (TR) 25.913 – was identified and is now fulfilled by the Release 8 standard, which was functionally frozen in December 2008.

LTE is optimized for IP based services providing high data rates and low access delays. One core requirement for LTE was to achieve data rates of at least 100 Mbit/s in downlink, and 50 Mbit/s in uplink for systems operating on a 20 MHz carrier. In fact, with 20 MHz of spectrum allocation, the LTE technology is able to reach much higher data rates. The physical layer technology allows over 300 Mbit/s. [15] Typical bitrates per user will be in the region of 30 Mbit/s.

The radio interface is based on Orthogonal Frequency Division Multiple Access (OFDMA) in downlink and on Single Carrier Frequency Division Multiplex Access (SC-FDMA) in uplink. LTE supports multi-antenna techniques such as MIMO and beam forming to increase peak and cell edge bit rates respectively.

Defined by the SAE work group, the Evolved Packet Core (EPC) consists two new network nodes for the packet switched domain. The EPC introduces enhanced Quality of Service (QoS) handling as well as interoperability with non-3GPP access technologies. The system architecture consisting of LTE and EPC is denoted Evolved Packet System (EPS) (see Figure 2.4).

In the IP based EPS, the number of nodes and thus the number of interfaces in the network architecture was reduced. The flat system architecture, consisting only of the Evolved NodeB (eNodeB) and the Gateway (GW), contributes to the low system latency. The terminal to eNodeB RTT is in the order of 10 ms. In first deployments, end-to-end RTTs below 50 ms are expected.

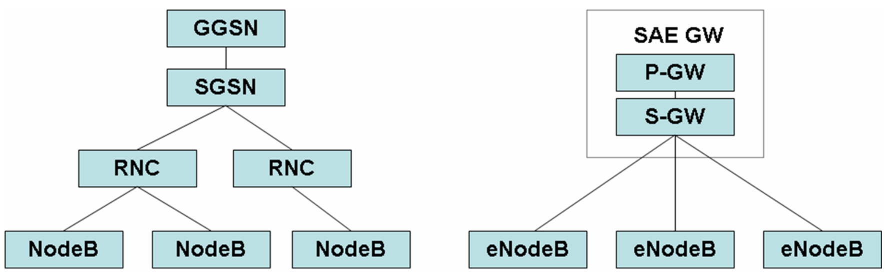


Figure 2.4: UMTS Architecture (left) and EPS Architecture (right)

Besides significant improvements in data rates and latency, a more cost efficient network structure through a much simplified network structure has been achieved. Additionally the spectrum flexibility was improved, allowing to operate LTE in frequency blocks (carriers) of 1.25 to 20 MHz and in frequency bands from 700 MHz to 2600 MHz. First commercial products are expected to be available in 2009 and various network launches are expected in 2010.

The LTE standard will further enhanced in various releases. The 3GPP Release 9 standard –

WiMAX already today.

[8] NGMN is an operator driven organization dedicated to pave the way to fourth generation mobile networks and mobile broadband. Their requirements on the next generation are e.g. listed in a white paper. [14] Two main camps are battling for market acceptance – LTE and Mobile WiMAX. Mobile WiMAX is an IEEE technology whereas LTE is the UMTS successor from 3GPP. See also www.ngmn.org for details.

currently under development and expected to be finalized end of 2009 – adds e.g. full VoIP support and MBMS. Release 10 will provide further major performance and capacity enhancements by means of carrier aggregation, self back hauling, relaying, etc. [16] This release is expected to fulfill the ITU requirements on IMT-Advanced systems. Standardization of Release 10 is expected to be finalized in 2011.

2.2.5 MBMS

MBMS is a 3GPP technology realizing broadcast and multicast services for existing and future cellular systems like Global System for Mobile Communication (GSM) and UMTS. It aims, in the first place, at efficiently distributing mass multimedia content to mobile users. The first MBMS standards were available for UMTS Release 6. [17] In the standardization of LTE, MBMS support was taken into account from the beginning.

Similar to other broadcast technologies like Digital Video Broadcasting for Handheld (DVB-H), Digital Multimedia Broadcasting (DMB) or Enhanced Packet Model Digital Audio Broadcasting (EPM-DAB), MBMS offers broadcast streaming services. The advantage of MBMS broadcast compared to unicast connections, which handle all traffic today, is the economical use of core network and radio resources, as illustrated in Figure 2.5. MBMS, defined in 3GPP Release 6 for UMTS, offers up to 256 kbit/s per MBMS bearer and between 800 kbit/s and 1.7 Mbit/s per cell.

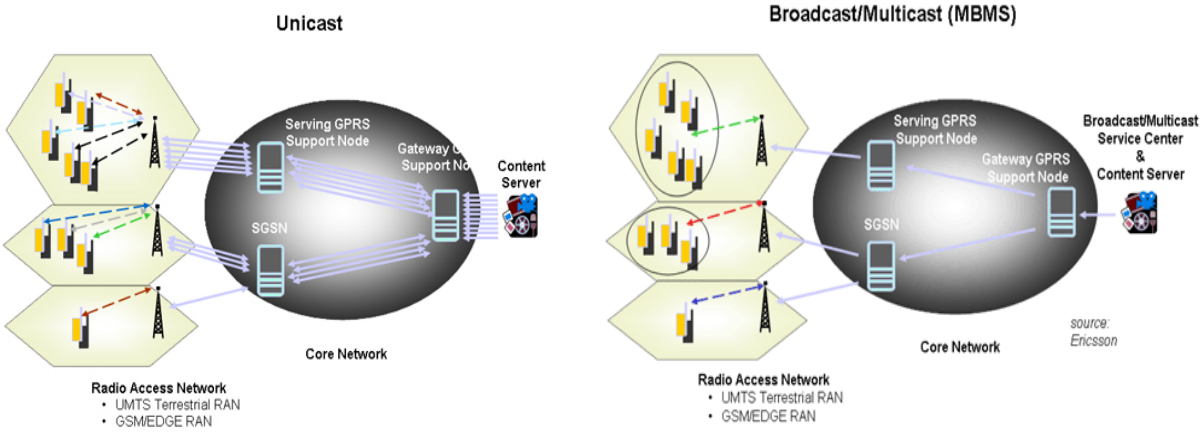


Figure 2.5: Comparison of Unicast and MBMS Broadcast/Multicast based on [18]

MBMS allows to define MBMS Service Areas (MSAs) that define as a collection of (independent) cells. In each of the defined MSAs different services can be delivered. In this way MBMS supports location based broadcast services within certain areas and is a prerequisite for CoCar.

One important difference compared to pure broadcast technologies is the MBMS multicast functionality of MBMS, which allows interactions between services and users. This makes a file download delivery method for "download and play" services possible. Another advantage, compared to other broadcast technologies mentioned above, is that MBMS operates within an operational UMTS network and does not need new infrastructure and spectrum.

MBMS does not require architectural changes to existing 3G networks but can be introduced by a network software update. The new functionalities provided to operators and service providers are summarized in a new additional node called the Broadcast/Multicast-Service Center (BM-SC). The BM-SC can be regarded as a functional interface between content delivery services and the MBMS service offered by a cellular network.

2.2.6 IMS

Very early in the UMTS standardization process, the mobile industry identified the need to manage the broadband connections they were about to roll out. Simple access to the bandwidth was not efficient and the resource shall be shared fairly among the customers. Secondly a system was sought that allowed to add and manage applications - for instance the selection of a certain codec in the call set-up phase should be supported as well as to switch from a voice only call to a video call whenever preferable. So measures had to be taken to, firstly, make the resource 'high-speed network access' available to all customers on a fair basis and, secondly, to introduce mechanisms that allow certain new business models and services to arise.

With the IP Multimedia Subsystem (IMS), the 3rd Generation Partnership Project (3GPP) standardized a general multimedia services architecture that allows the separation of access network UMTS Terrestrial Radio Access Network (UTRAN) and Core Network (CN) from the application layers above. The first IMS version was included in the UMTS Release 5 in 2005. IMS has since been continuously enhanced and is a core technology for LTE. IMS is not a service on itself; it is a building block for all the services, operators and third parties may want to offer. IMS offers some advanced functionalities that may serve as a building block for ITS services. Firstly, Subscriber Identity Module (SIM) based authentication and authorization mechanisms on a service level. Secondly, charging and billing capabilities that allow to charge based either on volume, session/event, or dedicated services. Other forms of billing can easily be introduced as combinations to the before mentioned mechanisms or newly set-up functionality. This allows to set up fine grained billing mechanisms that transfer existing transaction fee schemes into the automotive applications world. Thirdly, features like quality-of-service guarantees and always-on connectivity complement the list and promise to solve major challenges related to the usability and dissemination of automotive services.

3rd party services do not need to have their own control functions built in, as they may rely on IMS as the common horizontal control layer. Indeed IMS helps to manage a limited resource as it allows negotiating QoS parameters and by providing a control channel between the network and the client on IP level. In essence, IMS simplifies network signaling and will eventually replace the quite complex Signaling System #7 (SS7) infrastructure that makes up today's network signaling. SS7 was introduced as the circuit switched signaling system in the late 1970s and has grown far to complex to serve in a packet switched world. IMS is based on Session Initiation Protocol (SIP), the Internet Engineering Task Forces (IETFs) signaling solution for Voice over IP (VoIP) and Instant Messaging (IM) on the internet and has been adapted to serve in the even more complex mobile network world. Interconnections between cellular based and internet based services are achieved by interconnecting IMS and SIP via dedicated gateways.

IMS is network agnostic and services utilizing IMS can be rolled out on any IP based network. This includes GPRS/UMTS/LTE, Wireless LAN (WLAN)/WiMAX, TV Cable systems, and Digital Subscriber Line (DSL).

In-vehicle systems need to support IMS to make use of IMS and in fact, IMS is widely supported in operation systems that will likely be the base for such systems. Even Smartphones, PDAs and laptops, that may be used to act as nomadic devices, support IMS. Some software integration effort will be necessary to make the ITS services IMS-ready and interconnect to IMS, but as ITS services have to be planned and rolled out in a coordinated way, this adaption will presumably be performed by the system integrator providing mobile ITS service platforms and the necessary back end systems.

The support of IMS in cellular networks is considered to be a major step forward towards merging cellular and Internet worlds into one all-IP network, where everyone and everything is continuously connected. A variety of players started to make mobile services available on ITS platforms and the Mobile Network Operators (MNOs) continuously enhance their systems to support those offerings. Supported and envisioned services cover the unlimited access to certain mobile services and portals - those operated by the MNOs and those operated by third parties, Machine-to-Machine (M2M) communication, fleet-management service, and field force mobilization solutions as a few examples.

IMS will replace and extend the existing signaling systems and provides a simple way to interconnect internet based services in UMTS and LTE. These services may profit from the security and billing capabilities offered. For ITS services, this presents a unique opportunity to speed up the roll out and allows making the services available to a huge customer base.

Given the will and opportunity that vehicle TSPs, suppliers, OEMs and MNOs cooperate on the introduction of ITS services, IMS will enable the parties to quickly and securely deliver personalized services to drivers and passengers on a large scale, with built in billing support to allow to collect transaction fees for mobile services. Vehicle manufacturers will be enabled to rollout mobile services in a controlled and predictable way and to ensure secure and high quality services right from the start by providing the maximum control of their services.

Premier role of IMS is to act as the glue between the various vehicle manufacturers In-vehicle systems, back-end systems, and the MNO. Security and safety as well as QoS will be handled by IMS.

2.3 CoCar Performance

Within the CoCar project, first, a variety of CoCar pilot applications were identified, described and their requirements specified. In a second step, the system architecture and different CoCar protocols were designed. Finally, these protocols were tested using a different kinds of road traffic and communication simulators, resulting in a detailed performance evaluation. This section summarizes the performance results and concludes the technical feasibility of the CoCar pilot applications with UMTS and LTE.

The CoCar performance study lists and analyzes the most demanding CoCar pilot applications in order to test their feasibility on cellular systems. For example, the pilot applications *Emergency Warning* and *Manoeuvring Assistance* are very time critical and demanding. The pilot applications *Special Vehicle Warning* and especially *Cellular Hazard Warning (CHW)* are moderately time critical but have to be distributed to a large number of vehicles in the proximity at the same time, which may temporarily increase the network load significantly. Because of their high performance demands on cellular networks, these applications are in the focus of the CoCar performance analysis.

Other CoCar pilot applications like *Floating Car Data Collection* or the status upload for *Freight Load and Unload* are neither very time critical nor creating a very large network load. Therefore, from a technology point of view, they are under all circumstances feasible with UMTS and LTE - some even with GPRS. The same applies for applications like *Traffic Information (push)* or *General Internet Services and Audio/Movie Streaming*. These are entertainment applications that today's mobile data networks like UMTS are designed for.

2.3.1 Application Performance with UMTS

The overall C2C transmission performance in UMTS depends on two main factors: the chosen data channel and the actual terminal state. Regarding the *chosen data channel*, UMTS offers various alternatives. Usually, user data is exchanged via dedicated or shared channels. Dedicated Channels (DCHs) were introduced with UMTS Release 99. Shared channels, such as the High Speed Downlink Shared Channel (HS-DSCH) for downlink and the E-DCH for uplink, were added with HSPA (Release 5 and 6). In addition, common channels like RACH and FACH, mostly used to exchange control information, are also capable to transmit small amounts of user data. Regarding the *actual terminal state*, certain transmission delays will occur if network connections have to be established before user data is being exchanged.

Dedicated and shared channels

Dedicated and shared channels achieve the lowest transmission delays but are optimized for the point-to-point exchange of large amounts of data. For example, HSPA offers an average C2C latency of about 100 ms for message of 80 byte size. However, terminals are typically using these channels only for continuous data transmission. If no data has been sent for a while, they fall back into a dormant or idle state to conserve battery power and radio resources. A transition back into a connected state can then take between 300 ms and 3 s. These transit delays have to be added to the C2C latency for both, uplink and downlink transmission. Thus, the overall transmission delay is too long for the mentioned time-critical applications and therefore only constantly connected terminals should be considered when using dedicated and shared channels. However, it must be noted that the network capacity is limited and that the scenario with constantly connected dedicated or shared channels is feasible for an introduction phase only and as long as other applications should be realized with the same UMTS network, too. More details can be found in the publication on 'Delay Performance of Safety Application in UMTS' [19].

Especially applications like *Manoeuvring Assistance*, with every car sending and receiving status updates every 100 ms on a low latency bearer, are a challenge for a cellular network. Because of the characteristic that sender and receiver are in the very vicinity of a few dozens meters only, such applications benefit from more specialized communication systems. One candidate technology might be direct C2C communication based on 802.11p.

Common channels

For applications like CHW, CoCar research results suggest the use of common channels. If vehicles stay connected using common channels to send and receive only small amounts of data, no transition or connection establishment is necessary. Furthermore, the vehicles do not constantly block radio resources as in the afore mentioned scenario.

Assuming a CHW message size of 80 byte, today's UMTS networks including an attached CoCar Reflector can accomplish average transmission delays in the range of 300 ms. If other parameterizations were chosen and more resources were granted for these channels, this delay could be reduced down to 100 ms. However, a disadvantage of this scenario is the fact that although common channels are used, they can only address a limited number of users at the same time. Up to a certain transmission density, messages have to be transmitted quasi sequentially and thus, the transmission delay increases with the number of users.

Consequently, any pure unicast scenario is feasible for smaller deployments only. A large deployment scenario, with almost all vehicles connected, is not feasible with today's UMTS networks, especially in dense traffic situations. In that case, broadcast mechanisms might leverage their full effects.

Broadcast mechanisms

A MBMS broadcast service is the most promising solution for CHW and similar applications, because all users within a cell or a given area will receive exactly the same information at the same time. Therefore all users can be served by a single broadcast message. In general, a broadcast message is more resource consuming than a single unicast message because it has to be configured to reach also users with a rather bad radio link. But if one broadcast message is sent instead of dozens of individual unicast messages, broadcast is way more efficient.

CoCar research results suggest to operate a non-stop MBMS session to avoid session setup delays and enable short transmission delays required for the warning service. In this scenario, it is assumed to use the common channel RACH for uplink transmissions. In this scenario, transmission delays between 400 ms and 1 s are expected.

Service implementation

In addition to the mobile network performance discussed above, the way services are implemented also influences the C2C performance (throughput and delay) of CoCar applications.

Figure 2.6 depicts one exemplary set of simulation results for a CC2CC service implementation based on the conceptual CoCar communication model as introduced in section 2.1, combining both, data reflection and data aggregation. Therefore, the simulator uses both, MBMS bearers (labeled multicast) or common channels (labeled unicast).

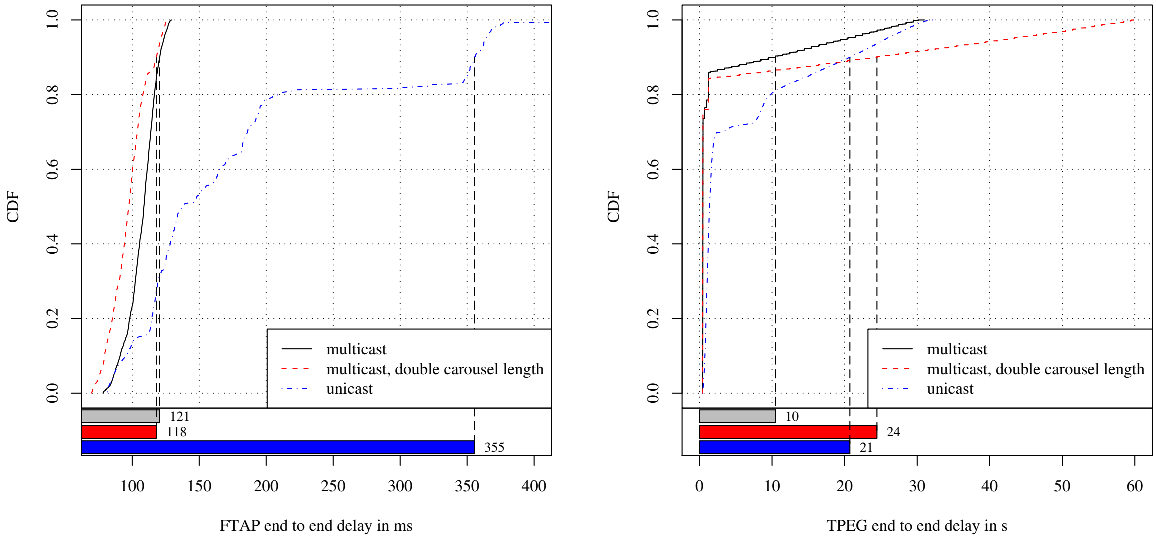
In case of *data reflection* in the vicinity of the hazard (here: same cell) the lightweight FTAP is used (see graphic (a)). In case of multicast simulation, quite fast MBMS channels accomplish the transmission in about 120 ms from vehicle to vehicle. The unicast solution based on common channels is much slower, since the simulation assumes a full deployment scenario and the message has to be distributed sequentially in the chosen simulation setup. This results in transmission delays of up to 400 ms.

Furthermore, the *Aggregator* sends out a regularly-updated TPEG stream (see graphic (b)). Thus, the hazard data is aggregated with other information and distributed in a much wider range. Because this information is assumed to be updated every 10 s in the exemplary simulation scenario, the delay is significantly larger than the transmission delay for the reflection via FTAP.

The target area for reflected and aggregated data as well as the update interval are system parameters that can be adjusted according to the application requirements. System parameters like quality of the broadcast channel can be adjusted to reduce transmission errors. Another parameter mentioned in Figure 2.6 is the carousel length, which can set to values that guarantee the repetition of data in case some user did not receive the first transmission properly.

Assuming more resource efficient MBMS parameters as shown in the simulation results, such as longer TTIs of 80 ms, lead to a reduced amount of base station power for MBMS, so that an average C2C transmission delay of not more than 500 ms is expected. This delay is considered adequate for CHW applications, in particular since all vehicles are able to receive the message at the same time, regardless of distance or penetration rates. For aggregated data, the transmission delay is additionally increased by the Aggregator processing time and method, the chosen update interval and the amount of data in the server queue as can be derived from the simulation example described above.

In addition to MBMS, Cell Broadcast Service (CBS) – a narrow-band broadcast system used in GSM mainly for SMS broadcast services – was investigated for a possible CoCar message



(a) vehicles in the same cell (b) vehicles in other cells

Figure 2.6: Time until a CHW message is received, depending on the system architecture

distribution. Although CBS is able to broadcast small amounts of data very efficiently, the delay constraints of time critical CoCar applications can not be met. Therefore, MBMS is the broadcast technology of choice to distribute both, time-critical warnings and other traffic related information that is of interest for a large group of users.

However, MBMS is not mandatory to introduce the CHW service. It is recommended to start CHW based on unicast bearers first and later to extend the system by using an MBMS broadcast bearer. This introduction procedure is feasible from technical and economical point of view and is able to cope the development cycles of vehicles by applying an introduction in three phases.

Figure 2.7 shows the concept of the proposed CHW introduction in three phases. Based on the expected penetration rate shown in the upper figure, the network load in the mobile cellular network would increase according to the blue curve. If only unicast bearers would be used, even if the penetration rate has reached a specific level, the network load raises accordingly (see dashed blue curve). In case a broadcast bearer will be used after phase 3, the network load can be reduced significantly. In order to use such an MBMS broadcast bearer, the MBMS capable vehicle client systems have been introduced beforehand (begin of phase 2). In phase 2 all vehicle client systems, unicast and broadcast systems, will use solely unicast. After MBMS has been activated, the MBMS capable clients switch to the broadcast bearer and the unicast clients keep using an unicast bearer.

2.3.2 Application Performance with LTE

As shown in the technology description in section 2.2, LTE data rates and system latency improved significantly from UMTS to HSPA. The requirements for Evolved UMTS Terrestrial Radio Access (E-UTRA) and Evolved UMTS Terrestrial Radio Access Network (E-UTRAN), which were defined in the starting phase of the LTE standardization, already give a good understanding of the performance that can be expected from the upcoming technology. [20]

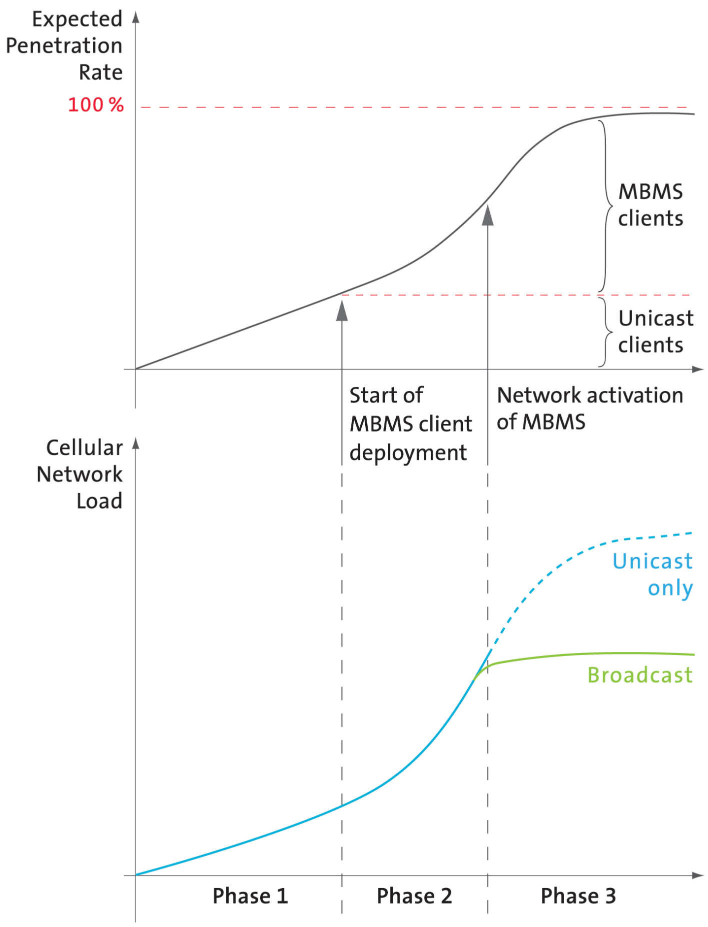


Figure 2.7: Three phases of CHW introduction by starting with unicast, introducing MBMS clients and activating MBMS

Data rates

Performance figures for LTE can be found in various publications. One example are the simulation results given in 'The 3G Long-Term Evolution – Radio Interface Concepts and Performance Evaluation'. [21] The results indicate that throughput requirements of at least 100 Mbit/s in downlink and 50 Mbit/s in uplink can be exceeded by the standardized technology for systems operating on a 20 MHz carrier. Furthermore, prototype measurement results from LTE test beds, e.g. in the 'Initial field performance measurements of LTE' [22], proof the feasibility of the system. The mentioned simulation and measurement results focus on realistic data rates for LTE, which are very important for improved application performance. However, to achieve short transmission delays for small warning messages, system latency and bearer setup times must be considered too.

Transmission delays

In case of CHW, the high data rates of LTE support the fast transmission of the small warning messages. Nevertheless, the system latency plays a major role for the overall CHW performance. One system requirement is a terminal-to-eNodeB RTT of less than 10 ms [20]. This value is needed to define LTE characteristics, but to define the overall C2C transmission delay, also the core network delays and the state transition delays have to be added. Furthermore and similar to UMTS, the transmission delay also depends on the state of the terminal. In LTE, the terminal can be either connected, idle or in a battery saving dormant state and the delays are reduced compared to UMTS.

For all given transmission delay expectations it should be noted that the final core network design has an impact on the delay performance and thus the individual network performance can vary.

For *connected terminals*, the CoCar performance study assumes an average C2C transmission delay of about 50 ms. Transmission delays of connected terminals can differ, depending on whether the terminal is e.g. kept synchronized or not.

The 3GPP contribution 'Delay analysis for idle to active transition' estimates 50 ms transition time for *idle terminals* for typical deployment scenarios, excluding a certain network specific interface delay and the terminal processing. [23] Therefore, the total transition delay from idle to connected state in future LTE networks should be achievable in about 100 ms for the sending terminal. The transition delay of the receiving terminal is a little longer, because it can only be reached in between sleep phases. Such phases can be between 50 and 200 ms. Assuming a paging interval of 100 ms, the C2C delay sums up to approximately 300 ms for terminals in idle state.

The third state is a the battery saving *dormant state*. This intermediate state saves battery from the connected state, but allows for faster transition to connected that from idle. With an assumed sleep interval of 50 ms, a C2C delay around 80 ms is expected, with the interval being a configurable network parameter.

Although the rough concept of terminal states is similar to UMTS, there are major differences between UMTS and LTE. One main difference is that the LTE concept does not include any common channels. In LTE, all user data transmission uses the Uplink- and Downlink-Synchronization Channel (SCH).

Capacity

The capacity requirements on LTE state that for VoIP "[...] at least 200 users per cell should be supported in the active state for spectrum allocations up to 5 MHz, and at least 400 users for higher spectrum allocations. A much higher number of users is expected to be supported in the dormant and camped state." [20] For CoCar applications like the CHW, these numbers can probably be exceeded significantly.

From a system design point of view, many users can be connected in parallel. The major system limitation will be the total amount of traffic in the network.

Broadcast

Although the number of constantly connected users in LTE is quite high, MBMS remains desirable for a resource efficient realization of applications where many users are interested in exactly the same information. Although MBMS is currently not defined for LTE Release 8, it is a 3GPP work item for LTE Release 9.

Vehicle speed

Another important requirement for C2C with LTE is that "E-UTRAN should support mobility across the cellular network and be optimized for low mobile speed from 0 to 15 km/h. Higher mobile speed between 15 and 120 km/h should be supported with high performance. Mobility across the cellular network shall be maintained at speeds from 120 km/h to 350 km/h (or even up to 500 km/h depending on the frequency band)." More about the dependency of data rate and velocity can be found in the above mentioned early prototype measurement results. [22]

2.3.3 Summary

To realize CHW with today's UMTS and HSPA networks, it is recommended to use common channels with an average transmission delay of 300 ms for a CHW introduction scenario. Dedicated and shared channels make sense for downloads and uploads or peer-to-peer applications exchanging larger amounts of data. For higher service penetration rates, i.e. a full deployment scenario, a resource efficient MBMS broadcast channel is recommended to distribute CHWs. MBMS is not rolled out yet, but is part of the GSM and UMTS standards family. With MBMS on UMTS an average transmission delay of 500 ms is expected.

The extreme requirements that applications like *Maneuvering Assistance* and *Emergency Braking* in the very vicinity put on UMTS cannot completely be met. As these applications have a very local focus, they are considered as typical applications for direct C2C communication based on 802.11p.

LTE is expected to support a large variety of CoCar applications – faster and with higher data rates than HSPA. With C2C transmission delays between 30 and 100 ms from connected and dormant state, some of the so far excluded time critical applications like the *Emergency Braking* in the very vicinity seem feasible.

However, if the high load created by *Maneuvering Assistance* applications can be realized with a reasonable amount of network resources, is for further study. A broadcast mechanism like MBMS will not be necessary for a CHW introduction phase, but might still be useful for high user densities also for LTE.

The CoCar feasibility study shows that many C2C applications and especially the CHW is feasible using cellular communication systems available today. From a cellular network technology perspective, the service introduction can start today. HSPA is already widely spread across Germany and Europe and offers sound system performance for the CHW in wide areas. Because GPRS – in many regions also upgraded to EDGE – offers almost full coverage, this technology can be used as fallback solution in case UMTS or HSPA is not available. Although the performance might be not as good as with UMTS/HSPA, it at least ensures full service coverage for an introduction scenario.

But time does not stand still. During the introduction phase, HSPA deployment will continue and LTE deployment will be established. This means that a few years after the CoCar service introduction, e.g. in 2016, the available cellular technology has been updated also, so LTE can be used in many areas.

Chapter 3

Commercial Feasibility

3.1 Service Identification and Description

Objective of this chapter is to identify, select and describe a specific CoCar service[1] that is of particular interest for this commercial research.

3.1.1 Service Identification

To identify the most suitable application for this commercial feasibility study, it is assumed that both, *safety improvement* and *CC2CC* are in the spotlight of the CoCar project. This kind of applications hold the highest level of innovation and obviously provide a high benefit, both for society in general and each individual. In contrast to a broad range of service center based applications, there hardly exist commercial studies for C2C services, dealing with value creation architectures, business models and business cases. The importance of such commercial considerations is undisputed for the successful introduction of new technologies. This results in a high research necessity especially for C2C services.

An important criteria for the choice of the research topic is its foreseeable suitability for cellular communication networks compared to alternative technologies like WAVE or Infrared or Dedicated Short Range Communication (DSRC). As previous performance results in chapter 2 have shown, applications like *Manoeuvring Assistance* will presumably be provided by WAVE, Infrared or DSRC more efficiently.

As a result of these considerations and after consulting all involved CoCar experts, **Cellular Hazard Warning (CHW)** has been chosen as the most suitable and valuable application to investigate within this commercial feasibility study. CoCar CHW is described in more detail in following subsection 3.1.2.

3.1.2 Functional Description of CoCar CHW

The functional set-up of safety-critical CoCar CHW is illustrated in Figure 3.1. In this exemplary set-up, a rear-end collision occurred on a single-lane rural road with two-way traffic. The preceding vehicle is signaling the warning-indicator-lights status to the succeeding vehicles that display this information and relative position on the in-car display. The cars are exchanging the

[1] The terms “service” and “services” in this report are used for products or applications targeted to a specific market segment and type of user. Therefore all identified CoCar applications can become services with their market introduction, too.

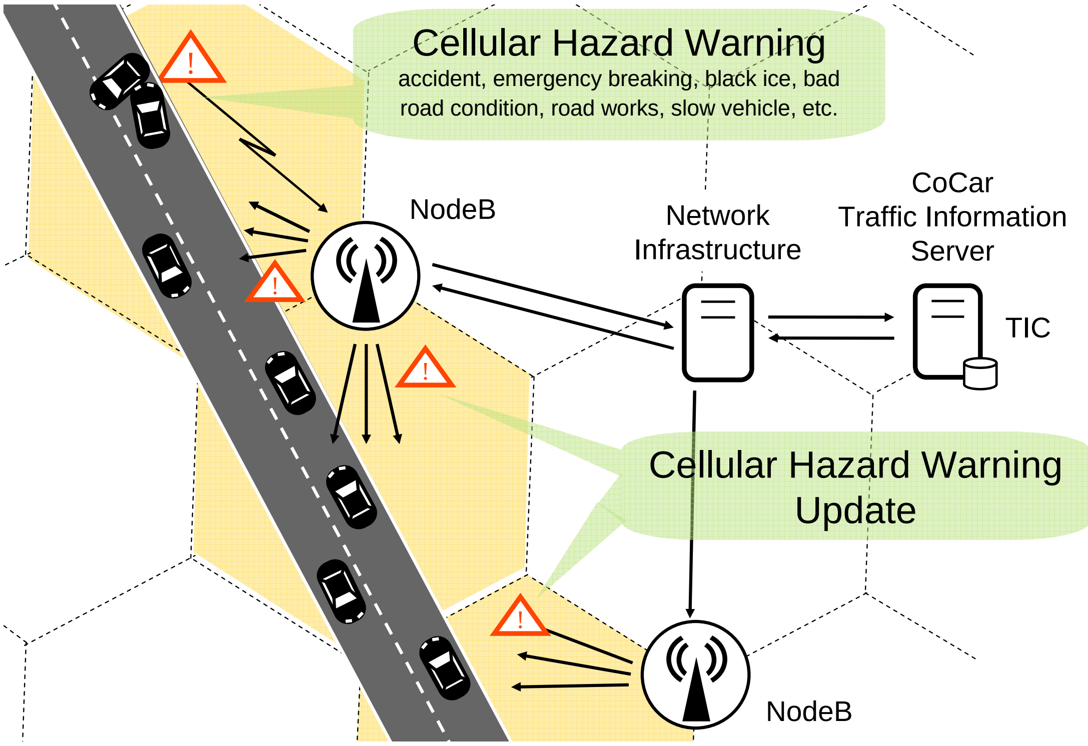


Figure 3.1: Functional-technical set-up of safety-critical CoCar CHW

information in high speed and with low latency using cellular communication system as a fast bearer to all cars traveling on the specific road in a predefined range around the accident. The commercial feasibility study assumes UMTS as communication system because it fulfills all requirements to realize CoCar CHW and is available already today.

The warnings are kept on the CoCar Information System for a predefined time and area, depending on the type of warning. Only drivers approaching the hazardous spot will get the warning displayed minimum 10 seconds before the driver reaches the hazardous spot. The system provides drivers with the opportunity to adapt the vehicle speed and inter-vehicle distance early, leading to a higher situational awareness of potential unforeseen danger. [24, p. 108] In other words, CoCar CHW will extend the telematics horizon.

CoCar CHW comprises a couple of safety-critical warning types, that are very similar in the technical set-up and content. They are all characterized by the commonness that vehicles automatically warn succeeding or preceding vehicles about safety-critical incidents in the traffic flow. *Vehicle-driven warnings* are characterized by the fact, that the vehicle's status itself requires a warning of other vehicles. Typical vehicle-driven warnings are:

- Warning-indicator lights
- Break-outs of vehicles (skidding)
- Emergency brake with a deceleration $> 0.5\,g$
- Airbag deployment and the release of other crash sensors

Environment-driven warnings are characterized by the fact, that hazards in the vehicles' environment require a warning to other vehicles. Typical environment-driven warnings are:

- Reduced friction caused by road conditions like black ice, aqua planning, oil film

- Low visibility due to weather conditions like fog, heavy rain, snow fall
- Obstacles, among them warnings about tail ends of traffic jams
- Wrong-way driving of the vehicle[2]

CoCar CHW depends on *direct network effects*. This means, that the benefit of the service for a single user increases with the number of users using the service. The number of users, again, corresponds with the equipment rate respectively the market penetration of the service.

In addition, CoCar CHW depends on the *critical mass phenomenon*: the core benefit of warning other vehicles reliably within a certain timeframe and with a certain probability, only exists, once a certain penetration is reached, like it is the case for many cooperative applications.[3] The necessary penetration rate for a proper functioning of CoCar CHW depends on a broad range of factors, among them:

- The requirements on the service, e.g.
  - Maximum RTT for a CHW to get transmitted from C2C
  - Minimum number of vehicles required to confirm the warning
  - Average probability a CHW is transmitted successfully
- Kind and length of road network
- Average speed on different kind of roads
- Traffic density
- Vehicle miles traveled

Previous studies analyzing Floating Car Data (FCD) and its extension XFCD, came to the conclusion, that the necessary penetration rates vary from around 2 % on highways at high traffic density to around 20 % on trunk roads or inner city roads at low traffic density. [26, p. 529] Other calculations in the field of direct C2C communication utilizing ad-hoc networks, take a necessary penetration rate of 10 % as a basis. [27, p. 5] Subject to further investigations, a necessary penetration rate of 10 % is conservatively taken as a basis for all further considerations within this report, too.

However, it has to be emphasized, that the just described phenomenon of necessary minimum penetration rates is even more critical in direct C2C communication that is generally enabled by ad-hoc networks. Unlike CC2CC, direct C2C communication additionally depends on network effects regarding the communication network. A comparatively high density of vehicles enabled with ad-hoc communication is required, before the communication between vehicles can take place at all and, as a result from that, a certain benefit is possible. In summary, the dependency on network effects is higher for direct C2C communication technologies like e.g. WAVE, than for wide range communication technologies like e.g. UMTS.

[2] BMW AG and OPEL AG are conducting research in safety applications that are able to warn drivers of wrong-way drivers. The wrong-way driving will be detected on-board of the wrong-way driving vehicle based on position and navigation data and be sent out to relevant cars via C2C and / or Car-to-Infrastructure (C2I) technologies. [25]

[3] Apart from the core benefit, any vehicle emitting CoCar CHWs can contribute to benefits from the very beginning, if the warnings will be forwarded over a CoCar interface to other traffic telematics services, that utilize the information within their dedicated channels.

3.1.3 CoCar CHW Customers, Needs and Benefits

This chapter analyses potential user groups, their specific needs and potential benefits from CoCar CHW in more detail. Potential CoCar CHW customers can roughly be grouped into the three main customer groups end customers (also referred to as *end clients*), Business-to-Business (B2B) customers and Business-to-Governmental (B2G) customers. The different customer groups and the specific benefits, CoCar CHW can provide to them, are illustrated in Figure 3.2.

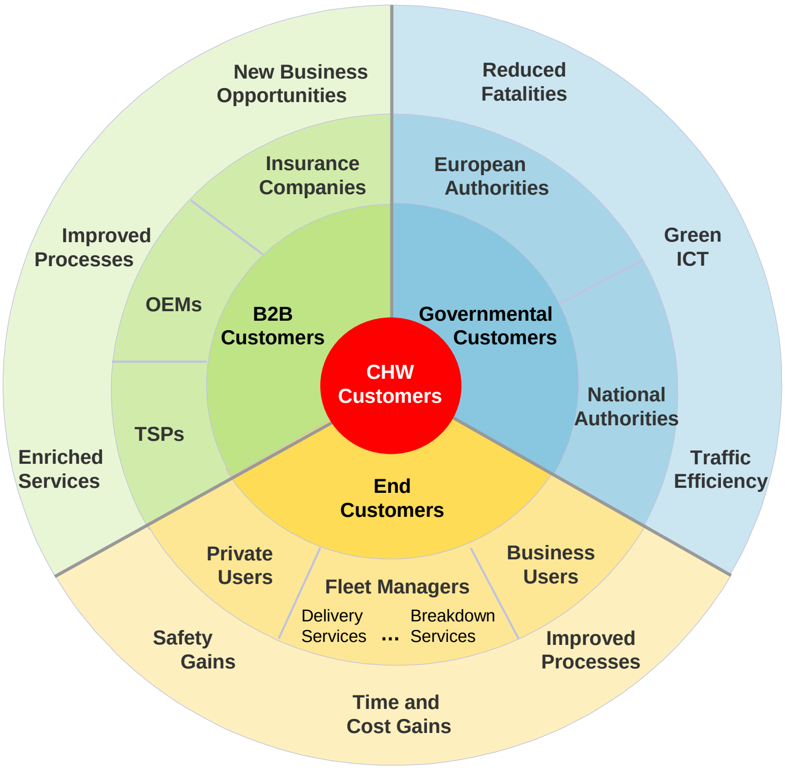


Figure 3.2: CoCar CHW customer groups and specific benefits

End Customers

End customers (end clients) of CoCar CHW are individuals using CoCar CHW in the vehicle while they are driving or supervisors, explicitly leveraging CoCar CHW at their drivers vehicles. According to their different needs, a distinction in (1) private users, (2) business users and (3) fleet managers is suitable. [27, p. 8]

(1) Several representative surveys among *private European drivers* indicate, that safety is the most important priority when buying a new car. [28, p. 13] [29, p. 13] Furthermore, a survey conducted by Cooperative Vehicle-Infrastructure Systems (CVIS) found out that “European drivers are willing to fit their cars with new systems if they imply a significant increase in safety; probably even if this means an increase of the car price, a concept that was considered as second priority among the drivers”. [29, p. 13] Regarding usefulness versus willingness to pay for obstacle warnings and road status report (which are comparable to the CoCar CHW service), the survey came to the following results:

- 75 % of all users assess obstacle warnings as very useful or quite useful and 44 % believe they are very worth or quite worth to pay for

- 71 % of all users assess road status reports as very useful or quite useful and 45 % believe they are very worth or quite worth to pay for [29, p. 15]

European drivers were also asked about the utility of possible information to be shown in their cars. More than 90 % of European drivers consider the information about a car travelling on the wrong side of the road (ghost driver) to be the most useful (very dangerous situation), followed by a “5 kilometres accident ahead warning message” and the status information about current traffic flow (see Figure 3.3). [29, p. 22] These kind of information are also typical for CoCar CHWs aiming at the prevention and avoidance of accidents due to unexpected conditions on the road ahead as CoCar CHWs extend the telematics horizon.

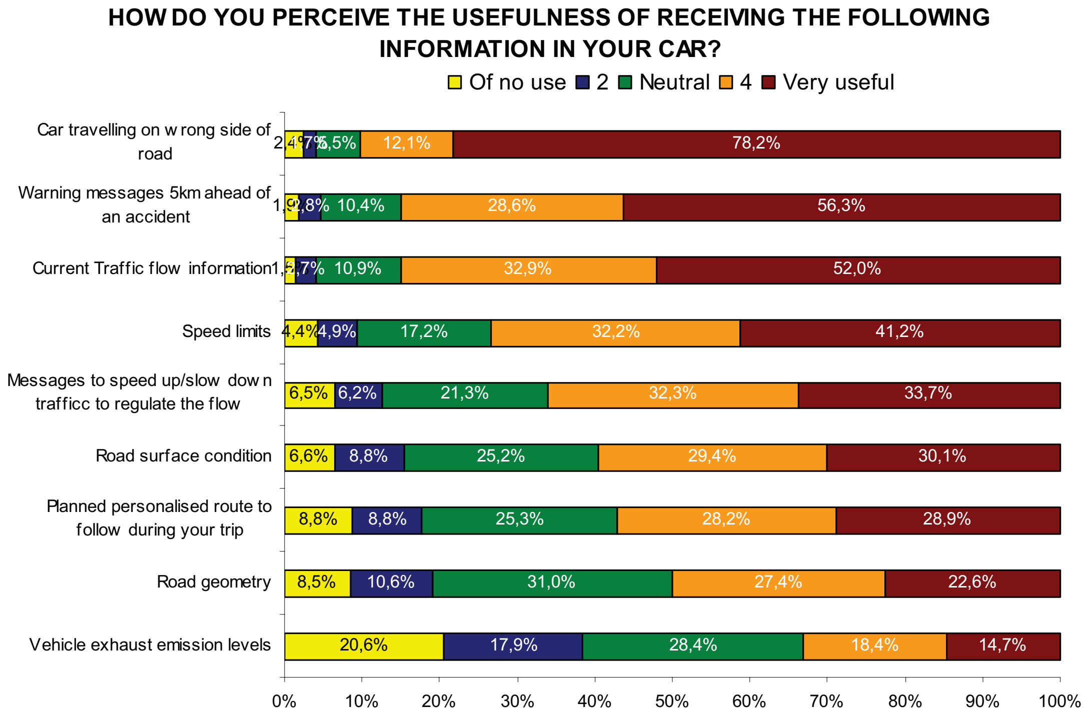


Figure 3.3: Usefulness of different kind of information received in the car [29, p. 13]

(2) *Business users* drive the car for professional reasons, without driving being the commercial task. Business users are generally preferred early adopters, as they have a high willingness to invest in new technologies, if these technologies bring advantages for the work progress, help to save money and outperform other technical alternatives.

CoCar CHW might be of superior interest for business users. Due to their over proportional driving performance and the company-induced journeys, driving safety and efficiency are of special importance. Avoided accidents and faster travel times have direct impacts on work process times, efficiency and costs. Therefore the willingness to pay for CoCar CHW functionality can be assumed as high in this user group.

(3) For *fleet managers* the vehicles themselves are the main source of income. A comparably small share of vehicles of about 5 % generate a large share of traffic (roughly 15 %) with each vehicle driving a multiple of privately owned cars. Therefore fleet managers have a high interest in everything that improves the business. They will invest rationally according to the anticipated process savings or improved business opportunities. For them, CoCar CHW can provide the highest value in terms of saved costs or induced additional revenues. Six fleet-operation businesses with different preferences are considered:

- Delivery services
- Transport companies
- Car rental companies
- Taxi services
- Breakdown services
- Emergency services

In summary, the benefit of CoCar CHW can be assessed as high from an individual point of view, as the driving safety is increased for particular safety-critical situations. Especially vehicle-driven warnings are of high value for both, the CoCar CHWs emitting drivers (e.g. drivers of crashed cars or standing cars at the end of traffic jams) and the CoCar CHWs receiving drivers, as both parties profit from preventing a collision. Once the critical mass has been reached, the benefit of the service is perceived regular and often by the drivers what is an important success factor for innovations in general and vehicle telematics services in special. [30, p. 33]

However, there also exist a couple of critical aspects that can be described as possible non-monetary costs of the service. Such individual perceived costs may comprise the fear or even the frustration about:

- miss-warnings (e.g. because the CoCar CHW system in another vehicle has generated false information)
- the overall system reliability (quality of generated warnings and all-clears in the background system)
- warning overload and
- data security and privacy aspects.

Among those perceived non-monetary costs of the service, the *data privacy* is of special importance. Asked about the kind of information European drivers would accept to be sent from their car, users accept mainly to send information about their warning lights or their position data (64 % and 54 % of respondents, respectively). Their availability to give information about their habits and preferences has the lowest percentages. These survey results indicate that the acceptance of CoCar CHW will be comparably high, as no habits and preferences related data will be exchanged. In contrary, the most important data to exchange will be emergency and crash sensor data in combination with position information.

B2B Customers

Besides end customers, B2B customers are a second focus group and important refinancing source of CoCar CHW. In contrast to end customers the B2B customers do not use the CoCar CHW service themselves for the optimization of their own journeys or the management of their fleets. Instead, B2B customers exploit CoCar CHW generated data to enrich other vehicle telematics services or to improve their business processes. They pay certain license fees to CoCar CHW service providers for the rights to exploit CoCar generated data for specific services.

The benefit of telematics services like traffic information or dynamic route navigation, highly depends on precise and up-to-date traffic data. Current traffic information services like RDS-TMC and RDS-TMCpro still suffer from delayed warnings and all-clears. CoCar CHW generated data could be a complementary source of information and improve other traffic information services of Telematics Service Providers (TSPs) that are not part of the CoCar value creation system.

Correspondingly, also Original Equipment Manufacturers (OEMs) that are not part of the CoCar value creation system, could buy CoCar CHW generated data to enrich own services or improve business processes. E.g. OEMs could offer improved traffic information or dynamic route navigation on their own behalf only to own customers for differentiation purposes. Brand and vehicle type centric analyses of warnings and accident statistics could allow for more efficient new product development and more effective utilization of safety margins. Other possible services for OEMs result from the possible exploitation of the wireless link to the vehicle in general:

- The possibility to remotely analyze and fix vehicle software failures reduces customer irritation and helps to avoid costly dealer interventions.
- The warranty and liability management can be improved, as problems can be noticed earlier and alternative ways to contact the customers exist.
- The car is more reliable, because actual and future problems can be predicted and taken care off better. The vehicle might therefore sell at a better price. [27, p. 14]
- Customer Relationship Management (CRM) helps the OEMs to stay in contact with his customers during the entire lifetime of the car.
- OEMs can offer their customers new cars early on and according to their customer behaviour.

Finally, insurance companies might be highly interested in offering their customers more individual insurance propositions. Therefore they rely on more valid and reliable data about their customers individual insurance risks. These data could be partially provided by the CoCar CHW service providers, knowing that data privacy and data security are extremely important issues in this context.

B2G Customers

Besides end customers and B2B customers, governmental customers like European and national bodies, may benefit from CoCar CHW. In especially, CoCar CHW can help to reach ambitious traffic related goals like halving the number of fatalities from around 50,000 to around 25,000 in the period of 2001 until 2010. The European Commission just announced a new action plan for the deployment of ITS in Europe. Among others, the Commission proposed the "promotion of deployment of advanced driver assistance systems and safety and security related ITS systems, including their installation in new vehicles (via type approval) and, if relevant, their retrofitting in used ones" as well as the "definition of specifications for Infrastructure-to-Infrastructure, Vehicle-to-Infrastructure and Vehicle-to-Vehicle communication in cooperative systems".[4] [31, p. 7 ff.] According to telematics experts, the German government is planning to establish a traffic data exchange platform (metadata platform) in order to allow and ease the data exchange for all market participants.

[4] See more details in Table 3.1.5

3.1.4 Socio-economic Benefits of CoCar CHW

It is crucial to know for the investment and subvention decisions of public authorities, whether the expected benefits of a service respectively a system will at least excel the expected costs. Also, it is very important to be aware of the socio-economic impact of different investment alternatives to be able to guarantee that limited resources flow to projects that promise the highest benefits.

CoCar CHW Safety Impacts

This section mainly refers to the research results from the most current socio-economic assessment project *eImpact*.[24] Among others, eImpact has estimated the potential safety effects of different Intelligent Vehicle Safety Systems (IVSSs) if all vehicles would be equipped with the particular system. The following Wireless Local Danger Warning (WLD) safety effects at a 100 % penetration rate can be expected for Europe based on the 2020 accidents projection of 20,791 fatalities and 873,695 injuries:

- 4.5 % decrease of fatalities, resulting in a total decrease of 936
- 2.8 % decrease in injuries, resulting in a total decrease of 24,463

Based on that assumptions, the CoCar CHW safety impacts for Germany at a 100 % penetration rate can be estimated at the following:

- Decrease of fatalities in total: 187
- Decrease of injuries in total: 4,893

The safety benefit of CoCar CHW can be estimated for Germany in 2023, when the system is nearly fully rolled out, as follows:[5]

Table 3.1: Estimated safety benefit of CoCar CHW in 2023

Category	**Safety benefit**
Fatalities	288 million €
Heavy injured	142 million €
Slightly injured	19 million €
Safety impacts, total	449 million €

In total, the safety benefit of CoCar CHW can be estimated at nearly half a billion € per year for Germany in 2023 alone.[6]

[5] The German Federal Highway Research Institute *Bundesanstalt für Straßenwesen* (BASt) set the socio-economic costs of fatalities at 1,161,885 €, heavy injured at 87,269 € and slightly injured at 3,885 € in 2004. [32, p. 32] From experience, the ratio of heavy injured persons to all injured is about 25 %. A yearly impact assessment increase rate of 3 % is assumed.

[6] This even seems to be a rather conservative assessment from other projects' perspective: NOW claims that with C2C communication about half of the approximate 450,000 accidents that happened in Germany in 2002 would have been significantly reduced. With a macro economic loss of 34 billion € due to traffic accidents in 1998, an actual

CoCar CHW Traffic Impacts

The impact of IVSSs go beyond the effects on road safety. Other effects, e. g. the reliability of arrival times, environmental aspects (greening of transport) or driver convenience, may also occur and they are also relevant when deciding on the implementation of IVSSs.

Based on a penetration rate of 93 % – as it is assumed for cellular based CoCar CHW in 2023 – the indirect traffic effects of avoided accidents are roughly estimated at approximately 200 million € for Europe and 50 million € for Germany.

CoCar CHW Benefit Cost Ratio

Within a cost benefit analysis, eImpact compared the IVSSs' benefits with the costs of the systems. The system costs comprise the costs of vehicle equipment, infrastructure equipment, operating and maintenance costs. [24, p. 34]

For WLD, eImpact estimates a European Benefit Cost Ratio (BCR) of 1.6 and 2.6[7] for the year 2020 high rollout scenario at a comparably low penetration rate of 8 %. [24, p. 37] This implies that even in this "conservative scenario" every spent € leads to societal benefit of 1.6 and 2.6 €. The BCR of the CoCar CHW scenario is assumed to be significantly higher for two reasons: firstly, the benefits will be higher due to higher penetration rates and the maturity of the system; secondly, the systems costs will be lower due to the utilization of an already existing CC2CC infrastructure compared to the huge investment needs of a still to build WAVE-based infrastructure. For these reasons, **the CoCar CHW BCR is carefully estimated at a factor of 2** based on a decreased number of accidents in 2020.[8]

Regarding the more specific *BCR of safety impacts and state-run subventions* it is assumed that national authorities subsidize the necessary CoCar CHW in-vehicle equipment with 40 € per newly equipped vehicle within the first two years before service operations and the first year of service operations. Additionally it is assumed that national authorities subsidize a quarter of the educational advertisement campaigns of yearly 5 million € for three years. In total, the *state-run subventions* add up to 231 million € within the first four years what represents a discounted amount of 224 million € state-run subventions at a yearly discount rate of 3 %. On the other side, *the socio-economic benefits* add up to a total of more than 2.3 billion€ at a yearly discount rate of 3 % within the 10 years of service operations. Based on a time period of 12 years (covering two additional years of system integration), the **CoCar CHW BCR of safety impacts and state-run subventions adds up to a factor of 10.38** for Germany.

In summary, it can be concluded that CoCar CHW will clearly contribute to socio-economic goals with significant safety and traffic impacts that result in a monetary benefit of nearly half a billion € per year in Germany in its fully rolled out version. The BCR is conservatively estimated

avoidance of just 10 % of these accidents would have resulted in a reduced loss of 3.4 billion € [27, p. 4]. The BMW AG funded study *Direkte Information und Warnung für Autofahrer (DIWA)* draws comparable results. The ratio of accidents that could have been avoided with an improved information and warning service for drivers, is estimated at 14 % of all accidents. This high estimation is all the more remarkable as the DIWA system incorporates only warnings that are emitted by the police. The DIWA study points out that the safety impact could be even improved, if driver and vehicle generated data could also be utilized in the future. [32, p. 46-50]

[7] The two values depend on the chosen accident base: the value 1.6 is based on decreased number of accidents in 2020, the value 2.6 is based on an accident base that is fixed in 2010.

[8] Nevertheless, this CHW BCR remains a rough estimation, that requires further research efforts. This research should take the specific characteristics of CoCar CHW into account. Also, the entire range of impacts that result from a working vehicle telematics market model, should be assessed. Besides safety and traffic impacts this a.o. comprises employment and environmental effects, tax incomes, future innovation capabilities and the improved competitiveness of the EU member states.

at 2 for the total system benefits and costs, respectively 10.38 for the ratio of safety impacts and state-run subventions. This implies that every spent € will lead to societal benefits of 2 € respectively of more than 10 €, if only the state-run subventions are considered as costs.

3.1.5 CoCar CHW Market Environment

Goal of this chapter is to describe, uncover and understand the main forces within the market environment of the potential CoCar CHW service providers.

Vehicle Telematics Market Developments in Retrospect

In the late 90s the telematics hype has risen the first time. During this period several technical solutions were developed to reduce traffic congestion while simultaneously increasing traffic safety. Much hope was put on telematics systems to offer new services and to create new markets for the automotive and the service industry. But most of these business models failed.[9]

In the following, research activities concentrated on decentral organized C2C solutions via *short range communication*. First results were promising even though roll out strategies are still missing, which is mainly caused by the network effect of cooperative applications.[10] So short range communication alone will not help to realize popular applications for the customers needs. In the meantime cellular communication technology obviously advanced. Most of the constraints, telematics services suffered from in former times, are now eliminated. The following table juxtaposes the telematics services' constraints in the late 90s with the opportunities of C2C technology available today.

Table 3.2: Telematics services: constraints of the late 90s and opportunities of today

Constraints of telematics services in the late 90s	**Opportunities of telematics services today**
low data rate (GSM at 9.6 kbps) ⇒ only two services viable	high data rate (UMTS at 384 kbps to 7.2 Mbps, with emerging communication technologies as HSPA+ and LTE even more) ⇒ infotainment services ⇒ attractive service portfolios ⇒ benefit for the first user

continued on next page

[9] In the USA, the customer is much more service oriented than in other regions, which made it possible for some telematics services to survive up till now. In Europe only services for highly priced cars were economically viable. In Japan some telematics services survived because of the customers' affinity to new technology on the one hand and governmental investigations on the other hand.

[10] Cooperative application generally need other users to have this application implemented. With short range communication like e.g. WLAN, the dependency on such network effects is much higher than with wide range communication technologies like e.g. UMTS. This is due to the fact that the equipment rate of cars needs to be much higher in case of e.g. WLAN in order to find another car to communicate with.

continued from previous page

no common communication standards for mobile phones and vehicles ⇒ outdated in-car communication technology	well-established wireless communication standards like e.g. Bluetooth ⇒ updatability of in-car communication equipment ⇒ fast market penetration achievable
network effect of cooperative applications	network effect avoidable due to attractive service bundles to push the technology platform for cooperative applications
mobile phone as a status symbol	mobile phone as a commodity
high SMS charges	low budget price plans even for high data volume
prioritization of speech	focusing on data communication
no transmission guarantee for SMS	high reliable message exchange possible
business model does not match the customers needs	flexible business models possible, which can be adapted to changing markets

In summary, the former business models did not match the users' requirements in any way. Traffic information with poor quality at high costs for communication was not acceptable for the customer. It could also be observed that the customer is not willing to pay that much for any kind of safety applications like e.g. the eCall. The new situation with broadband UMTS for a plenty of applications ranging from infotainment to traffic efficiency and safety allows flexible business models, which can be adapted to changing markets.

Political and Legal Environment

The European Commission proposed the ambitious goal of halving the number of traffic fatalities from approx. 50,000 to 25,000 in the period of 2001 until 2010 in its White Paper *European transport policy for 2010: time to decide*. [33, p. 66] This target has meanwhile been endorsed by the European Parliament and all member states. [34, p. 2]

On 16 December 2008, the European Commission published an *Action Plan for the Deployment of Intelligent Transport Systems in Europe*. The action plan suggests a number of targeted measures and a proposal for a Directive [35] laying out a framework for their implementation. The action plan aims to accelerate and coordinate the deployment of ITS in road transport, including interfaces with other transport modes. [31, p. 3] In particular, the plan is to avoid the emergence of a patchwork of ITS applications and services.

Economical Environment

In the first quarter of 2009, the automotive industry faces an exceptional rough economical environment. Triggered by the global financial crisis, the demand for new cars has dramatically decreased between 20 % to 50 % compared to the preceding year worldwide. Beside OEMs automotive suppliers suffer particularly from the crisis and some have seen forced to file for bankruptcy. Regarding the development of new telematics services, it can be assumed that the crisis leads to increased, anti-cyclical investments by some OEMs and suppliers as well as decreased spendings by others. It is assumed, that players currently shaping the market will continue their strategy and assess new telematics services as an important differentiation factor for the future's business.

The long-term future prospects for the vehicle telematics market remain optimistic, despite disappointing experiences around the millennium and the current automotive crisis. It is a common opinion among experts that within a couple of years any vehicle will contain at least one telematics system that again will provide one or more telematics applications. Therefore the market potential for Europe comprises all of approximately 250 million vehicles.

On the other hand experts rather disagree in the question, when vehicle telematics will become a mass market and what is driving its development. For this report it is assumed, that a strong demand for aftermarket vehicle navigation and tracking solutions will drive the growth in the short term. Medium term, the anticipated introduction of eCall will have a massive impact on the OEM segment, starting in early 2010. [36, p. 32] It is assumed that in 2011 or 2012 eCall will be integrated in all new cars based on industry-wide voluntary agreements (forced by politics). CoCar CHW specific market forecasts are given in section 3.3 and section 3.4.

Competitive Environment (Market Structure)

Compared to other markets the vehicle telematics market structure is notably complex. The market comprises company clusters from different industries with various dependencies. Figure 3.4 depicts the most important relationships between the relevant company clusters.

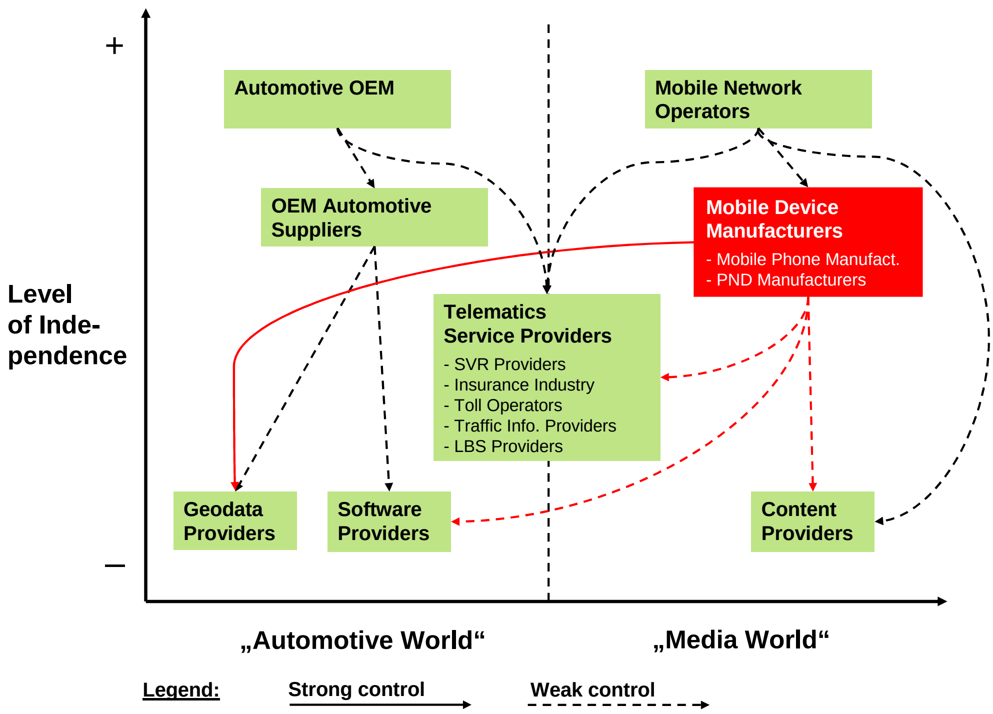


Figure 3.4: Telematics players and dependencies following [37, p. 33]

Traditionally, and enabled by the lack of standards, OEMs still control directly or indirectly large parts of the automotive value chain. But compared to the situation around the turn of the millennium the OEMs' control is constantly decreasing.

In relation to their suppliers the OEMs' position has been weakened in the same amount as the suppliers have been taken over (or were forced to take over) more and more parts of the value chain. Suppliers have even spent twice as much on Research and Development (RnD) as OEMs in the past years. The OEMs' control over the value chain is undermined from a second development, too. Independent mobile device manufacturers, such as mobile phone manufacturers and Personal Navigation Device (PND) manufacturers have strengthened their part by acquiring market leaders in the geodata/map and service provider segment.[11]

On the other hand, the OEMs' relations to independent MNOs is more counterbalanced nowadays compared to the situation around the turn of the millennium.[37, p. 33] MNOs have recognized the strategic relevance of the Machine-to-Machine (M2M) business in general and vehicle telematics in special. All bigger MNOs are meanwhile offering tailor-made solutions to their customers from the automotive industry.

3.2 CoCar CHW Value Creation and Business Models

CoCar services in general and CoCar CHW in particular are complex to develop and to deliver, as they require multi-functional skills. Specialized knowledge from at least four major industries is required: automotive, communication hardware, communication software and mobile communications. It is assumed, that none of these industries can develop and deliver CoCar CHW alone.

Moreover, all further considerations are based on the assumption that there will be no lawful obligatory introduction of C2C communication in general and CoCar CHW in special. This mainly depends on the necessity that the effectiveness of technologies and services has to be proven first, before a regulative solution can be considered. [12]

Objective of this chapter is to develop and to discuss promising value configuration models for CoCar CHW services. In especially, the challenges of *balancing costs and benefits* and *creating synergies in value creation* will be addressed. Thereby a special attention is paid to possible value creation architectures, as they represent footprints of working market models for the future. The challenge will be to design architectures that comprise all necessary capabilities of interdependent, specialized companies from the industries mentioned above that are able willing to contribute to the overall CHW value proposition. Obviously this requires competitors able and willing to cooperate while keeping some level of competition alive ("coopetition").

In preparation for the value creation architectures the stakeholders of CoCar CHW will be analyzed in a first step.

[11] E.g. Nokia acquired digital map provider Navteq and the German traffic information provider T-Traffic. TomTom acquired Navteq's most challenging competitor Teleatlas.

[12] In this context, Matheus points out that "in case of technologies without network effects (like e.g. safety belts) this might be achieved by crash tests and the limited introduction in the field. But in case of C2C communication, a certain penetration in the field is required before the effects can be unambiguously shown. Hence, it cannot be expected that a regulative order on the basis of expected safety and traffic flow improvements is issued before the penetration is reached".[27, p. 4]

3.2.1 Stakeholder Analysis

Following table shows the different stakeholders along with their most important interests and capabilities.[13]

Table 3.3: CoCar stakeholder analysis: Potential Customers

Stakeholder	Interests	Capabilities
End Customers	Safety gain, CHW could become a "must-have" service Complete information Anticipatory driving Risk minimization Data security and privacy	Demand Willingness to pay
Logistic Companies	Fleet optimization	High traffic telematics affinity
TSPs	Market entry in new business areas Improvement of existing offerings by CoCar generated traffic data Customer gains	End client insights Existing sales structures Independence Flexibility Source of direct and indirect revenues
Emergency Service Providers	Fast and precise information	Lobbying
Navigation Service Provider	Selling of services	Expertise in developing, providing and selling traffic related services
Insurances	Minimization of accidents New insurance offerings Individual contracts (PAYD) Reduction and better assessment of insurance risks	Data security Insurance of professional parties in case of claims Insurance mathematics
National Authorities *(In detail analyzed below)*	Minimization of accidents, fatalities and injuries Reduction of traffic jams Immediate protection of scenes of accidents Optimized traffic flow (throughput per hour) Optimization of socio-economic benefit Fast market launch	Regulation Ability to enforce rules Supporting of market participants in cooperative behaviour Data security Ability to initiate voluntary agreements of automotive industry

[13] The CoCar CHW stakeholders have been identified in the CoCar business workshops and as a result of the two questionnaires. The workshop results have been revised and grouped by the authors.

Table 3.4: CoCar stakeholder analysis: Automotive Industry

Stakeholder	Interests	Capabilities
OEMs	Optimal information for customers OEM accident research Avoidance of multi-vehicle accidents Improvement of safety Improved image Brand individual appearance Differentiation potentials Added value for customers Additional revenue streams	Standardization Research and development Lobbying Market introduction Best knowledge of end user demand Service provisioning Human Machine Interface (HMI) Customization Access to sensors and CAN-Bus
OEM Suppliers	Selling of system components and terminal equipment Differentiation from competitors	Vehicle technology Development and production of On-Board-Units (OBU) Further developments of OBUs for additional services Ability to propose, drive and offer standard solutions for all OEM
Automobile Associations	Providing safety information (new services) Differentiation potentials New business areas	Medial effects Lobbying Additional contracts with automotive end clients covering insurances, breakdown services, . . .) Flexibility Customer insight
Workshops	Additional business with CoCar CHW and related services (ADAS, e-Call, . . .)	Vehicle expertise Customer contact

Table 3.5: CoCar stakeholder analysis: Telecommunications Industry

Stakeholder	Interests	Capabilities
Mobile Network Suppliers (MNSs)	Selling of components, technologies and hosting services	Development and production of network components Ability to propose, drive and offer standard solutions for all MNOs Technical operation of networks and services

continued on next page

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MNOs	Additional business Higher market shares	Infrastructure Billing Authentification and privacy
Mobile Phone Manufacturers	Additional business Higher market shares	Development and production of mobile phones
PND Manufacturers	Additional business Higher market shares	Development and production of PND Expertise in selling services in addition to hardware

Table 3.6: CoCar stakeholder analysis: National Authorities

Stakeholder	**Interests**	**Capabilities**
European Commission and Parliament	Fast market launch Impact of safety relevant services	Supporting of market participants in cooperative behaviour
Legislation	Minimization of accidents, fatalities and injured Avoidance of traffic jams	Data security Regulation Ability to initiate voluntary agreements of automotive industry
Police	Fast protection of scenes of accidents	Ability to enforce rules
Traffic Management Centres	Throughput per hour Road network management	Variable message signs Traffic shaping
Traffic and Infrastructure Authorities	Accidents avoidance Socio-economic benefit Combination with tolling for passenger cars and lorries Optimized traffic flow	Legislation Building infrastructure resp. commissioning it

Business workshop and questionnaire participants have also been asked who of the identified stakeholders will most likely (a) hold the end client contact, (b) coordinate the value creation partners and (c) is able and willing to take financial risks. Following table shows the slightly revised results of the expert voting, whereas each expert had one choice for (a), (b) and (c) respectively.

Table 3.7: CoCar stakeholder assessment

Stakeholder	End client contact	Coordination of market partners	Taking financial risks
Original Equipment Manufacturer (OEM)	11	7	3
Automotive Associations	3	-	-
Telematics Service Provider	4	7	7
MNS	-	1	2
MNO	1	2	3
Legislation	-	1	3
Traffic Authorities	-	2	1
Insurances	2	-	-

From the experts' point of view the end client contact should be hold by the OEMs. Optionally, automotive associations and TSPs are also able to hold end client contacts. Regarding the coordination of market partners, both, OEMs and TSPs, seem to be realistic options according to the experts. TSPs also are the preferred actor to take financial risks, followed in equal shares by OEMs, MNOs and legislation.

3.2.2 Value Creation Analysis and Description

On its highest aggregation level, the value creation steps for safety-critical CHW can be illustrated as shown in Figure 3.5.

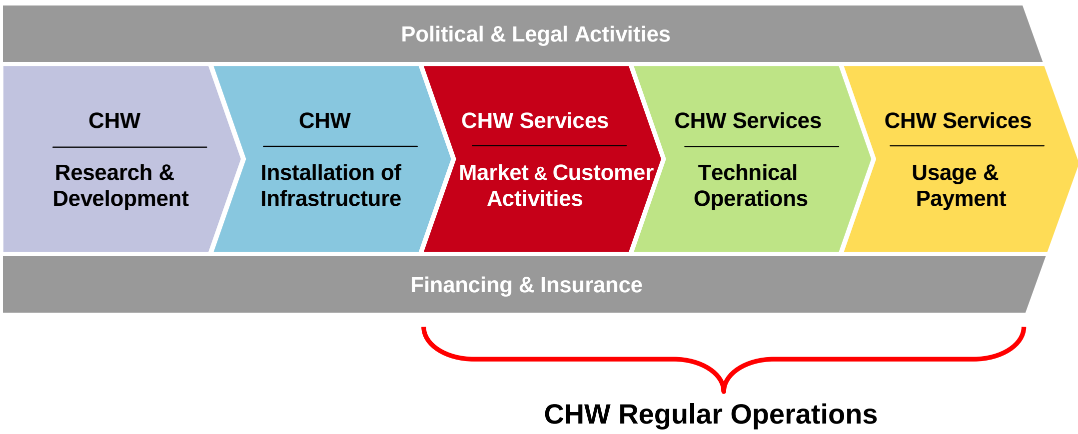

Figure 3.5: Generic CoCar CHW value creation chain

The single steps are described briefly in the following:

1. Research and development

   The first value creation step comprises all basic research and development activities, field tests of prototypes under real conditions, evaluations and final service configurations. The CoCar project already covers some essential areas of basic research and prototype development. The cross-company cooperation within the CoCar project underlines the increasing importance of cooperative value creation networks, especially in research and development.

2. Infrastructure installation

   Based on the research and development results, both, vehicles and mobile networks have to be altered respectively set up (system integration). On the vehicle side, CoCar CHW functionality has to be implemented by connecting

   (a) certain vehicle sensors with
   (b) a mobile communication interface,
   (c) a HMI and
   (d) a specific CHW intelligence that is able to control and interpret outgoing information and incoming warnings and all-clears.

   On the network side, the main focus is on

   (a) the area-wide coverage of mobile networks (geografical footprint)
   (b) the integration of newly developed communication protocols and
   (c) the integration of CoCar Information Systems, Data Reflectors and service aggregators into the network architecture.

   Finally, this value creation step also comprises the ongoing maintenance of vehicle and network infrastructures, among those extension and replacement investments as well as repairs.

3. Market and customer related activities

   Market and customer related activities comprise all marketing and sales relevant tasks of product configuration, communications, sales and distribution as well as customer relationship management and billing. This value creation step is analyzed in more detail in the following chapters because of its special importance for the operations of CoCar CHW.

4. Technical operations

   The technical operations of CoCar CHW services comprises all technical-operative activities that effect the operation of the CoCar CHW vehicle system and the CoCar background system to enable the generation and the reception of CoCar CHW. This value creation step is also analyzed in more detail in the following chapters because of its special importance for the operations of CoCar CHW.

5. Usage and payment

   End clients will use CoCar CHW, if the relative perceived benefits exceed the relative perceived costs. They compensate for this emerged value in form of direct or indirect payments. In addition to the end clients also business and governmental customers can derive data that have been created in the CoCar CHW environment, exploit them for their own purposes and compensate for them also directly or indirectly.

The further analysis of the CoCar CHW value creation steps focuses on the regular operations, namely the market and customer related activities and the technical operations of CoCar CHW services.[14]

[14] Experts emphasize that it is important to analyze these areas separately. One reason is the possibility to call for independent tenders in practice.

3.2.3 Integrated Value Creation Chain of Regular Operations

The following integrated CoCar CHW value chain combines the high-aggregated steps of market and customer related activities and the activities of the technical operations in the first, numerated row. The second row lists some important exemplary activities. Third and fourth row show – exemplary and not complete – a collection of potential companies, that could provide the activities on the different steps.

Value Creation Steps	1 CHW Marketing	2 CHW Sales	3 CHW Client Services	4 CHW Generation	5 CHW Techn. Operation	6 CHW Transmission	7 CHW Usage
Tasks	▪ Product & price policy ▪ Communication - Campaigns - Advertising - Public relations	▪ Sales support ▪ Personal and electronic consulting and sales	▪ Ongoing client communication ▪ Contract management ▪ Lifecycle-Managment ▪ Invoicing ▪ Collection	▪ Integration CHW HW & SW -------------------- ▪ Merging & interpretation of vehicle sensors ▪ Sending of CHW via Comm.-Module	▪ Validity check / Filtering ▪ Pre-packaging -------------------- ▪ Generation of CHW and all-clear ▪ Monitoring ▪ Playout	▪ Forwarding of CHW to operator ▪ Forwarding of CHW and all-clear to vehicle and B2B clients	▪ Usage of CHW & all-clear in vehicle ▪ Exploitation of CHW data for premium services ▪ Usage of CHW for premium reductions
Possible Actors	▪ Business Owner + Value Creation Partners ▪ EU / National Authorities	▪ OEM - OEM Retailer - Indep. Retailer ▪ MSP ▪ Automobile Association ▪ PND Manufact.	▪ OEM - OEM Retailer - Indep. Retailer ▪ MSP ▪ Automobile Association ▪ PND Manufact.	▪ OEM + Supplier ▪ PND Manufact.	▪ TSP ▪ IT Service Provider ▪ MNO ▪ Joint Venture	▪ MNO	▪ End Clients ▪ B2B Clients - Service Provider - OEM - Insurances ▪ B2G Clients - VMZ - Public Broadcast
Exemplary Actors	Continental, MAN, DAIMLER, ADAC, VW, EU, Vodafone	ADAC, TomTom, Vodafone, MAN, VW, BMW	TomTom, Vodafone, DAIMLER, VW, ADAC	DAIMLER, Continental, TomTom, BLAUPUNKT, ADAC, BMW	ATX, IBM, T-Systems, ERICSSON, vodafone	Vodafone, BT, kpn, orange, T-Mobile	TomTom, VMZ, TMC PRO, GARMIN

Figure 3.6: Integrated value creation chain of CoCar CHW regular operations

Value chain step one to three comprise the market related activities. Potentially all value creation partners that might profit from CoCar CHW are possible contributors for marketing activities (step 1), i.e. to increase awareness, desire and willingness to pay for CoCar CHW. Besides the industry, especially the European Union and national authorities might be able and willing to invest in corresponding campaigns. In contrast to the marketing activities, the industry alone is in charge to sell the CoCar CHW services (step 2) and provide client related services (step 3). Besides the OEMs also PND manufacturers and automobile associations possess valuable capabilities and resources.

Value chain step 4 to 6 comprise the technical operations. Precondition for the generation of CoCar Cellular Hazard Warning Informations (CHW-Is) (step 4) is the integration of all necessary hard- and software into the vehicle, which is obviously the task of the OEMs respectively their suppliers for new cars (line fit) and might be an additional offering of PND manufacturers in the after-sales market (retro fit).

Once installed, the fusion and interpretation of sensor data and the transmission and receiving of information is then autonomously performed by the dedicated in-vehicle devices. The according service creation (step 5) comprises a bunch of activities like validity checks and filtering, the generation of CoCar CHWs and CoCar Cellular Hazard Warning All-clears (CHW-As) as well as the monitoring of the complete CoCar CHW situation picture. Possible providers for step 5 are existing telematics service providers like ATX Europe or T-Traffic, IT service integrators like IBM or Accenture as well as MNOs and their suppliers. Step 6 covers the transmission of information from the vehicles into the background systems and vice versa. Existing MNOs seem to be the only realistic actor for this stage.

Regarding the usage of CoCar CHW (step), different customers come into consideration. Besides end clients, different business clients like TSPs, OEMs and insurances as well as governmental clients, like traffic management centres and public broadcasters, could be potential customers and refinancing sources.

3.2.4 Value Creation Architectures

Based on the CoCar CHW value chain discussed above, this chapter deals with the question, how the specific services can be provided most efficiently. In order to design stable value creation architectures based on the stakeholders, activities and roles identified above, the central research questions to be answered, are:

- Who should take which role and activities?
  - subject to his resources and competencies respectively
  - the effort to provide necessary resources and to acquire competencies?
- Who will shape the market and set the rules (which one)? Who will be the adopter?
  - who is able and willing to develop CoCar CHW services?
  - who is holding the primary end client contact?
  - who is taking the commercial responsibility?
  - who is taking the quality responsibility?
- Who is willing and able to take the risks?
- Will market partners sufficiently benefit from the value creation?
  - monetary and non-monetary benefits
  - stability of value creation

The Value Creation Architecture (VCA) design process is based on the assumption, that CoCar CHW will mainly be developed, implemented, operated and marketed by the *private sector*. The public sector might support the introduction of CoCar CHW, e.g. with regulatory facilitations or subventions. Additionally, the public sector might become a customer of the CoCar CHW service owner. Within such a kind of *Public Private Partnership* data can be sourced privately to support public services' quality (e.g. by multiple sources) while maintaining the Government's control over service scope and quality. On the other hand, the costs of private service chain components must be compensated. Additionally, this model harbors the risk of conflicts between aims of public and private stakeholders, if agreements are not clearly defined. [38, p. 9]

Also, the VCA design process falls back on some guidelines known from other research projects. For example, the highly regarded MACS project proposed the following value architecture design recommendations for mobile automotive services [30, p. 33–34]:

- Market participants should concentrate on their core competencies
- The service should be provided by an external service provider
- Service sales should leverage existing client relationships and sales channels
- Brand values should be used and extended with the positive image of mobile services

Despite of such recommendations, the conducted expert surveys regarding concrete value creation architectures for CoCar CHW did not result in a clearly preferred model. A couple of different architectures have been proposed and discussed with the experts:

1. OEM driven model
2. PND manufacturers driven model
3. Automobile association driven model
4. MNO driven model
5. Cooperative value creation architecture models

A crucial disadvantage of models 1 to 4 is the fact, that one market shaper alone will not be able and willing to invest in the necessary critical mass of CoCar CHW terminal distributions and, furthermore, to contribute sufficiently to positive direct network effects. Mainly for these reasons, market participants will have to cooperate with each other to increase the service's value and the single benefit of each partner conjointly.

Cooperative Value Creation Architecture Models

The central research questions to develop an appropriate cooperative model are:

- Which partners should cooperate with each other and how well can they cooperate with each other?
- How much cooperation between market participants is necessary and how much cooperation respectively coopetition is possible in view of industry internal competition and value creation competition?
- How can partners differentiate from each other despite of cooperation?
- Who is shaping the market?

Within a cooperative value creation architecture, market participants behave cooperative to reach common goals, commonly. Such a common goal in this context might be to reach a critical mass of CoCar CHW information contributors as fast as possible so the value of CoCar CHW services can be perceived satisfyingly by users at all. For this reason all market participants could bring in their sales and marketing competencies and sell CoCar CHW to their customers. To create efficient processes, a dedicated service provider should provide some or even most of the customer related services. Depending on the level of outsourced processes two generic customer service providing constructions are thinkable:

1) White Labeled TSP Construction

Market participants sell CoCar CHW within individual, company branded service bundles. In this case, one or few white labeled TSPs provide only selected processes for one, some or even all vendors. These processes could comprise first-level support and lifecycle management, among the latter one the initializing of build-in hard- and software, the execution of software updates and the switching-off of CoCar CHW systems.

The TSP plays a passive business role here so it is still the other market participants' role to coordinate the value creation network. Due to its exposed and important role in software and hardware development and integration, it can be assumed that the OEMs will be in lead to coordinate the network.

2) Branded TPP Construction

In this model, a Telematics Platform Provider (TPP) plays an active market shaper role. The TPP is the central contact point for end clients that *directly* or *indirectly* conclude a service contract with the TPP for the usage of CoCar CHW.

A *direct* customer relationship between end clients and the TPP either results from sales success of the TPP himself or of one of the other market participants, that sell the service on a commission basis for the TPP without holding the direct client relationship themselves. An *indirect* customer relationship between end clients and the TPP results from market participants that sell the service on behalf of their own and additionally hold the client contract. In this case vendors are more flexible in branding and pricing the service according to their own service platform requirements. In return the vendors will compensate the TPP for its service provisioning and charge their end clients directly.

In the direct model, the TPP provides comprehensive processes that additionally comprise second-level support, contract management and billing besides the first-level support and lifecycle management, as mentioned above. Even the technical operations of CoCar CHW could be provided by such a platform provider. Contrary to the white labeled TSP approach, in this model the other market participants bring in their sales capabilities only and are paid by the TPP according to their sales success. The TPP is clearly shaping and coordinating the value creation network. In the indirect model some processes such as contract management and billing will remain on the vendors' side.

Such a flexible value creation architecture based on a market shaping TPP allows all market participants, i.e. OEMs and PND manufacturers, to play CoCar CHW according to their competitive strategy. Either they focus on differentiation and promote CoCar CHW actively as an own service offer or they focus on cost leadership and choose the most efficient outsourcing alternative. A possible architecture of such a cooperative model is depicted in Figure 3.7.

From an organizational point of view, both the passive white labeled TSP as well as the active branded TPP can be an industry independent start up or partially or completely be owned by one or some of the market participants (e.g. OEMs and / or Mobile Service Providers (MSPs)).

Regarding the CHW data generation, both models assume that OEMs and PND manufacturers cooperate with each other in exchanging CoCar CHW relevant car data. OEMs will provide PND manufacturers and possibly other after-sales market players with a bundle of defined sensor data that will be exchanged via a dedicated data exchange interface. In return, OEMs receive higher customer value for their own line-fitted solutions, an increased customer satisfaction and a wider scope in pricing. Additionally OEMs might be able to licence the data exchange

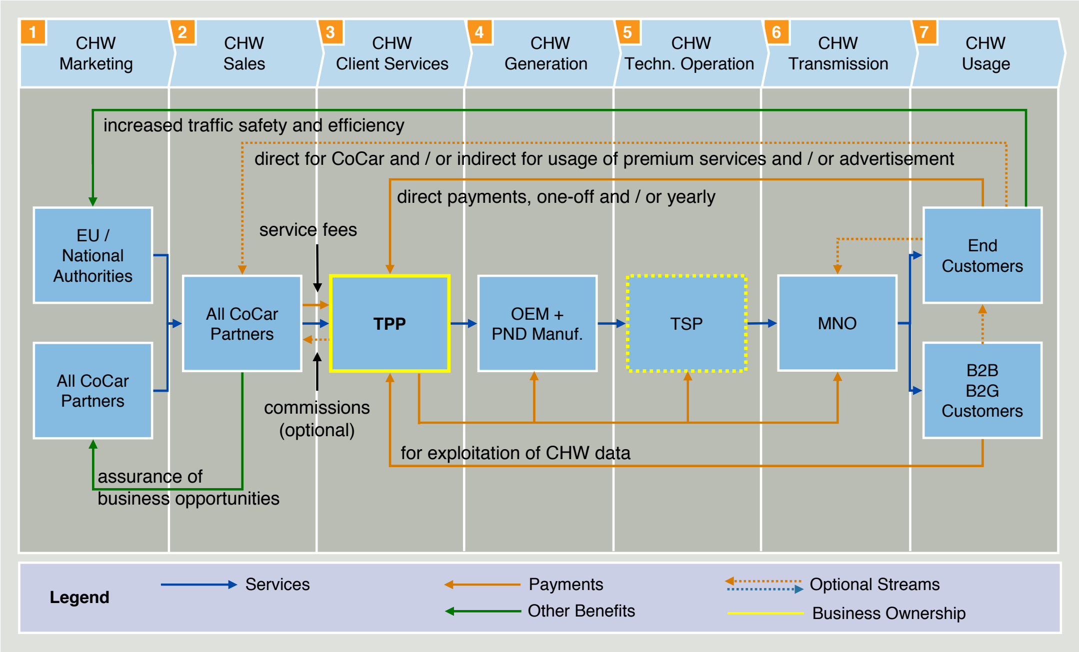

Figure 3.7: Cooperative CoCar CHW value creation architecture - TPP model

interface to any interested party that wants to use the data. Next to PND manufacturers and dedicated TSPs, national authorities and breakdown services could be interested in such an data exchange interface.

For efficiency reasons, the technical operations will be provided by a TSP for all CoCar CHW vendors. This operator could (but need not) be identical with the client services related TSP. The operator as well as the MNOs will be paid on a fixed basis by all CoCar CHW vendors according to their market share. The white labeled TSP and the TPP could – in addition to the roles described above – act as a payment clearing platform, that controls and allocates the revenue streams from the vendors to the service providers and in return from the end clients and business clients to the vendors.

Depending on the variants of cooperative service providing models described above, the end clients will either (1) be charged by a single vendor for a branded service solution, (2) be charged by a white labeled TSP on behalf of a vendor or (3) be charged by a TPP for a widely standardized TPP solution that has been sold by the TPP himself or commission based by vendors. Business clients will either be charged by a white labeled TSP or a branded TPP in their payment clearance function. The following table sums up the pros and cons of the cooperative model:

Table 3.8: Pros and cons of the cooperative model

Arguments for this model	Arguments against this model
Existing end client competence and sales networks of all actors are leveraged, critical mass can be reach within a three years period	High coordination costs (transaction costs, coordination costs between the actors
Leveraging economies of scale by outsourcing processes to specialized providers	Complex and difficult calculation and allocation of costs and revenues, potential for conflicts between cooperation partners
Potential synergies with other services can be realized individual by each vendor, e.g. OEMs and MSPs	Cooperative and transparent behaviour are a pre-condition for the success
	Difficult competition constellation

Even though some important arguments speak against a cooperative model, the arguments overbalance in the opinion of most of the experts. The main reasons are the critical mass phenomenon mentioned above and direct network effects that require the boosted efforts of all market participants.[15]

Since only a cooperative value creation architecture turned out to be feasible for the launch of CoCar CHW, a decision has to be made which cooperative model is the most promising one. Among the two described cooperative models the value creation architecture in its "branded TPP version" (model 2) is preferred by the experts. The main arguments for this model are:

- Reduced complexity:
  - The TPP is the central coordinator for all value creation partners
  - The TPP can act as the exclusive contact point for all end, business and governmental clients
- All client related processes can be provided by one entity what allows fast economies of scale (high efficiency)
- Lower risks for all market participants except for the TPP
- High risks but also opportunities for the TPP

[15] A good example for such a successful market introduction based on a consistently cooperative approach is the Japanese Vehicle Information and Communication System (VICS). The VICS is delivering traffic and travel information to road vehicle drivers using Car-to-Infrastructure Communication (C2IC) based on infrared, microwaves in the ISM band and FM, similar as RDS or DARC. The agreement to set up an organization that delivers road traffic information to vehicle drivers was arranged by the private sector, but strongly supported by different national authorities. The initial costs were covered from private sector donations (OEMs, electronic makers, communication equipment companies, banks, etc.). The costs for operations and maintenance of the facilities are covered from annual membership fees and technical disclosure fees per unit shipped. In the end the free of charge VICS services are indirectly financed by the VICS users but directly paid by the unit manufacturers (private sector fund).[39, p. 8]

3.2.5 Business Models

Goal of this chapter is to outline the different business models from the CoCar project partner's perspective. In general, each business model will answer the following main questions:

- What is the specific value proposition for the actor's customers and value creation partners?
- How does the actor create the value?
- How is he paid for the value creation (revenue models and other, non-monetary benefits)?

In this report, the section is focused on the first question regarding the value proposition which generally results from the exploitation of the market potential, that is primary but not exclusively financially driven. Other non-monetary benefits like brand improvements and the increase of customer loyalty could lead to valuable competitive advantages.

OEM Business Model

By supporting CoCar CHW, OEMs might benefit from the following competitive advantages:

- More satisfied and loyal customers because of subjective and objective improvement of customer's driving safety, lower crash and injury probability and time and cost savings by optimized travel routes
- Improved corporate image by positioning as technology leaders and innovators
- Wider price range, not limited to CoCar CHW, but also for other telematics services and passive safety options

Regarding the general opportunity of establishing a real-time and always-on communication channel to and from the car, the CRM and Vehicle Relationship Management (VRM) can be improved significantly, resulting in a huge business benefit for OEMs and potentially counter financing parts of the unit installations. Matheus gives an overview on the possible advantages that result from the proper exploitation of the comprehensive technical data, obtainable from the vehicles by the wireless link: [27, p. 14]

Main advantages in the context of VRM are:

- The remote diagnostics capabilities allow for more efficient new product development and more effective utilization of safety margins. They furthermore help with the choice of suppliers and the prove of reliability. The possibility to remotely fix vehicle failures reduces customer irritation and helps to avoid costly dealer interventions.
- The warranty and liability management can be improved, as problems can be noticed earlier and alternative ways to contact the customers exist.
- The car is more reliable, because actual and upcoming problems can be predicted and taken care off better. The vehicle might therefore sell at a better price.
- The data base enhanced repair allows for optimized scheduling and lower parts inventory. Fewer costly overnight deliveries are required.

The main advantage in the context of CRM are:

- Owing to detailed customer understanding and vehicle monitoring, suggestions for upcoming vehicle replacements with specifically tailored models are possible.
- The customer contact can be occasionalized. Instead of mass mailings just those with likely interest can be informed about useful equipment, software upgrades and alike.
- Thus enhancing the customer's seamless ownership experience is brand building.

MSP / MNO Business Model

Within the preferred cooperative value creation architecture, the MSPs / MNOs have a double function: on the one hand they utilize their existing sales channels, on the other hand they provide the mobile data transmission from and to the cars.

Their main benefit in participating the CoCar CHW value creation is the generation of additional turnovers by selling SIM cards, airtime and services. Depending on their communication strategy, car safety-critical applications might support their corporate image.

MNSs Business Model

MNSs might profit primary monetary from the CoCar CHW business via necessary investments in the mobile network infrastructure. These investments might comprise replacement and extension investments in existing 2G and 3G networks as well as investments in completely new infrastructure like MBMS network software upgrades and MBMS service centres.

Additionally MNSs could provide the technical operations of CoCar CHW in cooperation with a MNO or a TSP.

Other Market Participant's Business Models

The CoCar CHW business models of other important market participants will be outlined in the following.

Telematics Platform Provider: The TPP plays a key role within the preferred value creation architecture, as he is the central coordinator for all value creation partners and optionally could act as the exclusive contact point for all end and business clients. All client related processes and optionally the operations could be provided by the TPP. Such a business processes concentration could result in fast economies of scale and high efficiency of the system.

Independent from its organizational structure (owners), the TPP clearly faces the highest risks among all value creation partners. Complex processes have to be established from scratch. On the other side, the TPP might profit from superior chances: with the advised high equipment rate of CoCar CHW enabled cars, the TPP would possess a large customer base that can be exploited not only for CoCar CHW. This promising business opportunities can be verified in section 3.4, where the CoCar CHW business case is calculated.

The main value propositions of the TPP for the CoCar partners are the adoption of risks and efficiency gains by realizing economies of scale. To a certain extend, the TPP can be seen as the business enabler for all partners and the CoCar CHW in total.

The TPP provides comprehensive processes that comprise first-level and second-level support, contract management, billing and lifecycle management. Additionally, the TPP acts as a payment clearance platform: end, business and governmental clients will be charged directly by the TPP for the standardized CoCar CHW one-off or on a regular basis (e.g. yearly). Based on these revenues the other value creation partners are paid either on a fixed basis or in form of revenue shares:

- OEMs for sales support and hardware integration
- PND Manufacturers for sales support
- MSPs / MNOs for sales support and network operations
- TSP Operator for technical operations

PND Manufacturers: As emphasized above, it will be crucial for the perceived service value to reach very high equipment rates as fast as possible. For this reason it will necessary to address the after-sales market, too.

PND manufacturers might play an important role in this respect, as they have been very successful not only in selling navigation devices but also in integrating and selling related telematics services. In the preferred cooperative model they will be enabled to integrate and market CoCar CHW functionality in their navigation devices. OEMs will offer certain CAN-Bus data via a special interface.

PND manufacturers may amend their service spectrum with an interesting and valuable service, resulting in more satisfied and loyal customers. CoCar CHW might improve their corporate images by positioning themselves as technology leaders and innovators and widen their price scope. Other CoCar CHW value creation partners mainly profit from higher equipment rates and resulting customer values.

Comparable to the OEMs' business model, PND manufacturers also get paid in form of one-off mark-ups from end clients for the devices. Regarding the CoCar CHW service, they either get paid directly from end clients in form of one-off mark-ups or regular payments or in form of revenue shares respectively sales commissions from the TPP and - indirectly - in form of shared payments from business clients and national authorities.

OEM Suppliers: OEM suppliers produce and deliver interface suitable car components based on detailed OEMs' specifications. Casually, OEM suppliers cooperate with their OEMs in the development of new hardware and software solutions. The relationships between OEMs and their suppliers are well established.

Insurance Companies: It can be assumed that the probability to be in an accident and get injured, decreases significantly with the usage of CoCar CHW (see also subsection 3.1.4). Based on appropriate calculations, insurance companies could adjust their premiums according to the use of the service and offer their clients differentiated premiums.

National Authorities: It has already been mentioned that public authorities have a huge interest in CoCar CHW, because of its potential to significantly reduce the number of accidents as well as to improve the traffic flow and thus to lower the macro economic costs. In subsection 3.1.4 it was shown that the socio-economic benefits of CoCar CHW add up to nearly half a billion € per year for Germany alone. The BCR of benefits and state-run subventions mounts up to a factor more than 10, which implies that every spent € leads to societal benefits of nearly 10 €.

In addition to these CoCar specific benefits, there are other areas in which public agencies might profit from the CC2CC interface:

- CoCar CHW could enable cost savings for traffic management centres, e.g. supplement or even replace fixed black ice sensors or traffic jam sensors.
- The optimization of tolling is an urgent case all over Europe. The European Commission is asking for proposals on compatible, cross border, single contract, wireless solutions for charging Heavy Goods Vehicles (HGVs) in a first step and potentially private cars in the future. [40] A mobile communication interface in each car could significantly broaden the options. [27, p. 15]
- When considering network based law enforcement, it has to be kept in mind that allowing to track speeding and alike with help of CoCar would jeopardize completely the acceptance of C2C communication (even though its use might be desired by the authorities). Nevertheless, for some applications, where a wireless link is needed anyway, like observing the electronic tachographs or theft tracking, it might make sense to employ the communication platform for this purpose. [27, p. 16]
- Also government entities might be interested in collecting statistical data for their purposes [27, p. 16]

However, there are a lot of benefits for national authorities so it can be assumed that there exists a significant willingness to support CoCar CHW. The following support means are discussed among experts, listed by the level of intrusion into the free market:

- Paying market prices for CoCar CHW data that are exploited for national traffic services
- Tax reductions for car owners that have installed CoCar CHW functionality
- Subventions for OEMs installing CoCar CHW functionality in cars
- Statutory integration and usage of CoCar CHW

3.3 CoCar CHW Market Launch Scenarios

Goal of this chapter is to clarify how CoCar CHW and corresponding business models identified above can be launched successfully in the traffic telematics market. Therefore this chapter discusses critical success factors, risks and opportunities, depicts possible market diffusion scenarios and recommends appropriate marketing and sales strategies.

3.3.1 Opportunities, Risks and Critical Success Factors

Goal of this chapter is to discuss the opportunities (drivers), risks (barriers) and critical success factors in context of the development, the market launch and the operations of CoCar CHW.

Following Table 3.9 lists the detailed results of the CoCar business workshops and expert questionnaires, regarding both, the opportunities (drivers), potentially accelerating the CoCar CHW market launch, and the risks (barriers), potentially jeopardizing the CoCar CHW market launch.

Table 3.9: Opportunities and risks of CoCar CHW market launch

Factors	Opportunities (drivers)	Risks (barriers)
User related factors	Perceived improvement of driving safety	Fear of data abuse
	Getting faster from A to B	Fear of false alarm
	Avoidance of traffic jams result in time saving	Malfunctions like „an error has occurred“
	Saves lives, enables fast help in case of accident	Fear of radiation / electro smog
	Will be part of attractive telematics service bundles	Correctness of information
	User is used to technology thanks navigation	Missing consumer trust
	Enables relaxed and more comfortable driving	Negative image
	Cost savings because of early warnings	Useless and distracting HMI
	Feeling of being better informed than others	Willingness to provide location based information
		Willingness to pay for safety services
		Fear of high follow-up costs
		Fear of high communication costs
Business model related factors	Mobile communication price decreased over time	Interests conflicts between market participants
	Possibility of indirect business models	Cooperation ability and willingness of actors
	Cost savings by standardization	High complexity of business models and administration
	Fast evaluation of vehicle systems by the market / competition	Difficult to coordinate many actors
	Low development and maintenance costs for OEMs	Insufficient BCRs
	New market, new business opportunities (trigger)	Not enough equipped vehicles
	Efficiency by using synergies between actors	System costs too high
	Increase of customer loyalty	Cost of communications too high

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	Optimized deployment of emergency vehicles	Achievement of critical mass (even the first clients expect a benefit)
	Cost savings for road network infrastructure (e.g. black ice sensors or traffic jam sensors not necessary anymore)	No sufficient return of investment
	Governmental fundings	
Technological factors	Existing mobile network infrastructure fulfills CoCar CHW requirements	Flood of information difficult to handle in background system (processing / server) and front-end (display / driver)
	Emerging cellular broadcast technologies like MBMS	Lack of capacity and Quality of Service
	Promising CoCar simulation and demonstration results	No reliable, secure and exclusive transport medium available
	Existing vehicle data exchange interfaces like the Vehicle Application Interface (VAPI)	High complexity of system hardware endangers market launch (e.g. German tolling project)
		Insufficient data quality and inconsistency to justify any payment
		Insufficient bandwidths and data transmission rates
		Standardization of interface and data format results in long market launch process
		Insufficient coverage or latency for safety critical applications
Legal and political factors	Safety impacts: less accidents, less heavy injured, less fatalities	Privacy protection
	Traffic impacts: improved traffic flow, less congestions, less air pollution and noise emissions	Different legal preconditions in EU-countries and non-EU-countries
	Contributes to ecological resp. green driving; ecological discussions	Cooperation between cities, districts, countries necessary
		Difficult patent and contract arrangements in cooperative business models

Based on the identified opportunities and risks the CoCar project experts have been asked for the most important preconditions of a successful market launch of CoCar CHW (critical success factors). The following results of critical success factors are structured in a) functional-technical aspects, b) business modeling aspects and c) business case related aspects, corresponding with the structure of this chapter.

a) Critical success factors regarding functional-technical aspects

- Clearly arranged HMI
- Existing interface for read-out of vehicle (CAN-Bus) data introduced
- Standardized information exchange format
- Sufficiently full network coverage not only for highways but also for rural areas
- Technical feasibility and secure set-up
- Perceivable benefit for end and B2B customers
- Easy vehicles integration

b) Critical success factors regarding business modeling

- Acceptance among OEMs, because CoCar CHW are safety relevant and so touching the OEMs' core competency
- Some big OEMs like Volkswagen, Daimler and BMW as pioneers
- OEMs and MNOs stay independent from another (free choice of MNOs for OEMs)
- Easy service access
- Governmental regulations

c) Critical success factors regarding the business case

- Low additional Capital Expenditures (CAPEX) for OEMs
- Attractive price / performance ratio for end clients
- Attractive price models of MNOs for OEMs and / or end clients
- Transparent cost model and simple billing
- Reasonable operations and follow-up costs
- Achievement of critical mass in short time
- Fast market penetration

Functional-technical and business modeling related success factors have been considered as far as possible in section 3.1 and section 3.2. The business case related critical success factors will be considered in the CoCar CHW business case in section 3.4

Some of these identified risks and mitigation measures are directly addressed within this CoCar commercial feasibility study. This in especially includes the risks resulting from a wide range of different actors and stakeholders with opposing interests, the risks resulting from missing business models for each of the stakeholders, a missing global business case and a missing cost-benefit analysis. Nevertheless, some risks are not addressed explicitly in this chapter and should therefore be traced well in the future. These risks mainly comprise the identification of user needs in short, medium and long term on an ongoing basis, the complete identification of barriers to deployment as well as their corresponding mitigation and control strategies and the preparation of valid business cases for each of the actors and stakeholders.

3.3.2 Market Diffusion Scenarios

Forecasting the diffusion of CoCar CHW equipped vehicles is essential for a couple of important commercial considerations.

Firstly, the socio-economic impact depends directly on the equipment rate. Only those vehicles which are equipped with CoCar CHW functionality can contribute to safety and traffic efficiency impacts. The more vehicles contribute to the system the more vehicles benefit from the system - not only vehicles which are equipped and receive the warnings but also equipped vehicles involved in crashes and non-equipped vehicles involved in crashes with equipped vehicles benefit from the advantages of after-crash avoidance or crash mitigation effects [41, p. 54]. This leads to a second important issue: CoCar CHW need a minimum number of equipped cars for the technology to function correctly and to fully exploit their potential benefits. Thirdly, the CoCar CHW equipment rate is the most important input factor for the CoCar business case, as presented in section 3.4.

The market diffusion of a technological innovation in general and CoCar CHW in special, depends on a broad range of other influence factors. Some very important factors and their assumed characteristics in the CoCar CHW market diffusion scenario are listed in Table 3.10:

Table 3.10: CoCar CHW market diffusion influence factors and characteristics

Influence factors	**Characteristics**
Legislation	Service will not be mandatory
Infrastructure investment	Low investment necessities compared to other (new) technologies
Combinations with other applications	Combined with eCall, interfaces to existing vehicle sensors and telematics systems
Robustness of the system in different traffic situations	Regarded as high
Liability issues	Potential show stopper, liability must be excluded as far as possible
Market needs	High demand for safety improving services, explicit demand and support from policy side
Value creation architecture and business models	Based on the realization of a highly co-operative value creation architecture as described in section 3.2
Safety impact	High impact, visible and regular perceived added value

As discussed in section 3.2 it is assumed that the OEMs are willing and able to take the risks and moreover even support a cooperative value creation architecture that includes a close cooperation with after-sales-market providers.

This willingness to take risks mainly results from the promising business outlooks that can be achieved with a conjoint CoCar CHW approach. The CoCar business case results in a Net

Present Value (NPV) of more than 4 billion € for all market participants and the period from 2012 to 2023 (see section 3.4). This also includes the assumption that the investment risks are limited by state-run subventions in form of a 50 % allowance for every built-in CoCar CHW unit within two years before opertions and during the first year of operations. Another important benefit increasing the OEMs' motivation to install CoCar CHW units even before the services are operational, results from the general opportunity of establishing a real-time and always-on communication channel to and from the car. As discussed in subsection 3.2.5 CRM and VRM can be improved significantly, resulting in a high business benefit for the car manufacturers and potentially re-financing parts of the unit installations. The product liability risk remains a serious potential show stopper whose potential impact must be kept as small as possible by legal measures.

It is furthermore assumed that OEMs will finally support eCall starting from 2011/2012 and implement CoCar CHW functionality in conjunction with it. This results in an assumed starting point of service operations at 2014 with a two-year equipment rollout phase in advance. Such a rollout phase in advance of the service operations is necessary because a certain equipment rate has to be reached before the users will perceive a sufficient benefit from the service's core value proposition. This minimum equipment rate is estimated at at least 10 % of the total vehicle stock in line with other analyses regarding direct network effects of C2C communication. [27, p. 5]

Regarding the CoCar CHW equipment rate it is assumed that 50 % of new vehicles in 2012 will be equipped and that the yearly increase of this equipment rate is another 5 % resulting in 52.5 % equipment rate for 2013, 55.125 % in 2014 and so on. Additionally, retro-fitted vehicles contribute to the overall penetration rate what is not considered or not assessed in most of the other studies. For CoCar CHW it is assumed that the rate of retro fitted vehicles in year 2014 adds up to 5 % of all unequipped vehicles with a yearly increase rate of another 5 % resulting in an equipment rate of 5.25 % in 2015, 5.5125 % in 2016 and so on. The most important vehicle equipment calculation assumptions are listed in Table 3.11.

Table 3.11: Assumptions regarding stock of equipped vehicles (Germany)

Stock of equipped vehicles	**Unit**	**Value**
Stock of vehicles, end of 2007	number	49.300.000
Yearly registrations of new cars, end of 2007	number	3.400.000
Yearly stock increase of vehicles	percent / year	1
Yearly increase of new car registrations	percent / year	1
Rate of equipped new registered vehicles in 2012	percent	50
Yearly increase of equipment rate for new registered vehicles	percent	5
Rate of retro fitted vehicles in 2014, from stock	percent	5
Yearly increase of retro fitted vehicles equipment rate	percent / year	5

The corresponding equipment rate adds up to 15 % end of 2014, the first year of operations and increases with a yearly rate of 8 % to 9 % during the next nine years, reaching 93 % in 2023, the 10th year of operations.

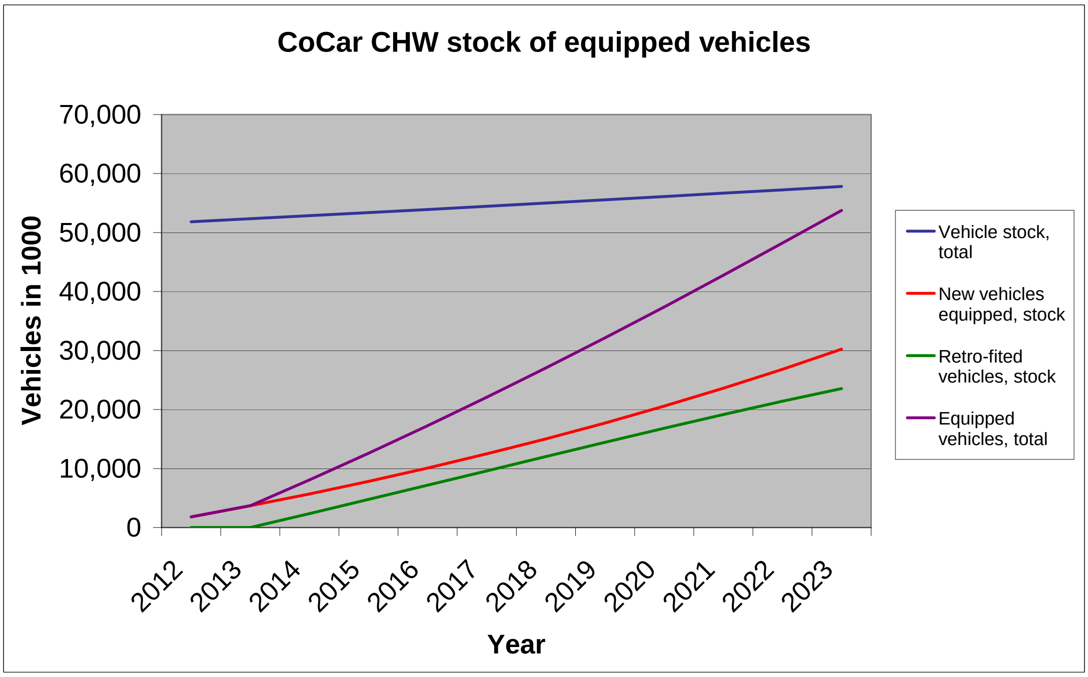

Figure 3.8: Stock of equipped vehicles (Germany)

3.3.3 Marketing and Sales Strategies

As discussed in section 3.2, a TPP will play an active market shaper role in the preferred CoCar CHW value creation architecture. Other market participants like OEMs, MSPs, PND manufacturers and automobile associations will sell CoCar CHW either on behalf of their own or widely standardized on behalf of the TPP. In case of the latter one, the TPP's sales partners will be paid commission based by the TPP according to their sales success.

Based on the central role of the TPP in shaping and coordinating the value creation network, it is also up to him to design the marketing and sales strategies that are capable to maximize the revenues and profits of the whole value creation network. The implementation of the chosen strategy is traditionally planned across the "4Ps" of marketing, the so called marketing mix. The marketing mix comprises the following elements and policies that the business will employ for the execution of the marketing strategy, covering the market entry as well as the consistent delivery of a compelling value proposition:

(1) Product (product policy)

(2) Price (price and conditions policy)

(3) Place (sales and distribution channels policy)

(4) Promotion (communication policy)

(1) The **product policy** comprises all decisions that affect the selection and the continuous development of a certain product or product bundle. Obviously the main challenge for CoCar CHW is its further *product development* after the basic research conducted in the AKTIV CoCar project. This comprises tasks like prototype development, field tests of prototypes under real conditions, evaluations and final service configurations. It will be essential that the cross-company cooperation of all value creation partners starts already in this early stage. Huge challenges

have to be overcome: the enormous complexity caused by the cutting edge technology, the large number of actors involved, the dynamics due to fast technological developments and interdependencies between legal, technical, organizational and business aspects of cooperative systems.[16]

A further central product decision to be made by all players affects the *product configuration*: will CoCar CHW be offered as a stand alone service or in combination with a product bundle or as a choice out of both alternatives? Some reasons speak for the latter option just depending on the competitive strategy of the players.[17] It is recommended, that CoCar CHW will be offered in a bundle with other services like eCall and dynamic route navigation. Such a service bundle would make sense from a functional, technical and commercial point of view:

Functionally, CoCar CHWs very well amend the existing traffic information with real-time data and can become an additional source of information for the dynamic route navigation. Furthermore, CoCar CHWs can be displayed on the dynamic route navigation's display. *Technically*, the three services will make use of the cellular communication interface what allows the realization of synergies. Additional services like remote software management and bCall are easily to include. *Commercially*, the bundle will provide an attractive added value for potential customers. This added value might be a crucial purchase driver for those customers that have been indecisive in buying a stand alone service. The willingness to pay for telematics services will be increased with complementary service bundles that together provide a higher value than its singles services alone.

Finally, regarding the *product variation* it has to be decided which further services can be derived from the basic service function in order to generate alternative revenue streams. E.g. it is planned to sell CoCar CHW generated data to business and governmental customers that are licensed to exploit these data to a certain extend for their own purposes.

(2) The **price policy** comprises all decisions that affect the pricing of the service, including pricing strategies for the market introduction, the lower and the upper price limit a well as conditions like terms and discounts. Price policy decisions have to be made not only for end clients but also for different B2B customers like other OEMs or TSPs and governmental customers like public authorities. Subject to further analyses, a retail price of 4 € per month, representing the price of a package of cigarettes, is seen as a realistic discussion basis. Yearly prices for business and governmental customers will vary between 500,000 € and 1,000,000 € (see also CoCar business case in section 3.4).

(3) The **sales and distribution channels policy** comprises decisions about the concrete sales and distribution channels used to sell the service and guarantee the necessary logistics for needed hard- and software. Sales and distribution are highly affected by the cooperative value creation architecture described in section 3.2 and comprises a broad range of instruments.

Regarding *sales*, nearly all players are enabled to sell the service on behalf of their own in flexible configurations as well as commission based and widely standardized for a TPP. Depending on the player the employed sales channels reach from personal sales through car dealers,

[16] In this context Safespot emphasizes the need of a decision-making process: "The goal of the decision-making process is to agree on solutions that are acceptable for all stakeholders. Naturally the decision-making to get to an extensive system takes place in different smaller settings. These setting are called arenas." [42, p. 10]

[17] Players that focus on further differentiation from competitors will probably promote CoCar CHW actively as a branded service offer within an existing telematics service bundle. Players that focus mainly on costs will use the TPP infrastructure, abstain from being the service owner and offer CoCar CHW either as a stand alone or a bundled service. A third type of players may not be interested in the service integration at all but interested in the commission based service sales. In this case, the TPP is holding the client contracts, offering either a stand alone or bundled service.

mobile phone shops and sales call centres to impersonal channels like internet sales portals, recommend-a-friend programs etc.. Due to complex value proposition and service integration, it is assumed that the personal channels will be dominating.

Regarding the *distribution* it has to be differentiated between the line-fitted and the retro-fitted option. OEMs and their suppliers will obviously play an important role in the line-fitted scenario by equipping new vehicles with necessary hard- and software. In the retro-fit scenario a broad range of after-sales market providers can be imagined as distribution channels: starting from dealer workshops and independent workshops up to the complete range of retailers that currently sell PNDs. However, this later channel assumes that end clients will be able to install the equipment by themselves what is not likely at all from the current point of view.

A further important function within sales and distribution channels policy affects the *lifecycle management*, under it the initializing of build-in hard- and software, the execution of software updates and the termination of CoCar CHW systems at the end of product life. For efficiency reasons, these functions should be provided centrally by the TPP. Therefore the TPP system architecture additionally requires a logistic interface that, among others, is able to initialize and deactivate CoCar CHW hardware.

(4) The **communication policy** comprises all decisions that target at the manipulation of stakeholder relations in order to support the market penetration discussed above as good as possible. Next to end and business clients, relevant stakeholders comprise other value creation partners like suppliers, competitors, insurances and investors as well as mass and specialized media, politics and society in general. The possible tools comprise a broad range of communication instruments, among those awareness campaigns, advertising, public relations, press and media relations and public affairs.

Awareness campaigns aim to extend public awareness about a product or service. Their final goal is to inform drivers and raise their knowledge and interest about CoCar CHW. CoCar CHW should slowly become a commodity for potential users that will obtain information about system distributors, about its description, operation, benefits and risks related to system. The awareness campaigns aim to cause a cognitive change, an inducing effect and a behavioural change in the public. [18] [43, p. 25]

Awareness campaigns will play an important role for the market introduction as CoCar CHW will be widely unknown, not to mention the missing interest and willingness to pay for them. Therefore it is proposed to start such awareness campaigns already two years in advance of the operational start. The CoCar business case in section 3.4 assumes that national authorities will subsidize parts of the campaign costs. The TPP will coordinate and finance the campaigns and will be rewarded with subsidies in return.

Advertising targets more directly at the consumer acceptance and their disposition to buy a certain product or service. Comparably to awareness campaigns, advertising will be an important communication instrument i.e. for those players that aim to differentiate themselves from their competitors. Possible advertising media comprise well known media like press, magazines, cinema, television, radio and posters as well as new media like the internet or mobile media. The latter one might fit very well into the context of use of CoCar CHW. It is assumed that each player finances advertising by his own, not subsidized by national authorities. [19]

[18] An overview about examples of awareness campaigns in the transport industry can be found in [43, p. 23-26].

[19] The Special Eurobarometer 267 "Use of intelligent systems in vehicles" investigated from which sources consumers expect to get reliable information about intelligent vehicle systems. The survey shows that EU citizens would trust specialized sources to give them information about intelligent security systems: 30 % name automobile clubs as a reliable source and 29 % car manufacturers. Consumer associations (26 %) and specialised media (25 %) follow next. Only 8 % of EU citizens spontaneously state that they would never look for such information. [28, p. 49]

3.4 The CoCar Business Case

The following business case will quantify all assumptions made in the sections above and assess their specific financial implications. The business case will cover the CoCar CHW service provision for a period of 10 years of operations. The case is calculated for Germany only in a first step and then extrapolated for Europe in a second step.

The business case analyses the CoCar CHW provisioning as a total system. Adopting this perspective in especially means that all necessary system inputs such as CAPEX and Operational Expenditures (OPEX) are opposed to the system outputs such as revenues, all together resulting in the system's Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA) and NPV. Additionally, the case should allow to identify the cost and revenue drivers, the minimum prices in relation to given costs respectively the value contribution of CoCar services to a joint traffic telematics platform.

Individual business cases for each value creation partner and the service provision between the value creation partners are not provided explicitly. Also, it has to be emphasized that the CoCar CHW business case can only be a rough projection as he depends on partially very uncertain assumptions that are introduced in the following.

General Assumptions

The following general assumptions regarding timeline and business case adjustments are made:

Table 3.12: General business case assumptions

General assumptions	Unit	Value
Timeline		
Considered period	year	2012 - 2023
CoCar CHW vehicle equipment start	year	2012
Investments in CoCar CHW infrastructure	year	2013
CoCar CHW service start / start of operations	year	2014
Business case adjustments		
Weighted Average Cost of Capital (WACC)	%	8

The chosen WACC is of special importance for the business case results, because all generated cash flows are discounted with this factor. In the CoCar business case, the revenues will increase above average compared to the costs, so a higher WACC will significantly worsen the results, a lower WACC will improve them.

Capital Expenditures

The CAPEX comprise all necessary investments to develop, test, integrate, replace and extend CoCar CHW hardware and software components before and during the operations of the service. The investments are split into vehicle related, technical operations related and client services platform related investments.

The estimated costs for each category in the business case assumptions represent the cost price. Cost prices reflect best the consumption of productive resources which are used for producing the respective component. The cost prices reflect the costs market participants (e.g. OEMs or MNOs) have to pay to their suppliers plus a mark-up for covering development and implementation costs on the vehicles.[20] In contrast to that, market prices, i.e. what the users actually will face, represent the appropriate cost figure for the revenue stream calculations.

The assumptions made for CoCar CHW CAPEX are listed in Table 3.13.

Table 3.13: CoCar CHW capital expenditures assumptions

Capital expenditures (hardware and software)	**Unit**	**Value**
Vehicle related investments		
Average cost for CoCar hard- and software, line fitted		
includes development, production and integration costs	€ / vehicle	80
does not include cost of eSIM from eCall, one-off	€ / vehicle	20
Average cost for installation, line-fitted	€ / vehicle	10
Average cost for CoCar hard- and software, retro fitted		
contains development, production and integration costs	€ / vehicle	60
Average cost for installation, retro-fitted	€ / vehicle	40
Yearly cost increase factor for vehicle hard- and software	factor	0.98
Technical operations related		
Technical operations platform, basic investment		
including development, testing, etc.	€	10,000,000
Technical operations platform, vehicle dependent		
including CoCar Information Systems	€ / vehicle	1
Technical operations platform, replacement & extension	% / yearly	10
Yearly cost increase factor	factor	0.98
Client services platform related		
CRM, Billing and Invoicing, basic investment		
including development, testing, office	€	10,000,000
CRM, Billing and Invoicing, vehicle dependent		
including server farms, licences, etc.	€ / vehicle	2
CRM, Billing and Invoicing, replacement & extension	% / yearly	10
Yearly cost increase factor	factor	0.98

The costs of the on-board components of CoCar CHW are of particular importance for the whole business case. The experts estimation of 90 € average cost for the line fitted version including installation, is based on the assumption that existing components of other in-vehicle telematics systems will be utilized for CoCar CHW as efficiently as possible. In especially it is assumed that a communication module already exists from an integrated eCall functionality whose costs alone are estimated at between 100 € and 150 € by the Socio-Economic impact of intelligent Safety Systems (SEiSS) study and at 61 € in 2010 and at 60 € in 2020 by eImpact. [41, p. 110] [24, p. 106]. Correspondingly, the costs for a stand-alone CoCar CHW solution are estimated at 132 € by eImpact for 2020. [24, p. 108]

The retro-fitted version is expected to be slightly less expensive regarding the necessary hard- and software components (60 €) but significant more expensive regarding the subsequent installation costs (40 €). The yearly cost increase factor of 0.98 for both, the line-fitted and

[20] E.g. the development costs of new Automotive Software and Services (ASS) are estimated at 60 to 70 million € in average by market experts. [44, p. 41]

the retro-fitted solution, allows for the fact that the average cost per unit will decrease with the produced quantity. The client services platform related CAPEX (and OPEX) are based on the following main assumptions regarding the system load:

- Vehicle owners are billed once a year
- First and second level support for all contract and invoice related questions
  - usual office times, workdays and weekend
  - assumption: one request / year, 10 minute answering time
- First level support for technical requests, forwarding of requests to MNO and OEM
  - 24/7 support
  - assumption: two requests / year each 10 minute answering time
- Interfaces to bank, collections, logistics, service activation and deactivation
- No migration of an existing system

10 million customers with one contractual respectively invoice related request per year result in about 27,400 requests per day in average. This adds up to 273,900 minutes respectively 4,600 hours at assumed 10 minutes answering time per request. At an assumed working shift of eight hours this requires 570 agents. Because of the unequal distribution of the requests the number of agents increases to about 700 for contractual related request alone. To cover the technical request another 1,400 agents are required so in total 2,100 agents are necessary for 10 million customers. The client services platform related CAPEX comprise the following main investment areas:

- Servers
  - Machines (incl. reliability, cluster) and air conditioning
  - Software (data bases, customer care & billing system)
- Clients (machines and software)
- Connection of clients and servers
- Workstations, including office, furniture, telecommunication
- Recruiting and training
- Software development, additional features
- Replacement and extension

Operational Expenditures

The OPEX comprise all necessary operational costs to operate and maintain the CoCar CHW service. Correspondingly to the CAPEX, the OPEX are also split into vehicle related, technical operations related and client services platform related costs.

Table 3.14: CoCar CHW operational expenditures assumptions

Operational expenditures	**Unit**	**Value**
Vehicle related operational costs		
Telematics data flat rate	€ / month	1.5
Technical operations related costs		
Technical operations platform, CoCar Information Systems		
Including rentals, labour costs, energy, maintenance	% of CAPEX	10
Client services related operational costs		
CRM, billing and invoicing		
Including labour costs	€ / client, yearly	6.3
CRM, billing and invoicing		
Including energy and maintenance	% of CAPEX	10
Ratio web invoices from all invoices	%	70
Costs per web invoice	€, yearly	0.2
Costs per paper invoice	€, yearly	1
Market Communication, year -1 to 3		
Including media budgets and labour costs	€, yearly	5,000,000
Sales costs		
Including communications and labour costs	€ / client	10

Again, the vehicle related costs are of particular importance for the whole business case. In this case, a mobile data flat rate of 1.5 € per month is seen as a hypothetical cost price offered by the MNOs to their B2B customers (either OEM suppliers, OEMs or TPPs).

The operations of the client related services is based on the system load assumptions made in Table 3.4 CAPEX. The labour costs for call centre agents, technicians, management and administration are of particular importance. As calculated above, 2,100 call centre agents will be necessary for 10 million customers and their contractual, invoice related and technical requests. Assuming an agent's average gross payroll of 25,000 € per year and a management and administration overhead of 20 %, this results in 63 million € labour cost per year or 6.3 € per customer.

The operational costs for energy and maintenance are set at 10 % of the corresponding CAPEX. Regarding the billing, an assumption had to be made for the ratio of web invoices and paper invoices. It is assumed that 70 % of all yearly invoices are shipped electronically at an average price of 0.20 € and 30 % are shipped conventionally at an average price of 1.00 €.

Revenues

The potential revenues of CoCar CHW comprise a broad range of different revenue sources and revenue types. Regarding the revenue sources, end clients as well as different types of B2B customers and national authorities are considered. Revenue types can range from direct payments to indirect payments and subventions. Table 3.15 sums up the most important revenue assumptions.

Table 3.15: CoCar CHW revenues assumptions

Revenues	Unit	Value
Direct payments from end clients		
Price of one package of cigarettes per month	€ / client / year	48
Av. direct payments from other TSPs and OEMs	€ / TSP / year	500,000
Number of paying TSPs and OEMs, year 1	number	4
Av. increase of private TSPs and OEMs, years 2-10	number / year	1
Direct payments from public authorities	€ / year	1,000,000
Indirect payments from end clients for premium services	€ / client / year	20
State-run subventions for OEMs		
limited to the years 2012, 2013 and 2014	€ / CoCar unit	40
State-run subventions for educational advertising	in % of budget	25

Direct payments from end clients are set at 48 € per year what corresponds with 4 € per month, nearly representing the price of a package of cigarettes. Other private TSPs, OEMs and public authorities that are not closely cooperating in the CoCar value creation, are assumed to pay directly yearly flat fees for a certain, limited usages of CoCar CHW generated data in order to improve their own services.

Besides their direct payments, end clients are assumed to pay also indirectly in form of higher prices for other premium services that are graded up with CoCar CHW generated data. Such a typical premium service that profits from CoCar CHW could be an improved dynamic navigation system.

In addition to this predominantly privately financed market model it is assumed that national authorities will grant state-run subventions to enable and to speed up the penetration of the service. These subventions will most likely be granted for OEMs based on the number of built in CoCar units as they bear the highest investment risks. It is also assumed that educational campaigns will be subsidized at least for a certain period (three years) and to a certain percentage (25 %). In the light of the substantial benefits that have been identified in section 3.1, such state-run subventions should be justified comparably easy.

Results

CoCar CHW business case calculations result in a NPV of more than 4 billion € at the chosen WACC rate of 8 % for the period of 2012 to 2023. Assuming that the subventions described above will be granted, the EBITDA won't be negative at any time.

Nevertheless, this positive result can not hide the fact that about half a billion € have to be invested before the start of the service. The break-even will not be reached until 2016, the third year of operations. The discounted cumulative cash flow will not turn positive before 2017.

These facts result in a business case with relatively high investment barriers on one hand and extraordinary opportunities on the other hand. Finally, it will depend on the assumptions made above, whether and to what extend the business case results will occur in reality.

Sensitivity Analysis

The purpose of the sensitivity analysis is to select the critical variables whose variations have the greatest effect on the business case results.

Regularly the selected WACC and the corresponding discount rate are critical variables. Doubling the WACC to 16 % leads to an almost halved NPV of 2.2 billion €. In contrast, a WACC of 4 % increases the NPV to 5.7 billion €.

On the CAPEX side, the vehicle related investments are clearly dominating the other infrastructure investments. Their share in the total investments varies between 83 % in year one before operations and 100 % in year two before operations. The share of vehicle related investments averages 97 % in the considered 10 years of operations. If the average cost for line-fitted and retro-fitted hard- and software was halved to 40 € respectively 30 €, the break-even could be reached already in 2014, the first year of operations, and the discounted cumulative cash flow would turn positive in 2015 already. In contrast, doubling the average cost for line-fitted and retro-fitted hard- and software to 160 € respectively 120 € defers the break-even to 2019, the sixth year of operations, and the discounted cumulative cash will not turn positive until 2020.

The OPEX side is also dominated by vehicle related costs. Their share in the total operational costs varies between 58 % and 70 % during the operations period. The share of vehicle related operational costs averages 67 % in the considered 10 year operations period. If the operational costs per unit was halved to 0.75 € the NPV increases by 1.5 billion € and the discounted cumulative cash flow will turn positive already in 2016. In contrast, doubling the operational costs per unit to 3 € will decrease the NPV by 3 billion € and defer the break-even to 2019, the sixth year of operation. In summary, the variation of the vehicle related OPEX is even more sensitive than the variation of the vehicle related CAPEX.

Business Case Results for Europe

Finally, the business case results calculated for Germany in a first step will be extrapolated for the 27 European member states in the following. In order to reduce complexity, most of the assumptions made above will be transferred unmodified to the other European countries. This mainly affects the chosen timelines, vehicle equipment rates, cost prices of vehicle and infrastructure related components, both, CAPEX and OPEX, cost increase factors, the structure and the value of revenues and the WACC. The following parameters have been changed for the European business case:

Table 3.16: CoCar CHW Business Case results for Europe

European business case parameters (changes to Germany)	Value
Stock of vehicles, end of 2007	260,000,000
Yearly registrations of new cars, end of 2007	19,950,000
Number of supporting mobile network operators	12
Number of supporting technical operations platforms	27
Number of supporting client services platforms	27
Market communication budget, year -1 to 2	50,000,000 €/year
Number of paying private TSPs and OEMs, year 1	27
Av. increase of paying private TSPs and OEMs, year 2-10	2/year
Number of paying public authorities	27

Under this assumptions, the European CoCar CHW business case calculations result in a NPV of more than 20 billion € at the chosen WACC rate of 8% for the period of 2012 to 2023. Assuming that the subventions described above will be granted, the EBITDA won't be negative at any time. Nevertheless, this positive result can not hide the fact that more than 2 billion € have to be invested before the start of the service. The break-even will not be reached until 2017, the fourth year of operation, and the discounted cumulative cash flow will not turn positive before 2017, too.

Comparably with the German case, the European business case also includes relatively high investment barriers on one hand and extraordinary opportunities on the other hand. Finally, it will depend on the assumptions made above, whether and to what extend the business case results will occur in reality. As pointed out above in the sensitivity analysis for the German case, the variation of the vehicle related CAPEX and OPEX and the chosen WACC have a great impact on the business case results.

Chapter 4

Conclusion and Outlook

CoCar CHW feasibility has been analyzed both from a technical and commercial point of view in this report. The technically feasibility is outlined and the underlying cellular technology is described in detail. Much effort has been put into the commercial feasibility study, which provides not only an overview on stakeholders, business models and business cases but also lists a broad range of available associated literature in this area. In addition, the study is based on the input from the CoCar project partners, the Aktiv partners and third parties.

From a technical point of view, CoCar CHW applications have been identified as feasible in today's 3G networks. The UMTS provides the required transmission delay of below one second and also the necessary capacity to exchange CoCar CHWs. For areas with a high user density, it is beneficial to apply a broadcast mechanism to distribute the warning information. The MBMS has been identified as the cellular broadcast technology of choice.

From a commercial point of view, it was satisfactorily shown that CoCar CHW can provide valuable benefits for individual drivers, business and governmental customers and society in general. Due to the critical mass phenomenon and direct network effects, the development, implementation and deployment of CoCar CHW will require the combined effort of all market participants. Two footprints for cooperative VCAs have been developed and discussed in detail.

The time for cooperative telematics services like CoCar CHW will be ripe with the comprehensive introduction of eCall, which is assumed to start as of 2011. In a bundle with eCall and existing dynamic route navigation, CoCar CHW can be introduced most efficiently from a functional, technical and commercial point of view:

Functionally, CoCar CHWs very well amend existing traffic information services with real-time data and therefore can become an additional source of information for dynamic route navigations. Furthermore, CoCar CHWs ideally will be displayed on the dynamic route navigation's display. *Technically*, the service bundle will make use of the cellular communication interface what allows the realization of synergies. Additional services like remote software management and bCall are easily to be included. *Commercially*, the bundle will provide an attractive added value for potential customers. This added value might be a crucial purchase driver for those customers that have been indecisive in buying a stand alone service. The willingness to pay for telematics services will be increased with a complementary service bundle that together provides a higher value than its single services alone.

The corresponding business case includes extraordinary opportunities on one hand, but relatively high investment barriers on the other. For Germany alone, the NPV is more than 4 billion € for the period of 2012 to 2023 and break-even will already be reached in 2016, the third year of operations. About half a billion € have to be invested before the operational start of the service.

In summary, the continuation of the CoCar CHW development and introduction is recommended unconditionally. Future research should cover more specific BCR analyses, more in-depth user requirements and the preparation of valid business cases for various actors and stakeholders. From a technical point of view, the performance of evolved cellular technologies, such as the emerging radio access technology LTE and the service management platform IMS, should be further investigated.

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List of Abbreviations

3GPP The 3rd Generation Partnership Project

ASS Automotive Software and Services

B2B Business-to-Business

B2G Business-to-Governmental

BCR Benefit Cost Ratio

C2C Car-to-Car

C2I Car-to-Infrastructure

C2IC Car-to-Infrastructure Communication

CAPEX Capital Expenditures

CBS Cell Broadcast Service

CC2CC Cellular Car-to-Car Communication

CHW Cellular Hazard Warning

CHW-A Cellular Hazard Warning All-clear

CHW-I Cellular Hazard Warning Information

CN Core Network

CoCar Cooperative Cars

CRM Customer Relationship Management

CVIS Cooperative Vehicle-Infrastructure Systems

DCH Dedicated Channel

DIWA Direkte Information und Warnung für Autofahrer

DMB Digital Multimedia Broadcasting

DSL Digital Subscriber Line

DSRC Dedicated Short Range Communication

DVB-H Digital Video Broadcasting for Handheld

EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortization
E-DCH	Enhanced Dedicated Channel
EDGE	Enhanced Data Rates for GSM Evolution
EPC	Evolved Packet Core
EPM-DAB	Enhanced Packet Model Digital Audio Broadcasting
EPS	Evolved Packet System
ETSI	European Telecommunications Standards Institute
E-UTRA	Evolved UMTS Terrestrial Radio Access
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
FACH	Forward Access Channel
FCD	Floating Car Data
FDMA	Frequency Division Multiple Access
FTAP	Fast Traffic Alert Protocol
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communication
HGV	Heavy Goods Vehicle
HMI	Human Machine Interface
HSDPA	High Speed Downlink Packet Access
HS-DSCH	High Speed Downlink Shared Channel
HSPA	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IM	Instant Messaging
IMS	IP Multimedia Subsystem
IP	Internet Protocol
ITS	Intelligent Transport Systems
IVSS	Intelligent Vehicle Safety System
LTE	Long Term Evolution
M2M	Machine-to-Machine

MBMS	Multimedia Broadcast Multicast Service
MIMO	Multiple Input Multiple Output
MNO	Mobile Network Operator
MNS	Mobile Network Supplier
MSA	MBMS Service Area
MSP	Mobile Service Provider
NGMN	Next Generation Mobile Networks
NPV	Net Present Value
OEM	Original Equipment Manufacturer
OFDM	Orthogonal Frequency Division Multiplex
OFDMA	Orthogonal Frequency Division Multiple Access
OPEX	Operational Expenditures
PND	Personal Navigation Device
QoS	Quality of Service
RACH	Random Access Channel
RAN	Radio Access Network
RF	Radio Frequency
RnD	Research and Development
RTT	Round Trip Time
SAE	Service Architecture Evolution
SC-FDMA	Single Carrier Frequency Division Multiplex Access
SCH	Synchronization Channel
SEiSS	Socio-Economic impact of intelligent Safety Systems
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module
SIP	Session Initiation Protocol
SMS	Short Message Service
SS7	Signaling System #7
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TPDP	Traffic Probe Data Protocol
TPEG	Transport Protocol Expert Group

TPP	Telematics Platform Provider
TR	Technical Report
TSP	Telematics Service Provider
TTI	Transmission Time Interval
UMTS	Universal Mobile Telecommunications System
UTRAN	UMTS Terrestrial Radio Access Network
VAPI	Vehicle Appliction Interface
VCA	Value Creation Architecture
VICS	Vehicle Information and Communication System
VoIP	Voice over IP
VRM	Vehicle Relationship Management
WACC	Weighted Average Cost of Capital
WAVE	Wireless Access in Vehicular Environments
W-CDMA	Wideband Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless LAN
WLD	Wireless Local Danger Warning

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