A New V2X-Communication Architecture
Content

More than just a vision ................................................................. 3
The goal: The quickest possible access to information on current traffic situations ........................................... 4
Flexible, open access, future-proof: The CONVERGE architecture ................................................................. 6
Validation scenario: Wrong-Way Driver Warning (WWDW) .......... 10
Validation scenario: Transport and Logistics ............................ 12
Ideas become reality .................................................................... 14
CONVERGE: Vital Role when deploying Intelligent Transportation Systems (ITS) ................................. 15

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» City of Frankfurt/Main

Hybrid communication
Overall authorization concept
Integrated Security Concept
Selective information dissemination
Cooperative backends
Services
Validation scenario
More than just a vision

Dear readers,

The CONVERGE research initiative has been ambitiously pursuing a goal since 2012: the development of a cooperative architecture for vehicle-to-x-communication.

Many of the previous concepts of V2X-communication have brought to us valuable, but eventually only proprietary solutions. A sum of individual solutions does not necessarily result in a coherent system. Therefore the time has come to evolve innovative approaches in thinking and research. The aim is to unite providers of ITS-Services and network access as well as road authorities, car manufacturers and last, but not least, the drivers to create one architecture (a single architecture/a common architecture), which is independent of individual systems and operators – just like the Internet.

Broad spectrum, which ranges from “saving time” to “saving lives”

The cooperative architecture for V2X-communication is far more than a vision. It’s gaining more and more outline and opening new dimensions for safe and efficient mobility. In future the individual road user will be able to act as both a recipient and source of information in order to enable an almost omniscient knowledge of the current traffic condition. Providing valuable information for private transport and logistics, information on traffic flow and disseminating hazard warnings are use cases of this intelligent and standardised network in which the users themselves act as information distributors.

The perceived value of that kind of knowledge will change from use case to use case. On the one hand it will simply prevent loss of time due to traffic jams or accidents; on the other hand it may save lives. In any case it will be worth the effort and energy as well as the commitment invested in CONVERGE. For we have reached our goal: a reference infrastructure design for delivering the right information at the right time in the right place.

Sincerely

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The goal
The quickest possible access to information on current traffic situations

The mere acquisition of information does not necessarily mean that the person for whom it would be most valuable in the moment is able to use it. Traffic flow data will only help a driver of a motor vehicle if he receives it without time loss, e.g. due to needed human intervention. The same applies to hazard warnings. Only when the information about an obstacle on the road or a wrong-way driver reaches the concerned road users in near real time, the flow of information serves its purpose.

Hybrid Access Networks
CONVERGE has created the conditions to ensure that the time between information acquisition and information usage is significantly reduced. Ideally, every road user will receive all relevant information on current traffic situations almost in real time. What counts is not only avoiding accidents. The optimal flow of information creates a lot of possibilities: the ability to bypass traffic jams or construction sites, the efficient utilisation of truck parking lots and driving more economically, just to mention a few examples.

The CONVERGE research project has developed a Communication Network for Vehicles on the Road in due consideration of a Global Extension of the end-to-end-system. The hybrid usage of different publicly and privately owned radio access providers facilitates high quality mobility data customised for future driver information and assistance systems. Therefore it was necessary for providers of information services as well as mobile network operators, traffic control centres, car manufacturers and other industries and institutions to agree on feasible methods and standards, not only concerning technology.

This puts the central needs of a new communication, service and organisational architecture on the agenda – an architecture that combines the infrastructure systems of different operators and
networks in a hybrid communication system. Already today most information needed for a highly efficient traffic management is at our disposal. Lacking up to now has been a cooperative and hybrid architecture for automotive WLAN (IEEE 802.11p and ETSI ITS G5) and mobile communications with coherent rules governing access to and use of this architecture.

The way forward: creating a cooperative architecture in a systems network

The companies and organisations participating in CONVERGE have developed an open yet secure system architecture. While previous research approaches for V2X communication required individual operators or a centralised system, the CONVERGE architecture is built operator independent following the example of the Internet. The aim is that the providers of services, infrastructure operators as well as manufacturers and users of vehicles can participate in this system architecture, without having to help shape it.

The essential characteristics of the operator-independent system architecture are:

» Modular design, scalability and reliability,

» Independence of the physical connection (e. g. mobile network, Wi-Fi, Ethernet),

» Distributed Internet architecture; high availability, even in case of failure of individual components (no single points of failure),

» Simplicity from a service provider perspective.

The CONVERGE architecture design adopts these proven Internet principles and complements them with characteristics of modern telecommunications networks, such as high security levels, international deployment capabilities and managed quality of service.
Flexible, open access, future-proof
The CONVERGE architecture

The concept of actors is central to the CONVERGE architecture. Actors in a CONVERGE system share information or provide communication services or backbone facilitation.

Actors, Clients and Interactions

Three important kinds of actors are forming the three level design:

» Actors providing information services e.g. vehicle manufacturers, road authorities or vehicle/fleet service providers ("Backend/Backbone Level"). In addition, on the same level, there are further actors ("System-Services") contributing certain system functions, such as naming services, addressing schemes, discovery mechanisms.

» Actors providing communication services e.g. mobile network operators (MNOs) or operators of ETSI ITS G5 roadside networks ("Network Level").

» Actors ("Mobility Level") who will exchange traffic and safety related information.
Actors exchange relevant and important traffic and safety related information to the benefit of their clients. Clients in this context are the connected vehicles or attached transport operators and transport authorities. Actors in a CONVERGE deployment are expected to adhere to a common governance structure with a mandated code of conduct on how to behave and operate as part of a CONVERGE systems network. The CONVERGE security principles are supporting the operational enforcement of the code of conduct.

**Open for further actors, new services and cross-border operation**

Actors in CONVERGE can function as different kinds of organisational bodies, authorities or service providers. A mobile network operator, for example, can adopt the acting role of a communication channel provider and that of a service provider. The inherent distributed design of the CONVERGE architecture allows for a cross-border and cross-authority deployment as well as multi-party operations. Another advantage of the distributed system architecture lies within the fact that an actor, for instance a service provider, can leave the system and get easily replaced by another actor, without having affect on the fundamental operation of the CONVERGE systems network.

**Novel architecture components and concepts**

To accomplish the above described behaviour, CONVERGE introduces the following novel architecture components and concepts:

» An organisational, operational and regulatory superstructure, known as the Governance Layer, which is responsible for organising and operating the system network based on common rules, conventions and agreements in order to guarantee the fair and efficient cooperation essential for ensuring the openness of the V2X System Network

» A service management concept based on distributed, hierarchical service directories supporting all kinds of services.

» A so-called bridge concept allowing clients to register for events and data related to topics (e. g. traffic information), attributes (e. g. information for trucks) and geographic areas. This allows for information to be pushed with the most efficient usage of available communication network capabilities (e. g. cellular GeoMessaging). Thus, a hybrid and efficient communication is achieved that doesn’t require knowledge about communication network capabilities or the details of its technology variants.
Given recent incidents, security, and privacy have become a rising concern for scientists, politicians, and the general public alike. From the very beginning, CONVERGE has had a focus on security and privacy, developing a security architecture for all relevant domains (network, application and system domains).

The privacy of users must be protected, ensuring their data will not be misused or stolen. Furthermore, the integrity, authenticity, and trustworthiness of communicated data must be verifiable by all of its recipients. Finally, the hybrid use integration of communication via cellular and ETSI ITS G5 in CONVERGE is particularly challenging.

The complete security concept comprises the following (selection):

- Integrated security mechanisms
- Conformity to international standards
- Role-based access control
- Specification of secure and privacy-preserving communication protocols
- Protection of personal data via pseudonymous certificates
- Specification and integration of security sub-systems
- Secure storage for cryptographic keys (e.g. hardware modules)
- Validation of security components using simulation

Information highway with integrated privacy protection
CONVERGE offers a simple, secure, and privacy-preserving solution for service usage: service providers receive digital certificates which confirm their identity as service provider for a specific service. Consequently, the CONVERGE security solution ensures that service users connect to authentic service providers. At the same time, the CONVERGE security solution offers pseudonymous digital certificates for service consumers. Using these certificates, service consumers can sign in to their subscribed services without revealing their real identity, thus preserving their privacy. Therefore, both service providers and consumers gain easy and secure access to the CONVERGE system without the need for complex individual solutions.

**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ETA</td>
<td>Estimated Time of Arrival</td>
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<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
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<td>GS</td>
<td>ITS operating in the 5 GHz frequency band (WLAN wave communication)</td>
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<td>IRS</td>
<td>ITS Roadside Station</td>
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<td>ITS</td>
<td>Intelligent Transport System</td>
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<td>IVS</td>
<td>ITS Vehicle Station</td>
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<td>MDM</td>
<td>Mobility Data Market</td>
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<tr>
<td>MNO</td>
<td>Mobile Network Operator</td>
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<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer (Car Manufacturer)</td>
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<tr>
<td>PKI</td>
<td>Public Key Infrastructure</td>
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<tr>
<td>V2X</td>
<td>Vehicle-to-Vehicle and Vehicle-to-Infrastructure</td>
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<tr>
<td>VPN</td>
<td>Virtual Private Network</td>
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<td>WLAN</td>
<td>Wireless Local Area Network</td>
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<td>WWDW</td>
<td>Wrong-Way Driver Warning</td>
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Validation scenario
Wrong-Way Driver Warning (WWDW)

In Germany approximately two thousand times a year a car moves head-on in the direction of oncoming traffic. Nearly 150 cases end up in a crash, half of which result in severe injuries or even death.

Scientists of the Bundesanstalt für Straßenwesen (BASt, German Federal Highway Research Institute) have found that information on wrong-way drivers mainly comes from other drivers on the road. It takes about five minutes until the information is broadcasted on the radio. That is a long time, considering that nearly 38 percent of all wrong-way driving ends after approximately 1000 meters; 67 percent of the distances involved are shorter than five kilometres, a distance that is travelled in five minutes at a speed of 60 kilometres per hour.

The chastening conclusion is: a great deal of wrong-way driving has already come to an end before a radio station has had the time to spread a life-saving warning.

V2X communication is able to diminish the dangerous time gap decisively. For instance, communication units along the roads, so called ITS Roadside Stations (IRS), or other road site detectors could detect a wrong-way driver.

After detection, the WWDW message will be distributed immediately within the CONVERGE Systems Network. The responsible Road Authority provides this information to other service providers, who then send corresponding warning messages via GeoMessaging over all available communication channels in near real time to all potentially affected vehicles in that area.

The detecting IRS immediately broadcasts warning messages to vehicles in its vicinity and the Road Authority sends the messages through their IRS network to oncoming upstream traffic. They can also integrate other roadside WWD detectors. The supplementing communications channels, cellular and ETSI...
ITS G5, represent the hybrid communication approach in CONVERGE. The conventional information path, through the police and national registration offices, remains available.

**CONVERGE architecture facilitates WWDW within the Systems Network ...**

The described information chains have already been tested previously before CONVERGE started but they are currently not yet in operation. The innovative approach of CONVERGE, with its cooperative and hybrid architecture, improves message transmission, accuracy of event location and creates the opportunities for further providers of WWDW services to integrate into the system without having to carry out any technical groundwork. That way an overall network of WWDW services can be generated.

... and many further applications

WWDW – Wrong-Way Driver Warning is only one of many applications of hybrid V2X-communication according to CONVERGE architecture. For example, the road authorities can send further information via IRS directly to the vehicles, such as “Temporary Roadworks Warnings”. ITS Vehicle Station (IVS) equipped vehicles will, in turn, continually send pseudonymous information to the IRS, of which an ITS Central Station can detect the local traffic situation and create traffic jam warnings and send them via IRS to following vehicles. This information can also be sent to other service providers, which send warnings or spacious re-routing recommendations around the traffic jam in near real time via the novel GeoMessaging concept.

The CONVERGE validation scenarios verify the architecture design principles by showcasing different examples of flexible information management, fast service creation and the easy and transparent utilization of different communication channels provided by different kinds of channel operators.
Companies involved in logistics processes will profit from the cooperative CONVERGE architecture in various ways. The integration of several service providers alongside logistic chains including car manufacturers, transport enterprises and their clients, operators of infrastructure and further actors can lead to considerably increased efficiency in transport and relieve roadways.
Pre-booking of parking space according to the traffic

Legal operating and prescribed off-times don’t leave much leeway for truck drivers. If a driver operates the vehicle over the legal time limit without taking the obligatory break – regardless of his reason – he will be faced with severe fines.

The increasing number of thefts, especially during resting hours at parking facilities, has led to the installation of secure parking spaces. For high value transports the reservation of a seamless chain of secure parking spaces along the route is an integrated part of the transportation planning and a mandatory requirement by insurance companies.

Accurate knowledge about the Estimated Time of Arrival (ETA) is a key element within the above-mentioned scenarios. In combination with a parking space booking service the driver can already avoid the tiring search for available parking space in the planning phase by simply booking a parking space according to the assumed ETA. In case of an unexpected event, which interferes with his schedule or affects the routing, an ETA-SERVICE will identify the deviation and inform all authorised and registered agents, e.g. the driver, the booking system or the fleet operator. Now that the knowledge about the delay is distributed, counter measures can be taken. One of the possible measures could be the booking of an alternative parking space, or a new schedule for the delivery. With this validation case CONVERGE will show its capability to facilitate the seamless interactions of the involved services and a transparent information distribution.

Even though pre-booking of parking space is not possible at public resting facilities in Germany, general information on the current situation of individual facilities can be published using the CONVERGE system. Truck drivers will appreciate that.
Ideas become reality

The CONVERGE project paves the way for future cooperative ITS scenarios based on truly distributed functionality together with standardised open interfaces, communication protocols and security solutions.

The CONVERGE architecture: open for future innovations and international deployment

» Reduction of development costs by means of a distributed and loosely coupled architecture

» Shorter time-to-market due to increased flexibility and defined roles along the utilisation chain

» Transparent and interchangeable use of various communication technologies

» Increased privacy due to distributed data storage – only the data required for a given transaction will be exchanged between the involved parties

» Increased safety due to an integrated security concept, which integrates all the components of the service provider through communication networks to the point of mobile nodes in the security system. No gaps - both technically and operationally

» Decoupling of the technical implementation of the requirements of the service provider; which allows the transorganisational and transnational use

» The first attempts towards a social realisation (Governance Layer)

The properties of CONVERGE enable a truly cooperative ITS future and the free flow of real-time information across national borders in Europe.
CONVERGE: vital role when deploying Intelligent Transportation Systems (ITS)

The task of CONVERGE has been to define the administrative and technical foundations of a cooperative architecture for V2X communication during the duration of the project from August 2012 to October 2015. The results of the project are publicly available. It enjoys national, European and worldwide recognition. First thoughts and activities, to convert the CONVERGE architecture into reality, are already underway.

The project team ends the successful cooperation in the belief that the solution defined by CONVERGE can play a vital role in the implementation and deployment of intelligent transportation systems (ITS) within three to five years.
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