Architecture of the Car2X Systems Network

Overview

- Governance
  - Definition of major rules all participants of the system have to oblige to
  - Inspection and enforcement rules
  - Top level security entities.

- Backend
  - Application blocks like the service providers
  - Service management
  - Geomessage distribution
  - Security components

- Communication network
  - Cellular Radio
  - ETSI ITS G5 WLAN
  - Geomessage-Distribution

- ITS Station
  - ITS-Vehicle Station
  - ITS-Personal Station
  - ITS-Roadside Station

General Concepts

- Distributed Functions (e.g. Service Management, Geomessage Distribution)
  - Sharing of operational tasks
  - Functional/Hierarchical Split

- End to End Quality of Service
  - Provision of several parallel communication bearers with different properties (latency, data rate, reliability)
  - Taking into account the features and characteristics of involved access media

- Sophisticated service concept
  - Open for new players
  - Adaptable to various kinds of services
  - Dynamical in case of change of actors
  - Publish-Discover-Invoke concept for service advertisement
  - Event-Subscribe-Notify mechanisms for load reduction

- Hybrid Communication
  - Usage of available access media parallel or complementary
  - Communication transparency for application layer

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**CONVERGE**

**COmmunication**

**Netw**ork

**VE**hicle

**Road**

**Global Extension**

BMW GROUP
Research and Technology

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Architecture of the Mobile Node

Goal
The Mobile Node (IVS) is integrated into the Car2X Systems Network and uses the most suitable communication technology for exchanging messages. The IVS provides a platform for all Car2X applications and matches all relevant security requirements.

Requirements
- The Mobile Node is integrated into the Systems Network by using defined interfaces
- The Mobile Node abstracts the applications from the underlying communication technologies
- The Mobile Node provides sensor data and related meta information
- The Mobile Node supports hybrid communication via cellular radio as well as via ETSI ITS G5 (WLAN)
- Depending on the use case, the Mobile Node has to communicate with all road users as well as the roadside infrastructure either promptly over short distances (e.g. time critical local danger warnings) or less time critical over long distances (e.g. traffic related incidents in a geographic area on the way)

Design
- The Mobile Node architecture
  - is derived from the goals and requirements
  - is taking into account existing architectures, e.g. ETSI-ITS
- To meet the requirements concerning hybrid communication as well as abstraction of communication access for applications, several new system components have to be considered, e.g.
  - Communication Hub
  - Incoming Event Alert
  - Rule Engine.
- Provision of QoS information is needed for selecting the most suitable communication link of the hybrid communication system (see also Poster “Network Access Selection & Message Distribution”)
- Support of Geomessaging (see also Poster “Geomessaging”)

Open Issues
- Hybrid Communication
  - How to design security in case of hybrid usage of the communication systems?
  - How to combine QoS mechanisms of cellular radio and WLAN (ITS G5)?
  - How to design the Network Access Selection & Message Distribution?
- Interface to Car2X Systems Network
Hybrid Communication

As one of the first C2X projects CONVERGE will introduce a concept of a hybrid communication system based on - but not limited to - the future-oriented technologies LTE cellular networking and ETSI ITS G5. This hybrid approach provides the possibility to use the advantages of both technologies tailored for respective applications. To achieve this goal, a mechanism to decide which communication path matches specific communication needs, was developed and integrated.

Characteristics

- Redundancy
- Support of trans-regional and international connectivity
- Support of provider-independence
- Flexibility
- Scalability
- Selection of appropriate communication paths for specific communication needs
- QoS
- Data Quality

| G5                                                                 |
|********************************************************************|
| Peer to peer                                                     |
| Anonym communication nodes                                      |
| Geo-referenced                                                  |
| Low latency                                                     |
| Ad Hoc communication dynamic network                            |
| Separate, standardized frequencies for safety relevant services and value added services |
| Created for automotive environment                               |

| LTE                                                                |
|********************************************************************|
| Flat architecture                                                |
| Radio Resource Management within eNBs                            |
| Coordination between eNBs                                        |
| Easy extendable and high scalability                             |
| IP Services independent from LTE architecture                   |
| QoS and bearer concept allows flexible modification of services  |
| Permanent IP Address                                             |
Geomessaging

General Concept

- A map overlay of square tiles is defined in the geomessaging server
- Each IVS contains a geomessaging client which is reporting GPS position to a server on crossing a tile border
- The server keeps track of the positions of clients on a per-tile basis

Warning Message Distribution

- Service is invoked from SP by sending message content (e.g. Wrong Way Driver Warning) and relevance area to GEOM System Service
- GEOM System Service relays the information to all GEOM Servers servicing the relevance area
- GEOM Servers (MNO/IRS) send message to clients which are in the tiles intersecting the relevance area

Geomessaging Architecture in CONVERGE

In CONVERGE, the geomessaging functionality will be implemented in two layers:

- The upper layer is in the system core. The System Service GEOM will act as a proxy towards the Geolocation messaging servers (GEOM MNO/IRS)
- It holds information about the coverage area of individual GEOM MNO/IRS entities
- Implementation might be analogous to today’s DNS architecture
- The lower layer is in the Mobile Network Operators (GEOM MNO) and the IRS Network (GEOM IRS)
- It informs the System Service GEOM about its coverage area
- It takes care of the actual distribution of the messages (e.g. via unicast, broadcast, IRS broadcast)
A service is the exchange and provision of application specific data via the systems-network.

Service management mechanisms have to ensure access to and quality assurance of available services.

Service Directory
The Service Directory is a key component of service management. It is a distributed database which offers interfaces to enter and to search for services.

Database entries contain links to registered services and tags which classify and describe them.

Service Directories are distributed and might be linked to each other such that a database search will not only include local entries.

Quality assurance
CONVERGE Services have to comply with the rules of the systems-network. These rules ensure overall quality of the service and final interaction.

Before services can be published at a Service Directory a Service Test and Certification Institution has to approve and certify them.

Conclusion
CONVERGE introduces general rules and a common database in service management for end-user and backend-user ITS services. It replaces a market where usage conditions and ways of access for services are completely provider dependent.

Especially for small companies, CONVERGE tears down barriers emerging from current complicated, high diversity markets by simplification of access. It therefore boosts diversity and facilitates networking to enhance overall service reuse and quality.
Institutional Role Model

Our goal:
Specify an organizational structure based on roles and actors to enable flexible interactions and new business models.

Good reasons:
• Minimize losses,
• Create sustainable and resilient solutions,
• Win-win for all actors.

Role:
• Describes a set of actions and the conditions under which these have to be executed.
• Economical roles also include obligations, liabilities, etc.
• Technical roles describe functionalities.
• Roles are impartible.

Actors:
• Companies/institutions/…, that fulfill one or multiple roles.
• A role can be fulfilled by multiple actors (companies/institutions/…).

Rules of the game:
Common rules and regulations for all actors.

Phases of the game:
Different actors with different roles in different phases.

Fair play:
Attractive (economic) conditions for all participants.

The show must go on:
Leaving actors can be replaced without drawback for the solutions.
Validation Scenarios

Abstract
Two validation scenarios have been carefully selected in order to assess the key architectural components of CONVERGE. The building blocks are defined by cooperative mechanisms on different communication layers of the overall architecture as follows:

• Fast and purposive message distribution using heterogeneous communications (Cellular, ETSI ITS G5)
• Comprehensive message dissemination via cooperative backend systems

Wrong Way Driver Warning
Today, a wrong way driver on a motorway is the worst-case scenario for every driver. Accidents that emerge from these events are rare but very severe. According to a study of BAST reported in December 2012, 27% of registered wrong way driving incidents are below 500 meters, 67% are below 5 km. Assuming a speed of 60 km/h this means 30 to 300 s incident duration.

The scenario aims to reduce detection and transmission time and enhance accuracy in distributing warning messages to the drivers using hybrid communication. This approach will have an impact on traffic safety.

Logistics Scenario
Today, a transparent information exchange between drivers and available parking space as well as dispatching entities, transshipment centers and customers cannot be guaranteed for the transport sector. This leads to economic inefficiencies like unpredictable trip times, increased CO₂ exhaust and accident hazards.

The aim of this scenario is to optimize the entire transport chain by improved service cooperation and better information exchange between fleet operators, drivers, transshipment centers or parking-lot operators.

Performance improvement of CONVERGE architecture
• Detection based on C2C Cooperative Awareness Messages (CAM)
• Purposive message distribution almost in real-time
• Alert message and on time warning
• Notification message and traffic re-routing possibilities
• Exact position of the incident

Performance improvement of CONVERGE architecture
• More flexible service cooperation and information exchange enhance logistics support services (e.g. parking space reservation) and thus reduce CO₂ exhaust and traffic hazards
• Reduction of trip times alongside the transport chain
• Improved capacity utilization of loading ramps or parking lots
**IT-Security**

**Communication Security**
- Security concept for hybrid communication
- Based on international standards (ETSI TS 103 097, TS 102 723 Draft)
- Dependable communication through end-to-end security, authenticity, integrity, and confidentiality protection, verifiable trust in messages
- Privacy-preserving PKI
  - Well-protected permanent identity
  - Regularly changing pseudonymous identities
  - Separation of knowledge within the PKI
- Misbehavior Detection

**PKI**

![Diagram of PKI](image)

**Pseudonymous Service Usage**
- **Motivation**
  - Uniform joining process for service providers
  - Support for decentralized billing
  - Prevention of tracking by third parties
  - Scalability
- **Concept: Pseudonyms + Application ID (AID)**
  - Dedicated pseudonyms exclusively for service usage
  - Pseudonyms include a service’s AID
  - IVS uses its pseudonyms and associated private keys to authenticate for service usage
Network Access Selection & Message Dissemination

Abstract
Hybrid communication systems allow the use of different radio access technologies and the selection of the appropriate communication interface that is suitable for a specific ITS application.

CONVERGE will focus on cellular communications and ETSI ITS G5 in order to provide improved availability and timeliness of relevant mobility information. Redundant access technologies may furthermore improve the robustness of sensitive communications by means of access diversity.

Benefits of hybrid communication
The application of heterogeneous communications increases the number of interconnected terminals in the CONVERGE Car2X Systems Network. This leads to an increased number of traffic participants that mutually exchange mobility information in order to improve traffic efficiency and -safety applications.

- Increased IVS penetration with hybrid communication technologies (Cellular, ETSI ITS G5) during market introduction of ETSI ITS G5
- Improved service availability

Adaptive network selection
The availability of different radio access techniques allows for a proper selection of suitable network resources based on functional requirements and the QoS-oriented parameters of the access networks. This will enable mechanisms for adaptive and dynamic network selection that are beneficial in terms of the economic distribution of available resources among all groups of stakeholders.

- Adaptive dynamic network selection for load balancing and efficient message distribution
- Message distribution with defined latency constraints and minimum resources

Next
- Network performance simulation of heterogeneous communications and adaptive network selection algorithms
- Performance assessment of key performance indicators like availability of information, latency and transmission resources

Figs. 1 & 2: Examplified message distribution efficiency in hybrid networks from network simulations
Data Classification

Abstract
The key purpose of the CONVERGE Car2X Systems Network is to facilitate the exchange of mobility data between all different stakeholders registered for a specific service. Therefore, different sources and sinks of information, spread across multiple stakeholders, exist in the CONVERGE Car2X Systems Network. Mobility data passes different processing steps, is aggregated and is being modified.

A standardized model for mobility data
CONVERGE empowers a cooperative backend architecture that allows for data exchange among different service providers. In order to support a quantitative assessment of data quality, a standardized model for mobility data needs to be defined. This includes information regarding accuracy, consistency and trustworthiness of data.
- **Standardized geographic data base** required since the validity of mobility data is limited by its specific geographic location
- Assessment of specific data attributes and meta information to characterize the semantics of mobility data

Need for data reconstruction
Data is being combined, modified and delayed at every step along the processing chain in the CONVERGE Car2X Systems Network. Since it is also being exchanged between different stakeholders, mechanisms need to be foreseen that allow for a reconstruction of the semantic content of original data.
- **Assessment of original data** relevant for driver assistance functions
- Traceability of data to be aligned with trust-, privacy- and security architecture in CONVERGE

Next
- **Identification of requirements and parameters** defining a unified framework for cooperative mobility data
- **Identification of standardization needs** for a unified model for mobility data

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Fig. 1: Unified model for mobility data

Fig. 2: Data dissemination and processing chain
Networking of Service Provider Backends

Initial Situation without CONVERGE

Example of a Wrong Way Driver Warning:

- Content Provider „State’s Traffic Reporting Office 1“ (CP STRO) receives a Wrong Way Driver Warning detected by traffic participants
- CP „STRO 1“ sends the WWDW to many Service Providers (public-service broadcasting, navigation services...), so every content provider has many individual direct communication links to different service providers
- SP receives the WWDW and transfers it to his customer via TMC
- As a consequence every SP must have contractual and communication obligations to every content provider to get a comprehensive service
- That means with an ascending number of SP or CP the number of individual contractual and communication links increases disproportionally high

Objectives of CONVERGE

- Decentralised operator independent service model
- Provision of concerted consistent mobility information and data
- Simplified access to the v2x market

CONVERGE Approach

- Every interested CP and SP is registered at the V2X system network for the WWDW-Service
- CP „Road Authority 1“ sends the WWDW to the V2X system network with access or communication information
- Every contracted SP is able to receive or pull the information needed for his services

Benefits

- Instead of having many individually specified communication links there will be one standardised communication link via internet/intranet as one access point
- The V2X system network simplifies organisational and communicational processes for mobility information services
- A business entering SP is able to provide his services without complicated contractual and communicational obligations
- The quickening of a comprehensive WWDW service will be supported by the possibility of simplified market access

CONVERGE-Approach