https://doi.org/10.37528/FTTE/9788673954875/TESi.2024.08

Digitalization of road infrastructure – V2X communication

Stefan Milivojević, Yunex Traffic d.o.o. Beograd, stefan.milivojevic@yunextraffic.com
Marijana Mladenović, Yunex Traffic d.o.o. Beograd, marijana.mosic@yunextraffic.com
Milan Radivojević, Yunex Traffic d.o.o. Beograd, milan.radivojevic@yunextraffic.com

Abstract: The digitalization of the road is an essential pillar for the mobility of the future: Intelligent communication technologies connect road users of all kinds with the infrastructure. The main goal of this paper is to describe available technologies in this field especially considering that C-ITS creates potential for increasing road safety and efficiency while reducing negative environmental impacts, which helps to improve the quality of life in and between cities. Increasing networking and comprehensive data exchange between road users and infrastructure are the essential building blocks for the future of mobility. V2X communication technology enables applications to increase traffic safety, optimize traffic flow, reduce negative environmental impacts, and increase operational safety while complying with the latest IT security standards. Through V2X technology, vehicles communicate with on-site infrastructure and cooperative traffic management systems. Not only motorized individual transport benefits from this technology. The intermodal networking of transport, in particular public transport, should be emphasized, which enables the V2X use cases. The introduction of V2X communication is a building block of the global strategy and has been tested and deemed useful in numerous research projects. In the future, these components will form the basis for autonomous driving applications. Countries should promote the development of an innovative and digital infrastructure through digitalization strategies.

Key words: C-ITS, V2X, road digitalization, traffic safety, communications technology.

1 INTRODUCTION

Digitalization of roads and intelligent communication technologies make the right base for the connected traffic. It helps cities and municipalities to improve the quality of life and form the basis for sustainable growth. Despite intensive efforts to provide attractive alternatives to individual and freight road traffic, a further increase in the volume of traffic can be expected in the future. Future connected mobility both on rural and urban sections provides the possibility for better and greater utilization of existing capacities, in addition to guaranteeing greater safety for all traffic users.

Focus of this paper will be on digital Vehicle-to-Everything (V2X) communication between road users and infrastructure systems through modern communication technology. System components explanation will be given through public transport use case.

2 VEHICLE2X COMMUNICATION (SYSTEM COMMPONENTS)

Vehicle-to-everything (V2X) is automatic communication and data exchange between the vehicles and other vehicles or infrastructure making a turning point for the future mobility. V2X communication technology enables applications to increase traffic safety, optimise traffic flow, reduce negative environmental impacts and increase operational safety while complying with the latest IT security standards. Through V2X technology, vehicles communicate with on-site infrastructure and cooperative traffic management systems via installed On-board units (OBUs) that are installed in vehicles and via Roadside units (RSUs) that are installed in infrastructure. This enables networking of vehicles and infrastructure. In the future, these components will form the basis for autonomous driving applications. Not only motorised individual transport (MIV) benefits from this technology. The intermodal networking of transport, in particular public transport, should be emphasised, which enables the V2X use cases. [1], [2], [3]

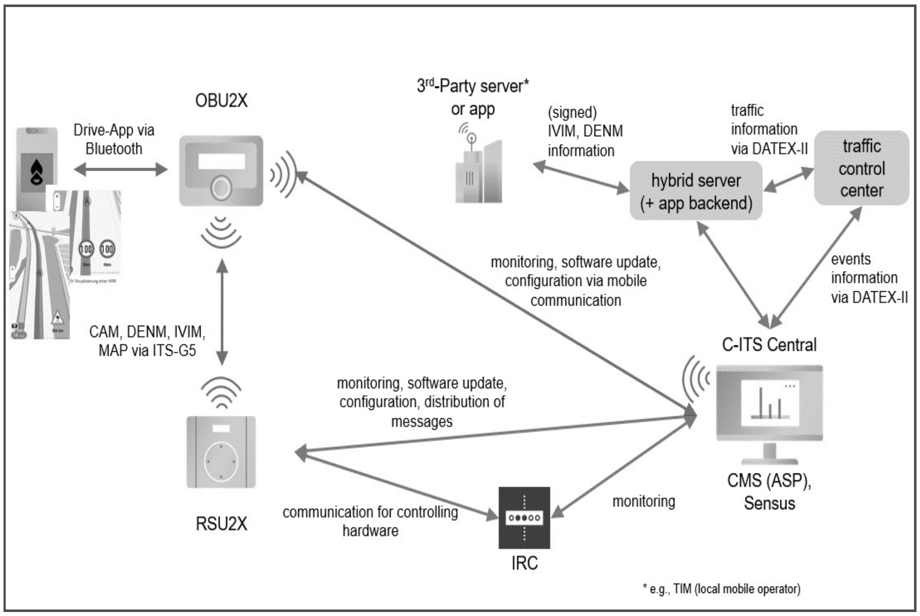

Figure 1. V2X system components overview, Source: Yunex Traffic C-ITS

2.1 Roadside Unit (RSU2X)

The RSU2X is the central interface for wireless communication between roadside infrastructure and the Onboard Unit (OBU). The bidirectional communication via the RSU2X enables both the transmission of information (e.g. speed limits) and the reception of Onboard messages in real time. A Roadside Unit (RSU) communicates with both, the traffic management center (CMS), and the vehicles:

- The RSU sends time-critical information (e.g. the current signal status) directly to the vehicles.
- Static and non-time-critical information (e.g. sign information) can be communicated to the vehicles either by the RSU or the CMS.
- Vehicles continuously report their current position, speed and direction of travel via their Vehicle2X Onboard Units.

- The RSU collects this information.
- The CMS uses this information to manage traffic more efficiently and in real time.

Figure 2. RSU2X with Quad-Core CPU edge computing and up to 4000 message verifications per second. Source: Yunex Traffic C-ITS

2.2 Onboard Unit (OBU)

The OBU integrates vehicles into cooperative ITS systems (C-ITS) and the deployment of infrastructure-driven C-ITS services and applications. Via the OBU, Vehicle2X can send hazard alerts to service vehicles or prioritize public transport and emergency vehicles. It enables road users to adapt their driving behaviour at an early stage, thus increasing safety for pedestrians and cyclists. OBU has a powerful transceiver for smooth communication with the RSUs and very high accuracy of position and speed determination. It is easily installed and is retrofittable and mountable in almost any vehicle.

Figure 3. OBU2X for windscreen installation with integrated V2X module Source: Yunex Traffic C-ITS

2.3 Cooperative Management System (CMS)

CMS is the main component which links and monitors the Roadside units (RSU) in a central system and sends messages via the RSUs to the vehicles. CMS allows flexible monitoring of RSUs and traffic at any time and any place. Cooperative and intermodal traffic management aims to minimise the negative effects of traffic, such as congestion, accidents, and environmental pollution. Modern sensor systems, floating car data (FCD) and V2X are used to determine the current traffic situation in detail. This traffic data is analysed in a traffic management centre, from which traffic strategies are then derived. This cooperative and intermodal centre forms the basis for the various V2X use cases (both in urban and interurban) and enables the digital control and influencing of traffic. Traffic controllers, dynamic display panels, apps, and prioritisation systems for various means of transport, such as buses and trams, emergency vehicles (e.g. fire brigade, emergency doctor, etc.) and bicycles, as well as traffic light systems are available for influencing traffic in the urban environment.

The CMS collects mobility data from all data sources, visualizes it and provides the information via standardized and modern interfaces. This then creates the conditions for V2X use cases. For example, Figure 4 shows hazard alerts in the traffic management center (CMS) that are created by the operator and sent to the vehicles. Reports from vehicles (e.g., accident) are forwarded to the CMS and visualized on the map.

Figure 4. Hazard alerts in the traffic management center (CMS), Source: Yunex Traffic C-ITS

The system is based on an open, scalable, secure and service-oriented architecture (SOA). With this SOA, the individual services are realized mainly independently of each other, which significantly increases the availability of the overall system. Services can be exchanged while retaining their external interfaces without affecting the remaining parts of the system. The platform itself fulfils the following requirements of cooperative traffic management:

- Cross-stakeholder access to all mobility information. This includes, among other things, traffic status, disruptions, events, incidents and road works.
- Detailed analyses for the evaluation of the traffic situation, including all the Data sources.
- Management and configuration of infrastructure objects such as RSU, OBU, (public transport) reporting points and map data (topology).
- Optimization of all mobility options and the entire road network, by flexible traffic management scenarios. Simulation models continuously test and evaluate the overall system based on real-time traffic, public transport and incident data.
- Complete transparency on the effects of traffic management strategies on the environmental situation. This is made possible by combining traffic and environmental simulation. Thus, it is possible to create scenarios and react to emission forecasts in a timely manner.
- The necessary degree of freedom to develop and modularly integrate customer-specific applications using flexible and open data services.

The system is compliant with the V2X requirements defined by the international Car2Car Communication Consortium, the ETSI (European Telecommunications Standards Institute) and the US-DoT (US Department of Transportation). Thanks to open interfaces, Vexicle2X can communicate with numerous controllers via standard connections and can also be extended later with additional communication modules. Vehicle2X offers a high level of IT security thanks to the Cyber-Security process and a defined security concept for maintenance and service. [1], [2], [3]

3 V2X-BASED PUBLIC TRANSPORT USE CASES

Public transport prioritisation favours public transport over private transport at traffic lights. The aim is to reduce energy consumption, emissions and travel times of buses and trains in order to increase the attractiveness of public transport. The reduction of travel times can make it possible to increase the frequency with the same number of resources. In addition, prioritisation avoids unnecessary braking and acceleration to a higher degree, which increases passenger comfort and safety.

Public transport prioritisation was introduced in the 1980s. With this established technology, buses or trams approaching an LSA receive clearance, usually via analogue radio. However, communication via analogue radio is obsolete. On the one hand, technological constraints, such as the discontinuation of analogue radio systems and open analogue radio communication, and on the other hand, innovative expansion potentials speak for a conversion of the existing systems to digital technology.

In recent years, two digital communication channels for public transport prioritisation have been developed and implemented in many projects. There is a local and a central communication path and their combination to implement the necessary modernisation.

A) Local public transport prioritization connects the OBU in the public transport vehicle to the traffic controller via RSU.

B) In centralized public transport prioritization, the OBU in the public transport vehicle communicates with the traffic controller via the cooperative traffic management center.

C) The local + central public transport prioritization uses both communication channels and thus combines their advantages. [1], [2], [3]

3.1 Local public transport prioritisation

In local prioritisation, the position and speed are determined with the help of a global navigation satellite system (GNSS). Communication with the LSA takes place via WLAN (short range) from the OBU via an RSU installed in the LSA. This prioritisation system has the advantage that the functional reliability is higher and the latency times are lower.

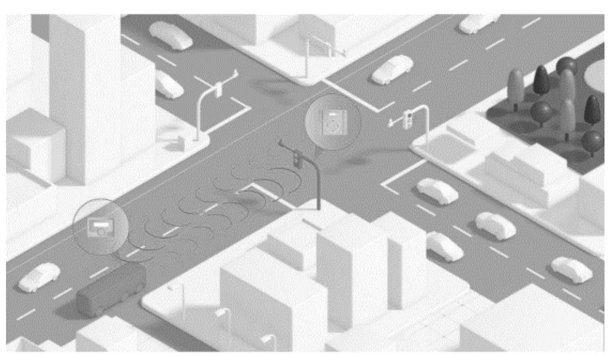

Figure 5. Local public transport prioritisation (short range)

V2X technology can reduce infrastructure construction costs. Currently, in many cities, sign-on signals are installed at the traffic lights to give public transport drivers visual feedback when public transport prioritisation is initiated. In the future, this use case can be virtualised and the registration signal can be shown on the vehicle display. In addition, speed recommendations can be shown to public transport drivers on the vehicle display. [1], [2] , [3]

3.2 Central public transport prioritisation

With central public transport prioritisation, the position and speed of the public transport vehicle is determined via GNSS, as with local prioritisation. Public transport vehicles are given priority at traffic lights via mobile communication. In the OBU of the public transport vehicle, trigger areas (reporting points) with coordinates are defined. If the public transport vehicle crosses these trigger areas at a predefined angle, the central public transport prioritisation is initiated. The OBU sends an information to the control centre. The control centre processes and sends to the LSA via an open interface. The LSA processes and initiates prioritisation.

Many traffic management applications have a lifespan of several decades. Systems for traffic control partly use communication technology from the eighties. For example, the communication of public transport vehicles with field devices such as traffic light systems (LSA) or switch control in Germany mostly takes place via analogue radio. Analogue radio is a robust technology, but it has been discontinued in many areas. This obsolete technology makes innovation difficult. Furthermore, discontinued technology is not acceptable from an IT security point of view, as security updates, for example, are often not possible.

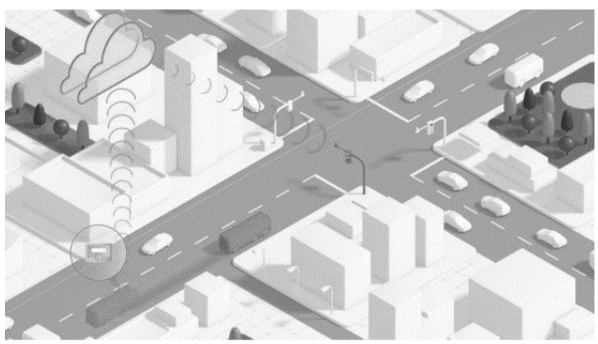

Figure 6. Central public transport prioritisation (long range)

3.3 Central + local public transport prioritisation

The system enables two-way communication and combines the advantages of central and local public transport prioritisation.

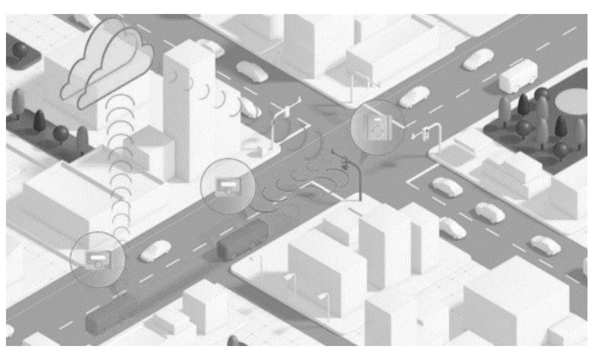

Figure 7. Local + central public transport prioritisation (short + long range)

Local + central public transport prioritisation combines the advantages of both systems. LSAs in the peripheral area of a city can be prioritised centrally. At very important intersections where many public transport lines meet, local public transport prioritisation can be used, as this reduces latency times and the direct communication path is independent of mobile phone providers. Furthermore, LSAs that require pre-announcement well before the stop lines can be prioritised centrally first and then locally within the range of the RSU. This two-way communication makes optimal use of a municipality's financial resources. [1], [2] , [3]

4 CONCLUSION

The digitalization of the road is an essential pillar for the mobility of the future: Intelligent communication technologies connect road users of all kinds with the infrastructure which makes V2X a building block of the global strategy.

The introduction of new V2X use cases in public transport sector results in many advantages such as a reduction of the number of stops of public transport vehicles, increasing the punctuality of public transport vehicles, reduction of the travel time and emissions, reduction of the required hardware e.g. through virtualization of login signals etc. However, it is important to ensure that analogue and digital technology can be operated in parallel. For example, it is possible to accelerate public transport vehicles at a traffic light using analogue and digital technology, which means that not all buses or trams have to be equipped with OBUs at the same time. Furthermore, in a first stage, the planning of public transport acceleration can be maintained. This simplifies the way into the digital world.

The conversion to digital technology from traditional (analogue) systems is a great challenge for the operators and for this reason must be implemented gradually with a migration concept adapted to the respective operator.

LITERATURE

The work is based on internal documentation, which is the property of Yunex Traffic and is partly publicly available.

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SUMMARY

Digitalizacija putne infrastrukture – V2X tehnologija

Rezime: Digitalizacija putne infrastrukture će biti od suštinskog značaja za mobilnost u budućnosti. Inteligentne komunikacione tehnologije povezuju učesnike u saobraćaju sa infrastrukturom. Osnovni cilj ovog rada je da opiše dostupne tehnologije u ovoj oblasti, posebno imajući u vidu da C-ITS ima potencijal za povećanje bezbednosti i efikasnosti na putevima uz smanjenje negativnih uticaja na životnu sredinu, sa pozitivnim uticajem na kvalitet života u gradovima, a i između njih. Povećanje umrežavanja i sveobuhvatna razmena podataka između učesnika u saobraćaju i infrastrukture su osnovni elementi za budućnost mobilnosti. V2X (vozilo i infrastruktura) komunikaciona tehnologija omogućava aplikacijama da povećaju bezbednost saobraćaja, optimizuju protok saobraćaja i smanje negativne uticaje na životnu sredinu uz poštovanje najnovijih IT bezbednosnih standarda. Putem V2X tehnologije, vozila komuniciraju sa infrastrukturom na svakoj lokaciji i kooperativnim sistemima za upravljanje saobraćajem. Benefite od ove tehnologije nemaju samo vozila, već i drugi učesnici u saobraćaju. Treba istaći intermodalno umrežavanje saobraćaja, posebno javnog prevoza, što omogućava različite slučajeve upotrebe V2X. Uvođenje V2X komunikacije je sastavni element globalne strategije upravljanja saobraćajem i testirano je, sa dokazanim pozitivnim uticajem, u brojnim istraživanjima. U budućnosti će ove komponente činiti osnovu za autonomnu vožnju. Zemlje treba da promovišu razvoj inovativne i digitalne infrastrukture kroz strategije digitalizacije.

Ključne reči: C-ITS, V2X, digitalizacija, bezbednost saobraćaja, tehnologija komunikacije