A GLOBAL TREND FOR CAR 2 X COMMUNICATION

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ABSTRACT – Inter-vehicle and vehicle to roadside communication (V2X communication) allow both passenger safety and driving comfort to be improved significantly. For example, a vehicle detecting an icy road could inform following vehicles and thereby prevent accidents. Vehicle to roadside communication could be used near construction sites to warn the vehicle driver about reduced number of lanes or to give him advice for an alternative route. For improved traffic efficiency, vehicles could exchange the latest traffic flow information.

The advantages of V2X communication have been recognized in many regions of the world. Research initiatives worldwide have started and have already produced valuable results. Additional projects to solve the open issues are on the way.

Many regional efforts are taken to consolidate the results from research projects in industrial standards. Industry consortia have been formed, namely the Car2Car Communication Consortium in Europe, the Vehicle Safety Communication Consortium in the US and the Advanced Cruise-Assist Highway System Research Association in Japan.

Unfortunately, the regional variance of boundary conditions for the development of V2X communication is standing against an easy worldwide harmonization. Still, the mutual awareness of the world wide initiatives is growing. An increasing number of companies try to bridge the gaps between the regional developments.

KEYWORDS – Car2x, V2X, IVC, VANETs, C2C-CC

INTRODUCTION

V2V, V2I, V2X, C2C, C2X,... are several of many expression for a set of communication patterns in the area of inter-vehicle and vehicle to roadside communication. It enables a variety of applications that are meant to increase vehicle passenger and road safety, as well as driving comfort. This variety ranges from applications like hazard notification, over traffic flow optimization, to passenger entertainment.

V2X applications and technology have specific requirements and characteristics resulting in several technical and political challenges. Many applications rely on position awareness of the nodes, to indicate an incident's location and to judge how to react to a received message. Another challenge derives from the mobility of vehicles that form the network; applications can not rely on sessions or stable routing.

Apart from technical challenges, political influences for these communication systems have to be considered. Radio frequencies have to be made available, installation of supporting roadside infrastructure has to be negotiated with the road administrations, and agreements on interoperable standards have to be achieved. Finally, there are significant challenges to create a robust business case for the market introduction of V2X technology. Usually, new technologies are introduced at first into the premium vehicle segment. As safety related vehicle to vehicle (V2V) communication requires a rapid market penetration of equipped vehicles, this is not an option.

In order to address the previously mentioned challenges, many regional efforts are taken to consolidate results from research projects in industrial standards. Industry consortia have been formed, namely the Car2Car Communication Consortium (C2C-CC) (1) in Europe, the Vehicle Safety Communication Consortium (VSCC) (10) in the US and the Advanced Cruise-Assist Highway System Research Association in Japan (AHSRA)(16). The outcome of these efforts is the IEEE 1609.x (6)(7)(8)(9) and IEEE 802.11p (5) standards in the US. In parallel, ISO already tries to tie together a standard for 'Continuous Communications Air Interface for Long and Medium Range' (CALM)(14). Recently, the ETSI established a technical committee for standardization in the area of intelligent transportation systems (TC ITS).
Furthermore, big field operational tests are on the way to support the consolidation of V2X technology, e.g., German Sim-TD (4), Japanese Smartway (15), European FOT in FP7, US CAMP CICAS-V FOT (13), etc..

The regional variance of boundary conditions for the development of V2X communication is standing against an easy worldwide harmonization. Whereas in Japan, there is already an existing infrastructure for Vehicle Information and Communication System (VICS) and for Electronic Toll Collection (ETC) in some areas, in Germany it is not likely that V2X communication will be allowed to use toll collection infrastructure. While the US also has to deal with long distance driving in sparsely populated areas, the main Japanese situation is that of small crowded narrow roads and stacking of several lanes like in the Tokyo Metropolitan Expressway. While the V2X trial specification in the US is mainly driven by infrastructure providers and the number of involved authorities is rather limited (Department of Transportation (DOT), Federal Communications Commission (FCC), …), in Europe a common infrastructure seems hard to achieve due to the fragmentation with many national authorities.

Still, the mutual awareness of the world wide initiatives is growing. An increasing number of companies try to bridge the gaps between the regional developments.

WORLDWIDE RESEARCH AND STANDARDIZATION ACTIVITIES

USA

The driving forces in the US are the government (DOT) and the vehicle manufacturers. The main efforts are concentrated in the DOT funded projects like the Vehicle Infrastructure Integration Program (VII) (12) and Cooperative Intersection

Collision Avoidance System (CICAS) (13). Industry consortia that support those efforts are the Vehicle Infrastructure Integration Consortium (VIIC) and the Crash Avoidance Metrics Partnership (CAMP).

In 1999 the FCC allocated 75 MHz in the 5.9 GHz band as Dedicated Short Range Communication (DSRC) spectrum, exclusively for automotive use with the primary purpose of safety use. Figure 1 shows an overview of the channel allocation.

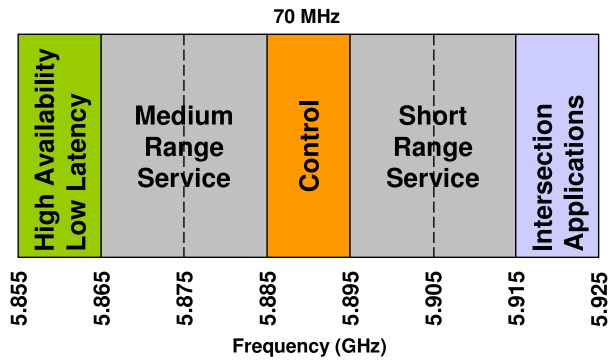

Figure 1: Frequency Allocation in the US

The communication protocols for V2X communication are standardized within the IEEE. The physical and MAC layer are defined in IEEE P802.11p (which is currently still in draft mode). Higher communication layers are defined by the IEEE 1609.x series, and together they form what is referred to as Wireless Access for the Vehicular Environment (WAVE). Figure 2 shows an overview on the resulting protocol stack.

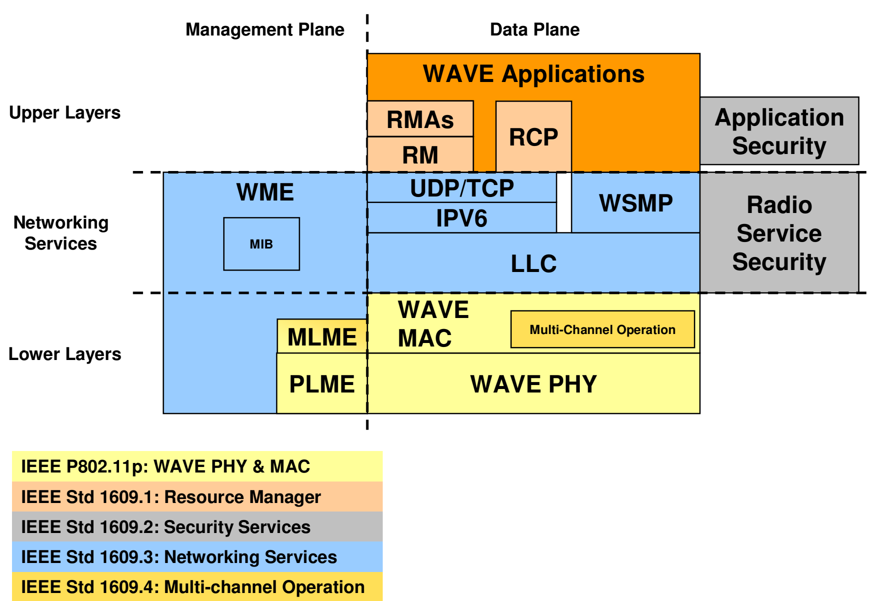

Figure 2: Protocol Stack in the US

The functionalities of the different layers above the physical and the MAC layer are described in the IEEE 1609.x document series:

- IEEE 1609.1 deals with managing multiple simultaneous data streams, memory, and other system resources.
- IEEE 1609.2 covers methods of securing WAVE messages against eavesdropping, spoofing, and other attacks.
- IEEE 1609.3 covers WAVE networking services and protocols.
- IEEE 1609.4 primarily covers how multiple channels - including control and service channels - should operate

JAPAN

In Japan, research, standardization and development of V2X communication systems are mainly driven by public authorities like the Ministry of Land, Infrastructure and Transportation (MLIT), the Ministry of Internal Affairs and Communication (MIC), Ministry of Economy, Trade and Industry (METI) and the National Police Agency (NPA).

As a basis for vehicle-to-roadside communication, the MLIT initiated the installation of an infrastructure for ETC which is already deployed and operated. The communication standard, developed under the assistance from the MIC is ARIB STD T55. Hence in Japan, assisting inter-vehicle communication via infrastructure is not yet supported.

More specifically for V2X DSRC, the communication standard also developed as a 5.8 GHz DSRC standard for Japan is the ARIB STD T75, which is different to WAVE 5.9 GHz. As it is based on the T55 standard, the connection is limited to roadside to vehicle only, which is also referred to as “Information Shower”: Within 30 meters, T75 specifies a full-duplex transmission rate of 4 Mbit/s to 56 vehicles within a service radius. To achieve that, the spectrum shown in Figure 3 is divided into a downlink and uplink spectrum with seven channels of 4.4 MHz each.

Furthermore, they develop a new communication standard that uses the 700 MHz band. The MIC decided to assign this frequency band for V2V use from 2012. Meanwhile, a slightly modified WAVE standard is used for the current V2X research and development.

Another basis for vehicle-to-roadside communication is VICS, which includes infrared beacon units located on roadside. This infrastructure has already developed and installed over Japan getting the support from NPA.

The relevant projects, i.e. public funded research, for V2X communication in Japan are Advanced Safety Vehicle (ASV), Advanced Highway Systems (AHS), and Driving Safety Support Systems (DSSS). The difference among these projects is that ASV focuses mainly on equipping vehicles with intelligent safety systems with no V2X communication assistance until generation three, but with it in generation four. On the other hand, the AHS program supported by MLIT focuses more on vehicle to roadside communication. It investigates the use of roadside sensors like cameras, infrared, etc so that AHS is able to provide information on the traffic situation to vehicles via 5.8 GHz DSRC. AHS is promoted by the Advanced Cruise-Assist

Highway System Research Association (AHSRA) (16). DSSS, which is promoted by NPA, also focuses on vehicle to roadside communication, featuring infrared beacon together with 5.8 DSRC.

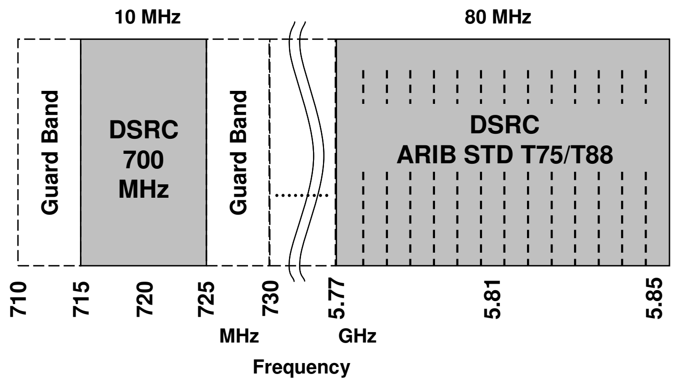

Figure 3: Frequency Allocation in Japan

AHSRA, whose purpose is to develop the Advanced Cruise-Assist Highway Systems, is having 16 full members like OEMs and suppliers. However, AHSRA has a broader scope on standardization of active safety systems in vehicles in general. Furthermore, AHSRA plans to develop these systems and introduce them to the market in tight cooperation with MLIT.

From the former project generations, Japanese OEMs have built fully-operational “Advanced Safety Vehicle”-prototypes and even market-ready products like “Navigation cooperative driving control system” (19). Larger public road tests of the technology developed within ASV-4 are planned to be tested within 2008. Also, during the next years, Japanese authorities and OEMs will perform multiple field operation tests with the developed systems through these projects, within urban areas like Tokyo and even nationwide field tests.

EUROPE

The European V2x communication activities are mainly driven by two entities, public funded research projects and the Car-2-Car Communication Consortium (C2C-CC). With respect to research, a huge number of European and national funded research projects produced and still produce valuable results in different areas of V2x communication. The upcoming generation of research projects is now targeting field operational test (FOTs) to validate proposed solutions suggested by previous research. One example for such is project is the aforementioned SIM-TD project (4) in Germany.

The huge number of projects was the reason to create the COMeSafety (3) project, which is in charge of coordinating amongst different projects. It guarantees that on the one hand, the results of the different projects are, at least to a certain extent, compatible with each other. On the other hand, it assures that the project results are taking into account the planning for standardization preparation in the C2C-CC.

The C2C-CC is the organization in Europe that drives the standardization process. It is an industry consortium where OEMs, suppliers and research institutes consolidate the input of the different research projects. Furthermore, the C2C-CC prepares and supports activities like the frequency allocation process. Those activities and the standardization are finally carried out in ETSI.

The current status of results of the C2C-CC activities can roughly be summarized as follows. Regarding frequency allocation, a dedicated bandwidth of 30 MHz will be available for traffic safety applications in the 5.9 GHz band (see Figure 4). Additional 20 MHz might be available as future extension, for road safety and traffic efficiency. Non-safety ITS applications might use 20 MHz in the ISM band below the 30 MHz. Further details on how to use the available spectrum are still under discussion, like for instance the number of channels, the placement of a control channel (placed in the center in Figure 4), or the number of radio modules that should be used (single vs. dual).

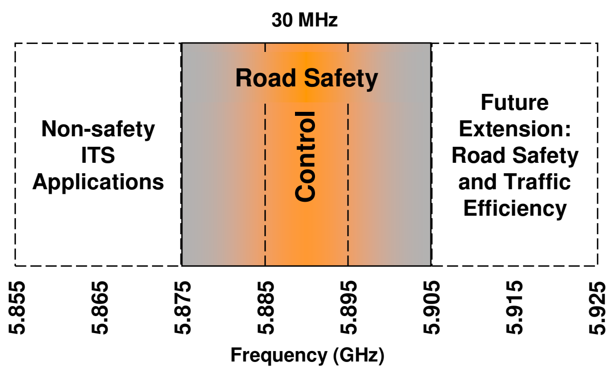

Figure 4: Frequency Allocation in Europe

With respect to communication protocols, Figure 5 shows an overview on the planned C2C-CC protocol stack. The most important difference compared to other V2x communication protocols as they are proposed in Japan or the US is the strong orientation towards direct V2V communication with less focus on V2I communication. This is reflected in the C2C-CC transport and network protocols that provide features like multi-hop message dissemination and geographic routing.

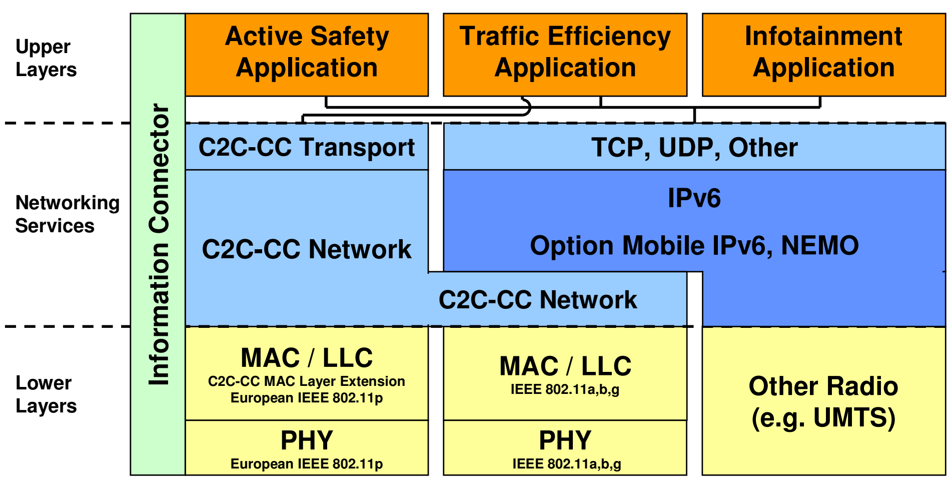

Figure 5: Protocol Stack in Europe (C2C-CC)

CONCLUSIONS - BRIDGING THE GAPS

The development of V2X communication reflects the local strengths and weaknesses. The progress of development in Europe suffers from large number of member countries and it is also slowed down due to the large number activities, projects and players, which sometimes even compete instead of cooperate. This in turn is where the advantages in Japan and in the US lie, there are only few focused projects. Probably the most supporting factor in Japan is the already existing tolling systems that are used as base for the development.

Although the developed protocols reflect the boundary conditions in the different regions around the world, in summary one can see communalities. Some of these communalities are visualized in Figure 6, where the different communication systems and the used technologies are summarized. It shows that there is a strong possibility that some of the communication standards worldwide will be based on technologies similar to IEEE P802.11p. This allows for a common communication hardware technology based on that standard. Then, only regional adjustments, e.g. communication driver parameters, MAC protocols, etc., have to be made to support the regional standard.

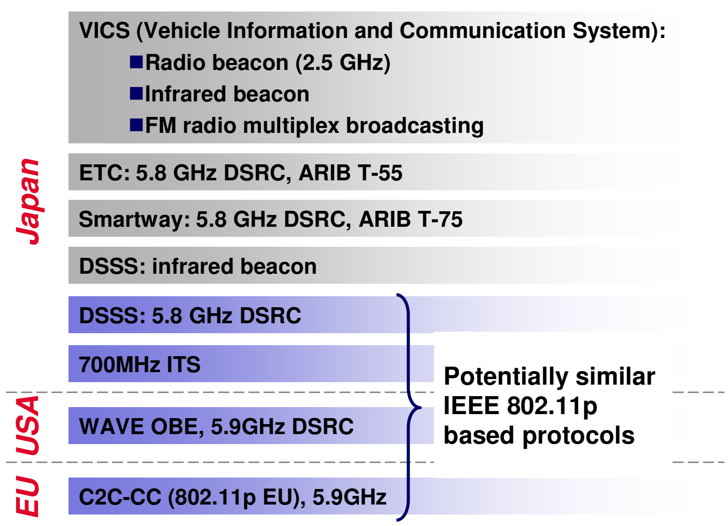

Figure 6: Communication Technologies Summary

Another common development in V2X worldwide is the trend to start nation-wide or even larger field operation tests. Based on recent hardware developments and intensive research, smaller-scope field tests with few vehicles have been performed, like in (20). Hence, the next step is to gain practical experiences via large-scope implementations.

With this in mind and knowing in addition that the envisioned applications worldwide are also similar, this results in the motivation for companies to bridge the gaps and tackle the remaining issues on a global basis. One of those issues is for instance security (see for instance (21)), which has been roughly defined in the IEEE 1609.2 standard, however only for a subset application of V2X communication.

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