C-ITS as multidisciplinary area with high demand on telecommunications solutions

Tomas ZELINKA,
Faculty of Transportation Sciences, Czech Technical University of Prague
110 00 Praha 1, Czech Republic

ABSTRACT

Cooperative Intelligent Transport Systems (C-ITS) are concentrated on transportation systems with goal to improve usability, efficiency and safety of the existing as well as newly constructed transportation infrastructure. These concepts are associated with high society expectations that C-ITS will principally participate in resolving of continuously growing transportation challenges. C-ITS represents typical multidisciplinary area where effective cooperation of wide range of different disciplines is the key condition of the success. Possible approach to treatment of requirements on telecommunication services in C-ITS applications is presented.

Keywords: ITS, C-ITS, VANET, ETC, telematics, performance indicator, multidisciplinary

1. INTRODUCTION

Transport systems in their complexity represent typical multidisciplinary area. Both design as well as operation of transportations systems cannot be any more based only on the traditional civil engineering, but these activities integrated branches like vehicles engineering as well as wide range of information technologies. Legal, sociological, psychological and safety understanding as well as ubiquitous financial aspect must be taken into considerations, as well. Action based on mix of these disciplines must be extremely carefully and efficiently managed to reach required result.

Expectations of transportation infrastructure clients use to be, at least in critical hours, much above available capacities and situation in most populated areas typically differs only in proportion of time transport infrastructure capacity is partially or totally collapsed. Number of active clients, i.e. vehicles, continuously grows as well as proportion of congested transportation networks.

There are two principle approaches how to reduce this trend:

- To expand transport infrastructure capacity by investment into transportation infrastructure – i.e. to build new capacities as well as to expand physical capacities of the existing streets, roads, highways etc.
- To improve existing infrastructure usage efficiency – approach based on ITS/C-ITS

Extensive approach has limits not only in restricted financial resources, but frequently also in reduced or no realistic possibilities of further infrastructure development. In many urban areas there is not available additional space to add any new infrastructure. In such cases the only potential can be identified in existing transportation infrastructure usage intensification and Intelligent Transport Services/Systems (ITS) are associated with expectations that ITS/C-ITS will significantly support society afford to resolve growing transportation challenges.

Setting of relevant mix of mentioned approaches can be very painful process thanks to specific investors and other decision makers strategies, even though close cooperation between those two streams is for sure the best alternative.

Transport systems management has got wide range of tools. Some of them directly influence traffic flow, some of them are based on user's restrictions and motivations like Electronic Toll Collection (ETC) variable charging. Decision on regulation mix must take into account that transport systems are principally influenced by human being acting e.g. as vehicles drivers and psychological, sociological as well as financial factors must be adopted in evaluation processes, as well.

2. COMMUNICATIONS SOLUTION FOR C-ITS

2.1 C-ITS and communications schemes

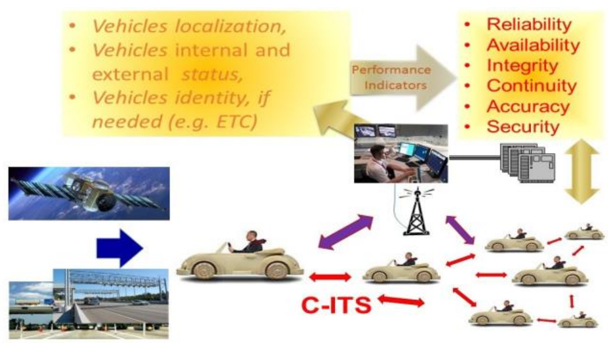

Figure 1. C-ITS background

Fig. 1 introduce simplified background of the C-ITS traffic management model. Road authority collects information about subjects localization, their internal and external status, and, if required, also about their identity. Data quality is quantified by performance indicators. Definitions of these system parameters – performance indicators - were developed in frame of the ITS architecture – see e.g. [1] - [3]. Localization is available via roads gentries or via GNSS services available still with limited, but step by step improving, quality and reliability. Communication between authorities and subjects on the road, i.e. Vehicle to Infrastructure communication (V2I), belongs to more or less standard ITS tools. New dimension in ITS, i.e. communication between subjects – Vehicle to Vehicle (V2V) - principally broadens possibilities of the ITS system to the cooperative approach (C-ITS). Any subject can share relevant information with any other subject in the served area.

Substantial part of the telematics performance analysis represents decomposition of the system into individual sub-systems of the chain. System decomposition enables application of the telematic chains follow-up analysis according to the various criteria.

Quantification of requirements on relevant telecommunication solutions in the telematic chains plays one of the key roles in this process. Mobility of the telecommunication solution represents one of the crucial system requirements namely in context of very specific demand on availability and security of

the solution. Communications performance indicators quantify telecommunications service quality – see e.g. in [1] - [3].
Impact of the telecommunications services on the telematics system performance is described by the transformation matrix *TM*. One of possible *TM* identification approaches is described in [4] or [7].
Requirements on latency of telecommunications solution depend on type of application:

- Direct/indirect traffic management requires typically response time of the whole chain in minutes and minutes fractions,
- Post-crash car autonomous systems like European e-Call system expect action within seconds and
- Pre-crash passive/active safety tools require total reaction time in sub-seconds. For active safety systems 100ms in total was accepted as the limit value.

Fig. 2 presents different data communication alternatives. Vehicle to Vehicle (V2V) communication in combination with communication Vehicle to Infrastructure provided on two levels (local/global) can support whole range of required functions. Base station antenna positioned outside of picture intends to stress, that this function is not provided as a part of the ITS service and that such services relay on publically provided mobile services.

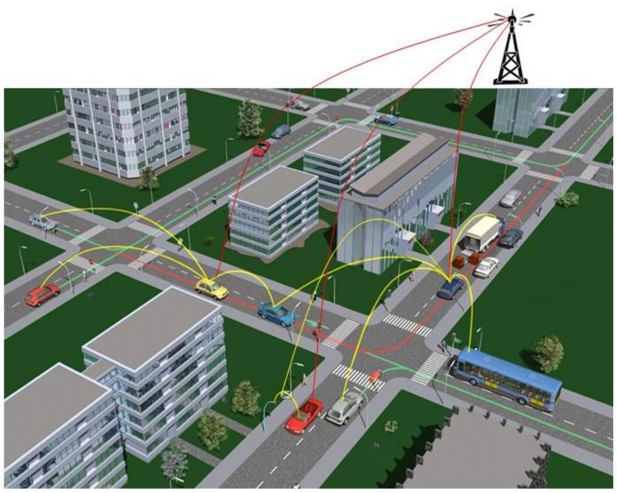

Figure 2. Tree levels of communication

Fig. 3 and Fig. 4 facilitate two telecommunication solutions generating different number of hops and relevant delays contributed to the overall service latency. Fig. 4 emphases communication scheme simplification and minimization of the final service latency.

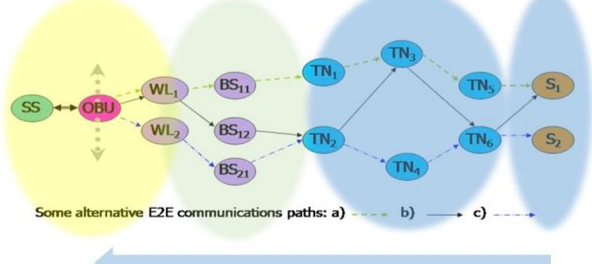

Figure 3. V2I communication architecture

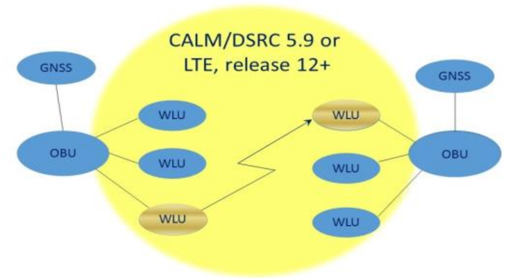

Figure 4. V2V communication

2.2 VANET

Vehicle Ad hock Network (VANET) is special case of Ad hock networking. VANETs are designed to support C-ITS applications with specific requirement on solutions:

- Constrained mobility,
- Highly dynamic topology,
- Frequent connects/disconnects,
- Extremely high security requirements.

High mutual speed of communicating vehicles can essentially reduce capacity of the shared communication system to fraction of nominal capacity. Newly designed routing protocols based on continuously identified network topology (each vehicle is equipped with GNSS unit) can support communication issue much more effectively, and, specifically vehicle grouping in carefully set clusters can remarkably reduce impact of this phenomena, as well.

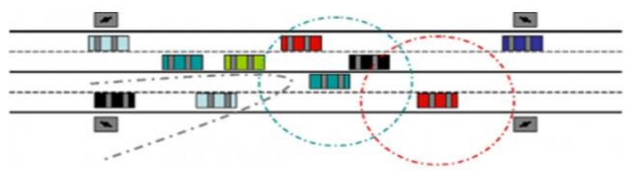

Figure 5. Clustering

3. MULTI-PATH ACCESS SOLUTION PRINCIPLES

Family of standards CEN TC204, WG16.1 “Communications Air-interface for Long and Medium range” (CALM) represents widely conceived concept of selection and switching to the best available wireless access alternative in given time and area. Substitution process of existing path by the alternative wireless access solution is understood as the second generation of the handover principles. CALM applies IPv6 protocol which allows to continuously remotely trace active applied alternative. Handover in CALM is accomplished on the L2 of the TCP (UDP)/IP model. Alternative approach based on standard IEEE 802.21 “leads” to the “general handover” using L2 switching as well, even though its system approach remarkably differs from that proposed by CALM.
Decision on handover action is based on evaluation of selected performance parameters. Bit Error Rate (BER), Packets Lost Ratio (PLR) or packet Round Trip Delay (RTD) are typical but not the only possible performance indicators used for decision processes.
Switching to the alternative path is accepted as relevant solution if active alternative is unable to resolve performance limits. Handover action, however, can be also evoked by identification of more suitable alternative to the active one. Reason for handover action can be identified e.g. in case of alternative service appearance where more suitable cost conditions are

offered even though existing alternative is technically acceptable as sufficient.
Handover decision processes represent basis for the efficient adaptability of the telecommunications wireless service. Solutions based on Policy-based Management (PBM) can be mostly identified and this concept has been traditionally applied in the IP based networking. This approach can be combined with Model Driven Architecture (MDA) approach. For example POETRY service creation framework applies such combination of PBM method and MDA model.
Alternative approach is based on application of Bayes statistics [11]. Set of measured parameters is extended by static parameters like service cost, corporate policy factors etc. Self-trained classification processes enables identification of the best possible selection. Classification algorithm is trained by time line of training data linked with correct assignment to the relevant class, i.e. selected path.
CALM standards represent extraordinary basis for future implementations and in combination with advanced decision processes there can be expected availability of effective ITS telecommunication solutions. These rigorously defined principles will most probably initiate some changes in approaches to the architecture of telecommunications solutions and potential of massive implementations so might represent good investment challenges.

However, no massive action to date have been noticed and some activities have been already redirected to the alternative principles based e.g. on standards IEEE 802.21 and not only to it.

4. AVAILABLE DATA SERVICES PERFORMANCE

Some ITS implementation identified significant problems with performance of GSM data services. We studied mobile data services performance in precisely defined laboratory conditions and presented results can be understood as the best possible reached values. Nevertheless, continuous afford in technology innovations enables step by step improvement of these presented limits.

4.1. GPRS

Fig. 6 shows in red average round trip delay (RTD) and in green packet loss ratio (PLR). GPRS technologies can be applicable only for applications where latency and high potential of packet losses are not critical.

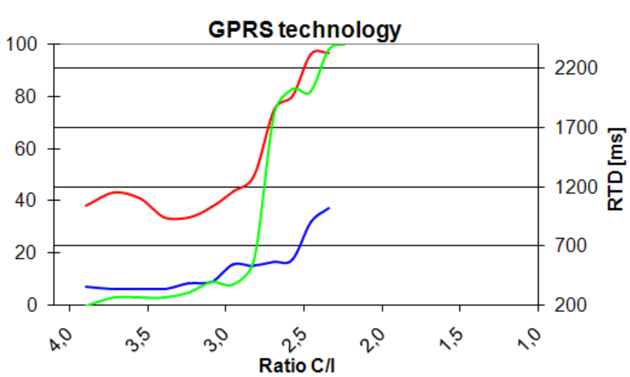

Figure 6. PLR and RTD - GPRS technology

4.2. EDGE measurement results

From Fig. 7 it is clear that due to improvement in average RTD (red) EDGE technology has got wider but still limited applicability in C-ITS solutions than GPRS.

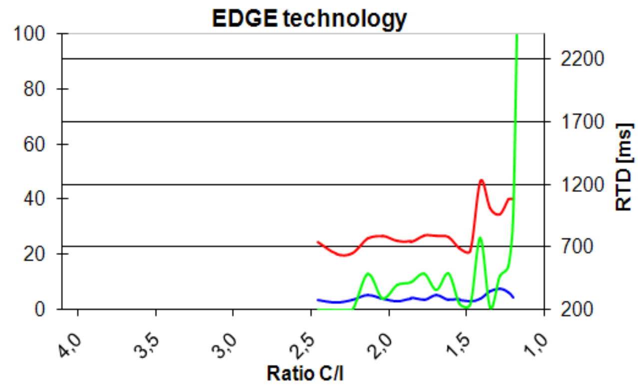

Figure 7. PLR and RTD - EDGE technology

4.3. UMTS measurement results

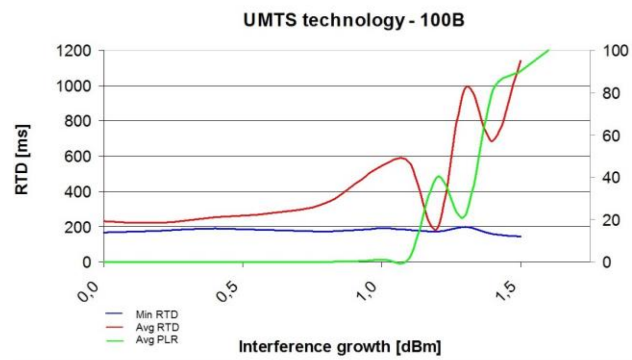

Figure 8 . Basic UMTS technology

UMTS is even more reasonable for usage in ITS applications if compared with EDGE, however, average RTD is still above expectations of proactive C-ITS applications.

4.4. WIMAX SERVICES PERFORMANCE

Technology based on IEEE 802.16d/e/m standards known as (Mobile) WiMax represented in time of introduction one of the most promising substitutions for ITS. Basic results of WiMax measurement in situ are in Table 1.

Table 1. – obtained parameters of the WiMax access

Site	Visibility	RTD [ms]	SNR [db]
1	LOS	45.6	33
2	LOS	47.1	32
3	NLOS	44.6	-26
4	NLOS	44.8	-27

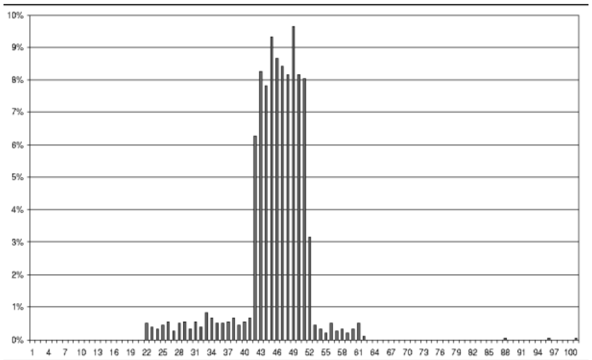

Figure 9. RTD spectra of LOS - SNR =+33db

RTD presents "Round Trip Delay" in ms, SNR is "Signal to Noise Ratio" in dB, and LOS represents "Line Of Sight" and NLOS "Non LOS". RTD results are displayed on Figure 9 and 10. We can identify that displayed RTD represents in average approx. 45ms and that it is one order faster than the GSM technologies (GPSR, EDGE). It is important to stress that average RTD is practically independent on radio conditions (SNR).

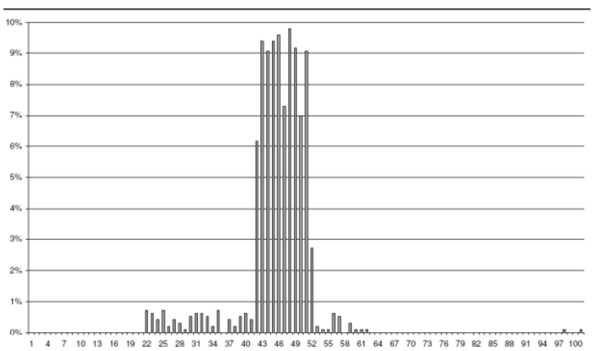

Figure 10. RTD spectra of NLOS - SNR=-27db

This technology implementations are much behind expectations, even though namely mobile version of this standard IEEE 802.16e/m might be acceptable for wide range of C-ITS. Most probably in key parameters comparable and potentially widely already on market available LTE based services demotivated ITS designers to apply this promising WiMax mobile technology.

4.5. WiFi data services performance

WiFi (IEEE 802.11) technology belongs to typical telecommunications „surprises". Due to massive penetration as the low end wireless access solution WiFi technology has been positioned as cheap product of the mass market. While in single user regime is latency in milliseconds, due to standardly applied CSMA/CA access protocol in multiuser regime latency depends on the cannel load, and in case of heavy load it can easily reach hundreds of milliseconds.
However, IEEE 802.11 standardization group has been step by step extending standard in direction which is welcomed by ITS applications.
For example Amendment IEEE 802.11e added tools for Quality of Service (QoS) management, i.e. important tool for sensitive on service latency applications.
Amendment IEEE 802.11p is locked to standard IEEE 1609 known as WAVE (Wireless Access for the Vehicular Environment) or DSRC (Dedicated Short Range Communications) 5.9. IEEE 802.11p acts as the MAC layer of IEEE 1609 standard. This Amendment supports remarkable extension in supporting mobile telematic applications. Solutions based on 802.11p enable both C2C and C2I with mutual speed tolerance up to 240 km/h.

Even though basic conditions for this standard application were already reached there must be resolved issue that IEEE 802.11p has got in conflict with European system DSRC 5.8GHz in their electromagnetic in-compatibility. This issue remains still as the hot topic for ISO/CEN and ETCI.

5. Solution for C-ITS Data Services

5.1. DSRC 5.9/WAVE

Standard IEEE 1609 known as DSRC 5.9 or WAVE treat communication structure, security mechanisms, and high-speed short-range wireless communication.
Standard is designed for specific dynamic transportations environment and its parameters are specifically tuned to requirements of ITS/C-ITS in summary:

- Both C2 I& C2C,
- IEEE 802.11p based Physical and MAC layer,
- Range up to 1000 meters,
- Velocity tolerance up to 240 km/h,
- Data rate - up to 27 Mbps,
- QoS management,
- Low latency (milliseconds) for single communication – total latency in VANET (below 100ms for 100 cars communicating in VANET),
- Strong security support provided (IEEE 1609.2),
- Based on off-the-shelf chip set & software with reasonable influence on OBU price.

However, to reach guaranteed telecommunications service parameters radio-base stations should be installed approx. in 1km distance in all around supported road network. Question is, if there is strong enough society demand backed with relevant resources to justify installation and operation of such base stations network on all roads and highways.

5.2. Beyond 3G standards

LTE (Long Term Evolution) is well designed solution for public services providers and it is understood as the basis of the next generation of mobile networks. Significant similarity of LTE with most of principles adopted with WiMax can be identified as very positive fact. Before 4G parameters are reached in implemented systems "beyond 3rd" generation category was adopted to stress fundamentally new approach to mobile services. This technology offers flexibility of the network configuration and high services availability. LTE successfully attacks mass market with promises of high transmission capacity and very low latency. Well supported QoS management tools are very important parameter for ITS systems. Interoperability with GSM, WCDMA/HSPA, TD-SCDMA and CDMA is resolved, as well.
ITU-R M.2134 defined 4G with following set of parameters included (both LTE and 802.16m were accepted as relevant alternatives for implementation):

- Mobility up to 350 km/h (guaranteed is connection),
- 1Gbps for low mobility users,
- 100 Mbps for mobile users,
- Latency for data below 10ms,
- Handover interruption max. 27.5ms (intra-frequency).

4G can is implementable as WiMAX (IEEE 802.16m) or 3GPP LTE-A (release 10 or higher). 3GPP release 12 should include between others also support of terminal to terminal single hop communication and both V2V and V2I communications could be supported in this case.

C-ITS applications requirements on guaranteed QoS are strict, and, there are serious doubt if mobile services providers will be ready to accept such type of business.

6. CONCLUSION

C-ITS represents new phenomena in modern transportations systems solutions. There are strong society expectations that C-ITS will help in improvement of transportation conditions with direct impact on quality of life. Telecommunication support is definitely one of necessary conditions C-ITS can appear as widely and massively accepted solutions.

Promising telecommunications alternative solutions were presented and even though each of them has got strong technological potential, none of them have clear future potential to win it. In telecommunications history we have been faced with both positive and negative discrepancies between expectations and reality. As examples can be presented telecommunications phenomena like IP, Ethernet or VoIP. There is strong tendency to explain their unexpected growths or fails as evolution processes and incompetence to predict their future has been accepted as status quo.

Alternative approach could profit from understanding of these processes as the multidisciplinary area. Technical disciplines should be combined with wide range of “soft” disciplines including those being able to qualify impacts like the ones related with the key market players decisions. We believe that approach based on multidisciplinary understanding of related processes can lead to much more efficient and better predictable processes enabling better concentration on the principle goals.

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