

The Information Technology Era of the Vehicular Industry

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ABSTRACT

In this note, we discuss the emerging era of information technology in the vehicular industry. After reviewing the motivations leading to the use of information technology in vehicles, we investigate the networking requirements of the necessary communication system based on IP (Internet Protocol). Existing work that could meet these requirements is highlighted together with some existing projects. We also briefly introduce some research and deployment issues that will have to be considered.

Categories and Subject Descriptors

C.2 [Computer-Communication Networks]: Internet-working

General Terms

Standardization

Keywords

IPv6, Intelligent Transportation Systems (ITS), in-vehicle network, Network Mobility (NEMO)

1. INTRODUCTION

In recent years, we have seen the spread of information technology to almost every aspect of our life. From mobile phones to security access cards, RFID (Radio Frequency Identification) and implants, data are now more often than ever exchanged between devices. This occurs either transparently to the human being (e.g. positioning information is transmitted over the cellular network) or deliberately (e.g. picking up the phone and calling someone). These electronic devices are either relieving us from repetitive tasks, helping us to find our way or put ourselves one click away from any third party. Automobiles are no exception to this trend. All vehicles are already equipped with several processing units, to enhance the performance of the engine's consumption and road safety. Next come navigation systems which are now embedded in most upper-range private vehicles. Complex multimedia systems are also more and more considered.

The desire from governmental agencies to spare life is probably the most important incentive leading to an even wider spread of information technology in vehicles of all kinds. For instance, the European Commission is funding several projects under the so-called eSafety initiative [2] launched in 2002 in order to halve the number of road fatalities by 2010 (in 2005 40,000 persons were killed and 1.8 mil-

lion severely injured in the sole European Union). Another incentive is the desire to limit traffic congestion and thus to optimize road density and the number of people in a given vehicle. Yet another one is consumption, which is indeed a function of the traffic congestion and advanced itinerary planning. All of these are the motivations behind Intelligent Car, one of the European Information Society 2010 (i2010) Flagship initiatives [2] adopted in February 2005.

In order to reach these objectives, communications are now considered necessary and will play an increasing role in the Intelligent Transportation Systems (ITS) era. Most ITS applications (road security, fleet management, navigation, billing, multimedia, etc) and usages (private, public, logistic and safety vehicles) will rely on data exchanged between the vehicle and the roadside infrastructure (V2I) and between vehicles (V2V). Vehicles currently sold already embed a proprietary communication system to exchange data between several components within the vehicle using the CAN (Controller Area Network) serial bus system specified by ISO (International Organization for Standardization) for real-time applications or the MOST (Media Oriented System Transport¹) standard specified for infotainment. However, such systems don't have provisions for exchanging data with other vehicles or the roadside.

Several solutions have already been envisioned to address this concern. The simplest one for V2I is the use of a mobile phone embedded in the vehicle to send a limited range of information between the vehicle and some server in the Internet. For V2V, which is generally relying on a minimum density of cars, a common solution is the use of limited-range wireless technologies to inform other vehicles in the vicinity about potential risks (slippery road, accident, etc). Such mechanisms have already appeared in commercial products and preclude the generalization of information technology in all vehicles produced in the very near future. However, as the types of usages and the number of vehicles increase, a communication system properly adapted to ITS applications must be designed.

2. ITS NETWORKING REQUIREMENTS

The communication system to exchange data between the vehicles or with the infrastructure will have to meet a number of requirements. In particular, it must:

- be persistent (ubiquitous),
- be reliable,

¹<http://www.mostcooperation.com>

- be able to scale to a large number of vehicles and amount of data,
- be able to serve for the lifetime of the vehicle and be sufficiently flexible to sustain system improvement, unexpected innovations and to accommodate a large panel of ITS applications and usages,
- require no or minimum human intervention and inquire minimum maintenance cost,
- preserve human privacy (e.g. location, identity) and security (e.g. data corruption, system control)
- adapt to various national policies.

For all these reasons, the data exchange system will have to rely as much as possible on existing, proven and open standards. As such, it became clear over the past few years that this exchange of data would use the Internet infrastructure and would be based on IP (Internet Protocol) as the underlying convergence protocol, as this could be witnessed by the numerous V2I and V2V projects around the world (see section 4). As discussed in [10, 7, 6], the basic functional requirements of an IP-based communication system for ITS usages include:

- the ability to deploy several nodes within a vehicle and to interconnect them through an in-vehicle network,
- the ability to maintain global connectivity while changing the in-vehicle network's point of attachment to the Internet,
- the ability for the in-vehicle network to attach to and use multiple access networks simultaneously,
- the ability to secure the data and the signaling transmitted over two end-points,
- the ability to configure the system remotely.

3. IPV6 COMMUNICATION SYSTEM

IPv6 [8, 11] appears as the prevalent IP version able to meet the ITS requirements, thanks to its extended address space, embedded security, enhanced mobility support mechanisms and ease of configuration (although somewhat outdated now, pros and cons of using IPv6 over IPv4 in ITS communication systems are discussed in [3]). As discussed in [7, 6], the IPv6 protocol stack already developed by the IETF (Internet Engineering Task Force), the standardization body defining the protocols of the Internet, meets a number of the ITS requirements, particularly its scalability (unlimited number of vehicles) and its flexibility (the protocol is extensible and any underlying technology could be contemplated, from GPRS to UMTS, M5, 802.11, 802.16, 802.21 and forthcoming 4G standards). The maintenance of the Internet connectivity can be provided by proper mobility support and routing mechanisms, in particular NEMO (NETwork MObility, i.e. moving networks connected to the infrastructure) and MANET (Mobile Ad-hoc Networking, i.e. network made of mobile nodes not connected to the infrastructure), often considered for V2I and V2V communications respectively. Ubiquity, reliability, and policy considerations can be ensured using secondary system components able to take over failed ones.

The work conducted by the IETF NEMO (NETwork MObility) Working Group² is going toward a direction that meets a number of the ITS requirements. The goal of the NEMO WG is to offer network mobility support in order to allow entire IPv6 networks (i.e. a *mobile router* and a number of connected devices such as sensors, servers, multimedia devices, etc) to change their point of attachment to the Internet topology. Cases of moving network include networks of sensors deployed in vehicles, access networks deployed in public transportation (trains, buses, aircrafts, etc), and also Personal Area Networks (PANs). In-vehicle networks are the preferred use cases.

The NEMO Basic Support protocol (RFC 3963) [5, 6] produced by this group is designed to maintain Internet connectivity between all the nodes in the moving vehicle and the infrastructure (*network mobility support*). This is performed without interruption nor failure of the data sessions under transmission, and transparently to the nodes located behind the mobile router embedded in the in-vehicle network, and the session peers. The mobile router is acting as a gateway between the in-vehicle network and the infrastructure. The solution requires all datagrams to transit through some remote network (the *home network*) using an encapsulation mechanism between the current point of attachment of the mobile router to the Internet and the remote network. This allows the in-vehicle network to remain reachable through a permanent IPv6 address taken from the home network. Other nodes behind the mobile router in the vehicle are standards IPv6 nodes, i.e. they don't need to be upgraded with any mobility support mechanism to benefit from the Internet connectivity provided by the mobile router. This network mobility support mechanism is thus very easy to deploy, at a minimum cost.

Note that network mobility support using RFC 3963 is to be opposed to the earlier specification on *host mobility support* using Mobile IPv6 [16] (RFC 3775, and specified by the IETF MIP6 Working Group) which provides Internet connectivity to a single moving host only. Mobile IPv6 is therefore inappropriate for the most advanced ITS use cases which usually consider more than one in-vehicle embedded CPU.

Basically, the entire IETF community is devoted to produce the technical specifications required by mobile communication users (IP telephony usages, ITS usages, military and security forces usages, etc): global mobility management (e.g. NEMO Basic Support, Mobile IPv6) and local mobility management (e.g. fast horizontal handovers with FMIPv6, micro-mobility management with Netlmm), security (e.g. IPsec, IKEv2), access control and authentication (e.g. Diameter, PANA), redundancy (e.g. managing multiple access technologies simultaneously, as investigated by the MONAMI6 Working Group recently set up at the IETF).

There is a profusion of papers discussing V2V communications using ad-hoc routing protocols like OLSR [9] as specified by the IETF MANET (Mobile Ad-hoc Networking) Working Group. For instance, [15] discusses the dynamics of ad-hoc networks for V2V communications. However, it remains to be seen how one could solely rely on ad-hoc routing given its constraint: the concept can only work provided there at least exists one other vehicle in the vicinity, and that could well not be the case particularly at night or in

²<http://www.ietf.org/html.charters/nemo-charter.html>

the countryside when it would be the most useful for safety purposes. A concept that might better work is a combination of MANET and NEMO (MANEMO), where fast ad-hoc routing protocols would be used for direct V2V communications when the possibility arises, whereas NEMO would be used for V2V communications via the infrastructure.

4. IPV6 RELATED PROJECTS AND ACTIVITIES

The protocols specified by the IETF are usually implemented as they are specified, so implementations are available and have been tested. Some of the implementations are even public (e.g. open source) so they can be tested at an extensive level by anyone who wants to validate a particular usage of the protocol. The most difficult part is basically the integration of all the desired protocols into a system architecture that fits the needs of a particular usage, i.e. ITS in the present case.

While the IETF is defining the protocols, other standardization bodies such as ISO are indeed defining the needed communication architecture for ITS based on the protocols defined by the IETF. At ISO, NEMO, Mobile IPv6 and other related protocols are parts of the CALM architecture³ [1] currently under specification within the Technical Committee 204 Working Group 16⁴. A *proof of concept* project of CALM is already going on in Japan. In Europe, this architecture is going to be implemented under the EC-funded CVIS (Co-operative Vehicle-Infrastructure Systems) project [2]. CVIS is a 4-years *Integrated project* from the 6th Framework. Starting this year, it will develop, demonstrate and validate a complete protocol architecture from the radio layer up to the application layer for V2I and V2V communications based on IPv6 and NEMO. V2V and V2I communications developed by CVIS will probably be used by other EC-funded projects such like Safespot, Coopers, and eCall (location aware emergency calls in order to improve responsiveness and thus decrease severity of casualties) which are all part of the overall eSafety initiative.

A few IPv6 experiments involving NEMO-enabled vehicles have already been performed. For instance, in Europe, the OverDRIVE project⁵ financed by the European Commission under the Information Society Technologies (IST) 5th framework has concluded and has considered NEMO as the underlying protocol to maintain Internet connectivity. In Japan, where there already exists a large number of implementations of NEMO Basic Support, both public (SHISA, NEPL) or commercial, several experiments have been conducted on vehicles. In particular, the InternetCAR project based at Keio University and within the WIDE organization, in association with the InternetITS consortium⁶ gathering car manufacturers, mobile system vendors, software companies and operators developing ITS applications and the necessary communication system, has performed several live trial experiments [6] for a number of years already, even before the NEMO work ever started at the IETF. The highlights of the experiments include traffic and weather data collection from a large number of taxis and switching sessions between multiple Internet access technologies offered

to IPv6-enabled vehicles. Nautilus⁷, though not directly related to ITS, is yet another project originated from the WIDE organization and working in association with other labs in France on the standardization, development and deployment of the underlying IPv6 mobility protocols.

Car manufacturers were involved in most of these experiments. In OverDRIVE, Daimler Chrysler was associated with Motorola Labs, France Telecom R & D and other partners and demonstrated the use of multicast over NEMO-enabled vehicles. In InternetITS, Toyota was associated with the mobile operator KDDI and Keio University which both developed their own implementation of NEMO Basic Support. Also, in 2003, Renault and Cisco won the Jun Murai award from the IPv6 Promotion Council in Tokyo, for their e-vehicle project, a car equipped with an IPv6 mobile access router and a number of ITS applications requiring Internet connectivity (vehicle remote diagnostic, enhanced navigation system and fleet management).

Further emphasizing the belief in an IPv6-based communication system, the sudden interest in IPv6 for ITS usages and particularly NEMO can be witnessed from the number of papers and talks on this topic in ITS-related conferences such as VTC and ITST (particularly the last edition held in France in June 2005⁸ for the latter), the WONEMO workshop held in Japan, January 2006⁹ and probably forthcoming ones such as the NEPT workshop to be held this summer in Canada¹⁰. At a much more commercial level, NEMO and other IPv6 demonstrations were performed at the ITS World Congress held in Nagoya in Japan in 2004.

5. CONCLUSIONS AND OPEN ISSUES

IPv6 is the underlying communication protocol that will be deployed for ITS applications. It is becoming notorious that the IPv6-associated concepts of network mobility (NEMO), ad-hoc networking (MANET) and other mechanisms meet the ITS communication system architecture requirements. The new projects recently set up in Europe and other countries in Asia and North America are evidences of the interest of many actors in an IPv6-based communication system and investors' belief that this technology can play a significant role into attaining the objectives, such as traffic congestion avoidance and preventing numerous accidents.

However, although several project have been set up recently with the objective to validate the concept of an IPv6-based communication system, several issues are still remaining.

From a research point of view, more work is needed to improve the performance of the overall system. It is difficult to guarantee a certain quality of service since the vehicle is very likely to use distinct access technologies to access to the Internet over a limited period of time, usually shorter than opened sessions. Assuming a communication architecture based on NEMO, standardized protocols and mechanisms allow to select the appropriate access technology and to take over a failed one, but not to deal with the change of delay and available bandwidth, where more research is needed [13]. Non-optimal routing between the moving entity and communicating peers is another issue linked with

³<http://www.calm.hu>

⁴<http://www.sae.org/technicalcommittees/tc204wg16.htm>

⁵<http://www.ist-overdrive.org>

⁶<http://www.internetITS.org>

⁷<http://www.nautilus6.org>

⁸<http://conferences.enst-bretagne.fr/itst2005>

⁹<http://www.ico.in.org/wonemo>

¹⁰<http://www.wnept.org/>

performance since it results in longer delays. As seen in section 3, the solution for network mobility support specified by the IETF does not offer optimal routing [14], but many solutions have been proposed, for instance [18] to cite one of the most recent work. The problem can be more or less alleviated in simple scenarios (e.g. the remote communication peer is located in the home network which provides the permanent address to the vehicle), but hard to bear when the communicating peer is located in the access network from where the vehicle is currently getting global connectivity (we remind that all datagrams still have to be routed through the home network), or very complex in scenarios where global connectivity to the Internet is provided via another vehicle. This latter scenario is either referred to a nested NEMO case (a NEMO-enabled vehicle becomes a subservient of another NEMO-enabled vehicle) [12] or a MANEMO case (combination of both MANET and NEMO where MANET nodes are made of NEMO-enabled vehicles) [17].

From an operational point of view, how the various protocols will behave once integrated is still unknown and many protocol fixes are to be expected. The operational deployment of the system will first have to answer a few questions, particularly how the addressing is going to be done (who owns the address space), how a secure access to various components is put in place (e.g. how authentication and authorization mechanisms are deployed [4]), where the various components of the architecture will be actually deployed, and last but not least who is going to pay for all of this and how the public is going to deal with vehicles ubiquitously connected to the Internet. This last point raises some security and location privacy concerns, so effective mechanisms must be researched into and integrated with the overall communication system.

6. REFERENCES

- [1] CALM - Medium and Long Range, High Speed, Air Interfaces parameters and protocols for broadcast, point to point, vehicle to vehicle, and vehicle to point communication in the ITS sector - Networking Protocol - Complementary element. Draft ISO/WD 21210, ISO, Technical Committee 204, WG16, December 2005. Work in progress.
- [2] European Commission eSafety Initiative. URL, As of March 2006.
http://europa.eu.int/information_society/activities/esafety.
- [3] C. Bettstetter. Toward Internet-based Car Communications: On Some System Architecture and Protocol Aspects. In *EUNICE Open European Summer School*, Twente, Netherlands, September 2000.
- [4] J. Bournelle, G. Valadon, D. Binet, S. Zrelli, and M. Laurent-Maknavicius. AAA Considerations Within Several NEMO Deployment Scenarios. In *1st International Workshop on Network Mobility (WONEMO)*, Sendai, Japan, January 2006.
- [5] V. Devarapalli, R. Wakikawa, A. Petrescu, and P. Thubert. Network Mobility (NEMO) Basic Support Protocol. Request For Comments 3963, IETF, January 2005.
- [6] T. Ernst, K. Mitsuya, and K. Uehara. Network Mobility from the InternetCAR Perspective. *JOIN: Journal on Interconnection Networks*, 4(3), September 2003.
- [7] T. Ernst and K. Uehara. Connecting Automobiles to the Internet. In *ITST: 3rd International Workshop on ITS Telecommunications*, Seoul, South Korea, November 2002.
- [8] C. Huitema. *IPv6 The New Internet Protocol*. Prentice Hall, 2nd edition, 1998.
- [9] P. Jacquet, P. Muhlethaler, P. Minet, A. Qayyum, A. Laouiti, T. Clausen, L. Viennot, and C. Adjih. Optimized link state routing protocol. In *IETF RFC3626*, October 2003.
- [10] W. Kellerer, C. Bettstetter, C. Schwingenshlög, and P. Sties. (Auto) Mobile Communication in a Heterogeneous and Converged World. *IEEE Personal Communications*, 8(6):41–47, December 2001.
- [11] D. C. Lee, D. L. Lough, S. F. Midkiff, N. J. Davis, and P. E. Benchoff. The Next Generation of the Internet: Aspects of the Internet Protocol Version 6. *IEEE Network*, January 1998.
- [12] B. McCarthy, C. Edwards, and M. Dunmore. Applying NEMO to a Mountain Rescue Domain. In *1st International Workshop on Network Mobility (WONEMO)*, Sendai, Japan, January 2006.
- [13] C. Ng, E. Paik, and T. Ernst. Analysis of Multihoming in Network Mobility Support. Internet Draft draft-ietf-nemo-multihoming-issues-05, IETF, February 2006. Work in progress.
- [14] C. Ng, F. Zhao, M. Watari, and P. Thubert. Network Mobility Routing Optimization Solution Space Analysis. Internet Draft draft-ietf-nemo-ro-space-analysis-02, IETF, February 2006. Work in progress.
- [15] M. Rudack, M. Meincke, and M. Lott. On the Dynamics of Ad Hoc Networks for Inter Vehicle Communications (IVC). In *International Conference on Wireless Networks (ICWN)*, pages 33–39, Las Vegas, USA, June 2002.
- [16] H. Soliman. *Mobile IPv6, Mobility in a Wireless Internet*. Addison-Wesley, 2004. ISBN 0-201-78897-7.
- [17] R. Wakikawa, K. Okada, R. Koodli, A. Nilsson, and J. Murai. Design of Vehicle Network: Mobile Gateway for MANET and NEMO Converged Communication. In *2nd ACM International Workshop on Vehicular Ad Hoc Networks (VANET)*, Cologne, Germany, September 2005. Poster.
- [18] M. Watari and T. Ernst. Optimal Path Establishment for Nested Mobile Networks. In *IEEE 62nd Semiannual Vehicular Technology Conference (VTC Fall)*, Dallas, Texas, USA, September 2005.