Architectural Crises in Vehicular Ad-Hoc Networks

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***Abstract*- Vehicular Ad-Hoc Networks (VANETs) deals with cars equipped with short-ranged radios communicating with each other exchanging the information for increasing passenger safety and comfort. VANET will enable both vehicle-to-vehicle and vehicle-to roadside communications. Vehicular networking protocols will require nodes, that is, vehicles or road-side infrastructure units, to communicate directly when in range, or in general across multiple wireless links (hops). In this paper we would like to exploit the various Architectural Crisis faced by the VANETS and consider various issues to be addressed by the protocols designed for VANET.**

I INTRODUCTION

According to the definition of IEEE 802.11 Mobile Ad Hoc Network(MANET) is A network composed solely of stations within mutual communication range of each other via the wireless medium (WM). An emerging application area for Mobile Ad hoc Networks (MANET) is the automotive sector. Vehicular Ad-Hoc Networks (VANETs) deals with cars equipped with shortranged radios communicating with each other exchanging the information for increasing passenger safety and comfort.

VANETs have similar characteristics as mobile ad hoc networks, often in the form of multi-hop networks. Due to the high mobility of nodes network topology changes occur frequently. All nodes share the same channel leading to congestion in very dense networks. The decentralized nature of VANETs leads to the need for new system concepts and information dissemination protocols. In addition, new approaches for data and communication security have to be designed to fit the specific network needs and to guarantee reliable and trustworthy services.

VANET will enable both vehicle-to-vehicle and vehicle-to roadside communications. Vehicular networking protocols will require nodes, that is, vehicles or road-side infrastructure units, to communicate directly when in range, or in general across multiple wireless links (hops). Nodes will act both as end points and routers, since vehicle-to-vehicle communication can often be the only way to realize safety and driving assistance applications, while the deployment of an omnipresent infrastructure can be impractical and too costly. In fact, vehicular networks are emerging as the first commercial instantiation of the mobile ad hoc networking (MANET) technology. VANET therefore is not an architectural network and not an ad hoc network but a combination of both; this unique characteristic combined with high speed nodes complicates the design of the network. Because vehicles in motion have short connection durations with roadside access points, efficient use of this duration is important.

State-of-the-art vehicle safety systems are based on various types of sensors, e.g. radars, lidars, and vision sensors. However, sensor based systems give rise to the following drawbacks: i) the limited range and Field-of-view (FOV) limit sensing to nearest vehicles that are immediately around the vehicle of interest, and ii) the cost associated with these possibly sophisticated sensors limits their applicability only to luxury vehicles. Therefore, there is strong interest in the automotive community to investigate the key role communication-based safety systems could play in either complimenting or replacing some of the sensing-based systems due to their versatility (ability to support a wide variety of applications) and competitive cost. This paper is organized as follows. Section II gives details about the services provided by VANET. W hile Section III exploits the Architectural Crisis in VANETs and concludes in Section IV.

II SERVICES PROVIDED BY VANET

A. Inter-Vehicle Services

Vehicle-to-vehicle communication can be used to disseminate messages of multiple services generating their content using sensors within the vehicle. These services can include accident warning, information on traffic jams or warning of an approaching rescue vehicle. In addition, information on road or weather conditions can be exchanged. More elaborate inter-vehicle services are direct collision warning or intersection assistance with information on cross traffic.

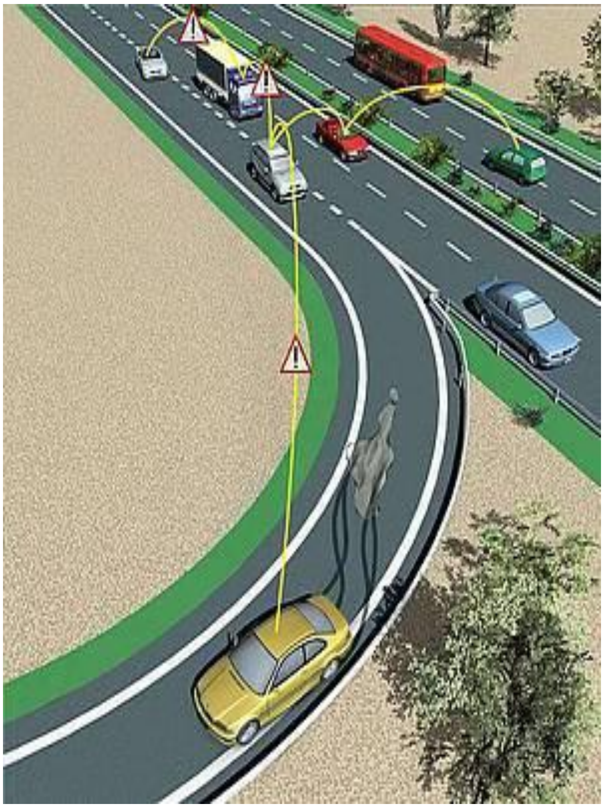

Fig 1: Inter-vehicle Services

B. Services Of Road Side Units

Communication between vehicles and RSUs can also increase safety. Traffic lights or road signs could be equipped with a communication device to actively inform vehicles in the vicinity. Hence, drivers can receive information on traffic flow, road conditions or construction sites directly from the respective RSU. In addition, static hazard areas, e.g. construction sites, could be equipped with a RSU to warn surrounding vehicles. RSU-based services will play an important role during the introduction phase, since they are almost unaffected by the penetration rate.

C. Portal-Based Services

Besides the safety related services, many other services related to the vehicle or providing entertainment to the passengers can be brought to future vehicles. The on board unit (OBU) inside the vehicle collects all incoming messages and sensor information. In addition, it relies on a server-based infrastructure providing many additional services. These can include information on parking or hotels as well as sightseeing information. A standardized solution opens the market to multiple service providers and reduces the time to market for service applications.

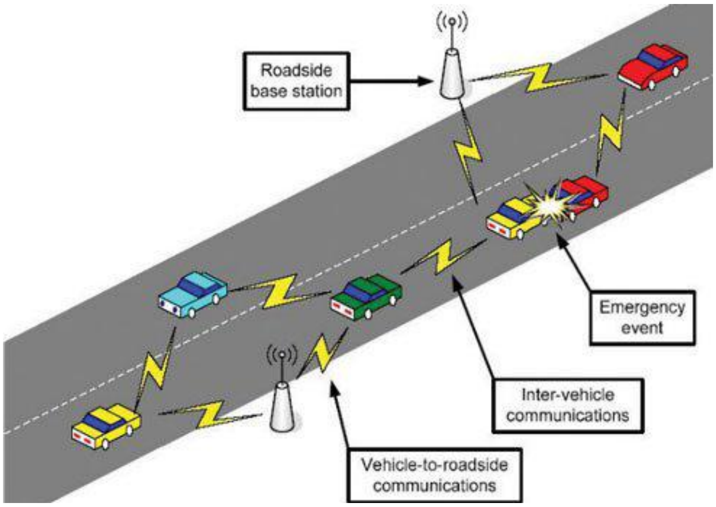

Fig 2: Services of Road Side Units

D. Integration Of Vehicles Into Backend Business Processes

Vehicles will certainly play a major role in everyday business processes that are currently handled by enterprise IT systems. Two different ways of integrating cars into business processes are considered valuable: First, data such as geographical position, covered distance or average speed may be transmitted to a company's backend system to allow for mobile asset management services. Logistics providers, for example, who nowadays run complex IT systems to manage their fleet, could feed real-time information into their applications to improve flexibility and adaptivity of their business processes. If such a system was enabled to receive the current, geographical position of all vehicles, the firm could react to customer demands more agilely due to better capacity forecasting mechanisms. Insurance companies and their customers might also be interested in connecting vehicles to backend IT services. Initiatives such as "Pay-as-youdrive" currently investigate the market potential of such applications. Drivers who only cover short distances and drive carefully would have to pay less than someone driving long distances. Besides the transmission of data from the car to backend IT application landscapes, the provisioning of car drivers with access to external data is a promising possibility of applying vehicular communications as well. Business people, which are always "on the move", such as sales persons or consultants, may be highly interested in leveraging their cars' onboard systems as a conventional workplace. Via speech input, drivers could trigger their cars to remotely access a company portal and to download crucial information for their next customer visit, for example.

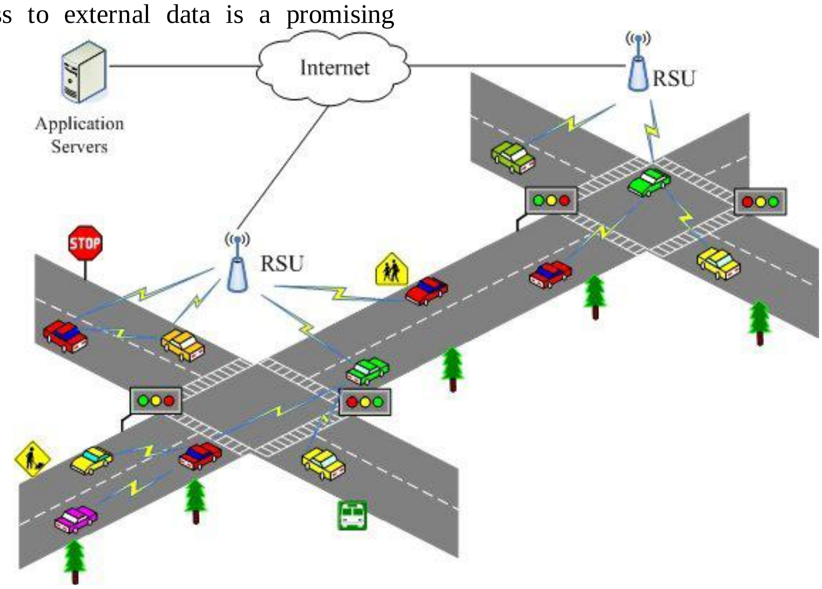

Fig 3: Integration of vehicles into backend business processes

III ARCHITECTURAL CRISIS

A. *Relationship To Sensor Networks*

While the notion of sensor networks usually stands for (non)-mobile wireless networks with lowpower and low-capability devices distributed gather sensor information, there are some important similarities between sensor networks and VANETs that might influence architectural considerations.

First, a vehicle can be seen as a high capability sensor device with sensors for environmental information such as road grip or temperature, and for information about the vehicle itself such as movement.

Second, the sensor information coming from different vehicles en route can be combined in order to eliminate redundancy, minimize the number of transmissions, and improve the quality of the sensor information. This 'data centric routing', as opposed to 'address-centric routing', is well known from sensor networks. In addition, the whole communication system might react to sensor information in the sense that sensor events are an integral part of network protocols. However, the main difference between VANETs and classical sensor networks is most likely that for VANETs, the main goal of these protocols is not the preservation of energy but a 'low channel utilization' to keep the system accessible for urgent safety messages.

B. *Packets vs. information*

Along the lines of the first observation, one has to differentiate between 'packets' and 'information': In classical networks, the data payload of a packet is meant to be delivered unchanged to the addressed application instance(s). However, VANET applications will most likely evaluate the information contained in a packet, merge it with their own state and then decide how to communicate this updated information. This operation is known as 'in-network' processing.

C. *End-To-End Notion Revisited*

In a traditional network, peer application and protocol entities are well-defined on all 'communication endpoints'—either by an ID or by a multicast group. However, the VANET communication entities might not only address specific peer entities, but also geographical or topological areas whose members are likely to change over time. Furthermore, a communication between two peers might only be possible in one direction but not vice versa.

D. *Network Protocol Requirements*

Among other things, the last observation directly leads to different requirements for multi-hop packet-forwarding protocols. On the one hand, traditional unicast and multicast protocols using ID-based addressing might still be needed for infotainment applications or the extension of hotspot access. On the other hand, the challenge for VANET network protocols lies in efficient geocasting and flooding. Additionally, there might be potentially severe requirements concerning reliability and/or timeliness due to the safety purpose of some applications.

E. Granularity Of Control

In classical network management, the control parameters are set as 'mid-term' or 'long-term' parameters. E.g., the setting of an IP address tends to be long-term and even in UDP communication sessions packet options are usually changed for every session (mid-term) but not for single packets within one session. In a VANET, however, it seems that various control parameters will have to be set on a per-packet basis, as when sending successive packets different MAC algorithms could be used, different transmission powers could be set, or the packets could be sent to different physical channels.

F. Information Sharing

In a VANET, the communication system generates information that is of high value to many protocol entities. Beacon packets could be used to generate a list of neighboring nodes, that could be used both for driver assistance and packet forwarding decisions. Thus, we observe the need to share information in an efficient and clean manner without creating complex control interactions. In addition, the integration of these events into protocol state machines demands a standardized means to access them, if implementation portability is desired.

G. Application Requirements Vs. Medium Conditions

The safety-focused nature of VANETs requires the communication system to be dependably able to deliver important packets. To achieve this, the packets have to contend with (a) the sending demands of other nodes and (b) the allocation of the radio channel by other nodes. In addition to that, the channel itself is highly probabilistic. Thus, in order to meet application requirements, not only will all nodes have to cooperate among themselves but also all applications and protocols on a single node.

H. Challenges In VANET Protocols

VANET protocols that are able to make it to the product will stage the need to work under very different conditions. For the first couple of years, a car equipped with a VANET system will find hardly any other cars with which to productively exchange messages. Thus, the first task of the protocols will be to operate under these conditions. They will—in the beginning—not care very much about channel usage to maximize utility. I.e., in the beginning, the probabilistic channel will be used frequently to increase the utility range of VANET messages.

However, as system penetration increases, the scarcity of the radio channel as a resource will increase. Paying this will imply the absolute necessity of minimizing its usage acknowledging the increasing likelihood of packet collisions. Consequently, a significant challenge lies in building protocols that work in both cases, and a great danger lies in building protocols that are hastily tailored to cope with the low-density situation. The high-density situation, however, creates the greater challenge of seeing the multi-hop effect of single-hop broadcasts. This means that whenever information triggers broadcasts, the subsequent message exchange is, in fact, part of a multihop protocol, which has to be evaluated on a non-local scope by people with knowledge in ad-hoc networking.
It is—in our view—simply not enough to provide singlehop broadcast to application developers and then let them worry about the rest.

IV CONCLUSION

The architecture of a future VANET system is still not clear, at least for the projects we were involved in. While many people consider this an academic discussion, it has some impact on how protocol development can be separated and cooperation can be stimulated. Obviously, the Internet's end-to-end paradigm has to be reconsidered, since there is technically no backbone vs. end system structure, but every node is both end system and router. For the cooperation part, the know-how lies in the hands of different groups: On the one hand, there are network researchers holding knowledge about multi-hop protocols, retransmission timing, broadcast redundancy etc., and on the other, there are people with an understanding of traffic flow, time-criticalness of information distribution and so on. In our opinion, since both groups directly influence any resulting protocol's "radio profile", a stronger interaction is necessary to avoid a system with protocols that either will not really work in the beginning or choke the channel later. Especially the extreme high density situation in a congested highway under the assumption that every car is running a VANET system will create the ultimate protocol challenge. Any available protocol design trick will have to be used to tackle these problems: from using infrastructure to control the channel or to coordinate information gathering, over the usage of classical algorithmic methods to increase scalability like hierarchization, up to methods involving the electrical properties of the signals like power control or different physical coding to stabilize transmissions. Moreover, the problems will have to be tackled quickly since the car manufacturing industry is eager to roll out a car-to-car communication system, and the consequences in rolling out a closed-box system have a long reach.

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