A window on Information Communication Technology

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Vehicular Wireless Communications

Among the most challenging yet exciting scenarios of future communications is the possibility for cars to exchange information with each other, on both an automatic and a user-generated basis. Car-to-car communication is one of the possible applications of the ad hoc communication paradigm we described previously in the April issue of this bulletin.

Car-to-car communication scenario

The automotive environment is a very interesting area for wireless communications. The exchange of data between cars or between a car and the infrastructure (road) could enable important applications related to safety and/or information/entertainment. In this enhanced communication scenario, a vehicle plays three different roles: as a source of information, as a transit node which receives data and forwards it to its final destination, or as the end point of communication.

Vehicles as information sources

During its normal transit on a road, a vehicle can acquire data which can help support other drivers in a number of different situations, such as the following:
Real time information about the weather conditions in an area could be useful for vehicles passing in the same area a few minutes later. The data in this case can be acquired using onboard light, temperature and humidity sensors.
Real time conditions about the road conditions can be easily obtained by a vehicle using onboard gyroscopes and/or acceleration sensors which can detect vibrations or shocks related to bad asphalt conditions.
More complex solutions could be used to detect the presence of ice or water on the road: in this case passing the information to cars further back could help avoid some dangerous situations.
Information about real time speed combined with the same information coming from other cars in the same part of the road could generate a slow or stopped traffic alert for drivers who are about to reach the same point.
A more sophisticated and futuristic scenario could be enabled by more sophisticated sensors, such as video cameras: vehicles could generate video streams to be sent to following vehicles in order to show the drivers what they are going to encounter in a few seconds.

Vehicles as forwarding nodes

Car-to-car networks represent one of the possible forms of ad hoc wireless communication infrastructures. In the most extreme case, the network would only be made up of vehicles. Just as in the ad hoc paradigm, in this case the network would exist only when a high enough number of cars equipped with the appropriate networking devices are in close proximity, as shown in fig. 1.
In a more traditional situation, the network could also be created using infrastructure devices installed along the road (for example, on traffic lights or light poles in the case of city roads, or on dedicated supports in the case of highways). Figure 2 shows an example of this architecture.

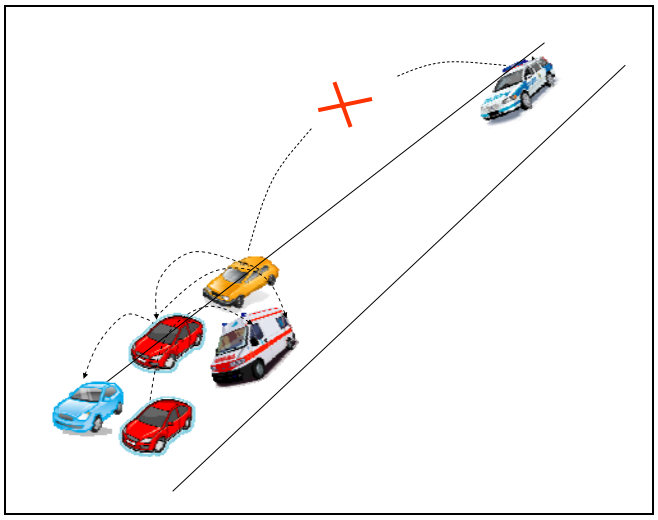

Figure 1. Vehicles-only ad hoc network

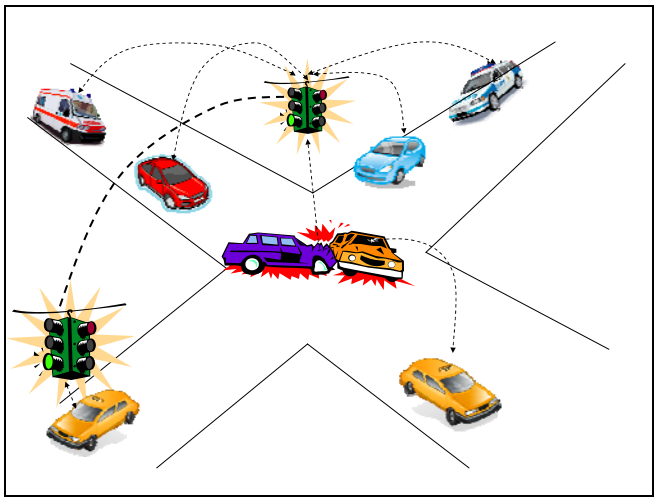

Figure 2. Mixed Vehicles-infrastructure ad hoc network

In both cases the resulting network would make use of any available node (and path connecting nodes) to transport the information to the destination.
From the networking point of view, the case in which vehicles represent a forwarding node - an intermediate step needed by the data to reach its destination - is particularly interesting. This happens if the data is directed to (or originates from) a vehicle which is not in the range of an antenna installed along the road.
In order to perform this action properly, the onboard networking devices need to have ad hoc routing capabilities which make them aware of the location of the possible sources and destinations, using principles which are similar to those underlying Internet architecture.

Vehicles as information destinations

The information collected by all vehicles has real meaning (as pointed out in the examples above) only if it can be processed and sent to the interested drivers and passengers. The form of the data sent to vehicles changes depending on who the final user is: if it is the driver, the presentation of the data must be synthetic and effective, in order to avoid distracting her from the activity of driving. Warning and alert signals must also be presented in a very visible/audible way, so that they do not go unnoticed. If the destination user is the passenger, data can be presented in a more traditional way, including multimedia for entertainment purposes (for example, music videos or movies can be sent to a playing device with a normal display installed in the car).

Technological challenges

The generation, transfer, processing and presentation of information, which represent normal steps in most of the Internet applications we use every day, all become more complex when the data sources and destination are mobile devices such those installed in vehicles. In this section some of the most interesting challenges related to the four aspects are described.

Data generation

Collecting information from a vehicle requires the onboard installation of dedicated devices. These can be either completely separate from the car's electronic equipment, or integrated with the existing onboard computers. It is obvious that the two solutions require a different involvement of the car manufacturer.
The highest level of accuracy can be obtained when a full integration is implemented with the car electronics. In order to accurately measure the car's speed and to be able to recognize situations such as an accident (commonly used information is, for instance, the deployment of the air bag) it is essential to have access to the onboard data bus (such as the CAN bus) which connects most of the electronic onboard devices. This requires the strong cooperation of the car manufacturer, which must play an important role in the design and installation of the sensing components and the communication system.
The need for integration also makes it difficult to have a market of sensing/communicating devices that can be bought and installed after the user buys the vehicle. Due to the differences between the timing of the car market and that of electronics (the first being measured in several-year cycles, the second in half-years), this situation could also slow down the adoption of such onboard devices and therefore the take off of car-to-car communication solutions.

Data transfer

Data transfer in a vehicle-to-vehicle communication scenario offers several very intuitive challenges.
In the fully ad hoc case, the reliability of the network infrastructure is heavily dependent on the number of properly equipped vehicles in a specific area. Therefore this solution cannot be used for general information and entertainment purposes: the availability of communication could be guaranteed only in heavy traffic situations.
Also, in order to facilitate the smooth adoption of communication to and from vehicles, in the near future we will see the activation of road wireless network infrastructures through which even a single car, if equipped with the right communicating devices, could send and receive information. Some cities/highways already have some pilot implementations in place.
The widespread adoption of full car-to-car and car-to-infrastructure communication solutions still requires a lot of work in the definition of communication standards, regulations and services. In the last few years several working groups and projects have been established with the participation of telecommunication operators, car manufacturers, system integrators and road operators, in most cases supported by the European Union.

Data processing and presentation

The amount of information generated by vehicles can easily become very large: the onboard sensors may generate large data units (such as a camera) or small data units at a high rate (i.e. vibration sensors). In addition, the number of cars performing data sensing will soon become large, further multiplying the overall data size which needs to be processed.
The processing of information generated by cars is quite complex, not only due to the size of the data set, but also because it is necessary to take into account the proper context (such as location and time of both source and destination). It is easy to understand that it would not be useful to generate information about the weather conditions in an area and send it to users that are very far away, or to generate information that is not accurate in time, or sent too early or too late.
A possible scenario for the data processing architecture will probably be based on a distributed and high performance solution such as the so called grid computing, which is very popular for very specific applications such as complex simulations.
The presentation of the information derived from the correlation of all the data gathered by the several vehicles will need to be sent to specific groups of users (users could be grouped automatically by location, or by specific services they actively subscribe to), in a way which, as pointed out before, depends on the relevance of the data (simple information, warning, alerts) and on its purpose (as stated previously, signals to the driver and entertainment for the passengers must be handled differently). Sophisticated human-machine interfaces will play a key role in this system architecture, whose design will require experts of ergonomics and user experience in addition to the more common database and networking designers.

Organizational challenges

It is important to point out that vehicular communication services will not take off if a set of problems (of which the technological issues presented so far are only a small portion) are not addressed and solved.
Finding the best technical solution to allow cars to talk to each other, or to process huge amounts of data is not enough. A real, usable service requires much more: a whole ecosystem which is ready to respond to the new system whose main challenge is the cooperation of players belonging to very different sectors, and for which the business model is not yet clear. A few of the major issues which need to be solved are listed below:
The provider of the onboard technology (data generation and communication device) must reach an agreement with the car manufacturers, so that they open their communication system, allowing the integration (or at least connection) of the new equipment.
A communication infrastructure installed along the roads must be provided. As an alternative, the existing wireless data networks (based on UMTS or other technologies) can be used, but their charging scheme must be adapted to the needs of the drivers, introducing flat rate offers which protect the user from expensive bills which could result from roaming conditions if the car is out of the user's home country.
International agreements and standards have to be established, so that emergency and information services are available to users wherever they are driving their vehicles.
Service providers must organize their solutions in an international, multilingual way in order for their services to be widely accepted.
For car-to-car communications to become a realistic solution, a high number of cars need to be equipped with the proper devices. Some estimates say that almost 50% of vehicles on the road need to be communication-ready in order to have reliable services based on the vehicular ad hoc network.
For emergency services, it must be clear which organization is accountable if part of the system fails (sensors, network, rescue services), particularly in case of an accident or other emergency situation.

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