Networking Needs and Solutions for Road Vehicles at Imara

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June 8, 2007 – ITST 2007

Outline

Introduction

Integrating research works into actual vehicles

A few key facts about Imara :

- 10 year-old research and integration project ;
- automated driverless vehicles ;
- driver assistance ;
- involved in several projects (CyberCars2, CVIS, Com2React, etc.) ;
- . . .

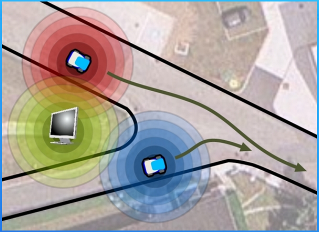
Increasing need for (reliable) communications.

Mobile Vehicles Scenarios Requiring Communication

Vehicle to infrastructure : Crossroads passing

Crossroads passing is a challenging problem in the case of driverless vehicles.

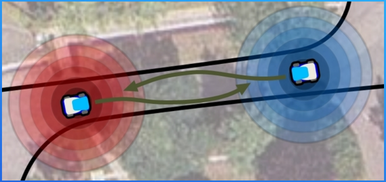
Several proposed solutions rely on the use of a centralized supervisor. **The vehicles need to find and communicate with this controller.**



Mobile Vehicles Scenarios Requiring Communication

Vehicle to vehicle : Trajectory exchange

Automated vehicles need to have has much information as possible about their neighbors' plans in order to decide what to do next. An example type of information are the currently planned trajectories.



Every vehicle can be assumed to require its neighbors' trajectories, and to publish its own. Along with **reliable communication, this setup requires the ability to broadcast information (**$\approx 10 \rightarrow 100\mathrm{kB}$**) to the neighboring vehicles.**

Mobile Vehicles Scenarios Requiring Communication

Global communications : Semantic networking

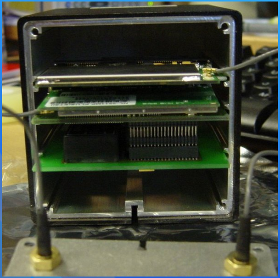
Even if the vehicles and infrastructures share a common base, it cannot be assumed that all of them are totally identical.

Specific things such as hardware (sensors, attainable speeds, current system health,. . .) and software (implemented algorithms, availability of the system, . . .) can change with depending on time and the considered entity. Using an **ontology based system** allows to represent and exchange this kind of information.

This requires the ability to locate the ontology service and connect to it and exchange textual (XML) data.

Hardware and Lower Level Networking Software

In-car router : the 4G Cube



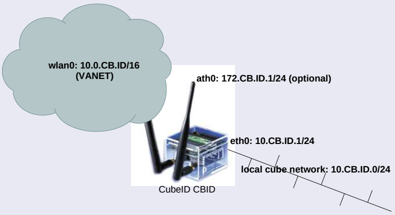
Wi-Fi (802.11) is used because of its wide deployments and null requirements on the infrastructure to get connectivity (Ad-Hoc mode).

The 4G Cube is a small MIPS-based computer running Linux. It sports one or two Mini-PCI Wi-Fi (b, g) cards and an ethernet interface. This makes it **a versatile embedded router providing connection to the VANET as well as wired or wireless connectivity for in-car devices**.

Hardware and Lower Level Networking Software

Network layer protocol : IP (v4 for now...)

Due to its well known and understood status, IP is chosen as the underlying network protocol. Moreover, this allows to **run without modification** every application which has not specifically been developed to run in mobile networks.

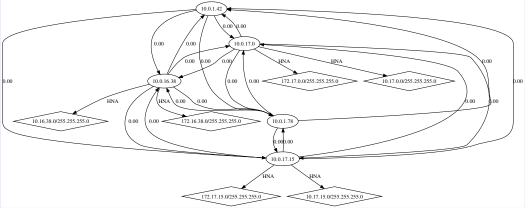


The addresses of the nodes (routers, in-car computer, architecture, ...) are chosen in such a way that the topology is **totally NAT-free**. This will allow for subsequent **seamless migration to IPv6**.

Higher Layers Software Components

Establishing a multihop meshed network using OLSR

OLSR [1] is used to establish a **dynamically reconfigured mesh network of vehicles**.



Using HNAs (Host Network Announcements), it is possible to **propagate routes not only to the routers, but also to the in-car network computers**, or even the whole internet (*e.g.* using a 3G modem in one of the cars).

Higher Layers Software Components

Using Zeroconf for service discovery

Apple proposed Bonjour (formerly Rendez-vous) to provide zero configuration networks.

We reuse **Multicast DNS** (mDNS) [2] to provide a **local namespace** to abstract the vehicles' network addresses.

On top of DNS (or mDNS), **Service Discovery** (DNS-SD) [3] can be used by the computers to **publish or query information about what applications are running** in the neighborhood.

Higher Layers Software Components

Using multicast traffic to send data to several vehiles at once

Multicast is a routable generalization of broadcast. It allows to reduce traffic destined to several clients by only sending ot once.

With the additional help of a multicast routes propagation daemon[1] it is possible to build a multicast-enabled VANET.

An implementation of the **PIM-SM [4] (Protocol Independent Multicast, Sparse Mode) routing protocol** has been installed in the embedded routers.

[1] keeping track of the IGMP (Internet Group Management Protocol) request from the clients

Short Overview of Ontologies

Semantically rich representation of capabilities and statuses

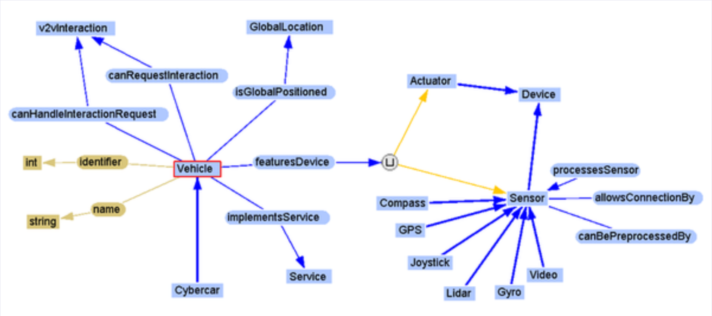
Ontologies are semantic networks used to **fully describe a domain** after it has been formalized.

The desired field is **completely** and **non-ambiguously** described by a set of concepts and relations linking them.

The logical representation of ontologies allows for **abstract queries** such as "Which car is able to sense the surroundings in front of it", and get answers listing all cars with LRF, cameras, etc.

Short Overview of Ontologies

Example : A (subset of) ontology for cybercars



Represented information :

- A cybercar is a vehicle ;
- A vehicle can be equipped with sensors ;
- A compass is a sensor ;
- Any logical combination of the above ;
- ...

Experimental Results and Comments

Physical and network layer performances

Using 9dB antennas, it was possible to achieve single-hop Wi-Fi connections between driving vehicles at up to $1200\mathrm{m}$. However, they proved to be really **reliable up to** $700\mathrm{m}$. In these conditions, the minimum achievable bandwith was around $1\mathrm{MBps}$.

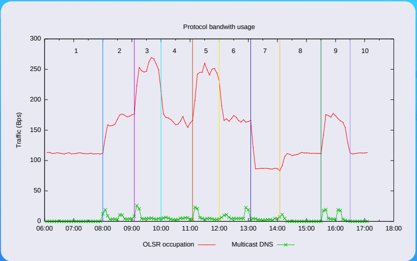
Passed this distance, the usage of **OLSR allows to update the in-car routing tables to use multihop**. However, a **switching time of up to** $15\mathrm{s}$ has regularly been noticed.

Experimental Results and Comments

Bandwith occupation of ever-running protocols

Measures gathered over a one-day period :

1. two OLSR routers ;
2. OLSR/Zeroconf node introduced ;
3. OLSR router with Zeroconf host computer introduced ;
4. latter router removed ;
5. OLSR router added ;
6. OLSR router removed ;
7. OLSR router removed (bis) ;
8. OLSR/Zeroconf node removed ;
9. OLSR/Zeroconf node readded ;
10. OLSR/Zeroconf node removed again.



OLSR consumes approximately 60Bps per node, while mDNS generates peaks of only 30Bps on introduction or requests. **This is just a small part of the minimum available bandwith.**

Experimental Results and Comments

Multicast routes establishment delays

Multicast traffic is only routed to a link when at least one client (which may be another router) on the link has joined it using IGMP.

In the presented architecture, **a delay of $5\mathrm{s}$ has been observed** between IGMP messages and traffic[2] appearance or removal from the link.

This is **acceptable for user-oriented applications**, but may be **too big a delay for safety or planning** operations.

[2] sent from another in-car computer behind a router

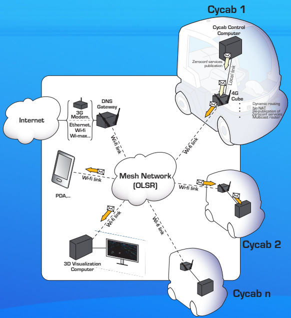
Conclusion

A working architecture, but much room left for improvements

The described network architecture is **already used daily at Imara**. It is, however, **still lacking some functionalities or updates** to declare it finished.

Future works include

- switching to full IPv6 (including NEMO [5]) ;
- using OLSR with multicast multihop support [6] ;
- testing other (unicast or multicast) routing protocols ;
- developing our own hardware-independent software distribution.



Thanks

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Questions ?

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