ARCHITECTURE AND SCALABLE TESTBED FOR COOPERATIVE SYSTEMS IN THE NEXTGENITS PROJECT

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ABSTRACT

In the past research has been done on cooperative systems resulting in, among others, the CALM architecture which is used in NextGenITS. The project focuses on the scalability issues of routing protocols and energy optimizations for cooperative vehicular ad hoc network (VANET) systems. The resulting solutions will be simulated using TraNS and Nsclick. Afterwards the architecture and routing protocols will be tested in real life on small and large scale.

KEYWORDS

scalability, cooperative systems, routing protocols, vulnerable road user, CALM, testbed, VANET

INTRODUCTION

In the last couple of years Intelligent Transport Systems have emerged as a promising field of research. This has resulted in the NextGenITS project (Next Generation Intelligent Transport Systems). This is a research project between industry and research centres in Belgium. In this project we focus on different topics of Intelligent Transport Systems like traffic information, e-call, intelligent speed adaptation, road tolling and cooperative systems.

The major research interest of the NextGenITS project, regarding cooperative systems, is the domain of routing protocols for vehicular ad hoc networks (VANETs). The consortium strongly believes that other aspects of cooperative systems such as the framework for and management of transparent heterogeneous communication, and the development of cooperative applications have already been extensively researched in European research projects such as CVIS and Safespot. The consortium is convinced that it can conduct novel and innovative research in the field of vehicular ad hoc network routing, a domain that receives less attention of the already mentioned European projects but fits closely to the competences of the NextGenITS research partners. Most attention will be given to IEEE

802.11p and VANET scalability issues (an important obstacle discovered by [1] and [2]), and to energy efficiency optimizations, trying to introduce ITS applications in the domain of vulnerable road users. These routing solutions will be implemented and tested both in a simulator and in real life.

The project aims to finalize with a demonstration, targeted at a less technical audience, focusing more on the cooperative applications made possible by the cooperative systems using scalable and energy efficient routing protocols then on the developed routing protocols themselves. Several cooperative applications will be integrated into a single demonstrator story line, and will include slippery road warning, approaching emergency vehicle warning, obstacle warning, traffic jam notification, intelligent traffic light with green wave speed adaption, and blind spot warning based on communication with bicyclists.

ARCHITECTURE

General Architecture

The system architecture, for cooperative systems, of the NextGenITS project is based on the CALM architecture [3]. A high level overview of the architecture is shown in figure 1.

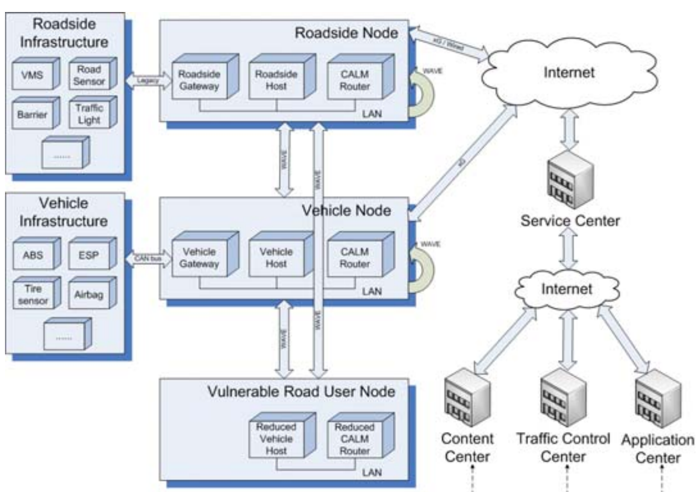

Figure 1 - General Architecture

As shown on figure 1, a distinction is made between *Roadside Nodes, Vehicle Nodes* and *Vulnerable Road User Nodes*. Roadside nodes and vehicle nodes are similar in functionality, both incorporating a CALM router, a host and a gateway. The most important component of these three types of nodes is the CALM router, responsible for the communication between the nodes and the different services connected to the Internet. The CALM router integrates multiple communication technologies, such as 802.11p WAVE, 2G or 3G networking, wired LAN and WAN interfaces, … It routes messages over the most appropriate interface, depending on the communication needs of the applications. Applications that require an Internet uplink (e.g. traffic information) will be communicating using the 3G Internet uplink, while vehicle-to-vehicle applications (e.g. local warnings) will use the VANET interface. The Roadside and Vehicle Nodes also incorporate a *Gateway*, responsible for connecting to the roadside equipment or on-board electronic systems of a car. The gateway is aware of the legacy protocols running on the attached equipment and can translate the information gathered to a data format that is suitable to use in other applications and on the network. In the vehicle node, the gateway will typically be connected through the CAN bus that can be found in most modern cars.

The Vulnerable Road User Node is similar to the Roadside Nodes and Vehicle Nodes, but offers less functionality due to the fact that it has a small form factor and is powered by a small internal battery instead of the power grid or a car battery. It only runs safety applications, informing vehicles and roadside infrastructure of its presence and issuing collision warnings to the vulnerable road user. The reduced vehicle host in these nodes is an embedded PC or a specially designed device with specific applications programmed in hardware. The reduced CALM router, found in the vulnerable road user node, is only equipped with interfaces for local communication and has no support for WANs. It runs a reduced version of the CALM architecture, supporting less management functionality and only a single routing protocol. Although the reduced vehicle host and the reduced CALM router are two separate entities from a logical point of view, they are likely to be combined in one single device.

The Service Centre has an important role in the overall architecture: it connects the different roadside and vehicle nodes with an arbitrary number of services offered on the Internet. When requesting some service, the roadside and vehicle nodes only contact the service centre, which in turn performs a lookup for the most suitable content, traffic control or application centre for that specific service and returns the coordinates to the roadside or vehicle node. Similarly, if content centres want to cooperate, the service centre performs the role of single point of contact.

The Content Centres can be roughly divided into three categories. The Traffic Control Centres, which are operated by the public authorities or road operators, monitor and possibly route traffic according to the current traffic conditions. The Application Centres offer free and paid applications that can be installed on the vehicle hosts. These Application Centres can either offer device independent or device specific applications, e.g. applications that can run only on cars of a specific brand. The third category are the general Content Centres, offering various content such as traffic information, tourist information, …

Routing in Vehicular Networks

The CALM architecture offers a range of communication technologies, e.g. UMTS, infrared, WLAN, etc. Applications in vehicles use these communication technologies in several different ways. For example infrared can be used to communicate with vehicles directly in front of or behind the current vehicle, while UMTS can be used for an Internet uplink. Although the environment for using these technologies is new, the way of using them is more or less the same as in other networks. The biggest difference lies in using the WLAN interface for intervehicular communication, also called the VANET interface. Intervehicular communication poses new challenges like:

- Vehicles move fast, causing link breaks very often

- The vehicular network is large-scale, consisting of many vehicles
- The network is often partitioned and thus end-to-end connectivity cannot be guaranteed

Topology based routing protocols (e.g. OLSR [4], AODV [5]) are unable to deal with the rapidly changing network topology and high number of participants. Furthermore, they cannot overcome gaps in the topology, which is sometimes necessary.

Due to these problems, one has to look at another type of routing protocols: position based routing protocols. Position based routing protocols do not suffer as hard under the constant mobility since they mostly use only information from their neighbours. Positional information is also more predictable since a vehicle's current position will always be close to its previous known position and the vehicle's movement is constrained by the road topology. Some protocols, e.g. GPSR [6] and CBF [7], are unaware of the road topology, while other protocols like VADD [8] and REACT [9] assume the availability of a navigation system in each vehicle. All these protocols assume the presence of a GPS receiver.

In this project, routing protocols will be studied with a focus on scalability and energy consumption.

SIMULATION AND TESTING

Simulation

For the realistic simulation, of the architecture and scalability of the routing protocols, different existing simulation technologies will be used together. The Traffic and Network Simulation Environment (TraNS) [10] links the SUMO traffic simulator and the NS network simulator (figure 2). The combination of these two simulators makes it possible to use realistic mobility models for the network simulator and to let the communication influence the traffic behaviour between the vehicles. The simulator also makes it possible to check the vehicle movement by generating a Google Earth document which depicts the movement of cars on a satellite photo of the simulated environment.

Furthermore the Nsclick network simulation tool ([11]) will be used. This tool is a NS-2 network simulator with a Click Modular router inside. This gives the opportunity to run a Click routing graph under NS-2 and on a real host. This structure has the advantage that nearly the same code of our routing protocol can run on the simulator and on our real life testbed (figure 2).

To run the simulation of large scale scenarios the Flemish Supercomputer Centre (VSC) can be used. The VSC consists of 4 Flemish supercomputers which are interconnected by 10GBit connections and have a centralized scheduler. The cluster situated in Ghent consists of 194 calculation nodes with a total of 1552 cores and 3,1TB RAM.

Real life experiments

As already mentioned, the aim of the project is to develop VANET communication solutions that do not only work in simulations, but are tested and enhanced using real hardware in real life. This is where choosing the Click modular router as the implementation framework proves very fruitful (figure 2). The implementation developed and tested in the simulator scheme described in the previous section, can directly be tested on real hardware. This makes it possible to easily test and tune the implementation on our wireless testbed. The real life experiments will be performed on a small scale in real vehicles, and on a larger scale on our IBBT Wilab and Virtual wall testbeds.

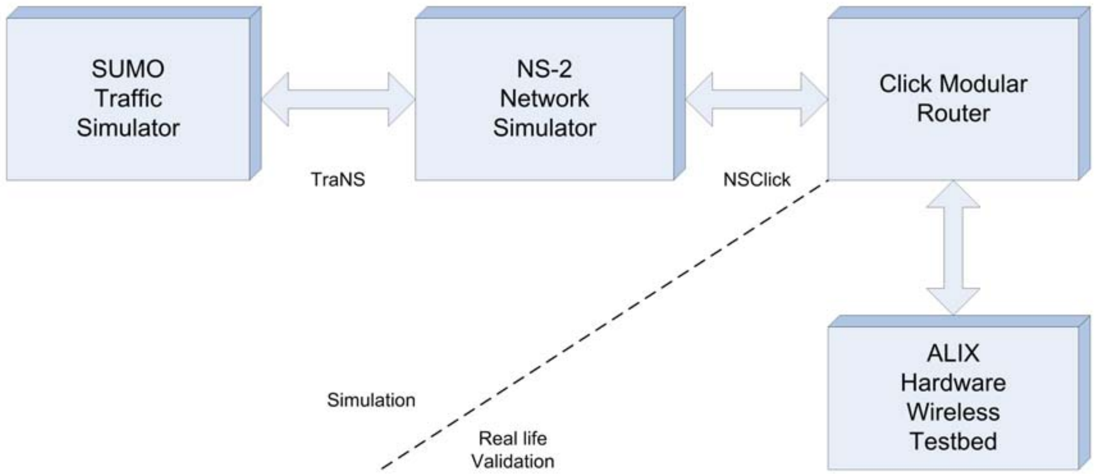

Figure 2 - Link between simulation and real life validation

IBBT Wilab is an extensive Wireless Lab facility, including wireless mesh and sensor network infrastructure, rolled out on 3 floors of the IBBT office (Figure 3). The network consists of 400 IEEE 802.11 wireless mesh network nodes, and 200 IEEE 802.15.4 sensor nodes, supporting a mix of wireless platforms. The Wireless Lab nodes are installed at 200 fixed locations at the ceiling of the IBBT office premises. They are installed in a grid like topology, with an inter-node distance of a few meters. This makes the testbed very suitable for testing the scalability of VANET routing protocols, using scenarios with dense traffic where VANET nodes are positioned just a few meters apart.

The IBBT Wilab is centrally managed for control and monitoring purposes & remote access. This leads to easy configuration and deployment, including installation of new software, protocols and middleware components within minutes. The testbed allows easy and flexible testing of functionality, performance, interference and scalability of advanced applications. Regarding sensor node testing, the testbed offers some unique features such as power control and measurement on all nodes; and environment emulation, implying that artificial sensor data can be generated on all nodes.

The small scale tests in real vehicles make use of the same equipment as installed in the IBBT Wilab. This equipment is extremely portable. It is extended with a 3G dongle, and antennas and a GPS receiver which both could be placed on the roof of the vehicle. Thanks to the small form factor and ruggedness of this equipment, in vehicle installation for test purposes can be done in a rapid way.

WiLab


Virtual wall

Figure 3 - Overview of the WiLab (left) and Virtual Wall test-beds (right)

The small and large scale tests both make use of the IEEE802.11a physical layer. This is a worst case approximation for an IEEE802.11p operation. Specifically the 802.11a physical layer is less tolerant to multipath propagation effects than 802.11p [12] [13] because:

- IEEE802.11p uses larger guard intervals, resulting in a higher tolerance for inter-symbol interference due to multipath
- IEEE802.11p uses smaller carrier spacing, allowing support for smaller coherence bandwidths in mobile conditions.

Complementary test capabilities for ITS applications are offered by the Qosmotec wireless shielded environment and the IBBT Virtual Wall. The goal of the Qosmotec testbed is to enable RF experiments over coax, leading to repeatable experiments not influenced by wireless spectrum interference. Using equipment for repeatable changes of attenuation in time, mobility can be emulated, and routing properties such as handovers can be tested. Experiments performed in this wireless shielded environment can be situated between simulation and real world. The testbed consists of four wireless shielded environments, interconnected by coax cables connected to a splitter/combiner panel with 4 splitters 1→4 and 4 splitters 1→2, and the possibility to insert 8 attenuators (0-93dB). This makes the testbed ideal for testing the developed VANET routing protocols in controlled and repeatable, small scale, mobile test scenarios.

The last component of our ITS test environment is the IBBT Virtual Wall (Figure 3). It is a dynamic testbed, shared between research projects, and enables testing on a large scale. Its facilities consist of 100 nodes (dual processor, dual core servers, 4-6x1 Gb/s interfaces per node) interconnected via a non-blocking 1.5 Tb/s VLAN Ethernet switch. A web-based management interface enables users to easily configure test-specific network topologies, network parameters and node configuration (operating system, software packages, etc. In contrast to the Wilab, which is ideal to test the scalability of VANET routing protocols with a small internode distance, the Virtual Wall is the ideal environment for stress testing ITS services in large scale scenarios with various network conditions and with several internode distances. This is because the Virtual Wall does not use real wireless interfaces, but emulates link characteristics. For that purpose, nodes of the Virtual Wall can take up the role of a configurable traffic shaper (Figure 4), which is connected to the VLAN switch, and emulates the wireless connectivity. The configuration of the traffic shaper is done by setting the bandwidth, latency and loss rate parameters to the preferred values.). One node can run two or three traffic shapers dependent on the number of network interfaces (4 or 6).

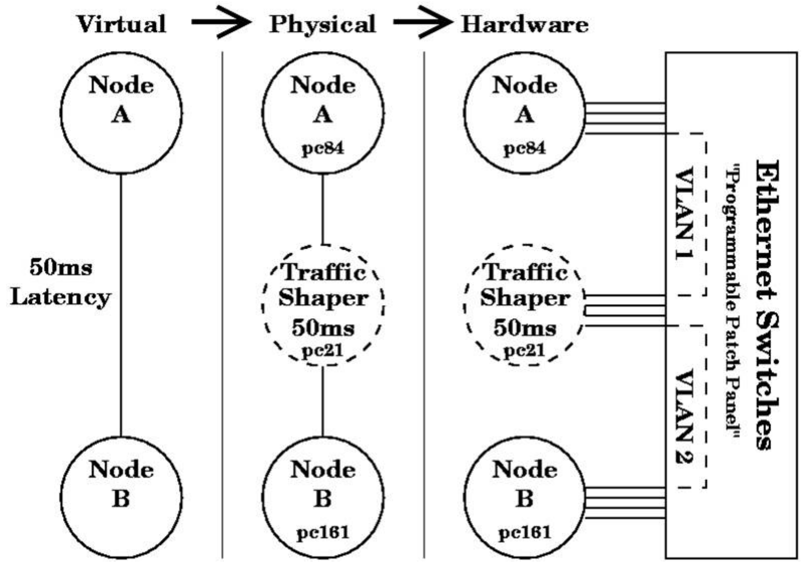

Figure 4 - Virtual wall configuration

CONCLUSION

Within the scope of the NextGenITS project, a simulation and testing environment will be setup to test the scalability of routing protocols and energy optimizations for cooperative vehicular ad-hoc networks. The project will model the CALM router in Click, and deploy the routing configurations seamlessly in different environments on the IBBT test infrastructure. As a start simulation in NS-2 will be used, continuing with small scale and later also large scale testing on real hardware components. This will enable validation of novel routing strategies.

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