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Modelling and Simulating Large Scale Vehicular Networks for Smart Context-aware Telematic Applications

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1. Introduction

Developing context-aware telematic applications for vehicles equipped with smart embedded computing devices and communication capabilities with the ability to provide the right information at the right time and place has always been a challenge for researchers. We can address this issue by providing the developers a way to model application specific abstractions for context-aware communication and to test various algorithms and communication protocols in a simulated environment. In this chapter we present certain requirements for modelling telematic application specific abstractions and a framework for simulating context-aware information mediation in large scale vehicular networks. We have used this framework to analyze the requirements by simulating plain broadcasting and our relevance backpropagation algorithms to compare context dissemination in large scale vehicular networks using OMNET++. Initial experiments show that taking the context of vehicles into account significantly improves the bandwidth, availability and context signal-to-noise ratio.

Intelligent telematic application development is a research area that has gained a lot of attention from the research community. In application areas include emergency message transmission, collision avoidance, congestion monitoring and intelligent parking space location. According to the European Transport Whitepaper (EC, 2001) in the year 2000 around 40,000 people lost their lives in the EU by road traffic accidents and 1.7 million were injured costing around EUR 160 billion. Mostly the cause of such incidents is directly related to human error with a very small number of technical or system failures. Such issues can be handled by making intelligent use of information provided by the embedded electronic devices inside vehicles such as GPS or PDAs which will assist drivers but also the information provided by other vehicles or stationary beacons next to the roads. For example, in Figure 1, the bus on the right-hand corner of the figure is interested in going to the right. But it was informed by the vehicles already there about road traffic congestion on that part of the road. Similarly, the same information about this traffic congestion is also being disseminated to the static nodes like parking meters so that parking on a congested road can be avoided and road signs so that the traffic flow can be redirected. In this example, it is clear that the information about the traffic congestion on a path should not be sent to every vehicle and static node but only to those vehicles and static nodes which are interested in such information. It implies that we have to model application specific abstractions by taking the context of the vehicles into account in order to optimize the message flow and reduce communication overhead. As a result a critical aspect in the development of such intelligent applications is *getting the right information at the right time and place* (Yasar et al., 2008).

Context is any relevant information that can be used to characterise the situation of entities and an entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves (Abowd et al., 1999). A system is *context-aware* if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task (Abowd et al., 1999). Context-aware dynamic settings in intelligent transportation and traffic management systems employ sensor network technologies to create new opportunities for co-operation and exchange of context information between nodes. Traditionally, ad hoc networks have been commonly in use as communication medium between mobile devices and/or a server at the backend (Riva et al., 2007). In order to establish intelligent transportation using the relevant context information flow between vehicles and other static nodes like a parking meter, traffic light or any other road sign we need to model abstractions for context-aware communication and analyze different algorithms and communication protocols incorporating the requirements over certain networks in a simulated environment.

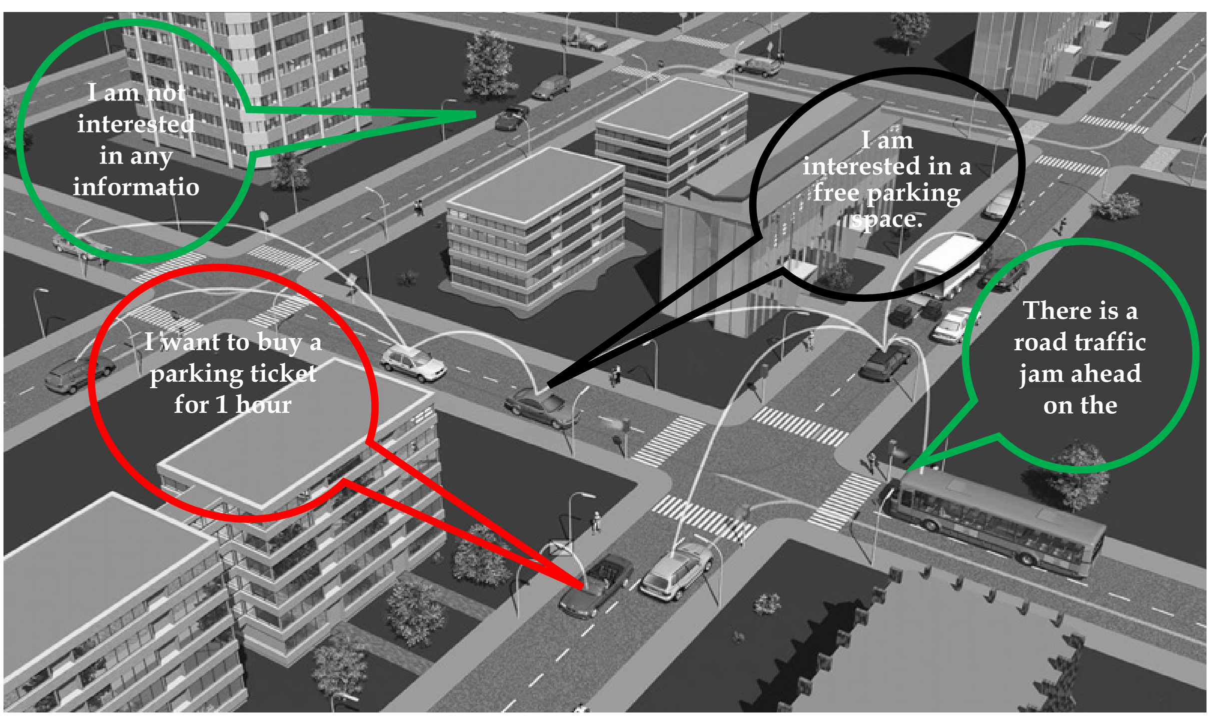

Fig. 1. City wide scalable mobile inter-vehicle communication network.

In this chapter, we will discuss both how we model context-aware telematic application specific abstractions for large scale vehicular networks and how we simulate interactions between moving vehicles and static nodes using broadcasting and our relevance backpropagation algorithms over Bluetooth and WiFi networks. Using our large scale vehicular network framework with context-driven adaptive communication protocols, we can not only model abstractions and investigate the impact of different communication routing schemes but also measure various quality of service parameters in vehicular mobility awareness for different traffic scenarios and versatile telematic application requirements using OMNET++ (Preuveneers et al., 2008) as shown in lower two layers in Figure 2. This figure illustrates our layered vision for smart telematic applications running on top of our middleware. Our relevance backpropagation algorithm resides in the middleware and models abstractions for telematic applications by filtering and routing of information in between the applications. We use simulate the large scale vehicular network using OMNET++ for relevant context information dissemination at the lowest layer.

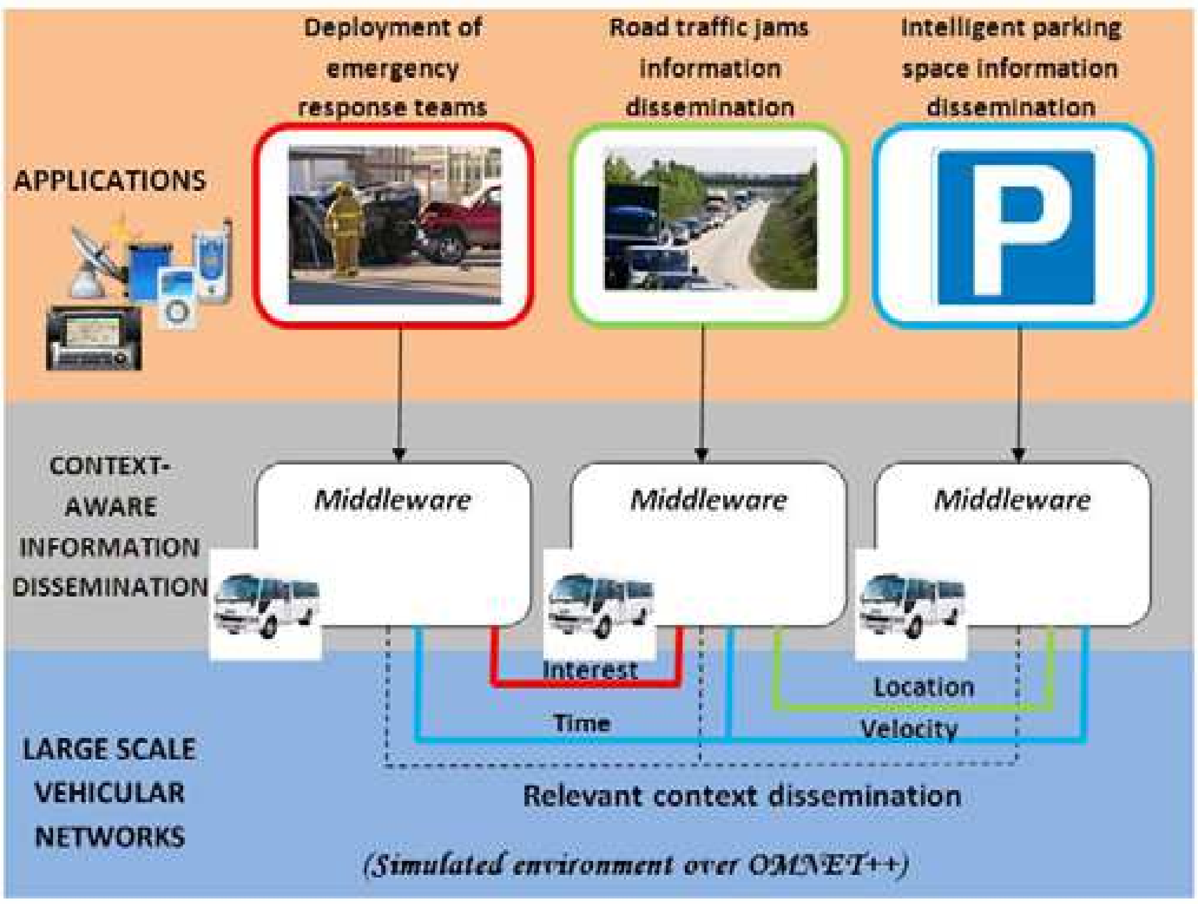

Fig. 2. Context-aware information dissemination in large scale vehicular networks.

We will describe the application specific modelling abstractions, certain set of requirements for context-aware information dissemination in a vehicle network and the design of our large scale vehicle network simulation framework in section 2 and 3 respectively. By means of simulated experimentation, we will illustrate the advantages and disadvantages of different communication schemes for a given telematic application in section 4. Moreover in section 4, we will provide insight on how telematic application developers can leverage from the simulation framework to analyze the behaviour of their applications in a simulated realistic vehicular network setting. In section 5 we discuss some of the related work. We end this chapter with our conclusions and research ideas about future work in section 6.

2. Large scale vehicular networks

The vehicle manufacturers worldwide are producing vehicles in a rapidly growing amount. They are equipped with highly efficient, reliable and cheap embedded computing devices due to the increased demand for smart vehicles to ensure a safe and pleasurable driving experience. With these technological advancements in vehicles, more and more mobile social vehicular networks will come into practice exchanging bulks of information. One of the key concerns for telematic applications in such networks is scalability. In this section we will define scalability, list some motivating scenarios and mention requirements for modelling and simulating various aspects of such networks.

2.1 Defining scalability

The expression '*Scalability*' has often been a vital but a complex facet to address. In terms of context-aware communication the '*Scalability*' can refer, but not limited, to the following properties;

- Large **number of participants** e.g. 100,000 vehicles in a metropolitan city like Brussels, London or Amsterdam.
- Large **number of interactions in terms of message passing between the participants** e.g. mobile social networking information exchanged between 50,000 passengers at an international airport.
- Large **area of interaction** e.g. playing geo-caching within a country or a continent.
- Longer **time span** e.g. maintaining context information about 10,000 vehicles inside a smaller city over a time span of one year to predict traffic congestions on a road.

For vehicular networks, in particular, we refer to it by covering both the aspects of the large number of vehicles and the large number of messages being passed. In order to further extend and explain the concept we present two scenarios in section 2.2 related to the deployment of emergency response teams and emergency messages dissemination and intelligent parking space information transmission to vehicles.

We deal with a large scale vehicle network in the scenarios involving different kinds of mobile and sensor networks like IEEE's 802.11x, Evolution-Data Optimized (EVDO) Rev X and Bluetooth. As it is very likely that there are other embedded devices like cellular phones, laptops, GPS etc, communicating over other kind of networks like GSM and satellite network are also present along with the vehicle's on board embedded computer can also be used for better and optimized performance.

2.2 Motivating scenarios

In this section we describe two motivating scenarios enabling the development of a middleware supporting scalable context-aware inter-vehicle communication. These scenarios are related to the deployment of emergency response teams and emergency messages dissemination and intelligent parking space information transmission to vehicles.

2.2.1 Deployment of emergency response teams and emergency message dissemination to vehicles in a traffic incident

Deployment of Emergency Response Teams to a traffic incident has always been a crucial point with authorities. Traditionally in case of an incident information is sent to the concerned authorities about the type, location and time of incident over the cellular or wired telephone networks and there might be a road traffic jam at the same place. The problem with the current system is that vehicles are often informed too late and the message itself is usually broadcasted to all the vehicles, also to those that are not in the neighbourhood of the accident. Let us consider a scenario where an accident occurs between two vehicles travelling from Leuven to Brussels on the highway E40 causing a traffic jam. A vehicle owner on the same side of the road informs the emergency response teams using his cellular phone after the incident has occurred. The emergency response teams arrive on the location after 10mins to rescue the victims and to put up a sign informing about the incident 500m away to inform the upcoming cars so that they can change their routes to avoid a traffic jam. But within this time frame quite a large number of vehicles are blocked on the road due to the accident which might take time to clear up.

In this scenario the 'large-scale' is mainly in terms of the number of participants and the messages passed between the participants. The types of interactions in this scenario can either be in the form of a query or a message, for example:

1. What is the location of the accident?
2. Which response team is the nearest?
3. Which network is suitable to send information?
4. Send emergency signal to all the vehicles traveling towards the accident.

The participants in a vehicular network will have such interactions in an ad hoc manner covering a large area.

2.2.2 Intelligent parking space information dissemination to vehicles in a metropolitan city

Nowadays, most of the new vehicles have an embedded Global Positioning System (GPS) device to assist the drivers while driving from one location to another. Let us take a typical case of Brussels city during the rush hours when there are thousands of vehicles on the roads. Brussels is one of the most popular cities in Europe and a tourist attraction as well. Several of these vehicles are in search for a parking space near their destination. The parking spaces are badly managed and are not intelligently used for providing parking information to the vehicles. Even the installed GPS is of no use in this situation. Traditionally the parking information is displayed on electronic boards within the city for different parking spots. In some cases when a particular vehicle finds a vacant parking space and reaches that parking space it is usually occupied by another vehicle as the information about free parking space was either too old or the information changed on the electronic board as soon as the vehicle passed by it. So in most of the cases either the vehicles park too far away from their destinations or waste a huge amount of time in search for a nearby parking space. In another case if someone wants to park in Brussels city near the central station on a Sunday at 6.30pm with a maximum parking charge of 1 EUR / hour but the nearest parking space in that location has limited timings on weekends between 6am till 6pm and higher parking fee of 1.50 EUR / hour. Such constraints can be taken into account in vehicular networks as well in order to make context-aware intelligent decisions.

In this scenario the 'large-scale' is mainly only in terms of the messages passed between the participants. Different types of interactions in this scenario either in the form of a query or a message are listed as under:

1. Is there a free parking spot within 500m?
2. How much is the parking fee?
3. What are the timings?
4. Inform other cars interested in a parking spot about a free space.

The participants in such a scenario will have such meaningful interactions in an ad hoc manner spreading the relevant information intelligently.

2.3 Requirements for modelling and simulating context-aware communication in large scale vehicular networks

In order to provide a context-aware scalable solution in terms of a modelling and simulation framework we have to identify a set of requirements supporting such communication. We will first briefly summarize the basic requirements (Yasar et al., 2008) for modelling large scale vehicular networks which are, but not limited to, mentioned as under:

R1: Location and direction-aware delivery of messages
It is always desirable to know the exact location of an incident for context-aware applications e.g.in scenarios 2.2.1 in case of an accident on the road the authorities should be notified about the exact location to react fast. Similarly, a context-aware application should be able to sense, manipulate and disseminate context information about direction and velocity of vehicles in the network to predict certain situations like traffic congestions or traffic accidents in specific regions.

R2: Temporal relevance
It is the desired behaviour of a context-aware application dealing with timeliness of information and routing efficiency. In a context-aware application on time arrival of information has always been a challenge using an efficient route. For example, if a road maintenance work is underway on 20th Apr 2009 between 10am and 5pm at Naamsestraat, Brusselsstraat and Lei in Leuven city so the information about traffic congestion or road condition is only valid on this specific date and time.

It is required that that only the relevant context information arrives at a particular node on the right time and place. Temporal relevance involves efficient filtering of irrelevant information at intermediate nodes for optimal routing and faster delivery of context information. For example, in scenarios 2.2.2 the information about free parking space at a certain location in Brussels should arrive on time to all the vehicles interested in parking information and the stationary nodes like sign boards. The vehicles and the stationary nodes can then further disseminate the information if considered relevant for their neighbouring nodes.

It is enviable to test and analyze several algorithms and protocols taking into account the defined requirements. This imposes a new requirement for our simulated framework in a large scale vehicular network. We will now briefly summarize them as follows;

R3: Analyze throughput, communication overhead and delivery efficiency
It is quite important to be able to quantify how much data that is being transmitted over the network is actually used by network peers both in total and on average for any given communication protocol scheme on an application basis. The quantification will guide the researchers to properly analyze, improve and compare various algorithms and protocols based on the parameters like throughput, communication overhead and routing efficiency.

The main goal is to use the requirements listed above and compare different algorithms and communication protocols for context-aware large scale inter-vehicle communication. Later in the chapter we will discuss and illustrate comparisons between several algorithms and communication protocols taking into account these requirements.

3. Modelling and simulating context-aware large scale vehicular networks

In this section we will discuss modelling criteria for context-aware large scale vehicular networks and types of available communication networks with regard to the type of network and dissemination technique in use. We later also talk about some of the available solutions for context-aware communication and the reasons for not using in vehicular networks along with our algorithm supporting all requirements.

3.1 Modelling context-aware large scale vehicular networks

In order to model application specific abstractions for context-aware large scale vehicular networks we need to know about;

- number of nodes in the network
- available communication links
- number of producer and consumer nodes
- context information being disseminated

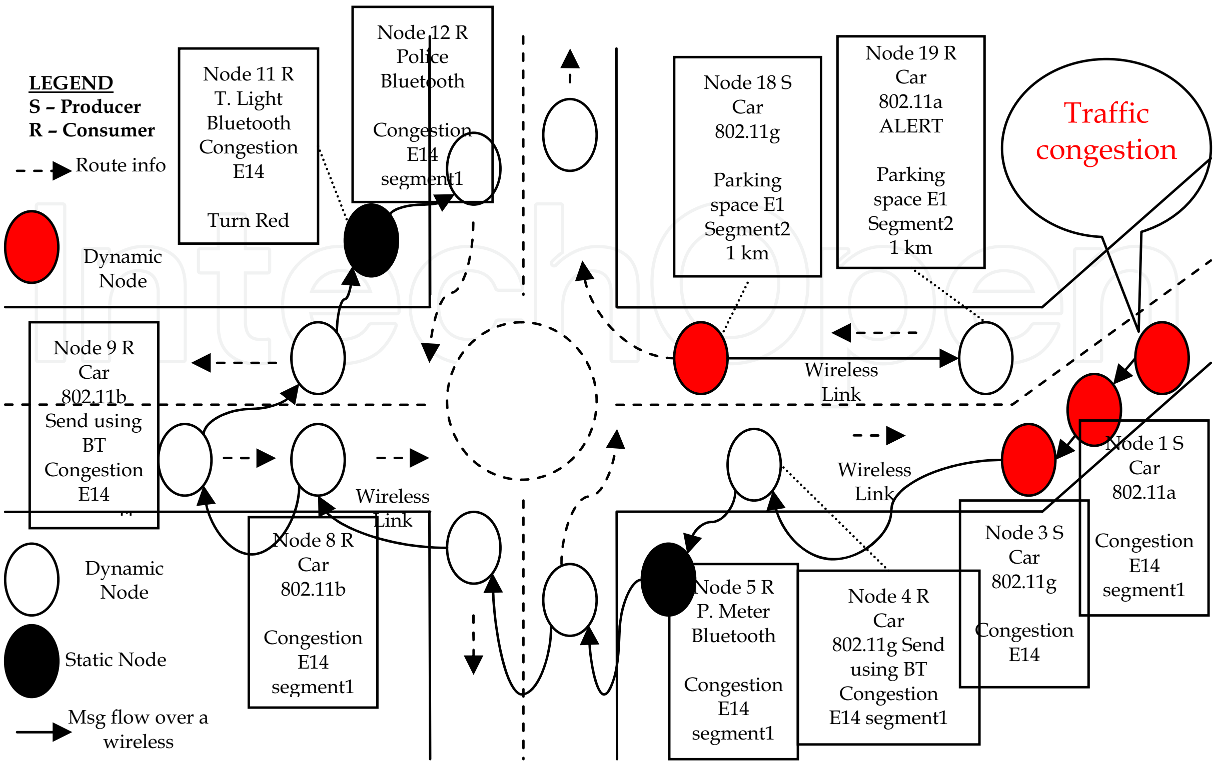

Fig. 3. Modelling context-aware large scale vehicular networks.

The model in Figure 3 shows several nodes in the network each with independent communication capabilities using various kinds of wireless networks. The red nodes and the white nodes are dynamic mobile nodes like vehicles in the network. Whereas, the black nodes are the static nodes like traffic lights, parking meters or road traffic sign. The red colour depicts that the node is an information producer which could either be either static or dynamic. The dotted arrows show the direction in which a node is travelling and the full arrows show an active communication link between two or more nodes using any kind of network mentioned in Table 1. Both arrows can have a different orientation for a single node. The boxes represent the context information the nodes are interested in which has been sent by a producer like the node's identification, preferred network, network in use may be due to receiver's limitation and the message. For example, in Figure 3, nodes will be only interested in information about the communication link to use and the throughput of the communication link being used but not the frequency information to perform computations about the fast and efficient available route.

- **Types of communication networks**

There are various kinds of wireless networks available for providing us with communication support. None of the available wireless networks are built specifically to serve the inter-vehicular communication needs. Researchers (Mahajan et al., 2007) working in this domain constantly test these available wireless networks like IEEE's 802.11x, Evolution-Data Optimized (EVDO) Rev X and Bluetooth to use for inter-vehicle communication.

Standard / Characteristics	IEEE 802.11x a.k.a WiFi			EVDO Rev X		Bluetooth	
	802.11b	*802.11g*	*802.11a*	*Rev A*	*Rev B*	*Ver. 1.2*	*ÈDR 2.0*
							
Throughput / Data Rate	11Mbps	54Mbps	54Mbps	3.1Mbps	9.3Mbps	1Mbps	3Mbps
Operational Frequency	2.4Ghz	2.4Ghz	5Ghz	CDMA 2000	CDMA 2000	2.4Ghz	2.4Ghz
Max. Range (outdoor)	200 - 250 meters	200 - 400 meters	50 - 150 meters	5 - 8 kms	5 – 8 kms	10 meters	100 meters
Modulation Scheme	CCK	OFDM	OFDM	16QAM	64QAM	GFSK	DQPSK
Spectrum Type	U.L.B.	U.L.B.	U.L.B.	L.B.	L.B.	U.L.B.	U.L.B.

Table 1. Characteristics of various wireless networks for inter-vehicular communication.

<u>**Legend**</u>:
- CCK – Complementary code keying
- CDMA - Code division multiple access
- OFDM – Orthogonal frequency-division multiplexing
- QAM – Quadrature amplitude modulation
- GFSK – Gaussian Frequency-Shift Keying
- DQPSK – Differential Quadrature Phase Shift Keying
- U.L.B. – Unlicensed band
- L.B. – Licensed band

In Table 1, we have listed several characteristics of some of the possible candidates like IEEE's 802.11x, the 3G EVDO flavours and Bluetooth network for inter-vehicle communication. EVDO Rev X has some potential advantages over WiFi such as the fact that signals can travel on same cell sites as cell phones, no limited coverage and seamless connectivity. The throughput / data rate characteristic mentioned in the Table 1 is hypothetical and the practical value may vary based on the operational environment. The values for the spatial coverage or maximum range are also for outdoor environments as these networks will be embedded inside vehicles. In our simulated experimentation over OMNET++ we make use of IEEE 802.11 and Bluetooth networks.

3.2 Simulating context-aware large scale inter-vehicle communication

The simulated environment enable the research community to test and analyze various kinds of algorithms and protocols over large scale networks like vehicular networks due to its efficient and accurate computation capabilities, low cost and no risk to human life. Simulators can be very efficiently used to create a close to real controlled environment to analyze the required things.

We incorporated the modelling requirements mentioned in section 2.3 along with our relevance backpropagation algorithm for reasoning and routing of contextual information, into our simulated environment over OMNET++ network simulator. We performed several experiments to test these requirements over two popular and most widely used networks namely WiFi and Bluetooth for wireless communication between various kinds of nodes. The details about our experimentation over a simulated environment are described in section 4.

3.2.1 Methods for information dissemination

In this section we discuss an important aspect of exchanging messages between the nodes and the context providers in a large scale vehicle network. Context information is either disseminated proactively using broadcast also known as the ***push model*** or ***on-demand*** also known as the pull model in applications for such a large scale network (Bokareva et al., 2004). We focus on the ***push model*** which has a potential of bootstrapping a large scale vehicular network (Bokareva et al., 2004). The aim of the data push model is to exchange context information among a set of moving vehicles on regular intervals. The pull model can also be implemented using the same techniques as used in the push model (Bokareva et al., 2004) (Ye et al., 2002). Two main techniques used by (Bokareva et al., 2004) to exchange contextual information are described below.

3.2.1.1 Flooding technique for communication

In the **flooding** technique also known as the plain **broadcasting** technique the context information received by a vehicle is stored locally and then the same information is forwarded using a re-broadcast to others. In a large scale, dynamic and mobile vehicle network flooding may overload the network especially in the case of high traffic volumes thus violating some of the requirements mentioned earlier in section 3.3. This technique is very useful in the case where the network under consideration is relatively small because efficiently routing the context information to specific nodes is more expensive in terms of network bandwidth and throughput.

3.2.1.2 Dissemination technique for communication

Dissemination is another generic technique which intelligently broadcasts the context information only to the interested nodes. In the case of a large scale vehicle network each time a vehicle receives the context information broadcasted by a context provider it re-broadcasts the context information only to the interested neighbours. The information about the interest of the neighbours is determined by themselves. The dissemination technique reduces the amounts of context information and does not overload the network, which makes it a scalable solution for transmission of context information over large scale networks. Some types of this kind of dissemination are discussed below:

- **Directed diffusion:** It is the data-centric communication technique widely used for wireless sensor networks. The vehicles request the context information by periodically broadcasting an interest for the required data. Each node will create a link with other nodes or a context provider from which it receives the context information of interest. The link also specifies the data rate and the direction towards which the context information should be sent. Once the link is created between the nodes and the context provider, the context provider will start sending information of interest to the nodes probably along multiple paths. As soon as the node wants to receive the context information, it will select a specific neighbour from which it will receive the information later on, thus defining a directed broadcast of the context information over a large scale network.

- **Two-Tier data dissemination:** It is a decentralized architecture where a grid structure is used to divide the network into cells. The context providers located at the boundary of the cell need to forward the context information to other cells. The context information is flooded within a cell. One tier is the cell at the nodes current location and the other one at the cell's boundary. The query is first propagated over the network to create a path between the node and the context provider and then the same path is used for the propagation of the context information. This technique involves a lot of intelligent routing mechanisms and information storage overhead creating complexities in the libraries for large scale networks application development.

- **Gradient broadcast:** This technique makes use of a cost variable during the transmission of context information. Initially the context providers set the cost to reach a node at infinity. The information is then broadcasted over multiple paths in the network where each of the intermediate context provider or a node calculates the cost of receiving the message (Bokareva et al., 2004). At the end each of the context providers or nodes would have calculated the cost for it to send the context information to a particular node. The cost data is later on used to optimally transmit the context information over the network with a minimal cost. This is highly efficient for transmission of context information over a large scale vehicle network but at the same time it creates overhead for each node to calculate the cost information. This could be an issue given the limited processing capabilities of nodes in large scale vehicle networks.

3.3 Adaptive context mediation in large scale vehicular networks

The network plays a vital role in a large scale environment to process and deliver information from one node to another. We list certain network specific requirements in detail for modelling and simulating adaptive context mediation in large scale vehicle networks. In our analysis (Yasar et al., 2008) we discovered three major requirements;

- **Throughput:** Throughput is an important factor for information propagation over a large scale dynamic mobile network. It measures the amount of relevant context information being sent over the network by the context provider and compares that with the amount that the context information received by the node that subscribed to that information.

- **Bandwidth:** In large scale and dynamic mobile networks bandwidth usage for context-awareness has always been a matter of concern. Therefore, the context information should be passed between the context provider and the nodes in an efficient manner.

- **Time to Live (TTL):** Some of the applications make use of the TTL to decide about the relevance of context information for a particular node in the network. If the TTL has expired the information is considered to be no more relevant to be transmitted over the network. TTL also participates in limiting the use of network bandwidth.

3.4 Relevance backpropagation algorithm

Current peer-to-peer communication protocols like Gossip, Pastry and Chord (Williamson et al., 2006) are inappropriate for scalable context-aware information dissemination as the relevancy of information cannot be determined at intermediate nodes during interaction between several nodes and also no routing algorithm takes relevance of context into account.

Algorithm 1. Relevance Backpropagation (input: fromPeer, contextMessage)

```
(messageRelevant, messageUnused, messageForwarded) = (false, false, false)
while (BeaconNewNode)
if (InFilterReceived(contextMessage.ID)) then
    BackpropagateMessage(fromPeer, DUPLICATE, contextMessage.ID)
else
    AddFilterReceived(fromPeer, context.Message.ID)
if (InFilterRelevant(contextMessage)) then
    messageRelevant = true
    BackpropagateMessage(fromPeer, RELEVANT, contextMessage.ID)
    if (InFilterUnsed(contextMessage)) then
    messageUnused = true
    LabelMessage(contextMessage, UNUSED)
else
    LabelMessage(contextMessage, IRRELEVANT)
if (contextMessage.hopsLeft > 0) then
   contextMessage.hopsLeft = contextMessage.hopsLeft – 1
   for each Peer p in ForwardFilter (adjacentPeers, contextMessage.ID) do
       messageForwarded = true
       ForwardMessage (p, contextMessage)
if (not messageForwarded) then
   if (not messageRelevant) then
      BackpropagateMessage(fromPeer, IRRELEVANT, contextMessage.ID)
   else if (messageUnused) then
         BackpropagateMessage(fromPeer, UNUSED, contextMessage.ID)
end while
RecalibrateNetwork( )
```

In order to solve these issues with the current available solutions we have extended the earlier work by (Preuveneers & Berbers, 2007) on the *relevance backpropagation algorithm* by integrating the requirements for large scale context-aware communication mentioned in section 3.1. The characteristics of the algorithm are as under:

i. The context information is initially plain broadcasted to the adjacent nodes unless maximum number of hops is reached. Each node forwards the information to its immediate neighbours and waits for the feedback backpropagated to it.

ii. Intermediate nodes will decide based on feedback backpropagated by the neighbouring nodes to reduce the number of peers to forward the information to. The feedback which is backpropagated contains information about the relevance of the context information received earlier as shown in Algorithm 1 lines 4, 9, 22 and 24.

iii. Each forwarding node reduces the hop counter, adds its identification and marks the message relevancy tag if the information is relevant for its purpose as shown in Algorithm 1 lines 7, 8 and 16.

iv. The feedback technique is based on context information like *position, velocity, direction, time-to-live, interest* etc that decides whether the data that was received is relevant or not and also help determine the information relevancy on the intermediate nodes. This way the irrelevant context information can filtered out at an intermediate node.

v. The feedback to the source node is backpropagated if the context information is *relevant, irrelevant, unused or duplicate* information is received as shown in Algorithm 1 lines 4, 9, 22 and 24. This will reduce the information dissemination only to the interested nodes.

vi. A vehicular network is highly dynamic in nature and application dependent. As the context information can be provided by the application itself the routing of the information is adapted accordingly and perhaps different for various applications.

vii. All the nodes in the network send out a beacon upon arrival in the network. So the network re-calibrates itself if a new node sends an arrival beacon or an old node no longer transmits the feedback after a certain period of time as shown in Algorithm 1 line 2 and 26.

viii. In this mechanism the goal is to efficiently filter and intelligently route the relevant information as close to the source as possible in a dynamic network. The routing information also directly proportional to the relevancy of information.

The conditions under which a node backpropagates a feedback are:

- **Relevant context:** The context information received by a node is either relevant for its own purpose or by one of its adjacent peers.

- **Irrelevant context:** The context information received by a node cannot be used for its own purpose and maximum number of hops has reached or it has no neighbouring nodes for which the context information might be relevant.

- **Unused context:** The context information received by a node is either not used or used infrequently. In this case the node will generate a message asking the transmitting peer to increase the transmission delay.

- **Duplicate context:** The context information received by a node has already been sent it by another node in the neighbourhood. In this case the node will ask the transmitting peer to stop sending this duplicate information in the future.

This algorithm is a best-effort algorithm which adapts itself according to the network configuration. The algorithm becomes intelligent with feedback information propagated in the network.

4. Evaluation of different protocols and algorithms

In this section we will discuss our simulated experimentations and the results obtained. In our scenario 2.2.1 and scenario 2.2.2 the solution we propose is to make use of the adaptive context mediation in large scale vehicle network. This can be achieved by using our relevance backpropagation mechanism in both the scenarios. In scenario 2.2.1 the context information will only be sent out to the vehicles moving towards the incident alerting them about an incident over a large scale network of vehicles. Similarly in scenario 2.2.2 the context information regarding the free parking space will also be disseminated only to the vehicles within a region of 2 km and moving towards the direction of the free parking space by making use of the relevance backpropagation to achieve adaptive context mediation in large scale vehicular networks.

4.1 Experimentation test bed

We use OMNET++ ver. 4.0, a real time discrete network simulator, to test our relevance backpropagation algorithm over a large scale vehicular network using real datasets. The OMNET++ simulator was setup over UBuntu ver. 8.10 (a flavour of linux) installed over a considerably powerful Dell desktop machine with 2.0 Ghz Core 2 Duo processor and 2 GB of memory.

We have used real time data from a multi-user distributed car simulator collected earlier by the authors (Yasar et al., 2008). The parameters we have taken into account are for each node to perform simulated experiments with OMNET++. We make use of these parameters and compute various factors to differentiate between the various algorithms and protocols used for communication in a large scale vehicular network.

(i) Time
(ii) Velocity
(iii) Direction
(iv) x and y coordinates
(v) Number of sent packets
(vi) Number of received packets
(vii) Number of forwarded packets
(viii) Time-to-live (TTL)

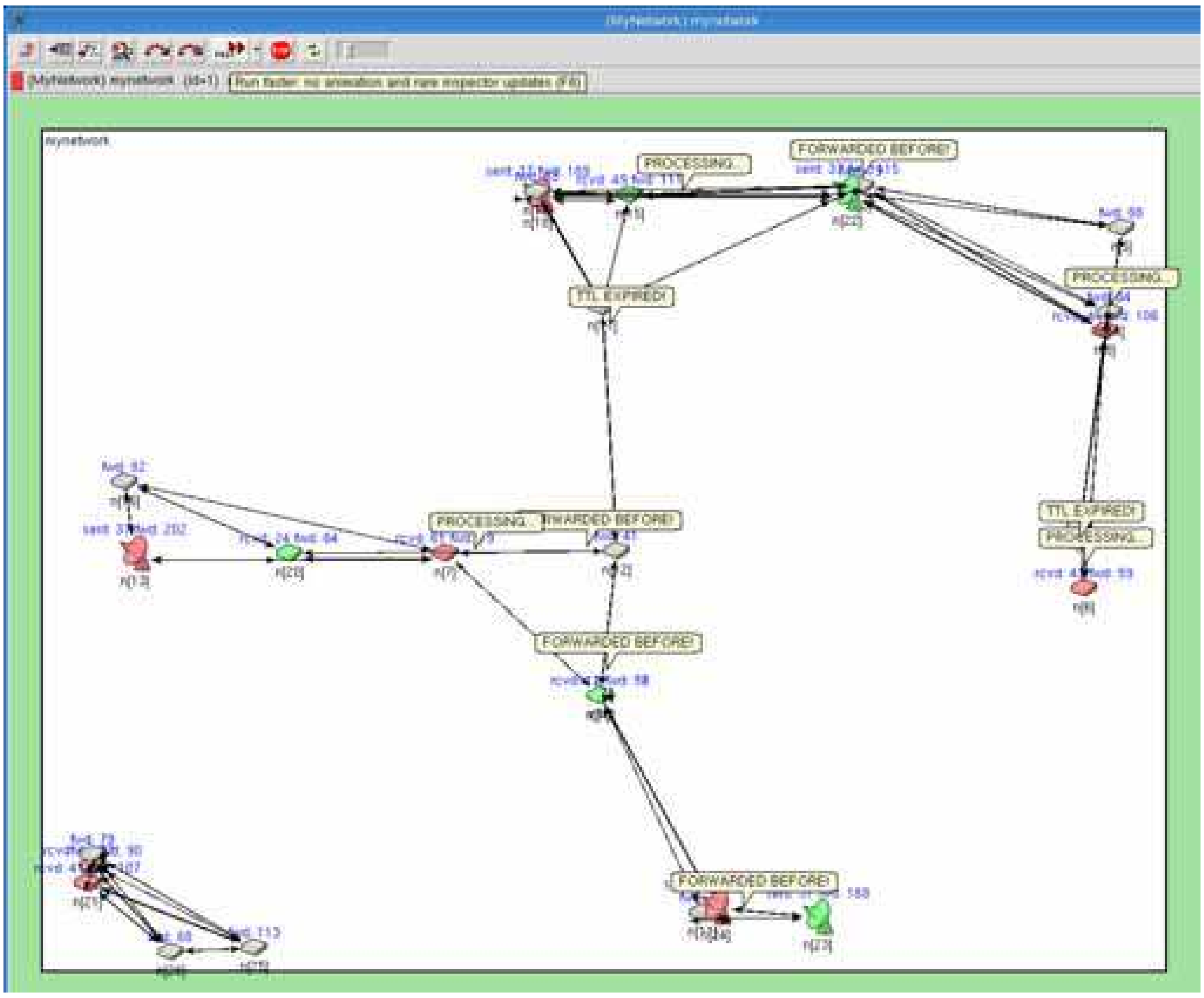

Fig. 4. Experimental test-bed over OMNET++ to simulate vehicular networks.

In our experiments, we let nodes move around like cars and let connections appear and disappear according to the range to other nodes. Some nodes acted as context provides whereas other nodes acted as context receivers. All nodes forward the information to their peers as long as the maximum TTL has not been reached and all context constraints are met. Figure 4 shows a visualization of the experiment with 27 nodes. There are green, red and gray nodes in the network where the colour depicts the information interest. The antennas are information producers whereas the other nodes are information consumers. We carried out 4 experiments with plain broadcasting and with our relevance backpropagation mechanism over WiFi and Bluetooth network configurations and simulated for a period of 1 hour of context dissemination each. The results for these experiments are explained more in detail below.

4.2 Discussion of Results

In the experiment using the flooding mechanism the context information was broadcasted in the network to every node. In our experiments with the relevance backpropagation algorithm only relevant context information was sent out to the interested nodes in the network.

- ***Bandwidth*** is the sum of all the sent and forwarded messages in the network and measure in megabits. It shows a significant difference in bandwidth utilization for our backpropagation mechanism up to 45% and 90% under wifi and Bluetooth networks respectively as shown in Figure 5. The results shown here have been rescaled on the x-axis and have no specific units.

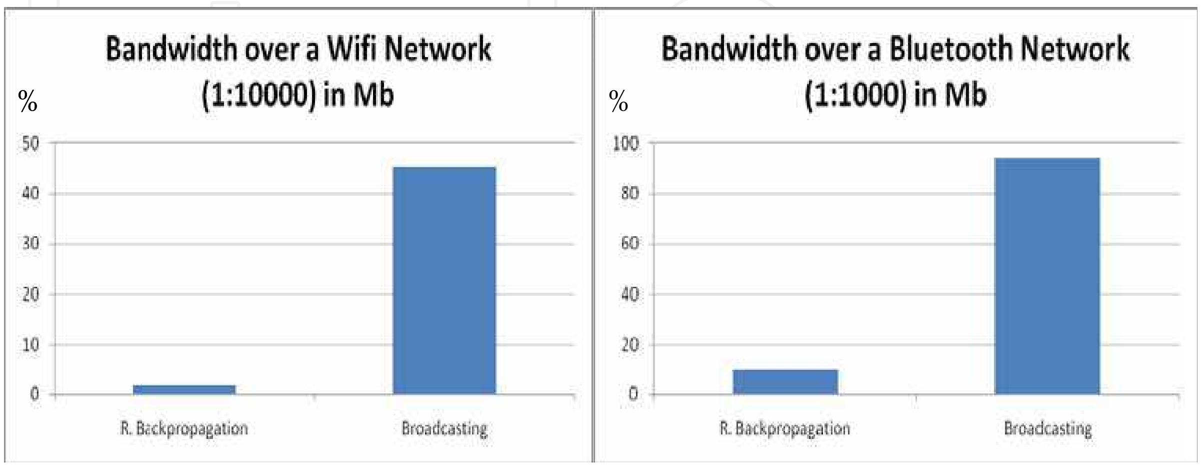

Fig. 5. Simulated (rescaled) bandwidth using plain broadcast and relevance backpropagation over WiFi and Bluetooth networks.

- ***Signal-to-Noise ratio (SNR) of the context information*** is calculated by dividing the total amount of received packets by the sum of total packets sent and forwarded by each node. It is also significantly about 25% higher in the relevance backpropagation mechanism compared to plain broadcasting over WiFi and Bluetooth networks. It illustrates that nodes get more relevant information (i.e. the nodes receive less information they are not interested in) as shown in Figure 6. The results shown here have been rescaled on the x-axis and have no specific units.

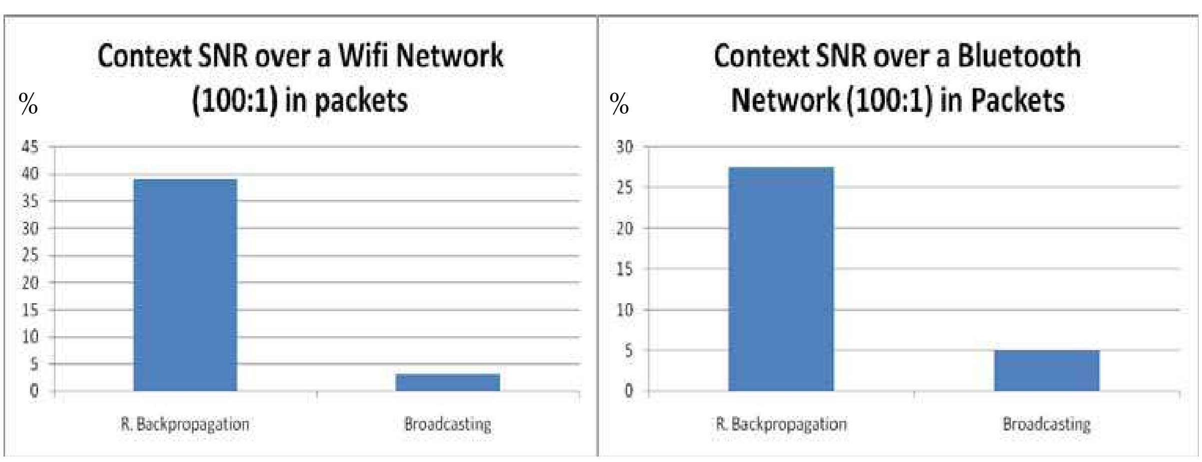

Fig. 6. Simulated (rescaled) CSNR using plain broadcast and relevance backpropagation over WiFi and Bluetooth networks.

- ***Throughput*** of the network is the ratio of the total amount of the information requested by the subscribers by the total amount of the information sent over the network by the context providers. The 15-20% lower throughput can be explained by the fact that messages are only routed where they are relevant, in some cases broadcasting may deliver messages that our approach does not. However this difference does not outweigh the bandwidth utilization as shown in Figure 7. The results shown here have been rescaled on the x-axis and have no specific units.

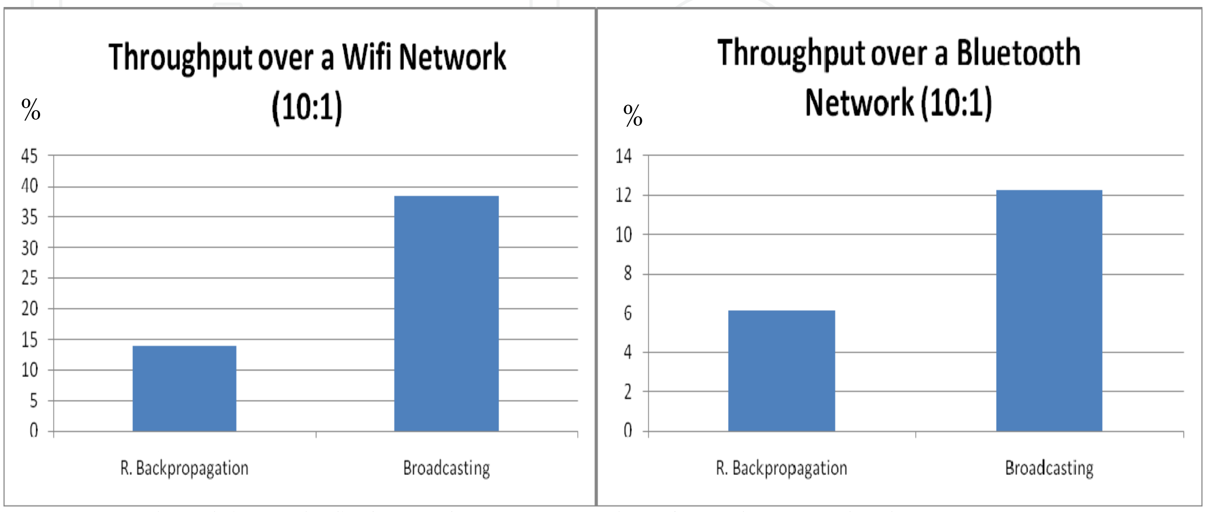

Fig. 7. Simulated (rescaled) throughput using plain broadcast and relevance backpropagation over WiFi and Bluetooth networks.

- ***Timeliness*** is the ratio of the number of messages dropped because the TTL was expired versus the number of messages forwarded by each of the node in the network. In relevance backpropagation the timeliness of the information is slightly higher than in plain broadcasting about 2% using WiFi and Bluetooth networks as shown in Figure 8. The results shown here have been rescaled on the x-axis and have no specific units.

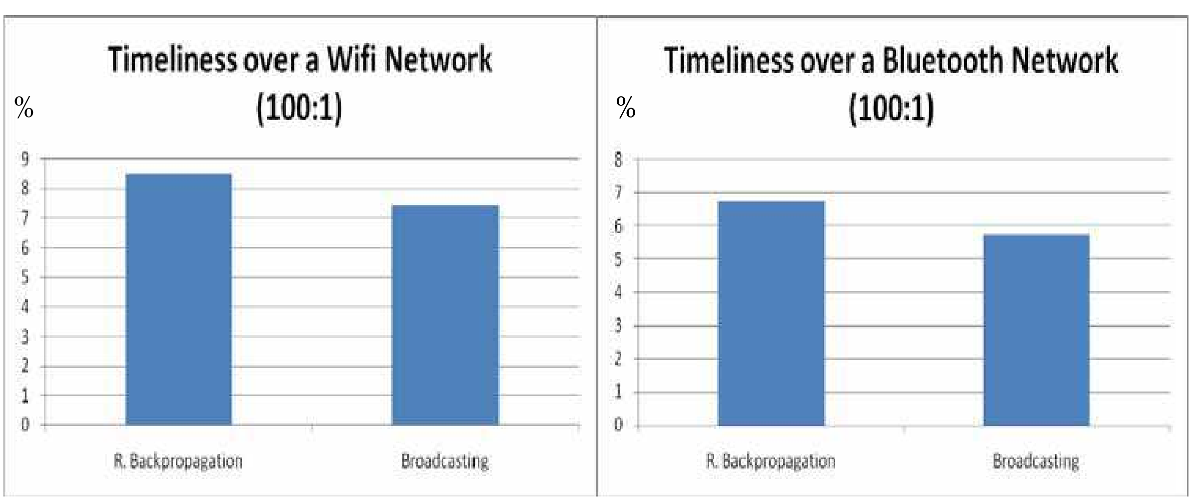

Fig. 8. Simulated (rescaled) timeliness using plain broadcast and relevance backpropagation over WiFi and Bluetooth networks.

- The ***availability*** parameter is the ratio of the sum of all the forwarded messages versus the number of messages that were received again and already forwarded previously. The availability of the context information is about 2% higher in the simulation results when using our relevance backpropagation mechanism in directed diffusion over a large scale network using WiFi and Bluetooth networks as shown in Figure 9. The results shown here have been rescaled on the x-axis and have no specific units.

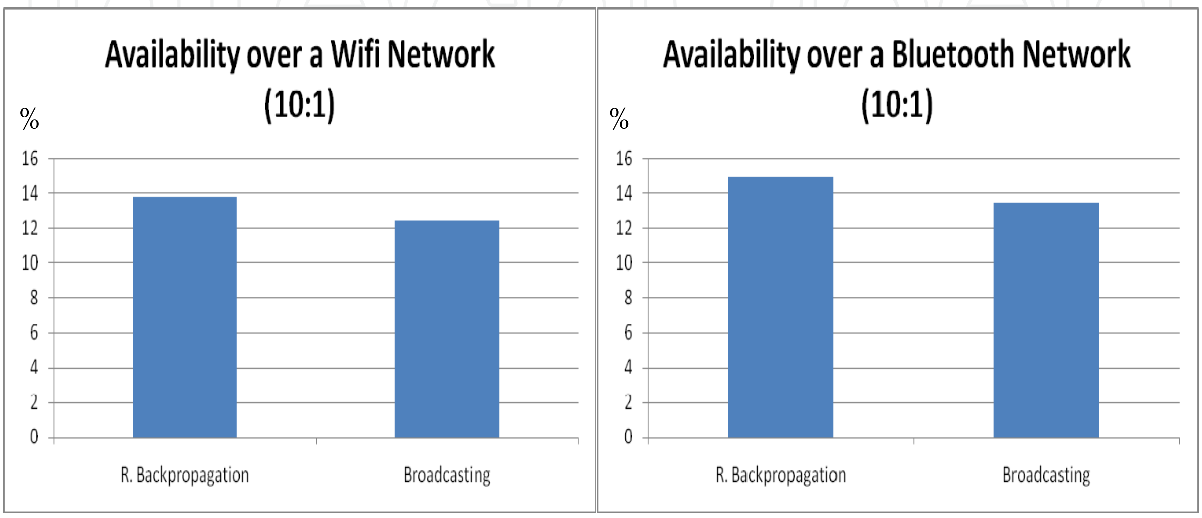

Fig. 9. Simulated (rescaled) availability using plain broadcast and relevance backpropagation over WiFi and Bluetooth networks.

Reduced bandwidth usage is an achievement in the area of network communications. One might argue that in the current modern era of technology and communication the world has enough bandwidth available for use. But with the growing demand for high speed communication this resource which we enjoy today will be scarce in the near future.

Using the current set of requirements into our relevance backpropagation algorithm, a best effort algorithm, we see a significantly reduced bandwidth requirement in a context-aware large scale vehicular network. In our research work we do not investigate the complete set of requirements for context-aware smart telematic applications into our algorithm over OMNET++ and on real vehicles so the results may vary accordingly. For example, we do not take the context of priority of information into account for urgent message delivery to the nodes in a vehicular network so we also do not know the effects on such constraints on the results in a simulated environment.

5. Related work

In (Nadeem et al., 2006), the authors present a formal model of data dissemination in Vehicle Ad-Hoc networks (VANETs). They measure how the performance of data dissemination is affected by bi-directional lane mobility. Three models of data dissemination are explained and simple broadcasting technique is found to be sufficiently enough in their simulated experiments. In our research, we deal with the directional dissemination of context information.

The authors present an idea about the WiFi-based connectivity and communication between base stations and moving vehicles in (Mahajan et al., 2007). Vehicles mobility cause gray periods of poor connectivity which according to the authors are caused by variability in the urban radio environment combined with the vehicle traversing areas of poor coverage. We envision that for large scale vehicle network the use of simple WiFi based communication will be impractical.

In (Celik et al., 2006), the authors address the issue of optimal data dissemination broadcasts to a network of wireless cells in a large mobile network. They propose that there should be a mix of a single broadcast for the entire network along with an individual broadcast for each of the wireless cells. The authors found a significant improvement in the performance of the network using their simulation results. Our approach uses the idea of disseminating the context information only within the area of spatial coverage.

The importance of caching context information has also been addressed in (Anandarajah et al., 2006). As disconnections between nodes in large scale networks may occur due to nodes mobility, the authors discuss smart caching algorithms that improve the traditional methods for distributed systems by using various kinds of meta-data. In our research, relevance backpropagation algorithm handles the dynamic nature of a mobile network without creating a communication overhead.

A comparative performance comparison between three data dissemination protocols (i) Directed Diffusion, (ii) Two-Tier Data Dissemination and (iii) Gradient Broadcast for wireless sensor networks is discussed by the authors (Bokareva et al., 2004). In our research, we found that two-tier dissemination and gradient broadcasting over a large scale network are not cost efficient in terms of implementation complexity and processing overhead. So we make use of a combination of directional diffusion and gradient broadcast of context information in a better manner by using spatial coverage and information relevance feedback acting as a cost function in gradient broadcast so that the context information can only be directed to a specific region with minimal cost and effort.

6. Conclusion and Future work

In this chapter, we describe certain requirements to model context-aware application specific abstractions in large scale vehicular networks and simulate interactions between moving vehicles and static nodes using broadcasting and our relevance backpropagation algorithms to evaluate context-aware telematics applications over Bluetooth and WiFi networks. Using our large scale vehicular network framework with context-driven adaptive communication protocols over OMNET++, we can not only model abstractions and investigate the impact of different communication routing schemes but also measure various quality of service parameters in vehicular mobility awareness for different traffic scenarios and versatile telematic application requirements.

The simulation results show that by using our relevance backpropagation mechanism significant reduction in bandwidth utilization up to 45% and 90% under WiFi and Bluetooth networks respectively. Similarly, timeliness and availability of context information also improves by 2% in both the networks. SNR of context information is also improved about 25% with a very minor overhead of about 15-20% in throughput under both network types.

We are planning to investigate the network and context properties to get a broader view of the communication mechanisms used earlier for our simulated experiments. We also plan to model requirements for simulating 3G networks like EVDO using our relevance backpropagation algorithm over OMNET++. We intend to further look into the *on-demand* communication technique and compare the results with our current push-model for communication.

In the future we also plan to investigate the same network parameters by inter-connecting a real embedded smart device like a PDA, GPS or an embedded vehicular computer with the simulation environment to analyze the behaviour of the real smart devices. Later on this will enable us to see how our relevance backpropagation mechanism can be improved over other large scale networks with real applications.

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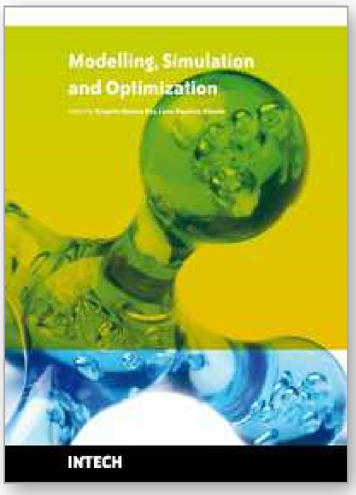

Modelling Simulation and Optimization

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Computer-Aided Design and system analysis aim to find mathematical models that allow emulating the behaviour of components and facilities. The high competitiveness in industry, the little time available for product development and the high cost in terms of time and money of producing the initial prototypes means that the computer-aided design and analysis of products are taking on major importance. On the other hand, in most areas of engineering the components of a system are interconnected and belong to different domains of physics (mechanics, electrics, hydraulics, thermal...). When developing a complete multidisciplinary system, it needs to integrate a design procedure to ensure that it will be successfully achieved. Engineering systems require an analysis of their dynamic behaviour (evolution over time or path of their different variables). The purpose of modelling and simulating dynamic systems is to generate a set of algebraic and differential equations or a mathematical model. In order to perform rapid product optimisation iterations, the models must be formulated and evaluated in the most efficient way. Automated environments contribute to this. One of the pioneers of simulation technology in medicine defines simulation as a technique, not a technology, that replaces real experiences with guided experiences reproducing important aspects of the real world in a fully interactive fashion [iii]. In the following chapters the reader will be introduced to the world of simulation in topics of current interest such as medicine, military purposes and their use in industry for diverse applications that range from the use of networks to combining thermal, chemical or electrical aspects, among others. We hope that after reading the different sections of this book we will have succeeded in bringing across what the scientific community is doing in the field of simulation and that it will be to your interest and liking. Lastly, we would like to thank all the authors for their excellent contributions in the different areas of simulation.

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