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Where People and Cars Meet: Social Interactions to Improve Information Sharing in Large Scale Vehicular Networks

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ABSTRACT

Efficient delivery of information in vehicular networks is crucial for the creation of useful and usable applications that need to cope with nomadic large-scale environments. Context-awareness is often key to improve efficiency of a vehicle network since it allows to make informed decisions on the data routing, data locality and data necessity for different moving objects. In this paper we show how the social network of vehicle residents, as part of the overall context, allows us to improve the information sharing in the vehicular network significantly. We demonstrate this by deploying a social ubiquitous-help-system (UHS) on top of a vehicular network. We analyze how UHS operates in a vehicular network using a network simulation of realistic large scale vehicular movement data and show that the social interactions increases the efficiency, relevance and quality of information in data delivery.

Categories and Subject Descriptors

H.3.3 [**Information Storage and Retrieval**]: Information Search and Retrieval—*information filtering, selection process.*; H.3.5 [**Information Storage and Retrieval**]: Online Information Services—*data sharing.*

General Terms

Performance, Experimentation, Context, Social.

Keywords

Vehicular network, large-scale, context-awareness, social network.

1. INTRODUCTION

Intelligent transportation system demands efficient delivery of information between vehicles for the creation of useful and usable telematic applications that need to operate in nomadic large-scale environments. Scalability for inter-vehicular communication can be in terms of a large number of participating nodes, a large number of messages exchanged between the vehicles or a large geographical communication region. Context-awareness is often key to improve the efficiency of a vehicle network since it allows to make informed decisions on the data routing, locality and necessity for different moving objects. Ever increasing use of embedded computing devices inside vehicles that serve us everyday made it possible to access information like road traffic conditions, collision avoidance, traffic incidents or intelligent parking space location almost instantaneously creating a social bond between vehicles as shown in Figure 1.

A social network is a networked structure of users connected by one or more interdependencies, usually sharing some common grounds such as friendship or belief. In this paper we show how the social network of vehicle residents, as part of the overall context, allows us to improve the information sharing in the vehicular network significantly. The goal is that vehicles are able to acquire relevant context information from the other nodes based on their social profiles and subsequently manipulate this information to perform context-sensitive tasks. For example, vehicles driving between metro-politan cities like Brussels or Amsterdam often encounter traffic congestions and problems with finding suitable free parking space near to their destination. It would be interesting if vehicles can have such information beforehand. In some cases this information can be shared by a

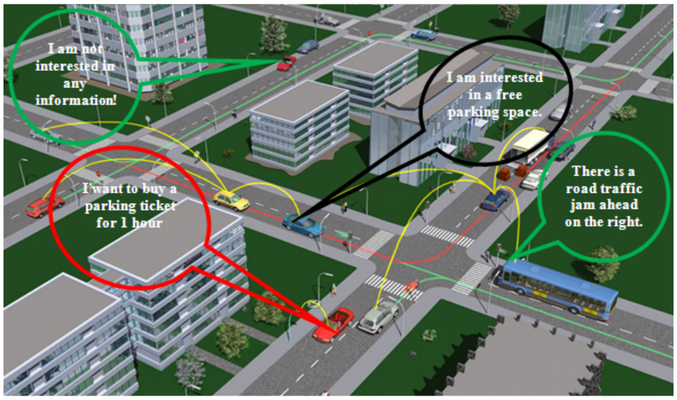


Figure 1: City wide scalable mobile inter-vehicle communication network.

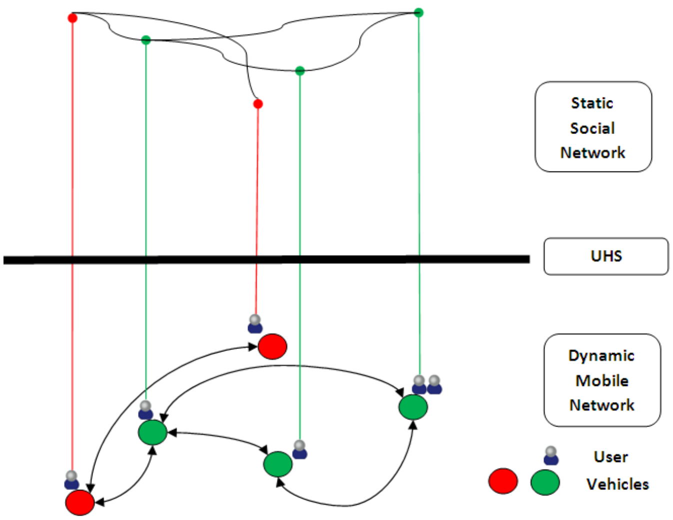


Figure 2: Bridging the gap between social and mobile networks.

friend or a friend-of-a-friend (FOAF). The advantage of social networks is that they limit the information exchange between the nodes in a mobile vehicular network by making sure that the information is trust-worthy.

We demonstrate this by deploying a social ubiquitous-help-system (UHS) on top of a mobile vehicular network as shown in Figure 2. In this system the static social interactions are relying on the actual physical and dynamic connections between vehicles interested in different context information, represented by the green and red colors in the figure, creating a social bond between them. Similarly, nodes in a vehicular network can acquire relevant and reliable context information from other nodes they know and trust. We analyze how UHS operates in a vehicular network using a OMNET++ network simulator with realistic large scale vehicular movement data and show that the social interactions increase the efficiency, relevance and quality of information (QoI) in data delivery.

In section 2, we present a motivating scenario. Requirements for scalable adaptive context mediation using social interactions are discussed in section 3. In section 4 we describe our ubiquitous-help-system(UHS). We discuss about the evaluation of the ubiquitous-help-system (UHS) in section 5. In section 6 we describe the related work. The conclusion and the future work is presented in section 7.

2. MOTIVATING SCENARIO

Noah is a young enthusiastic journalist working for a news agency in Leuven. For his profession he has to travel a lot and most of the cases he uses his office car because a car gives him a considerable amount of mobility. Noah has to visit many places wherever the news takes him on a regular basis. But almost in every case his visit ends with a dreadful experience of traffic congestions and it also takes a lot of time to find a parking place.

Today Noah has a meeting in Hasselt and he got a new car 'Alpha' equipped with the Ubiquitous-Help-System(UHS), an embedded device for communication and navigation. UHS greets him and asks for permission to access his agenda from his office computer and adjusts the current destination to Hasselt University where the meeting is scheduled.

Noah starts to drive and follows the GPS directions at around 8am in the morning which is usually a busy period on the highway. While on the way to Hasselt another car 'Beta' in the opposite direction going towards Leuven detected that some cars including Noah's car are interested in going towards Hasselt from their profiles. Car Beta has information about a traffic accident on the road towards Hasselt that caused a traffic congestion and it sends this information to all the interested cars in the vicinity. Noah's car receives this information and the UHS immediately recalculates the route to Noah's meeting location.

As Noah is approaching Hasselt the UHS checks for available parking spots. It receives two messages (1) from a friend who just left the same parking space saying that there is a vacant spot, and (2) another from an unknown nearby car who was not Noah's friend but a FOAF saying that there is no free space available. The UHS accepted the information provided by the friend's car based on this higher degree of reliability, sends a reservation request to the parking meter and drives the car towards the reserved spot. It also provides a positive feedback to the friend's car and a negative feedback to the other car based on the information provided earlier. Noah finally reaches his destination and successfully parks his car with a smile on his face.

3. REQUIREMENTS FOR INFORMATION DISSEMINATION IN SOCIAL AND MOBILE NETWORKS

In this section we will summarize basic requirements in terms of both social interactions and adaptive context mediation in large scale vehicular networks with reference to the motivating scenario described in the previous section.

3.1 Social interactions

In our work we use the FOAF based social networking technique in the domain of scalable inter-vehicle communication to assist people retrieve reliable information. This information is scattered over and shared spontaneously over a large space as illustrated in the case of sharing free parking space information in a certain area. To effectively use the FOAF based social interaction for adaptive context mediation we need to grade the quality of information(QoI) being provided by a friend with respect to its current contextual information. We will briefly summarize the basic set of requirements for social interactions in large scale mobile vehicular networks.

1. **Making Friends:** A social network is a map of so called social relationships among members of a network, which make invisible interpersonal relationships visible to the real world. A social network hence allows its users to actively search and find friends of a friend. This feature makes it possible to find people with similar interest and allows one to make new friends interactively.

2. **Grading Friends:** With the advent of new technology, we have hundreds of sources producing large amounts of information to deal with. This creates a significant cognitive load to sort-out trust-able information. Information with recommendation from a friend sharing similar interests is naturally trusted higher than otherwise. In a social network (SN), peers also produce and share information. A peer producing information is also subject to trust. A grading system, depending on the feedback voluntarily provided by the information consumer, helps to improve the overall quality of information shared in a social network.

3. **Distributed Feature:** FOAF allows the information about a friend in the network to be distributed without the need for a centralized database. In a dynamic large scale ubiquitous computing environment, where the number and presence of nodes in a certain time is unpredictable, this distributed feature allows a UHS peer to dynamically find and communicate with other peers with similar interests in the similar manner as a friend in a SN.

4. **Dynamicity:** Dynamically finding and updating information about peers in the neighborhood having similar interest as a friend in the vehicular network allows detection of the availability of reliable sources of information within the communication range.

3.2 Adaptive context mediation in large scale vehicular networks

Context information is either disseminated pro-actively 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. The aim of the data push/pull model is to exchange context information among a set of moving vehicles on regular intervals in a scalable environment. We will briefly summarize the basic set of requirements for adaptive context mediation in large scale vehicular networks.

1. **Spatial coverage:** It is always desirable to know the exact location of an incident for context-aware applications e.g. in case of an incident 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.

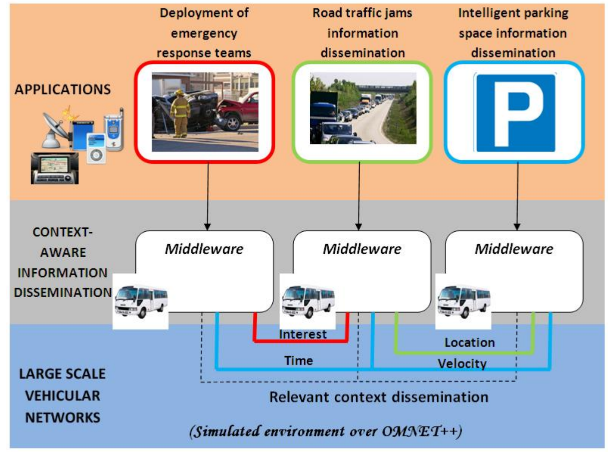


Figure 3: City wide scalable mobile inter-vehicle communication network.

2. **Timeliness of information:** It is crucial that only up-to-date context information reaches its destination as it can lose relevance after a certain period of time. It also involves efficient filtering of irrelevant information at intermediate nodes for optimal routing and faster delivery of context information. 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.

3. **Quality of information(QoI):** It is an important factor when the social information is involved for adaptive context mediation to make sure that the information being received at a particular node is reliable and trustworthy. Each node involved in the large scale vehicular network should have a social profile listing the information about its friends and (FOAF [1]) sharing some common interest with a QoI index for each. The QoI index will vary according to the reliability of the information provided by a node.

4. **Routing efficiency and efficacy:** 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 relevancy, communication overhead and routing efficiency. In this paper, we compared our FOAF based relevance backpropagation algorithm with the simple relevance backpropagation technique.

4. UBIQUITOUS-HELP-SYSTEM (UHS)

UHS [6] is a framework to integrate the social networks which are often static and connection oriented with mobile vehicular networks which are dynamic in nature as shown

[1]http://www.foaf-project.org/

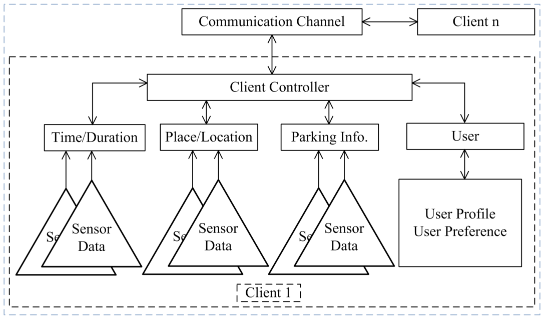


Figure 4: Client structure.

in Figure 2. The UHS resides in between the application and physical layer of a network as shown in Figure 3 and helps provide an input from the social network to the mobile vehicular network. In this section we explain both the social and the physical features of the UHS for information dissemination.

4.1 The social aspect of UHS

The Ubiquitous-Help-System(UHS) that runs on a portable computing device such as PDA or laptop keeps track of the users profile, preference, preferences and presence of other users, current location and time (see Figure 4). In the current extension, it also keeps track of available parking space in different places.

UHS uses FOAF to keep track of the other users. Typically it exploits three properties of the UHS clients that are searching and serving information about parking place: locality, common ground and reliability.

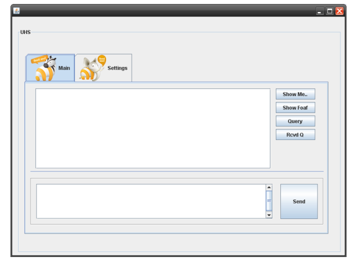
First, *Locality* implies that users often seek help and guidance related to the area they are located in or heading to. For example, inquiring about parking place in someone's home town is likely relevant while the person is traveling in a new city and going to a conference in particular. Similarly, people often want or need to know fine-grained information for parking space near her current destination while she is heading towards the destination.

The second property, *common ground*, indicates users feel more comfortable receiving help and guidance of other users they have something in common with. UHS uses a combination of the social network of a user and the context of use of all users in the social network to seek for the most appropriate information.

The third property, *reliability* indicates whether a source can produce useful information which is hard to determine at the first place. Each UHS replies with its identifier, information and quality index related to that information. Reliability is related with this quality index that basically represents history and shows that client served with better information in the past. But it does not guarantee that the currently provided information is accurate. The receiving UHS has liberty to accept or reject information received as response to any query it has initiated.

UHS uses the following process to obtain help and guidance,

- As a UHS client assumes that the car is moving to a particular destination and it needs to some parking information near the destination it prepare queries.



(a) Screenshot of social UHS prototype.

```
<foaf:Person rdf:ID="me">
  <foaf:name>Noah Marly</foaf:name>
  <foaf:title>Mr.</foaf:title>
  <foaf:givenname>Noah</foaf:givenname>
  <foaf:family_name>Marly</foaf:family_name>
  <foaf:mbox_sha1sum>617e3e9d9ac9239dbd5dc26c411e20fd6a393d83</foaf:mbox_sha1sum>
  <foaf:homepage rdf:resource="http://research.edm.uhasselt.be/~noah/"/>
  <foaf:status>busy</foaf:status>
  <foaf:parking>3</foaf:parking>
  <foaf:info_q>-5</foaf:info_q>
- <foaf:knows>
  - <foaf:Person>
      <foaf:name>Emma Jonson</foaf:name>
      <foaf:mbox_sha1sum>b513b6f7a7718967523b69fb38133bd21a5a42a0</foaf:mbox_sha1sum>
    </foaf:Person>
  </foaf:knows>
```

(b) Example FOAF file.

Figure 5: The social aspect of UHS.

- The UHS connects with other distributed UHS client devices by exploiting the ad hoc vehicular network. Then it disseminates the query among the clients.
- Clients that receive the query, process the query, and reply if they can serve as a source (as in Figure 5).
- Upon receiving responses from one or more clients, the UHS can select the convincing or apparent best information by looking at the quality index of the information. At the same time if the client itself can verify the received information, it can send feedback to the sender to update data and quality index.

We implemented the querying processing using SPARQL queries. A client seeking information initiates query and broadcasts among the peers. Receiving clients are responsible to process and if applicable reply to the query. The RDF [2] query language SPARQL [3] is used to allow efficient queries over the distributed knowledge base scattered in different client devices. Each UHS client updates its database constantly, and serves as data source node for others. When a UHS client finds match and able to provide information about available parking within the interest of the client asking for information, it replies with its identifier, information and quality index of the information.The client provides parking information and also a history that resembles the quality of information from past. The query initiator is able to justify and grade the quality of information provided by a particular UHS client. This also helps others to make decisions about information they receive from that particular client.

A matching algorithm matches the profile and preference and suggests its user whether she should responds to the

[2]http://www.w3.org/TR/rdf-syntax-grammar/
[3]http://www.w3.org/TR/rdf-sparql-query/

query or not. For example, a query for searching for a parking place near a particular shopping mall will be best processed by a client device which is already in the parking lot of that shopping complex and who wishes to serve as a client. Someone UHS that can provide information regarding parking in a local university should be matched with user's profile containing the university name and with keywords e.g. student or employee. This approach has the basic difference from our early work that the UHS client autonomously responds to the query as soon as it is inquired. It also automatically updates its database with newer information or with feedback about the served information.

4.2 FOAF based relevance backpropagation

We propose a new best-effort mechanism (as shown in Algorithm 1) for intelligent adaptive context dissemination using social interactions in a large scale vehicular network based on our earlier work [8, 9]. Each participating node has a list of friends and FOAF, QoI index and information about it relevant context information. The algorithm relies on feedback of neighboring nodes to reduce the number of peers to forward the information to. The information is initially forwarded to the adjacent nodes who are either friends or FOAF having certain degree of QoI unless a maximum number of hops is reached. Each forwarding node reduces the hop counter, adds its identifier and marks the message relevancy tag if the information is relevant for its purpose and grades the sending node positively adding it to the friends list. If a node provides any irrelevant or incorrect information the QoI index for that node will be graded negatively. 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 which helps determine the information relevancy on the intermediate nodes. The feedback to the delivering node is initiated if the context information is relevant, irrelevant, unused or duplicate information is received. It ensures that the information provided is from a trusted node which is supposed to be accurate and relevant for the receiver.

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. So the network re-calibrates itself if a new node sends an arrival beacon or an old node no longer transmits the feedback information. In this mechanism the goal is to efficiently filter and route the relevant information as close to the source as possible in a dynamic network.

Algorithm 1 FOAF based relevance backpropagation algorithm(input: fromPeer, contextMessage, profile)

```
(messageRelevant, messageUnused, messageForwarded) = (false, false, false)
while (fromPeer.IsFOAF and fromPeer.socialGrade not < 0) || BeaconNewNode) do
   if (InFilterReceived(contextMessage.ID)) then
      BackpropagateMessage(fromPeer, DUPLICATE, contextMessage.ID)
   else
      AddFilterReceived(fromPeer, contextMessage.ID)
   if (InFilterRelevant(contextMessage and InCurrentContext(fromPeer.ContextProfile))) then
      messageRelevant = true
      fromPeer.socialGrade + 1
      if BeaconNewNode then
         addInFriendList(BeaconNewNode)
         addFriendContextProfile(BeaconNewNode.ContextProfile)
         if (InFilterUnused(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, socialGrade)
   if (not messageForwarded) then
      if (not messageRelevant) then
         fromPeer.socialGrade - 1
         BackpropagateMessage(fromPeer, IRRELEVANT, contextMessage.ID)
      else if (messageUnused) then
         fromPeer.socialGrade + 1
         BackpropagateMessage(fromPeer, UNUSED, contextMessage.ID)
RecalibrateNetwork()
```

5. EVALUATION OF UBIQUITOUS-HELP-SYSTEM(UHS)

OMNET++ is a discrete event simulation environment. Its primary application area is the simulation of communication networks, but because of its generic and flexible architecture, it has been successfully used in other areas like the simulation of complex IT systems, queuing networks and hardware architectures. It can easily be adapted to simulate other scenarios including large scale, dynamic and mobile networks of vehicles.

We have used real time data from a multi-user distributed car simulator [9]. The parameters we have taken into account are (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 and (viii) time-to-live (TTL) for each node to perform simulated experiments with OMNET++ using our FOAF based relevance backpropagation algorithm and simple relevance backpropagation algorithm.

In the experiment, social interactions part of the UHS serve as an input to the simulator providing it with the relevant QoI index for each node. We let the nodes move around like cars and let connections appear and disappear according to the range to other nodes. Several 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 6 shows a visualization of the experiment with 27 nodes. We carried out the experiment with our simple and FOAF based relevance backpropagation mechanism under same network configuration and simulated for a period of 1 hour.

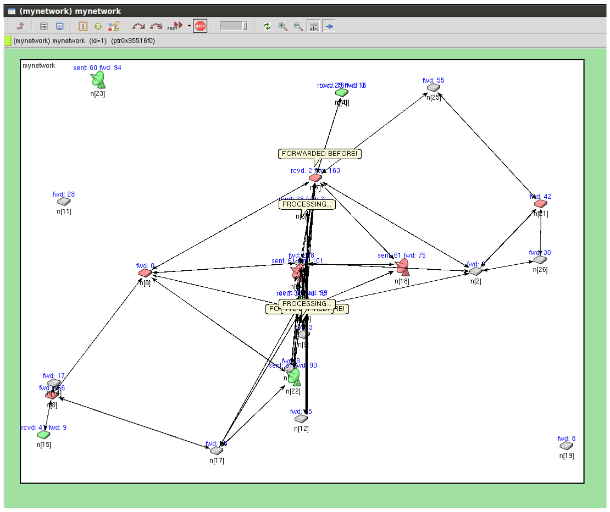


Figure 6: Simulated context dissemination in a network of vehicles.

5.1 Discussion of results

The results obtained from the simulated experimentation using our FOAF based relevance backpropagation algorithm and simple relevance backpropagation algorithm are shown in Figure 7.

- *Network Traffic* is the sum of all the sent and forwarded messages in the network per unit time. A lower network traffic usage is considered to be better. The results show a difference of about 1 to 2 % in network traffic when using the FOAF based relevance backpropagation algorithm.

- *Relevancy* is division of the number of packets received that are relevant for the node itself or for its peers by the total number of packets received. A higher relevancy ratio is considered to be better. In our FOAF based relevance backpropagation we discard information from non-friends even if the information is correct and relevant. This illustrate that taking into account the quality and relevance of information in our FOAF based relevance backpropagation algorithm the information dissemination is only limited to the set of interested nodes but the result remains the same.

- *Untrustworthiness* of the network is the ratio of the total amount of the information the nodes receive by the total amount of information sent over the network. A lower level of untrustworthiness is considered to be better for having reliable information. In simple relevance backpropagation algorithm every node in the network trust every other node in the network without taking into account the quality of information they could provide. Whereas, in our FOAF based relevance backpropagation algorithm each participating node in the network only trust a limited set of nodes (friends or FOAF) in the network which could provide relevant and reliable information.

- *Network Distance* 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. A lower network distance is a better output.

- The *availability* parameter is the ratio of the number of unique messages sent by the number of unique messages recevied for a given period of time. The availability of the context information is significantly higher to about 5% in our FOAF based relevance backpropagation algorithm making sure that the information required by a node is always available from a reliable source.

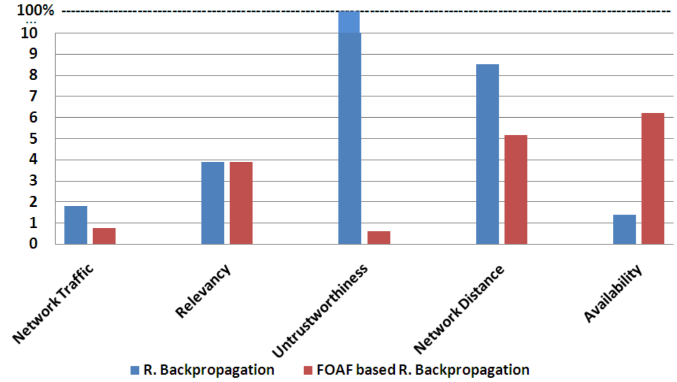


Figure 7: Simulated experimental results (%).

6. RELATED WORK

In [7], 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 using the social interactions for which plain broadcasting doesn't suffice.

The use of a propagation function for retrieving targeting areas and preferred routes for information delivery has been addressed in [3]. The authors integrate the propagation function with several probabilistic routing protocols with some performance overhead. In our research, relevance backpropagation algorithm based on FOAF social interaction capabilities handles the dynamic nature of a mobile network without creating a communication overhead.

In [4], the authors address the issue of optimal information dissemination in vehicular networks. The authors proposed a framework which integrates many of the existing broadcast based strategies that deal the reduction of the superfluous transmissions. Our approach uses the idea of disseminating the relevant context information using the social interactions. This technique also ensures the reliability and quality of information being delivered.

In [2], 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 to a limited set of nodes based on their social profile and QoI index.

A social network is usually place for sharing content in different forms. Recent works showed that in the emerging form of so called microblogging [5] showed that, people having similar intention form community by connecting themselves with each other and usually seek or share information. Most recent work [1] showed the potential of automatic updating of status information helps to reduce imposed cognitive load, as users must manually change their status on a near continuous basis in order to remain current within the network. Semiautomatic or automatic social networking systems for mobile users, such as Connecto provides automated information exploiting micro blogging system that provides automated updates about its user's whereabouts to an invited community.

Another emerging trend for empowering social networking is use of friend of a friend FOAF vocabulary. FOAF is a descriptive vocabulary expressed using the Resource Description Framework (RDF) which is a machine-readable ontology describing persons, their activities and their relations to other people and objects. Anyone can use FOAF to describe herself. FOAF allows groups of people to describe social networks without the need for a centralized database.

7. CONCLUSION AND FUTURE WORK

Efficient delivery of information in vehicular networks is crucial for the creation of useful and usable applications that need to cope with nomadic large-scale environments. Context-awareness is often key to improve efficiency of a vehicle network since it allows to make informed decisions on the data routing, data locality and data necessity for different moving objects. In this paper we show how the social network of vehicle residents, as part of the overall context, allows us to improve the information sharing in the vehicular network significantly. We demonstrate this by deploying a ubiquitous social help system (UHS) on top of a vehicular network. We analyze how UHS operates in a vehicular network using a network simulation of realistic large scale vehicular movement data and show that the social interactions increases the efficiency, relevance and quality of information in data delivery.

The simulation results show that our FOAF based relevance backpropagation mechanism achieves a significant improvement in terms of network traffic and availability of context information in comparison to the simple relevance backpropagation as discussed in section 5.1. The results in Figure 7 illustrate that with the help of the quality and relevance information provided by the social network we can limit the context message flow between a very small number of nodes having a high degree of reliability and untrustworthiness improving the overall performance of a vehicular network.

In the future we plan to investigate our FOAF based relevance backpropagation algorithm with a bigger data set for both social and mobile vehicular networks and compare the results with the current figures obtained. In this paper we only considered the social networks providing input to the mobile vehicular networks for interactions. We also plan to investigate the effects of mobile vehicular networks serving as an input to the social network so that users can interact based on their real physical connections.

8. ACKNOWLEDGMENTS

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