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Efficient Mechanisms and Performance Analysis of Routing Protocols in VANETs for Realistic Scenarios

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ABSTRACT

Vehicular Ad Hoc Networks (VANETs) are considered as a special case of mobile Ad Hoc Networks (MANETs) and are recently gaining a great attention from the research community. The need for improved road safety, traffic efficiency and direct communication along with the great complexity in routing, makes VANETs a highly challenging field. Routing in VANETs has to adapt to special characteristics such as high speed and road pattern movement as well as high linkage break probability. In this work, the authors show that traditional MANET routing protocols cannot efficiently handle the challenges in a VANET environment and thus need further modifications. For this reason, they propose and implement an enhancement mechanism, applied to the GPSR routing protocol that adapts to the needs of a VANET. The proposed mechanism's performance is evaluated through simulation sets for urban and highway scenarios and compared to the performance of the most common MANET routing protocols adopted in VANETs. The proposed enhancement is shown to be considerably beneficial and it significantly outperforms the rest of the tested routing protocols for almost every topology setting.

KEYWORDS

Applications, MANETs, Propagation, Routing Protocols, VANETs

1. INTRODUCTION

Vehicular Ad Hoc Networks (VANETs) are a special class of mobile Ad Hoc Networks (MANETs) with unique characteristics. Similar to MANETs, VANETs are an autonomous and self-configured wireless network that allows communications without any dependency on infrastructures or a central coordinator. Any vehicle can be an active node in a VANET if equipped with wireless transceivers. Most nodes in a VANET are continuously moving with a wide range of speeds and directions in the same way as a vehicle moves in a roadway or an urban area. The moving rates in a VANET are in the general case higher than that in a typical MANET but more predictable for nodes traveling on the same direction. This means that nodes in a VANET moving towards the same direction in a roadway, maintain similar speeds and thus longer radio communication periods of time than those moving in opposite directions. Another unique characteristic of VANETs is their challenging surrounding environment that contains blocks of buildings, roadways that limit the possible node movements and roadside infrastructures that may provide access points to the internet along with a rich variety of services and applications.

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The unique nature of VANETs, provides some key advantages over MANETs but also some challenging issues. A main advantage is the unlimited battery power of the vehicle when moving and the high energy levels that allow exceptionally high bandwidth links and integration with new technologies like LTE systems. However, a very important challenge in VANETs is the routing performance (Maan & Mazhar, 2011). Importing existing MANET routing protocols directly into VANETs could lead to abyssal network performance and unsatisfactory performance. Compared to MANETs, the node movement in VANETs is more predictable allowing more effective position allocation algorithms and routing protocols that benefit from GPS and electronic maps. However, the node density may vary a lot due to traffic conditions. An important issue in the environment of VANETs is the presence of buildings in urban areas, which adds negative effects on wireless communications and especially on multipath routes. Implementing a routing protocol able to select the best possible path which avoids passing through buildings and other obstacles in the topology is not an easy task.

In this work, we conduct an experimental performance evaluation of various routing approaches in MANETs, using simulations, for the case of VANETs in different topology and propagation settings, focusing on realistic conditions. The aim is to show that traditional MANET routing protocols need further extensions before their adaption in VANETs and that special characteristic of VANETs have to be used in the routing layer. The VANETs scenarios that are studied in this work are 3: highways, urban areas and Manhattan-Grid like urban areas with buildings affecting the propagation. We also propose an enhancement of the GPSR protocol that takes into account: (a) the dynamics of vehicles in order to estimate future positioning and (b) the nature of the urban environment in order to avoid transmissions through building obstacles and preserve longer route TTLs. This study compares the AODV (Ad Hoc On-Demand Distance Vector), DSDV (Destination Sequenced Distance Vector), DSR (Dynamic Source Routing), OLSR (Optimized Link State Routing), GPSR (Greedy Perimeter Stateless Routing) and the proposed modified GPSR, and measures the packet delivery ratio, the end-to-end delay and the power consumption for each routing protocol. The results show that in many cases, the performance of the studied routing protocols is not satisfactory, especially when the propagation model takes into account the buildings' presence. However, the proposed enhancement to the GPSR protocol outperforms the other protocols in all cases and shows a highly satisfactory average performance.

The following of this work is organized as follows: Section 2 refers to previous work that is related to the purpose and field of study of this work; Section 3 provides an overview of the routing protocols used in MANETs and VANETs that are the subject of study, and describes the challenges associated with VANETs in an urban setting; Section 4 presents the main challenges and problems of routing in VANETs that this work aims to solve; Section 5 describes the proposed enhancement to the GPRS protocol (named GPRS-Modified of GPRS-M for short); Section 6 presents the simulation setting and the reference scenarios; Section 7 presents and discusses the results from the simulations; Section 8 gives the conclusions of this work and finally section 9 describes ideas and directions for future work.

2. RELATED WORK

Routing in VANETs has been an important field for research the last years. A lot of previous works study and analyze routing in VANETs. In (Kakarla, Sathya, Laxmi, & B, 2011), (Kumar & Dave, 2011) and (Lee, Lee, & Gerla, 2010) several routing protocols in MANETs and VANETs are being studied and categorized according to their routing strategy. A comparative performance analysis of AODV, DSDV and DSR is conducted in (Abbas, Chaudhry, & Yasin, 2013) for rural and urban scenarios. In (Kim & Lee, 2011), general design ideas and components are being presented for reliable routing design and implementation and in (Kaisser, Johnen, & Vèque, 2010), a quantitative model for evaluating routing protocols on highway scenarios is proposed. In (Martinez, Toh, Cano, Calafate, & Manzoni, 2009), 3 realistic radio propagation models are presented that increase the simulation results' accuracy.

A novel routing protocol for reliable vehicle to road-side AP connection is proposed in (Wan, Tang, & Wolff, 2008) that uses an algorithm for predicting the wireless links' lifetime. In (Nzouonta, Rajgure, Wang, & Borcea, 2009), a road based VANET routing protocol is proposed that uses real-time vehicular traffic information to form the paths and is compared with existing well-known routing protocols. In (Katsaros, Dianati, Tafazolli, & Kernchen, 2011), a cross-layer position based routing algorithm for VANETs is presented that performs better than the GPSR routing protocol. The algorithm, named CLWPR (Cross-Layer Weighted Position-based Routing), uses information about link layer quality and positioning from navigation.

3. COMMUNICATION AND ROUTING

3.1. Communication Types in VANETs

A VANET is composed of static and mobile nodes, thus the common types of communication are:

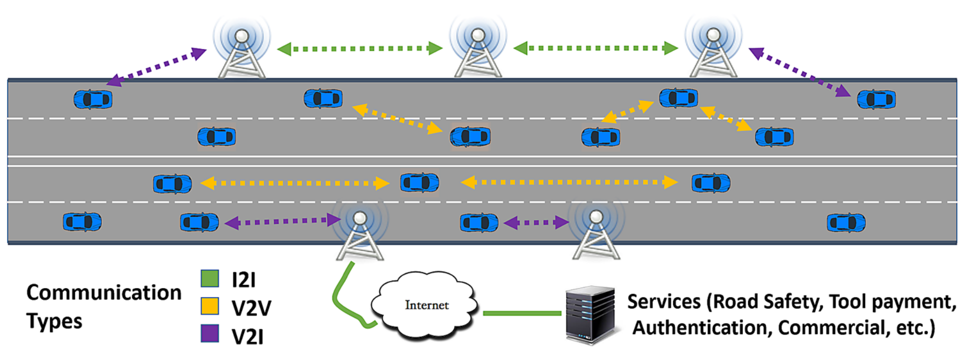
- Vehicle to Vehicle (V2V)
- Vehicle to Infrastructure (V2I)
- Infrastructure to Infrastructure (I2I)

V2V is the direct communication between vehicles, which may occur in every topology as long as there is node movement inside the communication range. V2I is the communication between vehicles and infrastructures, which provide services related to safety, convenience, commercial purposes, internet access and others. I2I is the communication between infrastructures, which may be roadside units (RSUs), tool ways and others. Except from these 3 communication types, a mixed communication may occur, especially in cases of large inter-vehicle spacing and low traffic density. In such scenarios, infrastructures such as RSUs may forward the desired messages to the destination. Vehicles and infrastructures may all interact together and form WLAN, Ad Hoc or Hybrid networks. Figure 1 shows the described communication types.

3.2. Overview of routing in MANETs and VANETs

Following are presented the routing protocols that are tested and evaluated in this work:

Figure 1. VANET communication types



- **AODV:** The Ad Hoc On-Demand Distance Vector (Perkins, Belding-Royer, & Das, 2003) is intended for use by mobile nodes in an Ad Hoc network. It offers swift adaptation to dynamic link conditions, low processing and memory overhead, low network utilization, and determines unicast routes to destinations within the Ad Hoc network. It uses destination sequence numbers to ensure loop freedom at all times avoiding common problems associated with classical distance from vector protocols.
- **DSDV:** Destination sequenced distance vector routing (He, 2002) is adapted from the conventional Routing Information Protocol (RIP) to an Ad Hoc network routing. It adds a new attribute and sequence number to each route table entry of the conventional RIP. Using the newly added sequence number, the mobile nodes can distinguish stale route information from the new one, thus preventing the formation of routing loops.
- **DSR:** Dynamic Source Routing (Johnson & Maltz, 1996) uses source routing, that is, the source indicates in a data packet's sequence of intermediate nodes on the routing path. In DSR, the query packet copies in its header the IDs of the intermediate nodes that it has traversed into. The destination then retrieves the entire path from the query packet and uses it to respond to the source. As a result, the source can establish a path to the destination. If the destination is allowed to send multiple route replies, the source node may receive and store multiple routes from the destination. An alternative route can be used when some link in the current route breaks. In a network with low mobility, this is advantageous over AODV since the alternative route can be tried before DSR initiates another flood for route discovery.
- **OLSR:** Optimized Link State Routing (Jacquet et al., 2001) operates as a table driven, proactive protocol, i.e., exchanges topology information with other nodes of the network regularly. Each node periodically constructs and maintains the set of neighbors that can be reached in 1-hop and 2-hops. Based on this, the dedicated MPR algorithm minimizes the number of active relays needed to cover all 2-hops neighbors. Such relays are called Multi-Point Relays (MPR). A node forwards a packet if and only if it has been elected as MPR by the sender node. In order to construct and maintain its routing tables, OLSR periodically transmit link state information over the MPR backbone. Upon convergence, an active route is created at each node to reach any destination node in the network. The protocol is particularly suited for large and dense networks, as the optimization done using MPRs works well in this context. The larger and more dense a network, the more optimization can be achieved as compared to the classic link state algorithm.
- **GPSR:** The Greedy Perimeter Stateless Routing (Karp & Kung, 2000) is based on positioning of the routers and assumes that every node has access to a location service and knows its position coordinates. GPSR makes greedy forwarding decisions using only information about a router's immediate neighbors in the network topology. The best next hop is considered to be the neighbor node with the least distance from the destination. When the greedy forwarding is impossible, the algorithm recovers by routing around the perimeter of the region.

4. THE CHALLENGES

4.1. Challenge #1: Vehicle Mobility and Positioning

The nature of VANETs is such that in order to maintain wireless communication links for an acceptable time period, positioning and mobility information has to be taken in consideration by the chosen routing approach. Doing so is not easy without taking advantage of location services such as the GPS system.

Vehicles' movement is limited to a known pattern for urban or highway scenarios. In highway scenarios, the average vehicle speed maintains high levels but the future possible directions are quite limited. In an urban scenario, the opposite happens: nodes move with lower average speeds but with higher unpredicted future directions.

4.2. Challenge #2: Operating Environment

The operating environment where communications may take place are either in a rural (highway) or an urban scenario. The challenge of the operating environment appears in the second case. In an urban setting, the presence of buildings in the area of the network topology, plays a determining role on the packet delivery success rate and adds a great complexity and challenge on the routing level. Buildings block the wave transmission and restrict the communication between the nodes of the VANET. The fact that communication in VANETs takes place in the high frequency of 5GHz (which is more-or-less the standard frequency used in VANETs) is another factor that makes the communication in areas with buildings even harder. These difficulties arise from penetration through buildings, reflections, refractions, diffractions, etc. At the same time, the relatively high speed of the nodes, the resulted increased mobility and the frequent topology changes add an additional challenge to the problem of establishing routes between the nodes of the VANET. Multi-hop communication and route maintenance in these scenarios are very challenging as links can be established only when the nodes are in line-of sight without any intermediate building obstacle (LOS) or slightly out of LOS (e.g., just behind corners and close to road intersections) and possibly for a relatively small time period as the involved vehicles may move in different directions.

As a result, the existing routing protocols are not expected to perform satisfactorily; and indeed, as shown in section 7, they do not. This leads to a need to come up with solutions that take into account the urban setting and design routing protocols that are more suited to it. In this direction, the proposed enhancement (described in the following section) takes into account the nodes' motion information to better estimate their position at each time, and also identifies that the crossroads are the places where nodes can be better intermediates. Thus, it tries to select as next hop a node that, at the time of the transmission, is estimated to be at a crossroad (i.e., the best intermediate).

5. PROPOSED ENHANCEMENTS

In this work, we propose 2 enhancement mechanisms for the 2 previously described challengers. The mechanisms are integrated in the GPSR routing protocol. The proposed GPSR enhancements are implemented in the NS-3 simulator and follow the implementation of (Fonseca, Camões, & Vazão, 2012).

5.1. Enhancement Mechanism for Challenge #1

Because of the intense and high-speed mobility in VANETs, the GPSR forwarding process may not be always efficient. Choosing as next hop the neighbor node with the least distance from the destination may easily lead to recovery state as the link may brake due to opposite directions or great speed difference between the next hop and the destination. While in recovery state, the routing algorithm moves back one step to the previous hop and tries from that point to reach the destination through the neighbors in a counterclockwise priority. The proposed mechanism enhancement is applied on the greedy forwarding process during the best next hop calculation and tries to avoid the recovery state. The modified process handles not only the positions of the routers but also the speed, direction and link quality. The speed and direction are sent as a velocity vector attached in the hello messages of the modified GPSR. The destination's position and velocity are added in the packet header in order to be available at the intermediate nodes. The position and velocity for every node are obtained from a location service that in the real world could be the GPS service. For link quality assignment, every packet is tagged with an SNR value at the physical layer. This SNR packet tag is extracted at the routing layer during the hello messages receipt. The position, velocity and SNR information is stored in the neighbor table of every node and then is included in the next hop weight calculation.

Except from the inclusion of velocity and link quality, the enhancement mechanism includes also a future position prediction process, a process for determining if nodes are moving in the same road and direction and a next hop weight calculation process. The future position calculation uses the formula:

FutPos.x = Pos.x + Vel.x * dt(speed);
FutPos.y = Pos.y + Vel.y * dt(speed);

where dt() is a mapping function that returns the prediction time from 1.0 up to 4.0 seconds based on the speed parameter. As the speed increases the returned time period decreases in the following way:

· speed <= 20km/h: dt = 4.0 sec,
· 20 km/h < speed <= 40km/h: dt = 3.0 sec
· 40 km/h < speed <= 80km/h: dt = 2.0 sec,
· 80 km/h < speed <= 120km/h: dt = 1.5 sec,
· speed > 120km/h: dt = 1.0 se

5.1.1. Algorithm and Architecture

Figure 2 presents a simplified overview of the architecture of the GPSR routing protocol with the enhanced methods and sub procedures. The top procedures (grey color) run periodically according to the hello interval initialization. The rest procedures run on demand after a need for a packet transmission occurs.

The proposed extensions and modifications include:

- GPSR Hello Packet Header: Addition of a vector velocity field that is going to be used for position prediction and direction determination for every neighbour node.
- SNR Tag: Addition of a piggyback field to hello messages for the SNR value from the MAC layer during packet receipt. This field may be used while storing neighbours to the index neighbour table.
- Modifications and additions on the presented procedures in Figure 2:

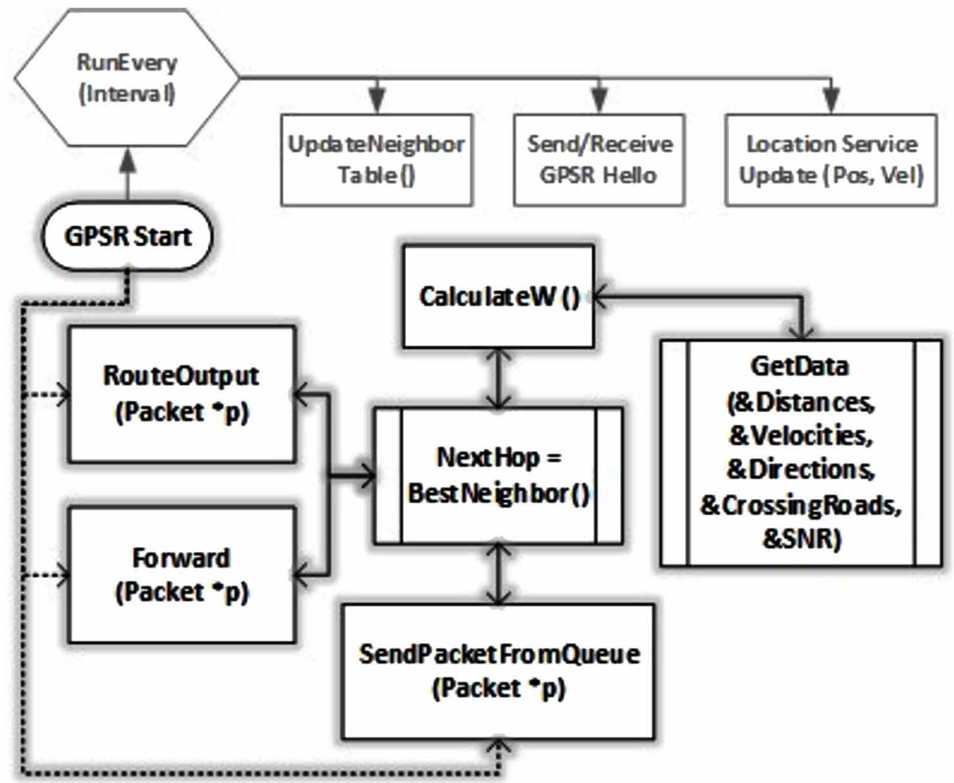
The Modified procedures of Figure 2 are:

1. RouteOutput(): Calls the modified BestNeighbor()
2. Forward():Calls the modified BestNeighbor()
3. SendPacketFromQueue():Calls the modified BestNeighbor()
4. BestNeighbor(): Uses the modified CalculateW ()
5. CalculateW(): The weight calculation process for the next hop
6. GetData(&): This sub process is in fact a simplified (for presentation purposes) set of implemented methods that calculate specific parameters

The main procedures of the proposed mechanism are the BestNeighbor and CalculateW and are executed every time a node executes the RouteOutput, Forward or SendPacketFromQueue. These procedures are shown below:

The BestNeighbor procedure iterates through all the stored nodes in the neighbour table of the index node and executes the CalculateW for each of them. After the weight of each neighbour node has been calculated, the procedure compares the weight of the index node with the smallest weight found in the neighbour table. If a node in the neighbour table has a smaller weight than the index node, then it is defined as the best neighbour and eventually as the next hop. In the opposite case, the procedure returns a zero IP address to the caller function and eventually the GPSR enters the recovery mode.

Figure 2. Mechanism schema




```
Procedure BestNeighbor (myPos, myVel, dstPos, dstVel)
initialW ← CalculateW(myPos, myVel,..,dstPos, dstVel, snr);
W ← CalculateW(myPos, myVel, nTable[0]->Pos, nTable[0]->Vel, dstPos, dstVel, nTable[0]->Snr);
for i ← nTable.begin()tonTable.end():
if W > CalculateW(myPos,myVel,i->pos,i->vel,dstPos, dstVel, i->Snr) then:
W ← CalculateW(myPos, myVel, i->pos, i->vel, dstPos, dstVel, i->Snr);
nextHop.addr ← i->addr;
if initialW > W then: return nextHop;
else return IpV4Address::GetZero();
EndProcedure
    Procedure CalculateW (IndxPos, IndxVel, DstPos, DstVel, SrcPos, SrcVel)
    GetData(&)
    /*Weights initialization*/
    W ← +INF, w1 ← 0.25, w2 ← 0.1, w3 ← 0.5;
    /*The Index and Dst are moving in same Road*/
    if inSameRoad(IndxFutPos, DstFutPos) then:
    /*The Index and Dst are moving in same Direction*/
    if getDirection(IndxVel) == getDirection (DstVel) then: w1 ← 0.0;
    else : w1 ← 0.75;
    /*The Index and Source are moving in same Road*/
    if inSameRoad(IndxFutPos, SrcFutPos) then:
```

```
/*The Index and Source are moving in same Direction*/
if (getDirection(IndxVel) == getDirection(SrcVel)) then:
w2 ← 0.0;
else : w2 ← 0.01;
/*Calculate W*/
W ← Node_DestFutDist*(1+ w1 + w2 + w3/snr);
return w;
Endprocedure
```

The CalculateW procedure is called for every neighbor node of the index node through the BestNeighbor procedure and returns the calculated weight of the examined node based on the input routing data. This procedure prioritizes neighbour nodes moving in a similar way (same road and direction) with the source and destination and maintaining short future distances with the destination. In addition, the link quality is also taken into consideration.

To examine if 2 nodes are moving in the same road and direction, the GetCrossingRoads process calculates the nodes' velocity vector angle, their line distance, and their dot product. If their velocity vectors are parallel and their line distance is less than the road width, the inSameRoadAndDirection process decides that they are moving in the same road. The required location data for the calculation of W is provided by the helper GetData sub procedure, which is presented below:

```
Procedure GetData(&)
SrcSpeed ← sqrt(pow(SrcVel.x, 2.0) + pow(SrcVel.y, 2.0));
IndxSpeed ← sqrt(pow(IndxVel.x, 2.0) + pow(IndxVel.y, 2.0));
DstSpeed ← sqrt(pow(DstVel.x, 2.0) + pow(DstVel.y, 2.0));
SrcFutPos.x ← SrcPos.x + SrcVel.x * dt(SrcSpeed);
SrcFutPos.y ← SrcPos.y + SrcVel.y * dt(SrcSpeed);
IndxFutPos.x ← IndxPos.x + IndxVel.x * dt(IndxSpeed);
IndxFutPos.y ← IndxPos.y + IndxVel.y * dt(IndxSpeed);
DstFutPos.x ← DstPos.x + DstVel.x * dt(DstSpeed);
DstFutPos.y ← DstPos.y + DstVel.y * dt(DstSpeed);
Src_DstCurDist ← GetDistance(SrcPos, DstPos);
Src_DstFutDist ← GetDistance(SrcFutPos, DstFutPos);
Indx_SrcFutDist ← GetDistance(IndxFutPos, SrcFutPos);
Indx_DestCurDist ← GetDistance(IndxPos, DstPos);
Indx_DestFutDist ← GetDistance(IndxFutPos, DstFutPos);
GetCrossingRoads();
GetSNR(&snr);
EndProcedure
```

The previously described procedures are called when a need for packet transmission occurs. Below is presented the forward procedure of the GPSR that calls the previously described BestNeighbor and its modified sub procedures.

```
Procedure Forward (packet)
if neighborTable.isNeighbor(dst) then: nextHop ← dst;
else nextHop ← neighborTable.BestNeighbor(myPos, myVel,
dstPos, dstVel);
if nextHop.addr->isValid() then: route->SetGateway(nextHop);
else RecoveryMode(route);
```

6. **return** *;*
7. **EndProcedure**

Two basic cases where the GPSR enhancement mechanism significantly improves the network performance are shown in Figure 3. In the left case, the mechanism forms the green route and avoids the route change that will occur in the red route in a very short amount of time. In the right case, the default GPSR forwarding process chooses the red route and shortly will fall in recovery mode. The proposed mechanism avoids that. The improvement gets more intense as the number of the intermediate nodes rises. The code of the mechanism can be found in the web site: http://ru6.cti.gr/ru6/research-areas/network-simulations.

5.2. Enhancement Mechanism for Challenge #2

This challenge for GPSR is to avoid as much as possible any route dead ends and recovery mode entries. Our proposed implementation for propagation in an area with buildings is based on a previous approach for optimization on highways and areas without obstacles. In the previous approach (Bouras, Kapoulas, & Tsanai, 2014), the GPSR routing protocol was enhanced in order to estimate future positions of nodes (using their speed and direction information) and hence select intermediate nodes that maintain higher route lifetimes and avoid link breakages while transiting data packets.

In an open field, without taking into account the building obstacles, the mechanism of (Bouras et al., 2014) can perform at relatively high levels without the need for further major modifications. However, in the case of an urban environment case, the GPSR protocol with this additional mechanism can easily fall into recovery mode and fail to reach the destination with the greedy algorithm in the first place. Figure 4, shows two common cases where the original and the modified (challenge 1) GPSR greedy algorithm of (Bouras et al., 2014) cannot avoid falling into recovery mode. More specifically, on the left case of Figure 4 the sender, by default, chooses the red route first and the green last in order to forward its messages. However, the vehicles located in the vertical road are moving and thus the communication path is cut very soon leading to rerouting or else to a recovery mode entry. On the right of Figure 4, the second common case of recovery entry is depicted and shows that the yellow link fails to reach the destination and the green is formed afterwards from the recovery state. In order to solve this, the weight parameters of the proposed mechanism have to be changed.

A key factor for multi-hop communications in a Manhattan-like grid with buildings seems to be any node located inside or very close to road intersections. Road intersections can function as joints for multi hop routes that do not follow a straight line. The important role of the vehicles that are currently located at intersections has been identified before, and this has been used to improve e.g., the broadcasting of emergency messages (see for example (Sanguesa et al., 2014) and (Fogue et al., 2012)). Figure 5, shows such a case.

Figure 3. Routing in a highway (left) and a junction (right). The red arrows represent the GPSR routes and the green the modified GPSR routes

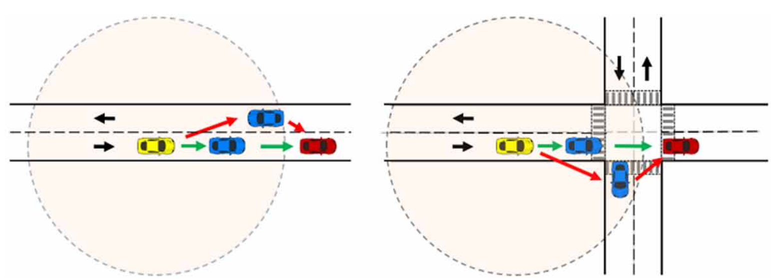


Figure 4. Two common cases of recovery mode entries

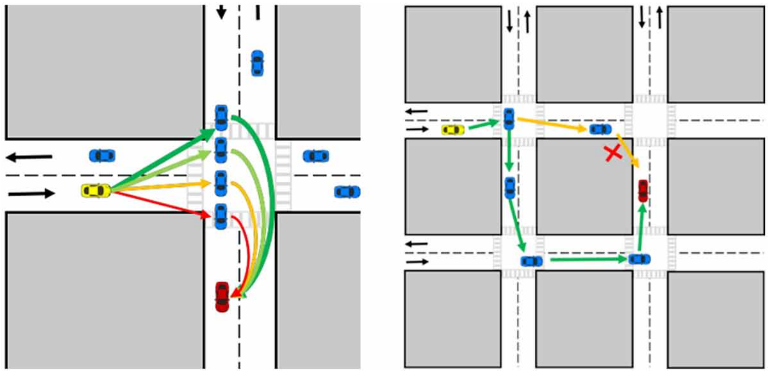
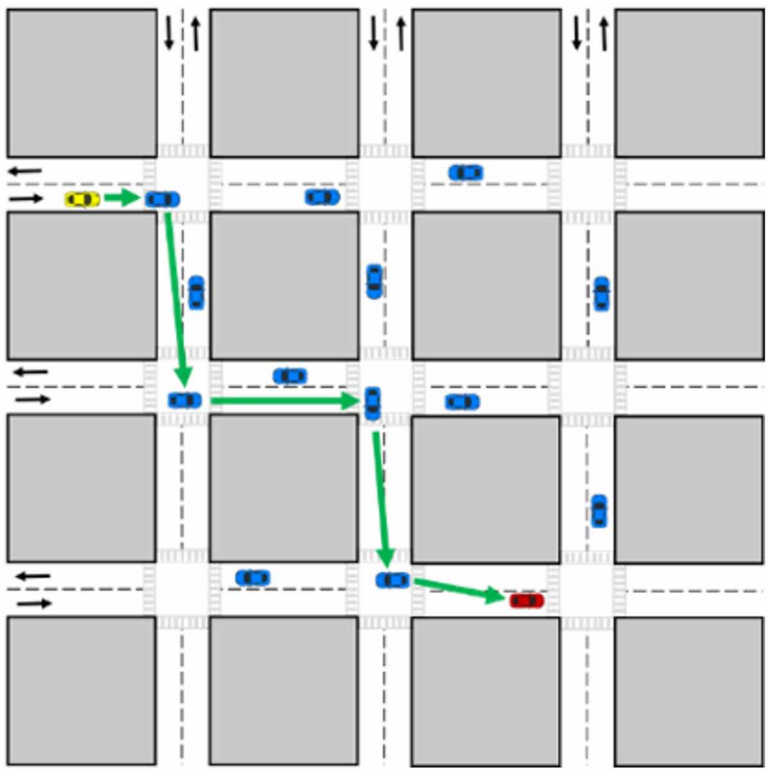


Figure 5. Multi-hop route from source (yellow node) to destination (red node). Nodes moving in road intersections function as route connectors



In the new extension of the GPSR routing protocol, the neighbor nodes that are predicted to be located for the longest time period on a road intersection (and thus in the LOS with the index node), are going to have the less weight among the other neighbors. The new proposed weighting algorithm gives higher priority to neighbor nodes moving towards the destination and those that are going to be longer inside the next road intersection in the same time. With this approach, the probability of keeping a route up is higher as intersections provide direct visibility with nodes on more directions.

Figure 6, shows the formation of 3 routes while utilizing the GPSR routing. The red route depicts the case of not including buildings on the propagation. As expected, the signal cannot reach the next desired hop by penetrating the building. The yellow one is the case of forming a route while utilizing the default (and first proposed mechanism) GPSR routing. As the algorithm is greedy and based only on current and predicted .future positions, it eventually reaches a dead end. The green route, which is formed when using the new proposed mechanism and giving priority on nodes located in resections, manages to reach the destination (red node) without falling on recovery mode.

5.2.1. Algorithm and Architecture

Figure 7 presents the simplified overview of the architecture of the GPSR routing protocol with the enhanced methods and sub procedures for the second studied challenge. The grey area consists of the previously described and not further modified procedures and the green area consists of the procedures with the new extensions.

The CalculateW has been furtherly modified and contains 2 modes based on the LOS and NLOS situation between the source and the final destination. The first mode is triggered when the source and destination node are in Line Of Sight and the second when they are not. For each case, a different calculation method of W is followed. In the first mode, the algorithm prioritizes neighbour nodes moving in a similar way (same road and direction) with the source and destination and maintaining short future distances with the destination. The second mode recognises 3 priority zones where zone 1 has the least weight and zone 3 the most. Zone1 covers areas in road intersections while zone 2 covers the areas that are in LOS with the destination. Finally, Zone 3 covers the remaining areas that have the least priority. See Figure 8 for an explanation of the two modes of the CalculateW procedure.

CalculateW uses specific routing data in order to proceed with the weight calculations. This data is received from the procedure GetData and is mostly related to current and future node positions, velocities and directions. In addition, several helper procedures define if a node is located in an intersection and whether or not it is with LOS with another node. Some of these helper methods are the inIntersectionTime, inLos, inLosTime, getDirections and dt. All these helper procedures are called directly or indirectly form CalculateW. The CalculateW procedure is called for every neighbor node of the index node through the BestNeighbor procedure and returns the calculated weight of the examined node based on the input routing data. The weight factors have been set after extended simulation tests for performance analysis of CalculateW. The pseudo code of CalculateW is presented below:

```
Procedure CalculateW (IndxPos, IndxVel, DstPos, DstVel, SrcPos, SrcVel)
GetData(&);
W ← +INF;
/*Source and destination are in LOS - MODE1*/
if inLoS(SrcPos, DstPos) then:
/*Weights initialization*/
w1 ← 0.25, w2 ← 0.1, w3 ← 0.5;
if inSameRoad(IndxFutPos, DstFutPos) then:
if getDirection(IndxVel) == getDirection(DstVel) then: w1 ← 0.0;
else: w1 ← 0.75;
if inSameRoad(IndxFutPos, SrcFutPos) then:
if getDirection(IndxVel) == getDirection(SrcVel) then: w2 ← 0.0;
else: w2 ← 0.01;
W ← Node_DestFutDist*(1+ w1 + w2 + w3/snr);
/*Source and destination are in NLOS - MODE2*/
else:
/*Weights initialization*/
w1 ← 0.5, w2 ← 2;
```

Figure 6. Multi-hop route from sender (yellow node) to destination (red node). Yellow route: Default GPSR routing. Red route: The route without the buildings propagation model. Green route: The GPSR route formation with the new proposed extension for challenge #2 scenarios

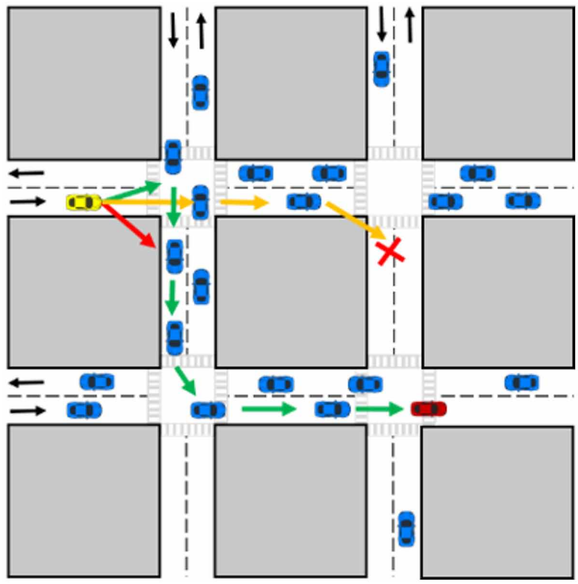
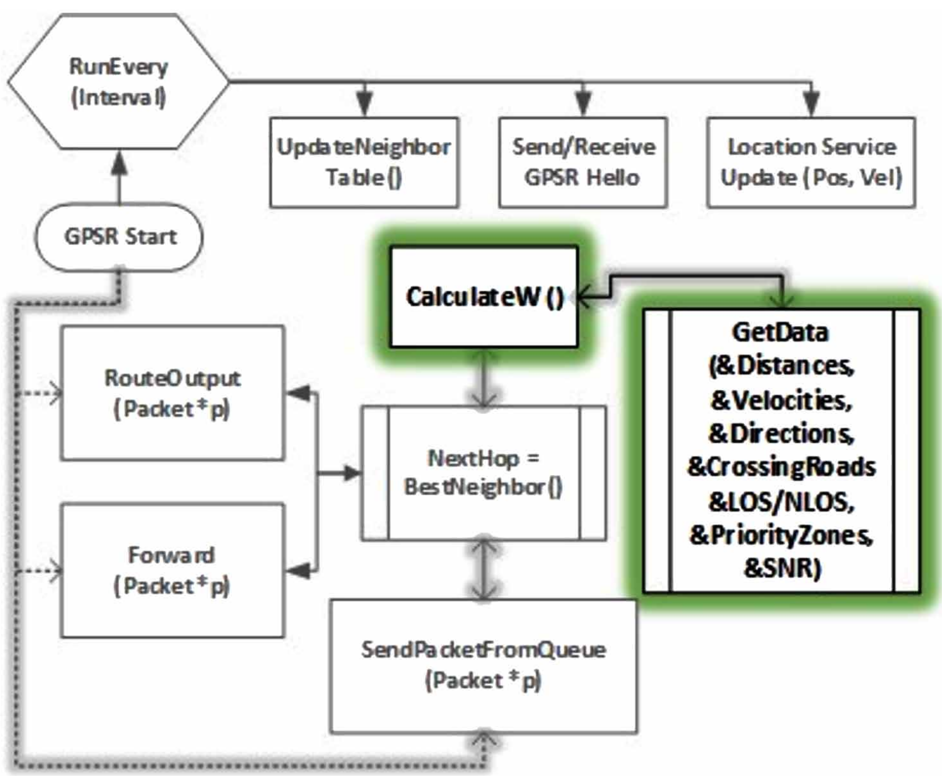


Figure 7. Enhanced GPSR architecture



```
InterSectionT = 0.0;
/*Zone 1*/
if inIntersection(IndxPos, IndxVel) &&
((Indx_DestFutDist - 0.25*Src_DstFutDist) < Src_DstFutDist) then:
InterSectionT = inIntersectionTime (IndxPos, IndxVel);
W ← Indx_DestFutDist*(1-w1-InterSectionT/100);
/*Zone 2*/
else if (((Indx_DestFutDist - 0.25*Src_DstFutDist) <
Src_DstFutDist) &&
(inLoS(IndxFutPos, DstFut-Pos))) ||
(((Indx_DestCurDist - 0.25*Src_DstCurDist) <
Src_DstCurDist) &&
(inLoS (IndxPos, DstPos)))
then: W ← Indx_DestFutDist + w2*Indx_SrcFutDist;
/*Zone 3*/
else: W ← 2*Indx_DestFutDist + w2*Indx_SrcFutDist;
return W;
EndProcedure
```

The implementation of the described mechanism for both challenges and the integration with the GPSR routing protocol is done in the NS-3 simulator. The full source code with the implementation of the proposed routing mechanism, the propagation model used in this work and its Pyviz extensions for NS-3 can be found in http://ru6.cti.gr/ at the research area of network simulators.

6. REFERENCE SCENARIOS

The evaluation of the proposed schema and the studied routing protocols in VANETs is conducted for 3 topology scenarios. The first topology is an Urban Area and the second a highway. For these 2 scenarios, no obstacles (such as buildings) are taken into consideration in the propagation model. However, the third scenario is dedicated to the analysis of the routing performance in realistic Urban Areas with buildings affecting the propagation. For all 3 scenarios, the tools JOSM (https://josm.openstreetmap.de/), SUMO (Krajzewicz, Erdmann, Behrisch, & Bieker, 2012) and BonnMotion (Aschenbruck, Ernst, Gerhards-Padilla, & Schwamborn, 2010) are used for the network topology generation. All simulations are executed in the NS-3 simulator. The common network parameters that the first 2 scenarios share are shown in Table 1.

6.1. Urban Area Scenario

In this scenario, an urban area from the city of Athens is simulated, extending for about 2 x 2 km. The city simulation process includes fetching the city map including all the road elements (traffic lights, junctions, road directions, etc.) with the use of JOSM, preprocessing it with SUMO to generate vehicles and road traffic and then import them to NS-3. The number of nodes is 130 with their movement following random vehicle movements with respect to the imported road network. The nodes are never allowed to move outside the area limits keeping the node density stable. Roads leading outside the selected area are properly edited to lead back any vehicles ap-proaching the limits. The maximum node speed is 85 km/h and the average 60 km/h. All nodes are equipped with Wi-Fi devices and transmission range up to 300m. The selected Mac layer is the IEEE 802.11p Wave with 6Mbps data rate and 10MHz channel bandwidth. Except from vehicle nodes, the simulated area contains 2 Base Stations for V2I or I2I communications. During the simulation, all 3 types of VANET communications take place. The application used for packet transmission is the UDP Server-Client Application with 128 bytes packet size and 0.01s packet interval. The simulation time is 150s with a warm-up time of

Figure 8. Modes in CalculateW. (a): LOS - greatest priority (Green), medium priority (Yellow), least priority (Red). (b): NLOS – Priority zone 1 with gradual weight (Green), zone 2 (Blue), zone 3 (Red)

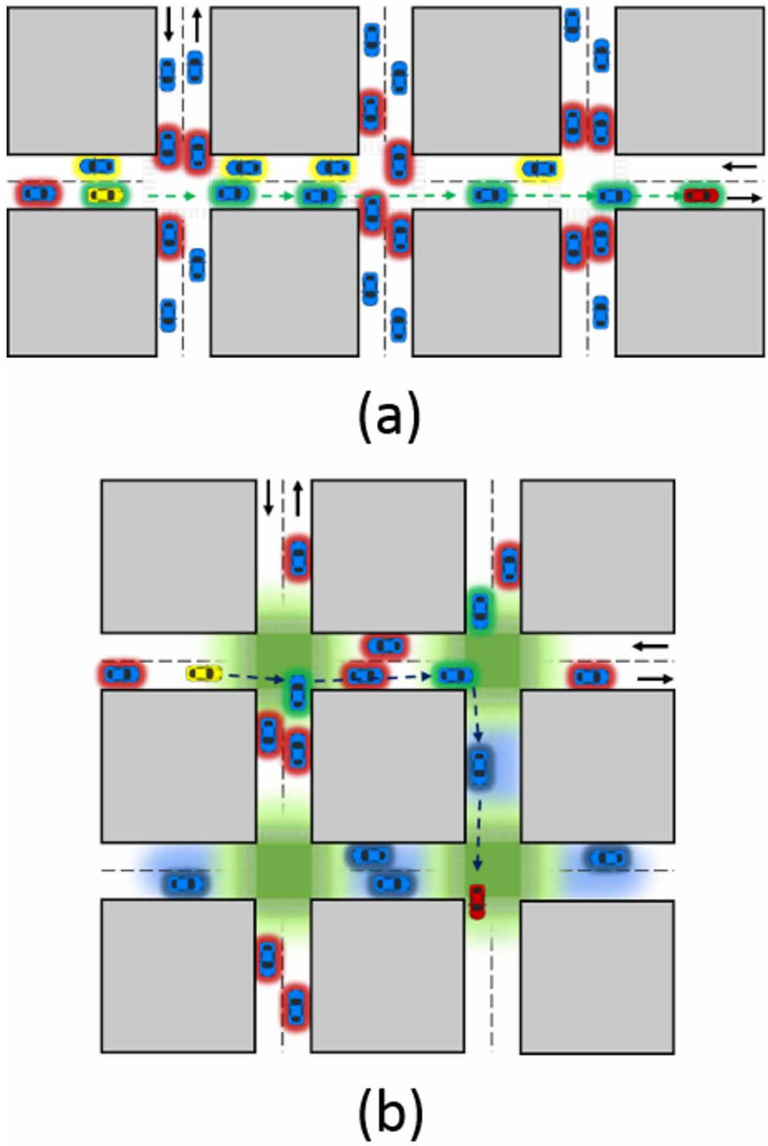


Table 1. Network parameters for both scenarios

Node Transmission Range	300m
Mac Layer	IEEE 802.11p Wave
PhyMode	Ofdm6mbs10MHz
Propagation Model	FriisPropagationLossModel
Packet Size	256 Bytes
Packet Interval	0.01s
Application	Udp Server-Client

30s. The number of flows in the net-work is 10 (7 V2V, 2 V2I, 1 I2I) and the minimum flow duration is 10s. The simula-tion is tested for the routing protocols OLSR, AODV, DSDV, DSR, GPSR and the pro-posed GPSR-M. The evaluation is based on packet delivery ratio, end to end delay and energy consumption (using the NS-3 WifiRadioEnergyModel). The scenario is presented in Figure 9.

6.2. Highway Scenario

The highway scenario simulates the case of high distance roadways with high vehicle movement speeds and course stability. In this scenario, the node's mobility route is more predictable and tends to keep its current state. Course changes take place main-ly when a vehicle moves to another lane. In the tested scenario, 100 nodes are mov-ing with average speeds varying from 20km/h up to 180km/h. The communication type is V2V with the source and destination node moving towards the same direction. The distance between them is 1 km and the nodes' transmission range is 300m. This scenario type is produced by a custom simple generator which can be found together with the simulation code. Figure 10 depicts the described scenario.

6.3. Buildings Map Model Scenario

In this scenario, the studied topology is an Urban Area and more specifically a Manhattan grid area with blocks of buildings. Compared to scenarios in open space (i.e., without buildings), this scenario's propagation model computes the effects of the buildings' presence to the signal path loss in street canyons. More specifically, the B1 – Urban micro-cell scenario of the WINNER II Channel Models (Kyösti et al., 2007) is used in our tests. As described in (Kyösti et al., 2007), all antennas are bellow the tops of surrounding buildings and both Line Of Sight (LOS) and Not Line Of Sight (NLOS) cases are modeled. The signal reaches the receiver nodes as a result of the propagation around corners, through buildings, and between them.

Table 2, presents the path loss calculation of B1 Winner Model in LOS and in NLOS. Figure 11, shows the simulated network graph for 200 wireless ad hoc nodes in NS-3 for the cases where buildings are absent or present in the scenario. As seen, in the case without buildings, the resulting graph has a very large number of links (the relevant part of the figure is difficult to see because of the number of links) and it is very strongly connected. In the case with the buildings, the resulting graph has a greatly reduced number of links and this already indicates that the expected performance of the routing protocols will be much different.

In the Buildings Map Model Scenario, 2 set of simulations are conducted. Each set is conducted for 3 scenario settings. For each scenario setting, each set of simulation is conducted for 5 different random node placements and mobility. For the node mobility generation the BonnMotion (Aschenbruck et al., 2010) software is used. All the network parameters and scenario setting are presented in Table 3.

Figure 9. The simulated Urban area scenario. On the left: The original area from the Open Street Map. On the right: The final road network to be tested

Figure 10. Highway Scenario

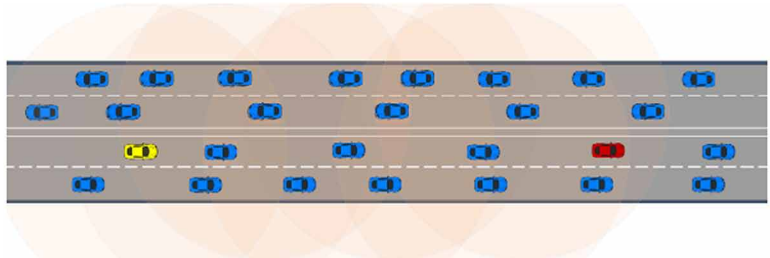
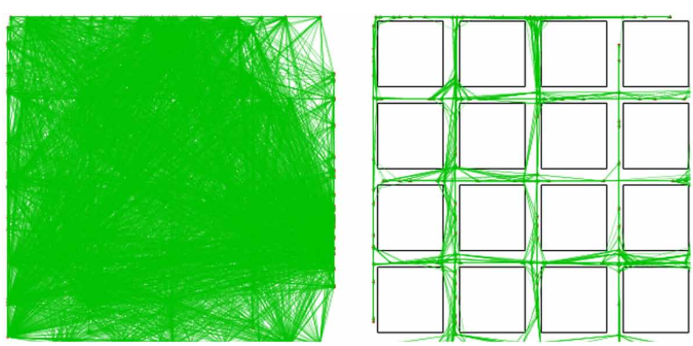


Table 2. Path Loss calculation at B1 Winner Model in LOS and NLOS

B1 Winner Model	Path loss [dB]	Shadow fading std [dB]	Applicability range, antenna height default values
LOS	$A = 22.7, \quad B = 41.0, \quad C = 20.0$ $PL = 40\log_{10}(d_1) + 9.45 - 17.3\log_{10}(h'_{BS}) - 17.3\log_{10}(h'_{MS}) + 2.7\log_{10}(f_c / 5.0)$	σ = 3	$10m < d_1 < d'_{BP}$ $d'_{BP} < d_1 < 5km$ $h_{BS} = 10m$, $h_{MS} = 1.5m$
NLOS	$PL = \min(PL(d_1,d_2), PL(d_2,d_1))$ Where $PL(d_k,d_l) = PL_{LOS}(d_k) + 20 - 12.5n_j + 10n_j\log_{10}(d_l) + 3\log_{10}(f_c / 5.0)$ and $n_j = \max(2.8 - 0.0024d_k, 1.84)$, PL_{LOS} is the path loss of B1 LOS scenario and $k, l \in \{1,2\}$	σ = 4	$10m < d_1 < 5km$, $w/2 < d_2 < 2km$ w = 20m(street width) $h_{BS} = 10m$, $h_{MS} = 1.5m$ When $0 < d_2 < w/2$, the LOS PL is applied.

Figure 11. Network graph for 200 nodes. Left: No buildings are modeled in the propagation. Right: buildings are modeled with the B1 Winner Model



The first set of simulations is conducted to evaluate the performance of the studied and proposed routing protocols in the case of LOS between sender and final receiver. In this set, during the whole transmission, the sender and receiver maintain positions that are in LOS. This case depicts the common case of vehicles moving on the same road and maintaining the same direction. In order to evaluate the routing performance in LOS scenarios, the sender and receiver nodes are either stable on the opposite edges of the same road or moving in the same road of the Manhattan grid area. The intermediate nodes are randomly placed and moving to random directions in the grid. This set of experiments triggers the mode1 of the proposed mechanism.

The second set of experiments evaluates the performance of the studied and proposed routing protocols in the case of NLOS between the sender and final receiver. In this set, during the whole transmission, the sender and receiver maintain positions that are in NLOS. This case depicts a challenging scenario as the sender and final receiver are located and moving on different roads for the whole packet transmission. In this set of simulations, the sender and receiver nodes are either stable in different roads or moving in different roads of the Manhattan grid area. The intermediate nodes are again randomly placed and moving to random directions in the grid. This set of experiments triggers the mode2 and mode1 (for less common cases where the previous hop is in LOS with the destination) of the proposed mechanism.

7. SIMULATION RESULTS

7.1. Urban Scenario Results

The results for the simulation of the urban scenario are presented below. Three metrics are presented: packet delivery ratio (PDR), end-to-end delay (E2E) and energy consumption.

Figure 12 shows the packet delivery ratio for each tested routing protocol. The AODV seems to be the worst performer while GPSR seems to be the best choice out of the existing protocols. This is expected as AODV (as a reactive routing protocol) is not very well suited for network with frequent topology changes (such as VANETs). OLSR and DSDV as pro-active routing protocols exhibit better performance in this case. DSR, although a reactive routing protocol, handles topology changes with less messages and adapts better that AODV bringing its performance in par with OLSR. GPSR, taking into account the position of the nodes has a much better performance. Still, the proposed enhancement improves the PDR from approximately 75% for GPSR up to approximately to 79%, which is a quite good enhancement. This is due to moving nature of the nodes in a VANET which constantly changes the position of the nodes. Thus the information GPRS uses can quickly get a bit outdated. The proposed enhancement anticipates this change and estimates a better position for the nodes at the time they are used to relay a message.

Figure 13 shows the (average) end-to-end delay achieved for each routing protocol tested. AODV is again the worst performer, but OLSR is the best choice for keeping end-to-end delay at a minimum level. GPSR is behind OLSR and DSR. This can be explained by the fact that the position information is getting slightly outdated by the time a node is used (and some time has passed from when its position was acquired). The change is small enough to not disrupt the network and sustain a high PDR (as discussed previously) but seems to be large enough to result in less efficient routes. However with the proposed enhancement applied, it overtakes DSR and moves in second place close to OLSR. The reduction of the end-to-end delay with the application of the proposed enhancement is quite impressive (the end-to-end delay drops to less than half), and is attributed to the better estimation of the then current position of each node.

Figure 14 shows the total energy consumption for each routing protocol tested. AODV is again the worst performer and must clearly be avoided for VANETs in such urban settings. This is probably due to the frequent topology changes that result in disconnected paths and the need to frequently re-run the route discovery. DSR uses the less energy with all the other protocols following using approximately the same energy. The proactive routing protocols manage to keep the energy consumption at this

Table 3. Simulation parametes

Network Parameters				
Node Transmission Range	250m			
Mac Layer	IEEE 802.11p Wave			
PhyMode	Ofdm3mbs10MHz			
Propagation Model	Winner B1 Model			
Packet Size	256 Bytes			
Packet Interval	0.01s			
Flow duration	20 sec			
Application	Udp Server-Client			
Scenario Settings				
Node Average Velocity	40 km/h			
Node Max Velocity	65 km/h			
Node Max Pause Time (traffic light)	5 sec			
Node turn probability	0.5			
RoadLength	150 m			
RoadWidth	20 m			
	Num of Nodes	**Num of Hops Min - Max**	**Grid (roads) x - y**	**Area (m^2)**
Scenario #1	50	2 - 4	3 x 3	~500
Scenario #2	100	2 - 7	4 x 4	~700
Scenario #3	150	3 - 10	5 x 5	~800

lower level as they update the routes regularly to avoid disconnections. DSR manages to use slightly less energy as it does not rediscover the route globally but somehow tries to re-route locally, and this proves more than enough. The proposed enhancement shows a very small reduction but no clear improvement. However, its application does not increase the energy consumption footprint of GPSR. This means that the proposed enhancement can be applied without any energy consumption drawbacks.

Looking at the combined results, GPSR with the proposed enhancement is a quite good choice for VANETs in such urban settings. The small deficits (with respect to DSR) for the end-to-end delay and the energy consumption are a small compromise for the increased packet delivery ratio. In cases where GPSR is used, the proposed enhancement either improves (even slightly) all of these metrics and therefore is a really nice contender to be applied.

7.2. Highway Scenario Results

The results for the simulation of the highway scenarios are presented below. The same three metrics (packet delivery ratio, end-to-end delay and energy consumption) are presented. However this time they are shown against the average vehicle speed.

Figure 12. Packet delivery ratio vs routing protocol

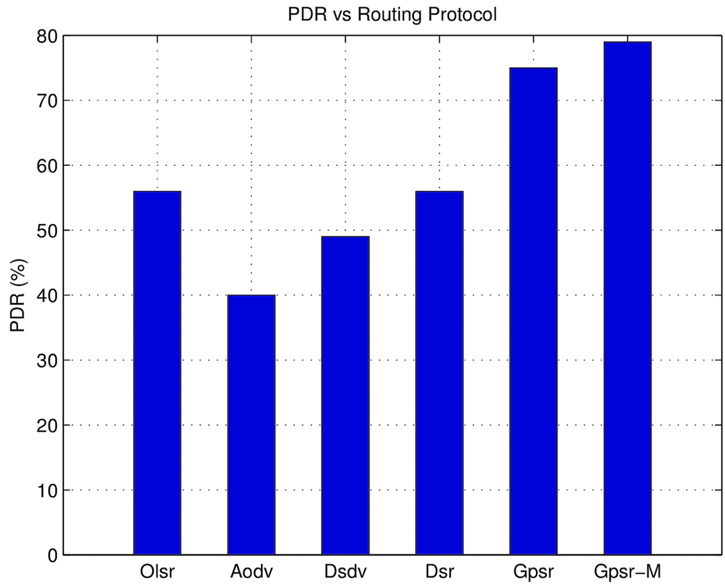


Figure 13. End to end delay vs routing protocol

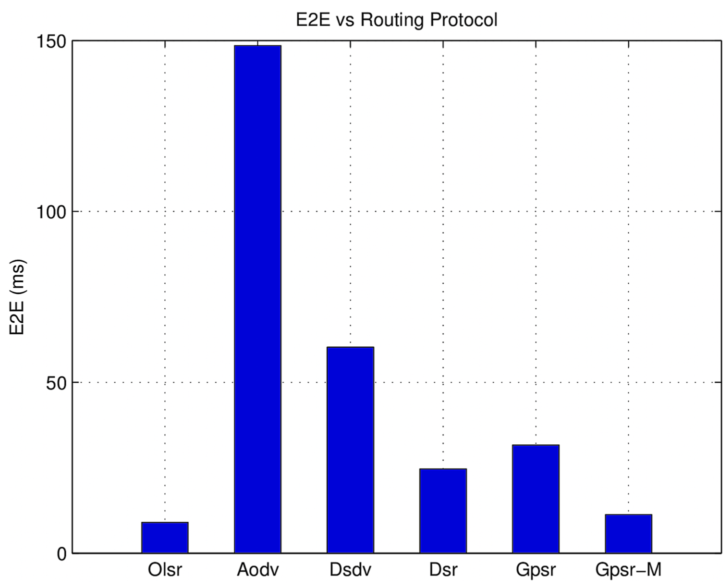


Figure 15 shows the packet delivery ratio for the tested routing protocols against the average vehicle speed. DSDV is the worst performer followed by AODV and OLSR, which seem to drop to very low level of PDR as the average vehicle speed increases. DSR displays an "erratic" behavior with large fluctuation in the PDR for different average vehicle speeds. This is due to the more frequent topology changes that result from the higher speeds. Clearly, these routing protocols are not suitable for such scenarios. GPSR has better PDR but this seems to drop as the average vehicle speed increases. This is explained as the higher speeds result in higher deviation of the actual position of a node from the reported position of that node when it was queried. The higher the speed is, the higher the

Figure 14. Total energy consumption vs routing protocol

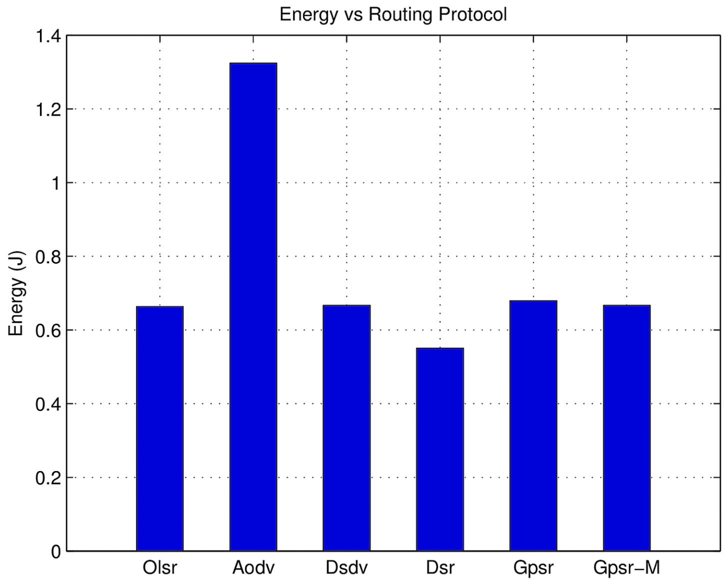
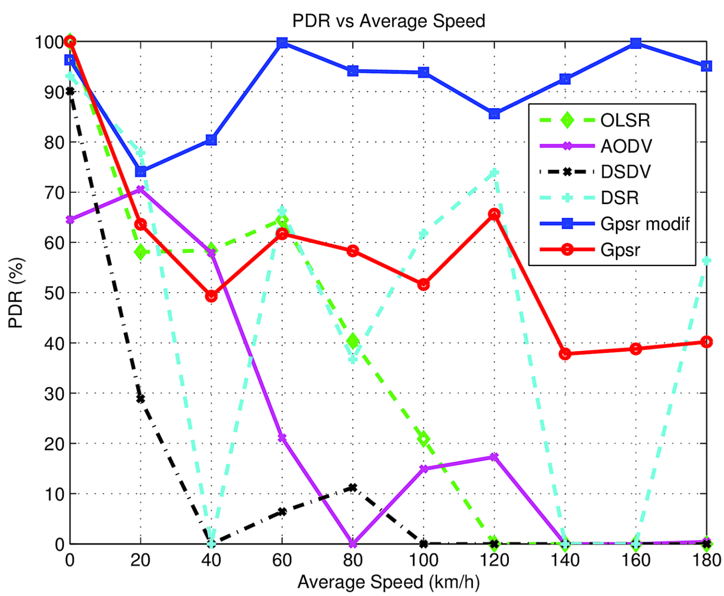


Figure 15. Packet delivery ratio vs average speed



variation is and the lower the performance get as nodes considered neighbors can actually be out of reach. GPSR with the proposed enhancement is clearly the best performer. The enhancement seems to improve GPSR quite a lot for such scenarios and improve the PDR above 90% in most cases. This is because this routing protocol considers the speed and estimates correctly the actual position of the nodes at each time. An important consequence of this is that it maintains same high levels of PDR for high vehicle speeds, with no indication that higher speeds will present any problem; i.e., it scales very well with the vehicle speeds.

Figure 16 shows the average end to end delay for the tested routing protocols against the average vehicle speed. The results indicate that OLSR maintains steady levels of delay up to 20 ms for speeds up to 100 km/h. DSDV follows the OLSR and shows lower levels of delay than DSR and AODV for speeds up to 60 km/h. The GPSR shows intense reduction of delay for speeds greater than 60 km/h and performs better than the previously mentioned protocols for high speeds. Above this speed, it seems that the error in the node position can be quite high as to result in disconnections (and the lower PDR seen above); however, when there is no disconnection, the route is good enough to result in low end-to-end delay. The enhanced GPSR mechanism seems to improve significantly the end to end delay of GPSR and performs better for almost all the tested speeds. As explained above this is due to the fact the enhanced protocol does not suffer from a bad knowledge of the actual position of nodes.

Figure 17 shows the energy consumption for the tested routing protocols against the average vehicle speed. AODV seems to be the most energy hungry protocol, while DSR is the best performer. All the other protocols are close together. GPSR with the proposed enhancement uses slightly more energy than GPSR but the increase is quite low. This is more-or-less the same picture as with the urban scenario.

The combined results demonstrate that GPSR with the proposed enhancement is a quite good choice for VANETs in such highway settings. Again, the small deficits for the end-to-end delay and the energy consumption are a small compromise for the increased packet delivery ratio.

The proposed enhancement improves the PDR of GPSR in all cases and improves the end-to-end delay and energy consumption of GPSR in several cases. In the rest of the cases, the deficit is quite small and tolerable for obtaining the higher PDR.

Therefore, the proposed enhancement is a strong contender to be implemented together with GPSR.

Figure 16. End to end delay vs average speed

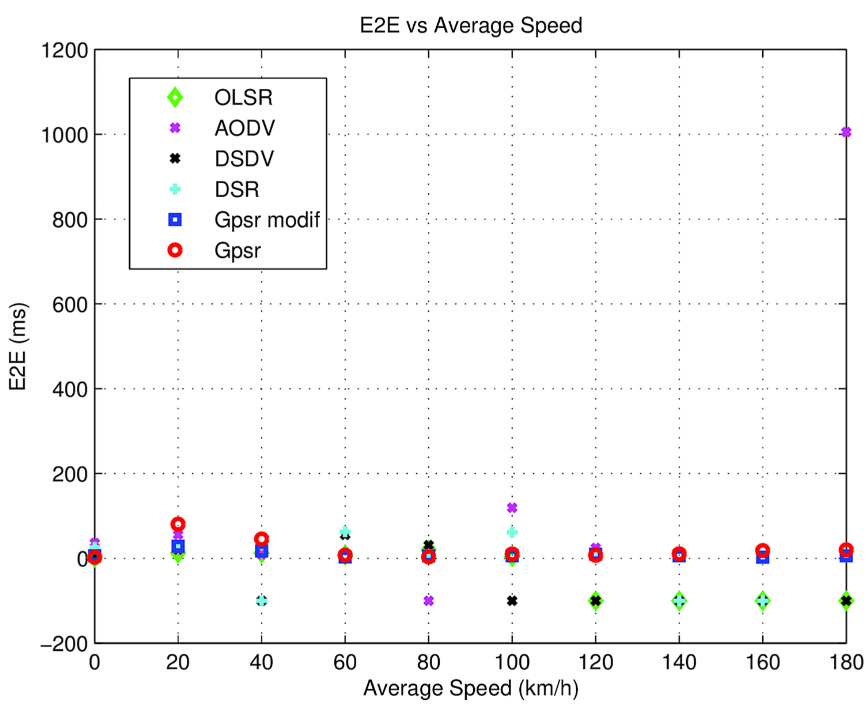
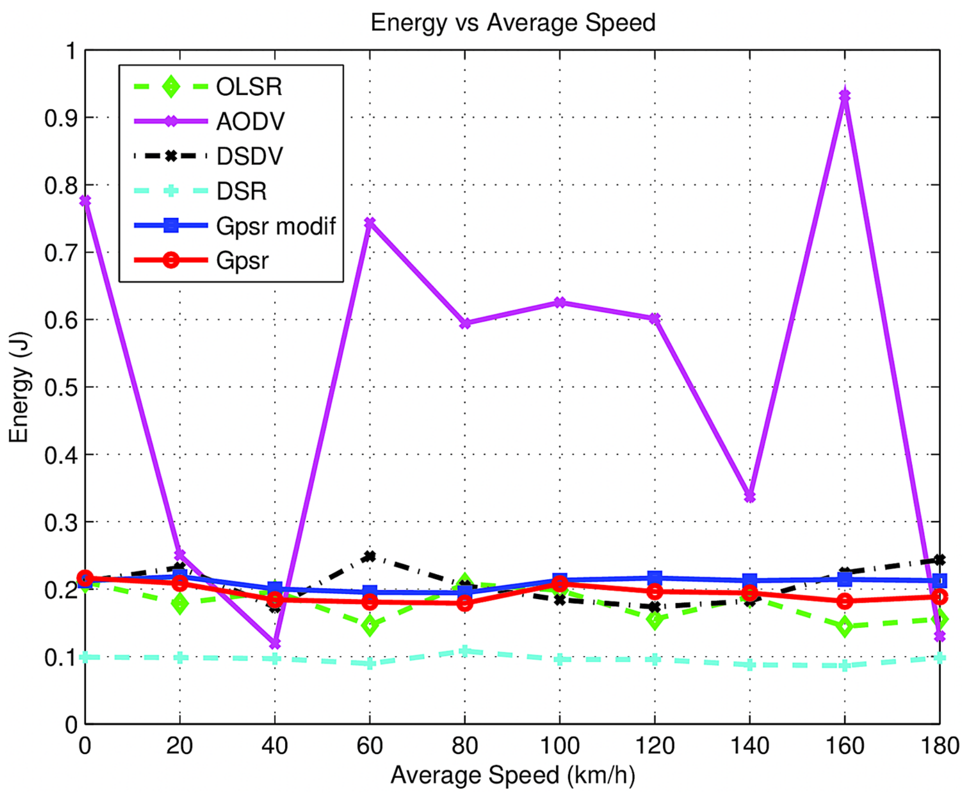


Figure 17. Total energy consumption vs average speed



7.3. Buildings Map Model Scenario Results

The first set of experiments where done for the case where the sender and the receiver are in a line-of-sight (i.e. they are both in the same street in the Manhattan grid). This mostly presents the best case for all algorithms and is used to set a base of what performance each algorithm can achieve without complicating the examined scenario.

Figure 18 shows the average (over the different simulation runs) packet delivery ratio achieved by each routing protocol, for the case there is line-of-sight between the sender and the receiver. In accordance with the results from (Bouras et al., 2014), the worst performer or this case is AODV, for all the different Manhattan grid sizes. The delivery ratio of GPSR is better that the delivery ratio of the other existing routing protocols, and this is due to the knowledge of the positions of the neighboring nodes that the protocol takes advantage of to select as the next hop the node closer to destination. As the existence of the buildings should not play a major role in this case, GPSR makes good choices and maintain a high delivery ratio. However the proposed modification to the GPSR protocol boosts the delivery ratio quite higher than the unmodified GPSR and is the best performer in terms of the packet delivery ratio achieved.

It should be noted that the delivery ratio drops as the size of the grid increases. This is due to the fact that with larger grids the chances that there is, a “gap” without intermediates, in the line-of-sight become bigger and bigger and in that case the route has to make a “detour”, which is no longer a simple case. The effect will be more evident with the end-to-end delay. However it is worth noting that the rate that the delivery ratio drops, as the grid increases in size, is less for the proposed modification to the GPSR protocol.

Figure 18. Packet delivery ratio, for the case of line-of-sight between sender and receiver

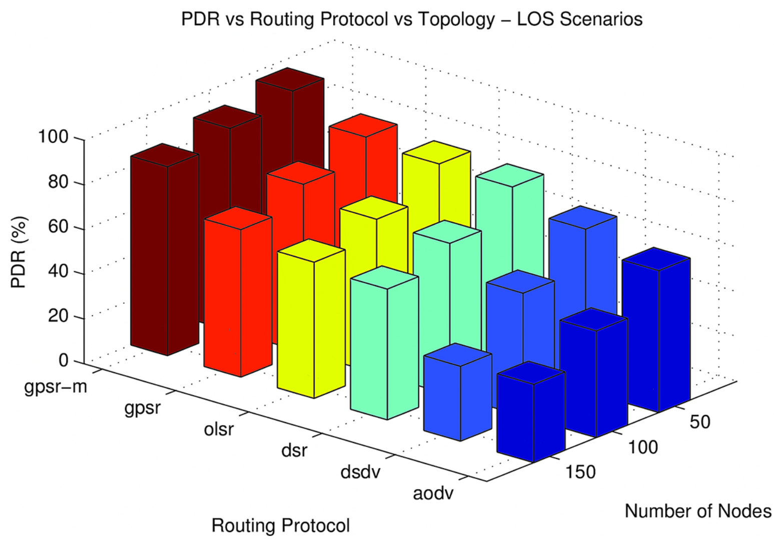


Figure 19 shows the average (over the different simulation runs) end-to-end delay achieved by each routing protocol, for the case there is line-of-sight between the sender and the receiver (please mind that the ordering of the routing protocols and the grid sizes is different from the previous figure, so that larger bars do not obscure smaller ones). It should be noted that end-to-end delay increases rapidly with the size of the grid. As already mentioned this is due to the "gaps", without nodes, that appear in the line-of-sight and require that another route is formed that detours the "gap". As already hinted this is not easily done in the urban setting, and for larger grid this case starts to look more like the case where there is no line-of-sight between the sender and the receiver.

Having said that, for the small grid the best performer is the proposed modification to the GPSR protocol, and for the large grid the best performer is DSR. This can be explained by the fact that the proposed modification to the GPSR protocol, maintains routes that deliver more packets even if for some of them the delay is large; i.e., there is a tradeoff between delivery ratio and delay. Still the proposed modification to the GPSR protocol manages to have better end-to-end delay than the rest of the routing protocols concerned.

Figure 20 shows the average (over the different simulation runs) power consumption each routing protocol, for the case there is line-of-sight between the sender and the receiver (please again mind the ordering of the routing protocols and the grid). The less power is consumed by the use of the DSR protocol. AODV, OLSR, GPSR and the proposed modification to the GPSR demonstrate a similar power usage. For the proposed modification to the GPSR protocol this means that the modifications can provide their benefits without increasing the power consumption.

The second set of experiments where done for the generic (and more interesting) case where there is no line-of-sight between the sender and the receiver (i.e. they are in different streets in the Manhattan grid). This presents the most usual case for all algorithms.

Figure 21 shows the average (over the different simulation runs) packet delivery ratio achieved by each routing protocol, for the case there is no line-of-sight between the sender and the receiver. In this case the worst performer is DSDV, with close second-worst the GPSR protocol. However the proposed modification to the GPSR protocol more than doubles the delivery ratio, and makes the GPSR-M the best performer w.r.t delivery ratio. This is explained by the fact that GPSR-M favors as intermediate nodes the vehicles that are (at the time of the transmission) in a crossroad and are more suited to route packets within the Manhattan grid. The original GPSR protocol greedily selects the

Figure 19. End-to-end delay, for the case of line-of-sight between sender and receiver

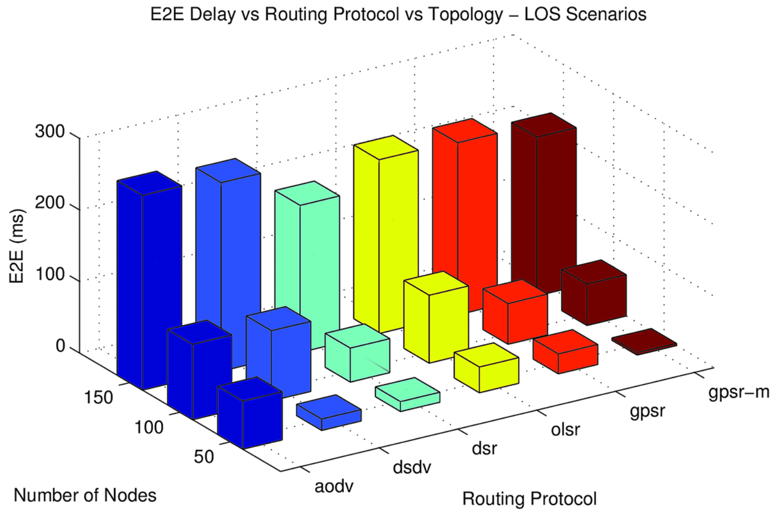
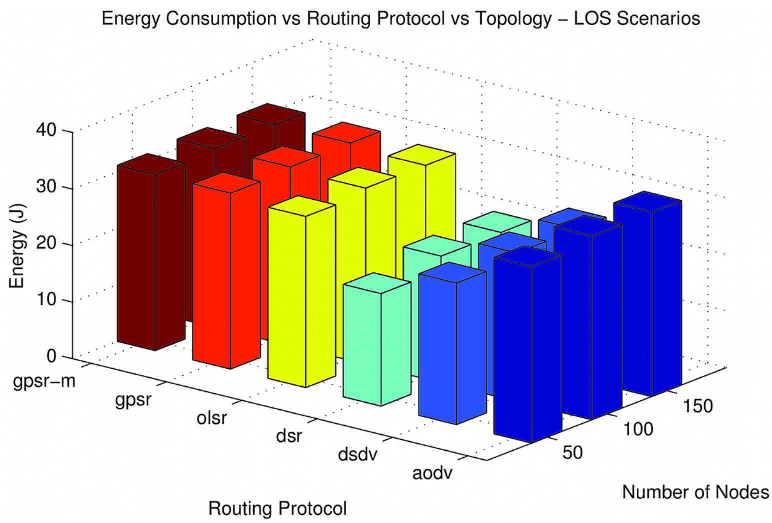


Figure 20. Power consumption, for the case of line-of-sight between sender and receiver



node closer to the destination without taking into account if packets can be forwarded from there. As in the previous case the packet delivery ratio decreases for all routing protocols as the grid size increases. However, the improvement that GPSR-M demonstrates over the other protocols is better as the grid size increases (for the large grid is almost triple of the second best).

Figure 22 shows the average (over the different simulation runs) end-to-end delay achieved by each routing protocol, for the case there is no line-of-sight between the sender and the receiver. W.r.t. the end-to-end delay, the proposed modification to the GPSR protocol, is in par with the DSR and the AODV protocols, but the best performer is the OLSR protocol. Still GPSR-M greatly enhances the end-to-end delay of the GPSR protocol. As in the previous case the fact that GPSR-M has a much greater delivery ratio impacts the average end-to-end delay.

Figure 21. Packet delivery ratio, for the case there is no line-of-sight between sender and receiver

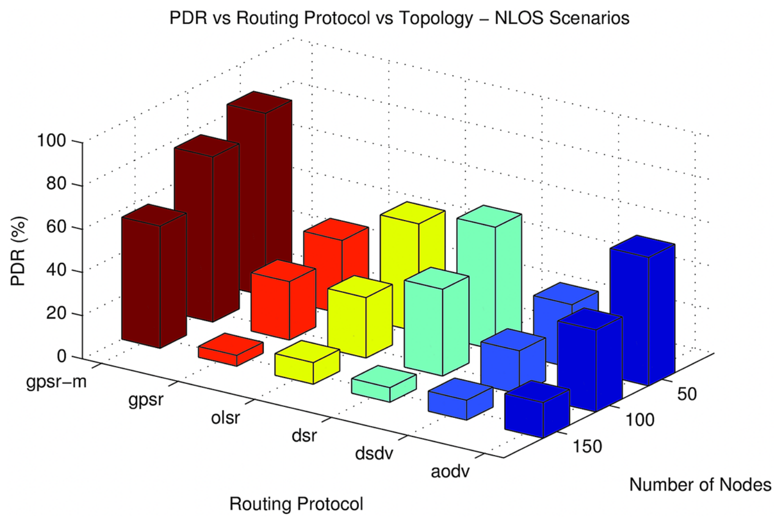
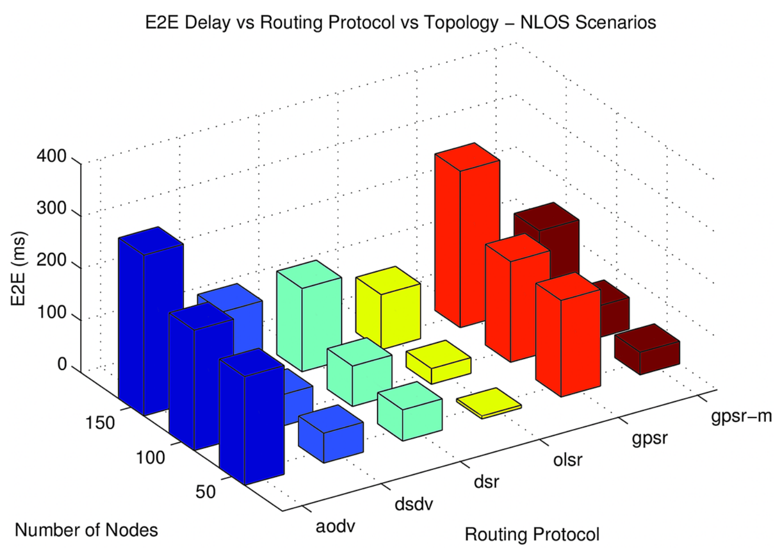


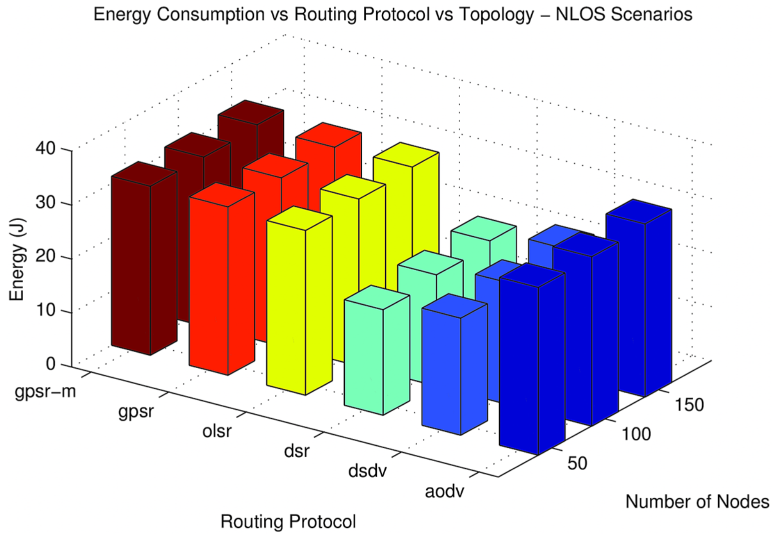
Figure 22. End-to-end delay, for the case there is no line-of-sight between sender and receiver



However, the overall performance of the proposed modification to the GPSR protocol is deemed better that the performance of the rest of the routing protocols, as the delivery ratio is more important that the end-to-end delay, and the resulting tradeoff is more than acceptable.

Figure 23 shows the average (over the different simulation runs) power consumption of each routing protocol, for the case there is no line-of-sight between the sender and the receiver. Again, the less power is consumed by the use of the DSR protocol. AODV, OLSR, GPSR and the proposed modification to the GPSR demonstrate a similar power usage. For the proposed modification to the GPSR protocol this means that the modifications can provide their benefits without increasing the power consumption.

Figure 23. Power consumption, for the case of no line-of-sight between sender and receiver



The combined results demonstrate that the proposed mechanism greatly improves the GPSR performance for both LOS and NLOS scenarios and outperforms the other examined routing protocols. In all cases, the modified GPSR showed greater packet delivery ratio and maintained quite satisfactory results even in very demanding scenarios of NLOS cases. Therefore, the proposed enhancement is a strong contender to be implemented together with GPSR.

8. CONCLUSION

In this work, we fulfill two purposes. Firstly, we evaluate the performance of the most commonly used routing protocols of MANETs adopted in VANETs and show that further modifications and enhancements that use real time data from the topology and nature of VANETs are needed for efficient results. We pay special attention to the characteristics and unique nature of VANETs, present the main challenges in routing and conduct simulation tests for many different topology and environment settings. Secondly, we propose an enhancement mechanism for routing in VANETs and present its performance when deployed on the GPSR routing protocol. The presented solution contains 2 versions which target the high mobility related challenges and buildings obstacles related challenges as well. The mechanism makes use of location and direction information as well as link quality metrics to produce routes that improve the performance of the network. The enhanced protocol is tested (with simulations) against several other routing protocols.

The proposed enhancement is shown to achieve higher packet delivery ratio for the network, a low end-to-end delay (but not the lowest), while keeping the energy consumption at the same low levels (again not the lowest) of GPSR. However, overall it is shown to be the best choice as the small deficits in end-to-end delay and energy consumption are quite small compared to the achieved improvement in the packet delivery ratio. These improvements are noticeable for both versions of the mechanism and targeted challenge.

9. FUTURE WORK

Our plan for future work includes the improvement of the weight calculation algorithm by implementing a more accurate positioning and direction model. This is going to be achieved by extending the existing location service model and introducing road models from existing city maps. This extension will improve the accuracy of the algorithm in terms of vehicle positioning, direction, velocity and thus in route lifetime calculations in urban and rural environments. Furthermore, our future work includes the testing of our proposed mechanism with more proposed solutions that are focused on vehicle positioning and environment monitoring. Our goal is to achieve a more accurate VANET simulation model and efficient routing mechanisms in order to introduce more demanding applications like video streaming and multimedia.

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