EGRESS: Environment for Generating REalistic Scenarios for Simulations

Sridhar K. N., Shuai Hao, Mun Choon Chan and A. L. Ananda
School of Computing, National University of Singapore, Singapore 117543
{*sridhark, haos, chanmc, ananda*}@*comp.nus.edu.sg*

Abstract

In MANETs, majority of performance studies are carried out via simulations, where node mobility and radio propagation models play a crucial role. However, popular simulation tools, like NS-2 [1] and GloMoSim [2], use simplistic random mobility patterns and free space radio propagation models. Such simplification ignores many crucial details in environment where movements are not random and obstacles are common. To have a better understanding of MANET protocols, there is a need for a tool that can generate more realistic mobility scenarios and provide better radio propagation model.

This paper presents EGRESS, which is built on top of NS-2 and consists of two major components: SGT and ORPM. SGT is a tool that generates node movements in an urban environment with buildings and pathways. ORPM is an obstructive radio propagation model, which enhances the existing radio models in NS-2 by taking into account obstacles in a 3D environment. We believe EGRESS is the first open source tool that provides such integrated and more realistic features for simulating urban environment. Our simulation results show that using more realistic scenarios can have a significant impact on network topology and performance of routing protocols.

1. Introduction

Mobile Ad-hoc Network (MANET) is an autonomous system of mobile hosts (nodes), operating via wireless link and without any pre-existing infrastructure support [3]. In MANET, each node typically acts as both host and router to relay packets for other nodes. Since the nodes are mobile, topology changes are common in MANET and such dynamic changes in topology have a profound effect on network performance. As a result, routing in MANET is very different from routing in conventional wired or infrastructure-based networks. Factors such as characteristics of the media, battery life in mobile nodes, radio propagation and movement pattern of nodes make it a challenging task to design efficient routing protocols.

For complex performance studies, computer simulations are often the only viable solution [4], and the majority of performance studies in MANETs depend heavily on simulations [5]. Simulation in MANETs involves specification of different parameters like number of nodes, behavior and movements of nodes, characteristics of traffics, medium, etc.

The mobility model decides the initial placement of nodes and dictates how the nodes move within the network. The radio propagation model determines whether communication between two given nodes is possible, and if communication is possible, also determines the bit rate and error rate. These two models (mobility and radio propagation) are essential building blocks of simulation-based studies in MANETs and have a significant effect on the results produced by the simulations.

A variety of mobility and radio propagation models have been proposed for MANETs [6], and a survey of mobility models is provided in Section 2. Random Waypoint (RW) and Free Space (FS) are the most commonly used mobility and radio propagation models. In RW, a node randomly picks a destination within a specified area and proceeds in a "straight-line" trajectory at a random (but constant) speed. FS models radio propagation in an obstacle-free space, where signal strength decreases only with the square (or some other power) of the distance between the sender and receiver. Obstacles are not taken into account.

However, random mobility models often do not correspond to real world movements. For example, people in college campuses and shopping centers do not move in random directions. They tend to move along well-defined paths to reach their destinations. Also, in an urban, outdoor environment, people generally move along the paths that are interconnections between buildings. Further, the destinations are not random, and the destination are usually buildings, benches, or some other specific locations of interest. Previous research [6] has shown that the mobility model in use can significantly impact the performance of routing protocols, including packet delivery ratio, control overhead and data packet delay. In addition, walls and floors of buildings create obstacles that significantly degrades the quality of radio signal compared to the FS model. Therefore, it is important to use mobility and radio propagation models that provide more realistic scenarios so that the performance of protocols under evaluation can be better studied.

In this work, we develop EGRESS (Environment for Generating REalistic Scenarios for Simulations) which includes the combination of a Scenario Generation Tool (SGT) and an enhanced large-scale path loss model, called Obstructive Radio Propagation Model (ORPM).

In our implementation, the mobility patterns generated can be used by NS-2 simulator. Similarly, the indoor radio propagation model is also developed using NS-2 to support 3D and constrained movements, and incorporates modelling of obstacles. Using EGRESS, we carried out a series of simulations to study the impact of more realistic scenarios on both network topology and performance of routing protocols and found that the performance impact can be significant.

We believe EGRESS is the first publicly available, open source tool that provides such integrated features for simulating urban environment. EGRESS is available online for download at [7]. Both SGT and ORPM are packaged together along with user manuals. Due to its modular design, EGRESS can be easily ported to GloMoSim and will be considered in future work.

The rest of the paper is organized as follows. Related work is presented in Section 2. Section 3 describes the SGT tool, which explains generation of campus mobility patterns. Section 4 covers the description of ORPM. Section 5 presents its evaluation including robustness study. Finally, Section 6 concludes the paper and discusses future work.

2. Related Work

Currently, there are two types of mobility models used in MANET simulations: traces and synthetic models. Since traces need observation of mobility patterns from real-life, they usually suffer from the high cost and long observation period. Therefore, synthetic models are more popular. They fall into two categories: entity models and group models.

Entity models include Random Waypoint (RW) [8], Random Direction [9], etc. RW model is the most popular mobility model and is used in the majority of performance studies. The properties of RW model have been extensively studied in [10]. There have been attempts to improve mobility modelling for RW. The Boundless Simulation Area Mobility Model [11] deals with area boundaries differently, where a mapping between the rectangular simulation area and a torus is used. The Gauss-Markov Mobility Model [12] can eliminate the sudden stops and sharp turns by reusing the old speed and direction in the calculation of new ones.

There have also been works on developing specific mobility models for different event types. Authors of [5] proposed three mobility scenarios: Conference, Event Coverage and Disaster Area. To simulate networks in a city section, the City Section Mobility Model [13] and Manhattan Grid Mobility Model [14] were proposed, where city streets form a grid and the nodes are allowed to move on the predefined paths along the grid. [15] developed a visual tool named CAD-HOC to generate realistic scenarios like airports, bus terminals and highways. The Obstacle Mobility model [16] uses automatically-generated Voronoi graphs to model building-to-building movement in a campus.

Group models include Reference Point Group Mobility Model (RPGM) [17], Column Mobility Model, Nomadic Community Mobility Model and Pursue Mobility Model [18]. Among these models, RPGM is the most common one.

Several groups have explored the use of various radio propagation models for MANET protocol simulation. NS-2 comes bundled with Free Space, Two-Ray Ground and Shadowing models. [19] have attempted Ray Tracing, but its application has been limited to very small floor plans due to the high computational cost.

3. Scenario Generation Tool

Majority of the existing mobility models assume open, unobstructed area where nodes are free to move according to the constraints of mobility model. However, in real-life, nodes normally move in environments which include many obstacles like buildings. By obstacle, we refer to any object or collection of objects, which interferes with the communication between two or more nodes, and introduces constraints to the node mobility.

In this work, we focus on an urban environment, in particular the campus scenarios. Campus scenarios cover the environments like college campuses, technology parks, etc. We will enhance our tool to develop other scenarios as part of future work. The basic features of SGT include: (1). *modelling of obstacles:* three types of buildings are included: lecture theaters (LTs), offices and canteens; (2). *modelling of predefined pathways:* pathways in both straight line and curve form are designed to capture the constrained node mobility in outdoor environment; (3). *modelling of 3D movements:* node movements between different floors are included. As per our knowledge, this is the first attempt to add 3D feature in MANET simulations; (4). *modelling of heterogeneous nodes:* three categories of nodes are included: students, professors and visitors, each having different behaviors; (5). *application of studies on human walking:* research findings from psychology and social science studies are applied to capture realistic human walking patterns, such as conscious travelling and inertial walking behaviors [20].

In the rest of this section, we will describe configurations for different node types, and node mobility in both indoor and outdoor environments.

3.1. Node Configurations

In our model, each type of nodes (students, professors, visitors) behave differently. For example, students may spend more time moving between LTs and canteens than professors. On the other hand, professors may spend more time inside offices than students. We use a preference matrix to model these kinds of behaviors.

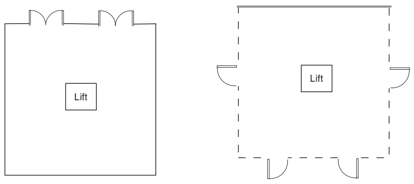
Table 1. Preference matrix for node types

	LT	Office	Canteen	Path
Student	0.5	0.1	0.2	0.2
Professor	0.2	0.5	0.2	0.1
Visitor	0.1	0.1	0.2	0.6

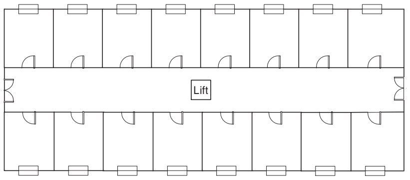
Table 1 shows a preference matrix for different node types. Each entry in the matrix can be understood as frequencies or probabilities for a node being in a building or on a path. For example, a value of 0.5 for student and LT means a student will choose to be inside LT with a probability of 0.5. Entries for professor and visitor can be interpreted similarly. It is clear that entries in a single row sum to 1. The preference matrix is used as probability threshold while placing and moving nodes to generate node movements. These probabilities are configurable. Traces on peoples' activity frequencies can also be conducted to obtain more accurate modelling for a specific environment.

3.2. Indoor Node Mobility

Indoor node mobility refers to movement within a single building, including movement between different floors and within a single floor. There are three types of building defined, namely: LT, office and canteen. Each building type has a different floor layout and the layout is the same on all floors.



(a) LT and Canteen



(b) Office

Figure 1. Layout of 3 types of buildings

Figure 1 shows the layout of LTs, canteens and offices. Due to space constraint, we only describe node mobility inside LTs. The cases for canteens and offices are similar. LTs have four side walls and two main doors. We use lifts to model node movements between floors. Nodes inside LTs can choose to go outside or stay inside according to the probability in preference matrix. If a node chooses to go outside, it will randomly select an exit point (main door), move there, rest for some pause time and then resume movement using an outdoor mobility model. If the node selects to stay, it will move either within the same floor or to other floors. In the decision process, a threshold is used to reflect the inertial behavior of humans: people are more likely to remain on the same floor rather than go to other floors [20]. If the same floor is chosen, the node will move to the destination directly. Otherwise, the node will first move to the lift, destination floor and finally the destination place.

3.3. Outdoor Node Mobility

Outdoor node mobility deals with how nodes move in an outdoor environment. Figure 2 depicts a typical outdoor scenario. Nodes can only move along predefined pathways in straight line or curve forms (curves are linearized into line segments). Once nodes reach end of the path, they rest for some pause time and then decide on direction and speed for the next movement. While at a cross point, nodes will randomly select a path connected to the cross point and continue the process. A threshold is set in the decision process at these cross points, forcing nodes to select paths other than the original path the nodes are currently on. This is reasonable according to [20], since most people exhibit the conscious travelling feature. Therefore, they tend to keep the direction towards destinations instead of wandering around the same path. While facing a building, nodes will decide according to the preference matrix (see Table 1) whether to go inside the building or not. If yes, the nodes will move inside and continue with the indoor mobility. Otherwise, they will go back along the same path and continue with the outdoor mobility.

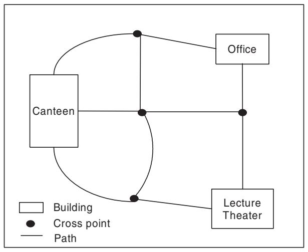


Figure 2. A typical outdoor scenario

We implemented SGT in Java. It has a GUI to allow users to create campus scenarios by manipulating buildings and pathways. Then with created scenarios, users can place nodes either in random or user-defined manner. Finally, node movements are generated in the format compatible with NS-2. To facilitate ORPM, SGT also generates a file that contains all the obstacle information in the same scenario and will be used as input file for NS-2 simulations.

4. Obstructive Radio Propagation Model

For simulations in MANETs, free space and ground-reflection (two-ray) are the widely-used propagation models. NS-2 comes bundled with Free Space, Two-Ray Ground and Shadowing models. However, these models do not consider the issue of obstacles and are more accurate for larger distance. ORPM enhances NS-2 by providing an indoor propagation model, which is different with respect to the distance covered (much smaller) and to how strongly the propagation is influenced by features of the building. Partitions which form the internal structure of a building will act as major obstacles for the propagation. Therefore, it is very important to consider these partitions in an internal propagation model [21].

ORPM can be basically considered as a free-space model enhanced with indoor propagation models that takes into account multiple obstacles. It models a time-invariant channel where the obstacles blocking the primary ray are responsible for majority of the loss in signal strength perceived by the receiver. The remainder of the signal strength attenuation is a function of the distance that separates the communicating nodes.

ORPM uses the technique of attenuation factor model (Section 4.11.5 of [21]) to compute the received signal strength. In this technique, the primary ray travels in a single line between the transmitter and receiver. The received signal strength is computed by summing the partition losses along this primary ray and given as:

$$P_r(d) = P_0(d_0) - 20\log\frac{d}{d_0} - \sum_{i=1}^{\sigma} m_i AF_i \qquad (1)$$

where $P_0(d_0)$ is the power at any nearby reference distance d_0 (usually around 1m), m_i is the number of obstacles of type i along the primary ray path, AF_i is the attenuation loss factor due to material type i, and σ is the number of distinguishable material types $(1 \le i \le \sigma)$. Note that we have simplified path loss exponent to 2 and combined the attenuation terms for floors and partitions.

In Equation (1), we obtain the values for m_i by counting the number of walls of various material types that intersect the path of the primary ray. For AF_i, seven types of materials are currently defined in EGRESS: floor, wood (for doors), glass (for windows), metal (for lifts), soft partition, hard partition and exterior wall. More material types can be easily defined. The attenuation factors for these different material types are listed in [21]. Table 2 lists the respective AF used. It is important to note that using the existing framework, it is trivial to add new material types or modify the path loss exponent in Equation (1).

Table 2. Building types and their AF

Materials	$AF(dB)$	Materials	$AF(dB)$
Floor	10.50	Soft partition	4.92
Wood	2.48	Hard partition	9.13
Glass	3.11	Exterior wall	12.52
Metal	11.20		

In implementation, given two communicating nodes, we need to obtain the count of obstacles of each material type the primary ray intersects and to compute the resulting signal strength during run-time. Since SGT outputs the obstacle information file, we load this file in ORPM in advance and reconstruct all the buildings in the scenario under simulation. To speed up processing, we divide the complete area into quadrants, into which obstacles are classified. It should be noted that an obstacle can belong to more than one quadrant. So, when we compute the signal strength between sender and receiver, we consider only those quadrants, through which the primary ray is passing. This technique helps us to consider only the relevant obstacles, reducing the processing time. Algorithm 1 shows how to calculate the number of obstacles the primary ray intersects. Note that, we assume that all walls of the same type have the same AF_i.

Algorithm 1 Calculates the count of obstacles the primary ray intersects

```
Input transmitter position $P_t$, receiver position $P_r$, building list $b\_list$
Output int [ ] $wallCount$
Initialize $wallCount$;
for each building $b$ in $b\_list$ do
    if exterior walls of $b$ intersect line $P_tP_r$ then
        for each wall $w$ of $b$ do
            if $w$ intersects line $P_tP_r$ then
                $wallCount$[material of $w$]++;
            end if
        end for
    end if
end for
return $wallCount$;
```

In its present stage, ORPM assumes a time-invariant channel and neglects the effects like reflection, diffraction and scattering. Small scale fading and multipath are also not modelled. However, ORPM offers a much more realistic model than the existing large-scale path loss models used in NS-2 for simulation of indoor environments.

In general, there are more complex and exact algorithms like ray tracing to compute the receiver power. ORPM is an efficient approximate to that complex approach. Ray tracing basically considers all the rays casting from the sender and reaching the receiver via reflection, refraction and diffraction. The heavy computation in some sense limits ray tracing to only small indoor environment simulation. As for ORPM, we have an approximate solution but broader application range. Also ORPM can be extended easily to achieve higher accuracy by adding second-order or third-order primary ray.

5. Experimental Evaluation

In this section, we present the simulation evaluations of EGRESS and compare its performance to unmodified NS-2. All implementations are based on NS-2 [1] version 2.28, augmented with the CMU wireless extensions. In the simulation, SGT outputs a movement file and an obstacle information file. These files are then fed into NS-2 enhanced with ORPM.

In the evaluation, we compare the performance of ORPM and FS model. We first study the performance impact of using EGRESS in terms of *normalized link change count* and *normalized neighbor density*. Next, we study the parameters related to routing protocols like *average path length* and *average number of route requests*. Further, the performance impact on specific routing protocols like AODV and DSR is evaluated. Finally, we study the impact of increasing the "density" of buildings in the simulation area.

Unless otherwise stated, the topology used has 9 buildings (3 office buildings, 5 lecture theaters and 1 canteen), contained within a 500m by 500m square. The average walking speed is uniformly distributed between 0.5 m/s to 2.5 m/s, and pause time is 5s. All simulations ran for 500 seconds and each data point is the average of 7 runs.

For completeness, we will first describe the routing protocols (AODV and DSR) used in later simulations, followed by the simulation results.

5.1. Routing Protocols

Ad hoc On-demand Distance Vector (AODV): AODV is a reactive distance vector routing protocol. Whenever a node needs to find a route to another node, it broadcasts a *Route Request (RREQ) message* to all its neighbors. The RREQ message is flooded though the network until it reaches the destination or a node which has a fresh route to the destination. If the destination is found, the route is made available by unicasting a *Route Reply (RREP) message* back to source. On its way back to the source, the RREP message initiates the creation of routing table entries for the destination in intermediate nodes. Routing table entries expire after a certain timeout period.

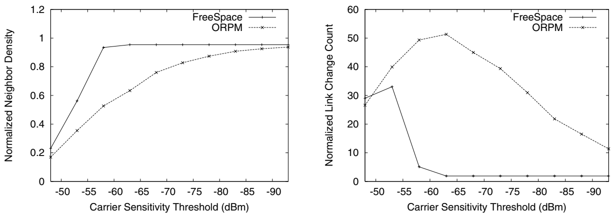
Dynamic Source Routing (DSR): DSR is a reactive routing protocol which uses source routing to deliver packets. Each packet carries in its header the full route to its destination. Intermediate nodes just forward the packet to the next hop in the source route. Routes are maintained in a cache, which is filled when the node discovers route on demand, or when node overhears the route from packets placed in its channel. When a node needs a route but it is not present in the cache, DSR sends a route request broadcast message with an empty source route. On receiving a route request, an intermediate node attempts to answer it with a cached route, or appends itself to the source route of the request and rebroadcasts it. Eventually the request will reach the destination, and a unicast route reply message will be sent using the route constructed by this process. Whenever a node fails to send a packet to its next hop, DSR assumes the link is broken, cleans its cache of routes which were using the link, and sends a unicast route error message to the originator of the packet, who will try to retransmit the packet using another route.

5.2. Topology Parameters

In this experiment, we consider *topology parameters* such as *normalized link change count* and *normalized neighbor density*. The link change count is the measure of the average number of connectivity changes between each node pair over the simulation duration, which is normalized by the total number of links. Neighbor density is a measure of the average number of nodes within transmission range from each other. We normalize this quantity by the number of nodes in the network minus 1. These two parameters are similar to the parameters used in [22]. It is important to note that these metrics are independent of the routing protocol and simply reflect the stability of the network topology. In the simulation, carrier sense threshold (*CSThresh*) and average node speed are varied. 20 nodes, with randomly chosen node types, were used. Since the default *CSThresh* value used in NS-2 simulations is 1.559e-11 Watt (-78 dBm), we varied the values from -48 dBm to -93 dBm, with a step of 5 dBm. Decrease in *CSThresh* value corresponds to increase in the carrier sensing range and vice versa.

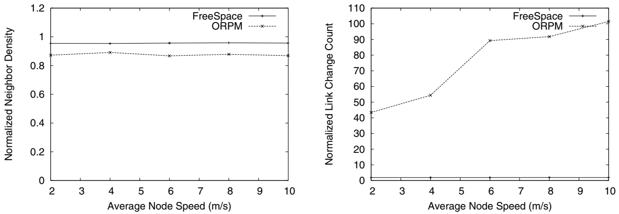
Figure 3(a) shows the normalized neighbor density for FS and ORPM with respect to decreasing *CSThresh* values. For convenience, the x-axis uses the absolute *CSThresh* value. As *CSThresh* value decreases, neighbor densities of FS and ORPM both increase. However, neighbor density of FS is always larger than that of ORPM and the key point to note is how the neighbor densities change in both cases. The density change is gradual in the case of ORPM, whereas the increase in the case of FS, the change is much more steep. The neighbor density of FS increase form 0.223 to 0.976 when the threshold decreases from -48 dBm to -53 dBm, and remains almost the same (0.976) for *CSThresh* < -58 dBm. On the other hand, the density did not reach 0.976

even with a threshold of -93 dBm for ORPM.



(a) Normalized neighbor density (b) Normalized link change

Figure 3. Varying carrier sense threshold



(a) Normalized neighbor density (b) Normalized link change

Figure 4. Varying average node speed

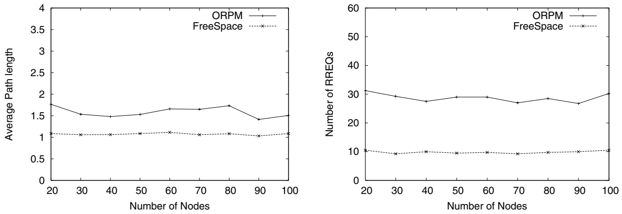
Figure 3(b) shows the normalized link change for FS and ORPM. For *CSThresh* values from -48 dBm to -53 dBm, link change for FS and ORPM are similar. This can be attributed to the smaller sensing range and obstacles do not have much effect on propagation. However, for *CSThresh* values larger than -53 dBm, there is a large differece in link changes between ORPM and FS. From -53 dBm to -58 dBm, link change count for FS drops rapidly from 30 to 5, and remains the same till -93 dBm. Whereas for ORPM, it first increases as the threshold is gradually reduced (or range is gradually increased) due to the fact that it finds more neighbors and at the same time tends to lose them due to mobility or existence of obstacles. The later decrease in link change count is due to the lesser threshold (larger sensing range) and a relatively small simulation area. The behavior of FS is again due the fact that the obstacles between nodes are not considered, and FS only considers the distance between nodes as the only deciding factor for transmission between nodes. In the case of ORPM, apart from considering distance between nodes, ORPM also considers signal attenuation due to obstacles. This results in higher link change count compared to FS.

Figure 4(a) shows that average node speed has very little effect on neighbor density for both cases. However, the neighbor density values are comparatively lower for ORPM. The differences are due to the consideration of obstacles in ORPM, which attenuate the signal strength and reduces the sensing range. Thus, signals from nodes in ORPM will reach less neighboring nodes than that of FS, resulting in lower neighbor density. The difference in behavior between ORPM and FS is much more evident in the case of figure 4(b). As the node speed increases, link breakages happen much more often in the case of ORPM. Whereas, for FS, the node speed has very little effect on the link change count. While the link change count is less than 2 for FS in most cases, the count is more than 40 and 100 for ORPM at speed of 2 and 10 m/s respectively.

This difference in topology parameters significantly impacts the routing performance, which is discussed in the next two sections.

5.3. Routing Protocol Parameters

In this section, we study the impact of using ORPM on *routing protocol parameters* such as *average path length* and *average number of route requests*. The first parameter gives a measure of the average value of the path lengths of the paths obtained by the routing protocol and the second parameter is a measure of the number of times the routing protocol initiate a *route discovery* mechanism. In this simulation, we use AODV as the routing protocol and 10 CBR sources. We vary the number of nodes from 20 to 100.



(a) Average path length (b) #initiated route requests

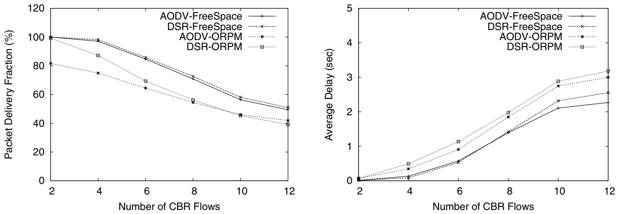
Figure 5. Routing protocol parameters

Figure 5(a) shows the average path length, and figure 5(b) shows the number of route-discovery process initiated, with different number of simulated nodes. As expected, the existence and consideration of the obstacles affect the average path length of the routes found by the route discovery mechanism. The average path length for FS is close to 1 as the simulation area is small. On the other hand, the average path length for OPRM is around 1.5, indicating that many communicating pairs need a relay even though they are within communication range if the obstacles are not taken into account.

AODV initiates its route discovery mechanism whenever it has data to send, and when the route to the destination is not present in the routing-table. Link breakage has an effect on this mechanism, which is evident from Figure 5(b). For FS, because the route rarely breaks due to the small simulation area, the number of discovery processes will be almost equal to number of flows the network carry. As we use 10 CBR flows, the number of discovery messages for FS is around 10. In the case of ORPM, due to obstacles, there are much more link breakages as the results in the previous section have shown. Figure 5(b) shows that there are almost 3 times more RREQ messages initiated compared to FS.

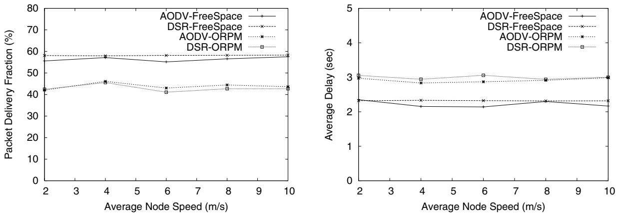
5.4. Network Performance Parameters

In this section, we compare the performance of AODV and DSR routing protocols using ORPM and FS. We consider different *performance parameters* such as *packet delivery fraction* and *average end-to-end delay* for CBR traffic, and *throughput* for TCP traffic. We also vary the number of sources (both CBR and TCP flows) and the average node speed. Our goal is to determine the impact of the mobility model on the network performance, rather than attempting to evaluate the routing algorithms. Hence, we are more interested in the differences in behavior achieved by the same routing algorithm under different mobility and propagation models.



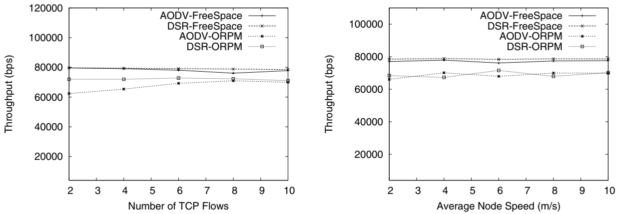
(a) Packet delivery fraction (b) End-to-end delay

Figure 6. Real-time traffic with varying number of CBR flows



(a) Packet delivery fraction (b) End-to-end delay

Figure 7. Real-time traffic with varying node speed



(a) TCP Throughput (b) TCP Throughput

Figure 8. TCP throughput with varying number of TCP flows and node speed

Figures 6(a) and 6(b) show the packet delivery fraction and average end-to-end delay for real-time traffic with varying number of CBR flows, respectively. Whereas 7(a) and 7(b) show the packet delivery fraction and average end-to-end delay for real-time traffic with varying node speed, respectively. The end-to-end delay values include route acquisition latencies for discovering the route.

It can be seen from Figure 6 that with FS, AODV and DSR have similar packet delivery fraction and delay values, with DSR having slightly better packet delivery fraction, and AODV has slightly better delay values. With ORPM, DSR has higher packet delivery fraction for 6 CBR flows or less and has larger delay values than AODV, which can be due to higher packet deliveries. However, it is important to note that the packet delivery fraction and delay values are much worse for ORPM, compared to FS. The difference in performance between FS and ORPM can be attributed to the inability for routes to be discovered between sources and destinations that are completely obstructed due to presence of buildings. For example, if the nodes are separated by buildings with high attenuation, then it is impossible for these nodes to find a path to each other.

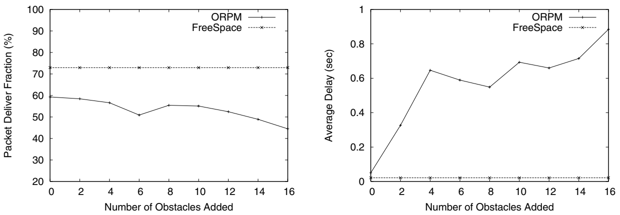
Figure 7 shows the performance when average node speed is increased from 2 m/s to 10 m/s. In this scenario, the difference in performance between FS and ORPM is significant. For packet delivery fraction, FS's delivery ratio is almost 30% better than ORPM. The increase in speed has limited effect on the overall performance because of the small simulation area.

Figures 8(a) and 8(b) shows the throughput for TCP traffic with varying number of TCP flows and node speed. Similar to CBR traffic, the performance of AODV and DSR are almost the same using FS, with DSR performance slightly better. It can be seen that FS has better throughput values than ORPM, for the same reasons as mentioned earlier. However, Figure 8(a) shows that DSR performance is much better than AODV with ORPM radio model when the number of TCP flows is small.

The reason behind the better performance of DSR may be due to the reason that route acquisition procedure in DSR allows more routes to be detected and cached than in AODV, which obtains a single route per RREQ. With DSR, packets wait less during route acquisition than with AODV. Further the routes obtained are short in this simulation, which reduces the byte overhead of DSR.

5.5. Varying Environment

In previous simulations, the single topology of buildings was used. In this section, this topology is varied. Starting with a base topology with 10 buildings and pathways, we place nodes randomly and generate the movement file. From the base topology, additional (from 2 to 16) buildings are added. For each scenario with the same number of buildings, 7 different random positions are tried and the results are averaged. It is important to note that the node movements are the same for all the cases. The motivation behind this experiment is to study the effect of the density of obstacles on network performance. With more buildings, we choose to use a larger simulation area of 1000x500 meters and 50 nodes. We measure packet delivery fraction and end-to-end delay of real-time traffic using AODV routing protocol.



(a) Packet delivery fraction (b) End-to-end delay

Figure 9. Varying environment

Figures 9(a) and 9(b) shows the packet delivery fraction and end-to-end delay for CBR traffic, respectively. It can be seen that as the number of obstacles are increased, the packet delivery fraction decreases, and delay increases, which is expected. The changes in delay are higher compared to the packet delivery fraction. This effect can be attributed to more path breaks, which can result in buffering of packets or triggering of fresh route-discovery mechanism.

6. Conclusions and Future Work

In this paper, we proposed SGT to incorporate more realistic mobility patterns in MANET simulations. Towards this goal, buildings and predefined pathways were included. They are used to model indoor and outdoor node movements, respectively. Buildings also obstruct the radio transmission between communicating nodes. We model this effect by proposing ORPM, which takes into account the attenuation factor of obstacles. With ORPM, we studied the effects of more realistic scenarios on network topology and performance evaluation. Experimental results showed that it is important to consider more realistic mobility scenarios in MANET simulations.

SGT is an initial step towards realistic mobility modelling. This work will be improved in the following ways as part of our future work. We consider campus mobility patterns as a case study in EGRESS. This will be extended to include similar cases, such as technology parks and entertainment parks as a first step. Further we propose to add group mobility among different node types. Realistic pause time will also be included in the process of node movements. For example, a student may encounter his/her friends while moving and he/she may stop and talk for a certain duration. For the effects of obstacles on radio propagation, in our current model–ORPM, we neglect the width of walls, people moving around and assume a time-invariant radio channel. This assumption will be further enhanced and studied. Finally, more detailed performance evaluations of MANET routing protocols will be performed.

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