# Performance Evaluation of Distance Vector Routing Protocol on a Wireless Circular Model


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**Abstract-In this paper, a wireless Circular Model over the Distance Vector routing protocol is presented and analyzed. The performance of this algorithm, which is an implementation of Distributed Bellman-Ford algorithm has been evaluated by using the simulation environment of NS-2. We conducted an extensive evaluation study for various mobility schemes in order to incorporate the behavior of nodes and the routing protocol in a real-life hotspot situation. In the test-bed model, while the number of source nodes was allowed to arbitrarily vary, there was exactly one destination node, closely modeling thus real-life situations where a single hotspot/access point exists. Finally, different constant bit rates (CBR) were used in order to estimate the throughput of receiving, dropping rates, the number of lost packets, as well as the average packet delay under various traffic conditions. This study is aimed to help wireless network designers in choosing the best suited routing protocols for their networks, through making explicit performance figures for common network setups.**


## 1. INTRODUCTION

In the recent years, much research effort has been focusing on studying and improving the performance of routing protocols in Mobile Ad-hoc NETworks (MANETs) [1].

One significant classification scheme of routing protocols is based on the content of the routing tables. In the context of this classification scheme, two major classes of routing protocols can be identified, namely the Distance Vector (DV) and Link State (LS) protocols [2]. In a DV routing protocol such as the Routing Information Protocol (RIP) [3, 10], a vector is kept at each node, containing the cost (i.e. hop distance) and path (next hop) to all the destinations. In this protocol class, nodes exchange with each other a list (vector) of distances to the destinations, and each node maintains the routing table of the shortest paths to each known destination. DV protocols are generally known to suffer from slow route convergence and tendency of creating loops in mobile environments. On the other hand, a LS routing protocol such as the Open Shortest Path First (OSPF) protocol [4], overcomes the problem by maintaining the topology of the network (links state) at each router through periodical flooding of link information about its neighbours. Consequently, *medium or high mobility rates* entail frequent flooding. Unfortunately, this LS advertisement scheme generates larger routing *control overhead* than DV. In a network with population *N*, LS updating generates *routing overhead* in the order of O($N^2$). In large networks, the transmission of routing information will ultimately consume most of the *bandwidth*, at the expense of the useful bandwidth available to applications, which will be therefore blocked applications. Consequently, LS protocols are considered inappropriate for *bandwidth-limited* wireless ad hoc networks, especially if these have medium or high mobility rates.

Another important classification scheme for routing protocols in Mobile Ad-hoc networks is based on the time that routing information is updated. Under this classification scheme, the classes of Proactive Routing Protocols (PRP) and Reactive Routing Protocols (RRP) [11] can be identified. Furthermore, a converged approach such as hybrid routing protocols considered.

Finally, another classification of routing protocols distinguishes them into source routing and hop-by-hop routing protocols. In source routing, the sources compute the complete path towards the destinations, leading to a loop-free routing protocol. On the other hand, in hop-by-hop routing, each intermediate node computes the next hop itself. Thus, the hop-by-hop routing protocols reduce the chance of *failed routes*, a parameter of crucial importance especially in mobile networks, which are more prone to the specific error type due to the fact that their topology changes much faster as compared to wired networks. Consequently, source routing protocols -such as the Dynamic Source Routing (DSR) [5]-

allow intermediate nodes (and even overhearing nodes) to modify the route, adapting thus better to the nature of mobile networks. Most MANET routing protocols such as Optimized Link State Routing (OLSR) [6] and Ad-hoc On-demand Distance Vector (AODV) protocols [7] have adopted the strategy of hop-by-hop routing.

In this paper we study the performance of the Distance Vector routing protocol over various *mobility rates,* while the network topology follows the Circular Model. In particular, the following cases have been studied:

- *no mobility*
- *medium mobility*, where a medium amount of links fail and restore during the experiment period
- *high mobility*, where a large amount of the links fail and restore

We also, consider different traffic conditions and varying *packet size*, in order to study the effect of these parameters on the overall performance of the routing protocol.

The remainder of this paper is organized as follows: in section 2 we illustrate and analyze the test-bed wireless Circular Model over the Distance Vector protocol. Section 3 presents the results of our performance analysis, which has been conducted through simulation experiments, while section 4 provides the concluding remarks.

## II. THE MODEL ANALYSIS

In this paper we analyze and evaluate the performance of DV routing protocol over a wireless Circular Model which is equivalent to the well-known ring topology used in standard Ethernet networks. It is worth noting that *traffic* in the presented model is routed along a route with the shortest number of hops from the *source node* to the *destination node*. This routing feature is closely resembles the strategy adopted by the AODV protocol. An important consideration of this model is that, although there are many *source nodes*, there is exactly one *destination node*, representing a single hotspot/access point.

This Circular Model simulates a number of *nodes* connected to a wireless hotspot, with the ability to have an alternative route established through the remaining *nodes*, when a *node-link* breaks. The network simulator NS-2 [8, 9] has been used for simulation study in order to investigate the potential problems in the terms of route maintenance and link failures. Unfortunately, NS-2 is very memory- and CPU-intensive, and therefore contributed to the small scale design and implementation of the models. Consequently, the slow simulation speed and large memory requirement of the NS-2 models prevented us from using larger networks at this evaluation study. The following Circular Model configuration was chosen to represent the behaviour of *nodes* and the routing protocol in a real-life hotspot situation:

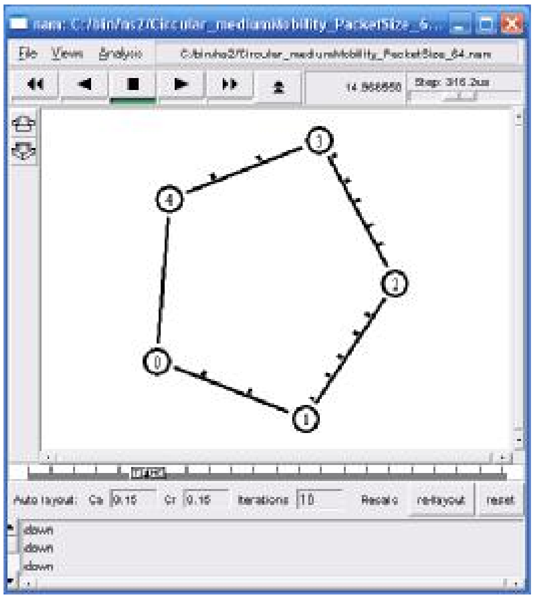


Fig. 1 Network Animation output for DV routing protocol on a *medium mobility* Circular Model under a stability of all *node-links*

- A five *node* Circular Model, consisting of four *source nodes* (0, 1, 3, and 4) all sending packets to the *destination node* 2, representing a single hotspot/access point. All links were set to a speed of 2 Mbps, with *propagation delay* 10 ms.
- The constant bit rate (CBR) *traffic* was used in the simulation by an *interval* of 0.004 sec (or 250 packets per second).
- The *packet size* was fixed either to 64 Bytes or to 512 Bytes for *low* and *high traffic* conditions respectively. In a slight variation the measurements presented in [13], the effect that different *packet size* may have on the performance will be investigated.
- The route with the smallest number of hops was being taken using the Distance Vector protocol which is an implementation of Distributed Bellman-Ford algorithm [12].
- The *simulation time* was adjusted to 60 sec.
- Three different *mobility* settings were implemented. In a *no mobility* setup all *node-links* were stable during the *simulation time*. In a *medium mobility* setup, a medium amount of links fail and restore during the *simulation time* (8 fails of a total duration 10 sec), while in the *high mobility* setup a large amount of links fail and restore (18 fails of a total duration 20 sec)

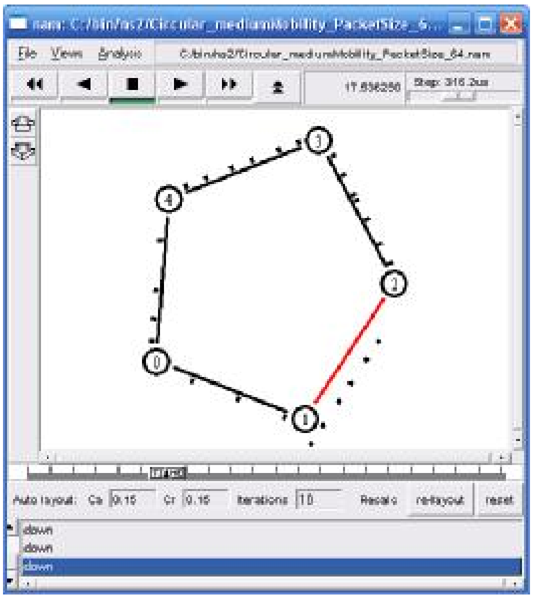

Fig. 2 Network Animation output for DV routing protocol on a *medium mobility* Circular Model under a *node-link* goes down

As illustrated in figure 1, the shortest route was taken by each *source node* (0, 1, 3, and 4) to the *destination node* 2. The routes were: 0→1→2, 1→2, 3→2, and 4→3→2. In figure 2, the link between *nodes* 1->2 was non-operational for a certain *time period* due to a *mobility* factor. During this period, the route for *node* 1 was changed from a single hop (1→2) to 1→0→4→3→2, while the route for *node* 0 was changed from 0→1→2, to 0→4→3→2. It is also seen at Network Animation output in figure 2 that a number of packets were dropped at the *node-link* 1→2, during a link failure.

## III. PERFORMANCE AND SIMULATION RESULTS

The performance of the Distance Vector routing protocol over a wireless Circular Model under various *mobility* and *traffic* conditions has been evaluated by the NS-2 simulator [8, 9]. All simulations used a generic distance-vector routing protocol agent, as described by NS-2 manual [9]. The implementation sends periodic route updates every *advertInterval*. This variable is a configurable parameter that remains constant throughout the simulation, and its value was set at 2 seconds. In addition to periodic updates, each agent also sends triggered updates; it does this whenever the forwarding tables in the node change. This occurs either due to changes in the topology, or because an agent at the node received a route update, and recomputed and installed new routes. Each agent employs the split horizon with poisoned reverse mechanisms to advertise its routes to adjacent peers. "Split horizon" is the mechanism by which an agent will not advertise the route to a destination out of the interface that it is using to reach that destination. In a ``Split horizon with poisoned reverse" mechanism, the agent will advertise that route out of that interface with a metric of infinity. Each DV agent uses a *preference_* of 120. The value is determined by the class variable of the same name. Each agent uses the class variable INFINITY (set at 32) to determine the validity of a route.

The following performance and operation metrics were collected:

1. *Number of dropped packets*. This metric was collected for all node pairs (*X, Y*), where *Y* is the sending node and *X* is the *receive/drop node.*
2. *Number of lost packets*. This metric was collected for all node pairs (X, Y), where *Y* is the sending node and *X* is the node that the packet was addressed to.
3. *Throughput of receiving bits*. This metric was collected for the *destination node* and the evolution of its value along the simulation time axis was recorded.
4. *Rate* of dropping bits at *receive and drop nodes* vs. *simulation time*.
5. *End to End Packet Delays*. The metric was collected and cumulative distribution diagrams were created to concisely present the effects of mobility and network load to this performance parameter.

| **Circular Model** ***Low traffic*** **(64 Byte packets)** | ***Total Packets Generated*** | ***Total Packets Dropped*** | ***Total Packets Lost*** | ***Average Delay*** **(sec)** |
|---|---|---|---|---|
| *No mobility* | 59330 | 0 | 0 | 0.015 |
| *Medium mobility* | 59455 | 34 | 32 | 0.016 |
| *High mobility* | 59613 | 73 | 72 | 0.018 |

TABLE 1: Packet information under *low traffic* conditions

| **Circular Model** ***High traffic*** **(512 Byte packets)** | ***Total Packets Generated*** | ***Total Packets Dropped*** | ***Total Packets Lost*** | ***Average Delay*** **(sec)** |
|---|---|---|---|---|
| *No mobility* | 59330 | 0 | 0 | 0.019 |
| *Medium mobility* | 59455 | 3497 | 2405 | 0.045 |
| *High mobility* | 59613 | 7851 | 4652 | 0.056 |

TABLE 2: Packet information under *high traffic* conditions

Tables 1 and 2 depict packet information regarding total packets which were generated, dropped and lost at *low* and *high traffic* conditions respectively, using the DV routing protocol over various *mobility* schemes for the circular model nodes. Metrics for the *average packet delay* are also shown, and it follows that the average packet delay is greater at *high mobility* setups. Furthermore, the *average packet delay* deteriorates considerably under *high traffic* conditions at both *medium* and *high mobility* configurations (181% and 211%, respectively), while in the "no mobility" setup the deterioration does exist, but is much less (26,6%).

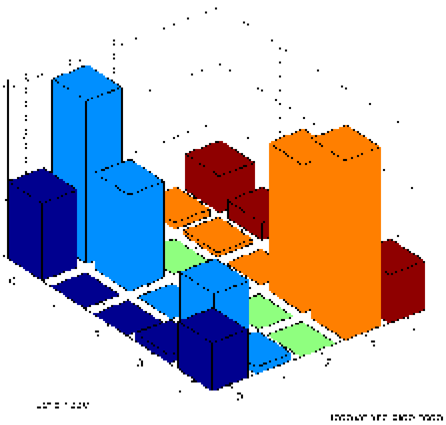

Fig. 3 *Numbers* of dropped packets at all *nodes X*: receive and drop *node Y*: send node

The graph in Figure 3 illustrates the number of dropped packets for all *node* pairs (*X, Y*) where *X* is the *node* that has received and subsequently dropped the packet, and *Y* is the original packet source. The metrics presented in these figures correspond to the circular model network setup described in section 2, which uses the DV routing protocol and exhibits high *node mobility* and high *packet rate* (0.5 Mbps per source). We may notice here that *node* 2 has no dropped packets at all, since packets having reached this *node* are considered to have reached their destination. *Nodes* neighbouring with *node* 2 (nodes 1 and 3) exhibit a higher number of dropped packets, since when their communication link to *node* 2 fails (*links* 1→2 and 3→2, respectively), this affects not only packets originating from these *nodes*, but for *nodes* 0 and 4, which use *nodes* 1 and 3 as intermediate hops for reaching *node* 2. Figure 3 illustrates the dropped packets at each *source node* (0, 1, 3, and 4), while figure 4 represents the lost packets at the *destination node* 2.

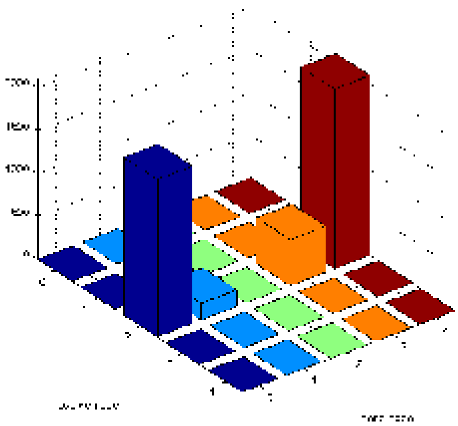

Fig. 4 *Numbers* of lost packets at all the *nodes X*: send *node Y*: receive node

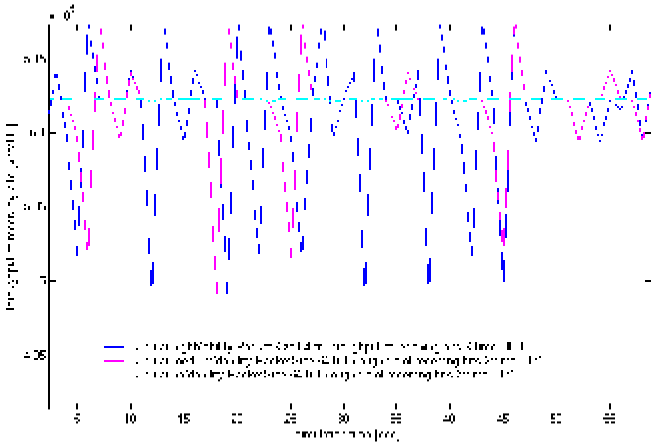

Fig.5 *Throughput* of receiving bits at *destination node* 2 vs. *simulation time* under *low traffic* conditions

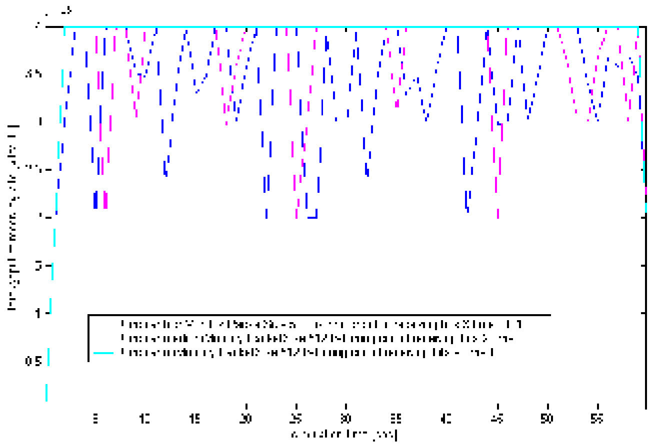

Fig.6 *Throughput* of receiving bits at *destination node* 2 vs. *simulation time* under *high traffic* conditions

Figures 5 and 6 depict the *average throughput* of receiving packets at the *destination node* 2 expressed in bps (bits per second) in the context of *low* and *high traffic* conditions respectively using the DV routing protocol. In each diagram, metrics for all mobility settings (high, medium and no mobility) are shown. The sharp performance drops that can be noticed for high and medium mobility setups are owing to link failures, as a result of mobility; this is also the reason that the "no mobility" setup does not exhibit such behaviour. It is worth noting that the *throughput* of receiving packets deteriorates slightly at *low* source transmission rates, under both *medium* and *high mobility* configurations. On the other hand, the *throughput* of receiving packets deteriorates considerably, under both *medium* and *high mobility* setups, when the source transmission rate becomes high. As can be seen from the diagrams, this difference can be attributed to the fact that in the low source *transmission rate*, the network has enough capacity to serve both the "regular" communication and the retransmitted (or rerouted) packets after a link failure. This explains the *throughput* spikes following the sharp drops in figure 5, and these spikes partially compensate for the *bandwidth* lost due to link failures. On the contrary, when the source *transmission rate* is high, the network appears to not have adequate *bandwidth* to serve both regular communication and packet retransmissions/reroutings: in figure 6, the maximum *receiving throughput* observed is that of the "*no mobility*" setup, and no "spikes" above that limit are observed.

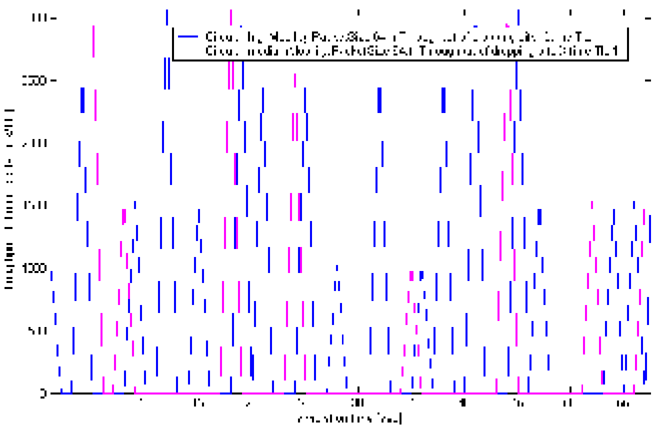

Fig.7 *Rate* of dropping bits vs. *simulation time* under *low traffic* conditions

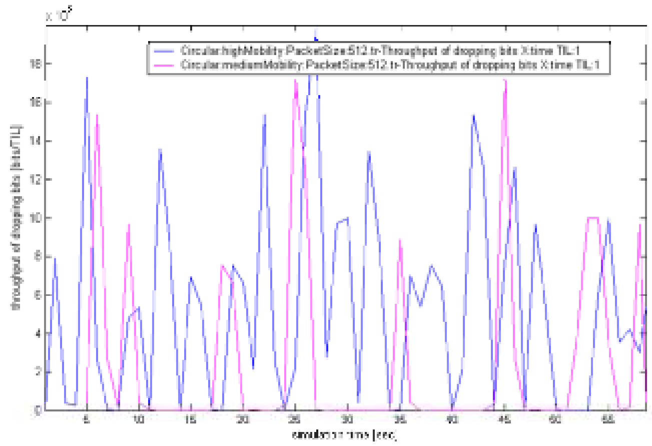


Fig.8 *Rate* of dropping bits vs. *simulation time* under *high traffic* conditions

Figures 7 and 8 represent the *cumulative rate* of dropping bits at all *receive* and *drop nodes,* under *low* and *high traffic* conditions respectively. It is noticed that the rate of dropping packets ranged from negligible to tolerable at *low traffic* conditions, under both *medium* and *high mobility* setups. On the other hand, the *cumulative rate* of dropping packets increases considerably in the case of *high traffic* configurations.

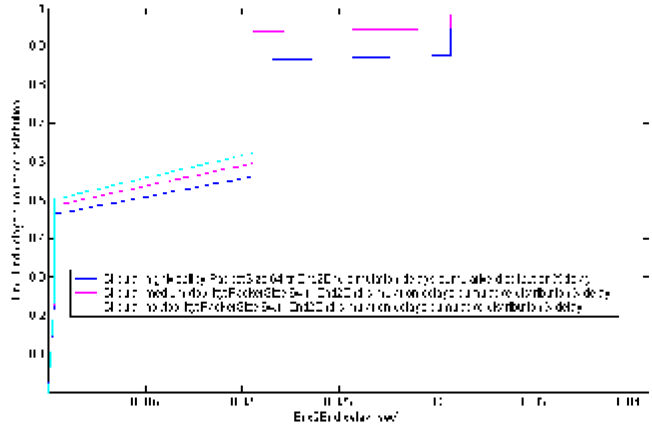

Fig. 9 *End to End Simulation Delays* vs. *Cumulative Distribution* under *low traffic* conditions

Finally figures 9 and 10 illustrate the *End to End Simulation Delays* vs. *Cumulative Distribution* using the DV routing protocol on various mobility patterns. Under the low traffic scheme and the "no mobility" setup we notice that packet service time effectively falls into two areas, the first one ranging from 0.1 to 0.2 sec and effectively corresponding to packets needing one hop to reach their destination (approximately 50% of the overall number of packets), while the second area corresponds to packets needing two hops to reach their destination. The variation in service times in the first area can be attributed to queuing delays at the source node, for the cases that the link is occupied by forwarding packets originating from other nodes to their destination when a new packet is generated. For medium and high mobility schemes, a third area is introduced to accommodate service time for packets needing to be retransmitted and/or following lengthier routes, due to communication link failures.

In the case of high traffic condition, the end to end delay presents a small increase under the "no mobility" scheme, mostly owing to the increase of queuing delays, since the probability that some link is occupied is greater than in the case of low traffic. For high and medium mobility patterns the end to end delay increases considerably, since –due to link failures owing to mobility– (a) packets follow lengthier routes and (b) the network appears not to have adequate capacity to effectively serve packets that need to be retransmitted and/or follow alternative routes.

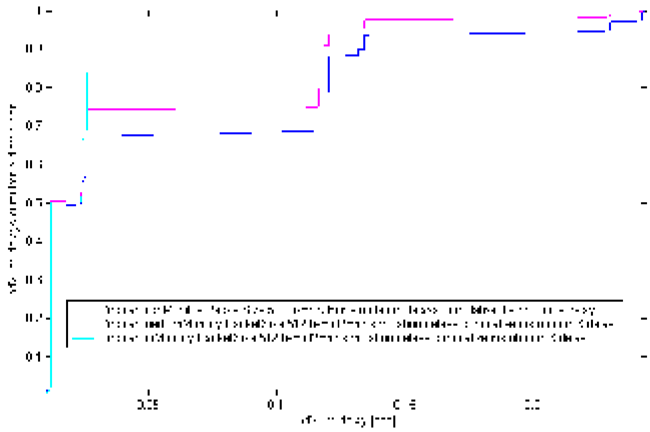

Fig. 10 *End to End Simulation Delays* vs. *Cumulative Distribution* under *high traffic* conditions

## IV. CONCLUSIONS AND FUTURE WORK

In this paper an extensive performance evaluation of wireless Circular Model over the Distance Vector routing protocol conducted under various *mobility* schemes. We observed that the *throughput* of receiving packets deteriorated slightly under low *traffic* conditions, at both medium and high *mobility* configurations. On the other hand, under high *traffic* conditions, the *throughput* of receiving packets deteriorated considerably, due to the flooding of sending packets at the last hops of the alternative *routing path* during a certain *time period* when a *link* between two *nodes* was inoperative due to the mobility factor. Moreover, the *average packet delay* was incremented dramatically at both *medium* and *high mobility* setups under *high traffic* conditions. The performance analysis is also uniformly applied to several representative networks such IEEE 802.11b and IEEE 802.11g providing a basis for fair comparison of *traffic* parameters and *mobility* conditions under tolerable *bandwidths* of drop and lost packets with acceptable *packet delays*.

Future work will include studying configurations with varying node populations, setups with multiple hotspots as well as setups where mobility does not lead only to communication link failures, but to alteration of route paths (e.g. when a node moves closer to the hotspot, it may directly transmit packets to it instead of using an intermediate hop). Correlation of network loads and packet rates to application classes (for instance web browsing, file transfer, streaming media and so forth) and study of network performance different under application usage patterns will be also considered.

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