Evaluation study of a wireless multimedia traffic-oriented network model

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Abstract. In this paper, a wireless multimedia traffic-oriented network scheme over a fourth generation system (4-G) is presented and analyzed. We conducted an extensive evaluation study for various mobility configurations in order to incorporate the behavior of the IEEE 802.11b standard over a test-bed wireless multimedia network model. In this context, the Quality of Services (QoS) over this network is vital for providing a reliable high-bandwidth platform for data-intensive sources like video streaming. Therefore, the main issues concerned in terms of QoS were the metrics for bandwidth of both dropped and lost packets and their mean packet delay under various traffic conditions. Finally, we used a generic distance-vector routing protocol which was based on an implementation of Distributed Bellman-Ford algorithm. The performance of the test-bed network model has been evaluated by using the simulation environment of NS-2.

Keywords: Performance Evaluation, Distance Vector Protocol, Routing Information Protocol, Mobile Ad-hoc Networks, Mobility, Multimedia
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INTRODUCTION

During the last decade, much research effort has focused on studying and improving the performance of routing protocols in Mobile Ad-hoc NETworks (MANETs) [1]. Efficient routing schemes are especially important in wireless networks, since the available bandwidth and IMP memory sizes are limited, while node mobility may cause link transitions from the “down” to the “up” state and vice versa. In a number of cases, power considerations for nodes participating in MANETs exist as well.

Routing protocols are mainly classified based on the content of the routing tables. Within this classification scheme two major classes of routing protocols can be identified, namely the Distance Vector (DV) and Link State (LS) protocols [6]. In routing protocol belonging to the DV class (e.g. the Routing Information Protocol (RIP) [9, 11]), each node maintains a vector of elements, where each element holds the cost (i.e. hop distance) and path (next hop) to all destinations. Participating nodes communicate to each other a list (vector) of distances to destinations, and based on this information the shortest path to each destination is selected by each node. Known limitations of DV protocols are slow route convergence and increased probability of creating loops in environments with mobile nodes.

On the contrary, link-state routing protocols (e.g. the Open Shortest Path First (OSPF) protocol [14]) address this issue by monitoring the network topology (practically the state of communication links) at each router; the main approach for keeping this information up to date is the *periodical flooding of link information*, where each node transmits link state information about its neighbours. If flooding is also triggered by link state changes, *medium or high mobility rates* lead to frequent flooding, which in turn results in larger routing *control overhead* than DV. Routing overhead of LS protocols has been quantified to be in the order of $O(N^2)$, where N is the number of nodes comprising the network. Since the overhead magnitude is super-linear, the performance of this protocol class does not scale well in large network setups, effectively because routing information exchange consumes a large portion of the bandwidth. Under such conditions, applications have limited bandwidth available and therefore frequently become blocked, waiting to receive or transmit network packets. Based on the above observations, LS protocols are considered improper for wireless ad hoc networks with limited bandwidth, especially these expose 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) [12] can be identified. Furthermore, a converged approach such as hybrid routing protocols considered.

A final 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) [3] and Ad-hoc On-demand Distance Vector (AODV) protocols [7] have adopted the strategy of hop-by-hop routing.

Nowadays, there is an increasing demand for high-speed, high bandwidth accessible mobile devices, allowing a typical user to work and play on the move. Initial multimedia services have already been offered in the second generation systems (2-G). Then, the third generation systems (3-G) were being deployed in order to support up to 2 Mbps packet-oriented data services. Nevertheless, the always increasing demand for higher data rates and the variety and number of high quality services has already lead to the development of fourth generation systems (4-G), which are designed to take each user's quality of service (QoS) requirements into account.

The Wireless 802.11 standards family was published by the Institute of Electrical and Electronics Engineers (IEEE) in 1997. Although these standards cover a number of aspects of wireless technologies, such as different speeds and frequencies, the standards 802.11b and 802.11g were the ones that gained acceptance and were incorporated in customer products. The 802.11b standard is also known as Wi-Fi, and provides a wireless Ethernet standard of communication for wireless connections between Personal Computers, laptops, PDAs and networks.

In this paper we study the performance analysis of a wireless 802.11b based network model using the Distance Vector routing protocol over various *mobility rates,* while the network topology follows the multimedia design as described in [13]; this design is important, since it provides the underpinnings for guaranteed QoS over the fourth generation systems (4-G). The performance analysis presented in this paper on a wireless multimedia traffic-oriented network considers the following cases:

- *no mobility* setup
- *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

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

THE MODEL ANALYSIS

Figure 1 depicts a typical setup of a multimedia traffic-oriented network, employing the 802.11b standard for node-to-node communication and the Distance Vector protocol [12] for performing routing activities. The modelled network consists of 7 nodes, 3 source and 3 sink ones; real world networks may include more nodes, however the requirements of the NS-2 [2, 10] simulator (which we used in this performance analysis) increase rapidly when the node population grows, thus the experiments in this study were confined to networks of modest sizes. Optimizations in the NS-2 simulation engine would enable the modeling and simulation of larger networks.

The main goal of the simulation and performance analysis presented in this paper is to investigate the potential problems in the terms of route maintenance and link failures under various *mobility* configurations. As it is seen at Network Animation output at figure 1 a number of packets are dropped (falling down) at the node-link 3→4, during a link failure. Real-time services such as VoIP (Voice over IP) and video streaming are relatively restricted with delay compared with non real-time services such as web browsing and ftp data transfer which are called *best effort services*. In 4-G systems, it is necessary to provide the End-to-End QoS for different types of multimedia traffic. The following test-bed configuration was chosen to represent the behavior of a wireless multimedia-based network scheme, where multimedia services are roughly categorized with data rate requirements and delay sensitivity.

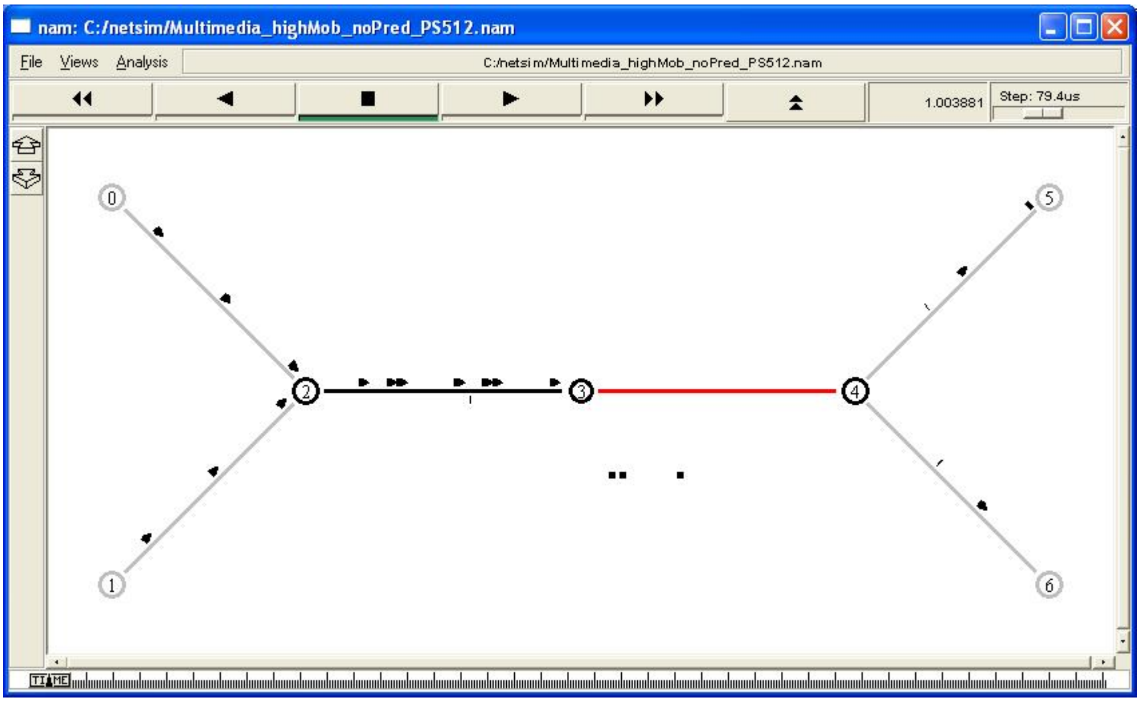

Fig. 1 Network Animation output for a multimedia-based network under a *high mobility* setup using the DV protocol, when a *node-link* goes down

- A seven *node* multimedia-based network model, consisting of three *source nodes* (0, 1, and 2) all sending packets to the *destination nodes* (4, 5, and 6) via the packet data gateway *node* 3 was evaluated.
- All links were set to a speed of 10 Mbps, with a *queuing* and *propagation delay* of 10 ms, simulating a wireless IEEE 802.11b model over a packet domain network.
- Constant bit rate (CBR) *traffic* was applied at each *source node* of simulation with an *interval* of 0.004 sec (or 250 packets per second).
- The *packet size* was fixed to 512 Bytes incorporating a 1 Mbps *offered load* per source.
- The routing of packets was based on a generic distance-vector protocol, which is an implementation of Distributed Bellman-Ford algorithm [12].
- 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* (6 fails of a total duration 8 sec), while in the *high mobility* setup a large amount of links fail and restore (18 fails of a total duration 23 sec)
- The *simulation time* was adjusted to 60 sec.

PERFORMANCE AND SIMULATION RESULTS

The performance of a wireless multimedia traffic-oriented network scheme over a fourth generation system (4-G) has been evaluated, under various *mobility* conditions, using a generic distance-vector protocol by the NS-2 simulator [2, 10]. In our implementation the routing protocol was configured to send periodic route updates every 2 seconds during all 60 sec simulation period. Moreover, each agent sent triggered updates, whenever the forwarding tables in a *node* were changed. Finally, each agent employed 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 agent used the value of 120 as *administrative distance metric*, while, the class variable *INFINITY* was set at 32 in order to determine the validity of a route.

The following performance and operation metrics were collected:

1. *Number of dropped packets*. This metric was collected at all source and sink nodes.
2. *Number of lost packets*. This metric was also collected at all source and sink nodes.

3. *Cumulative sum of dropped bytes*. This metric was collected and cumulative distribution diagrams were created to concisely present the effects of *mobility* and *network load* to this performance parameter.
4. *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.
5. *Throughputs of dropping bits* at all *receive and drop nodes* vs. *simulation time*.
6. *End to End Packet Delays*. These metrics were collected and cumulative distribution diagrams were created to concisely present the effects of *mobility* and *network load* to these performance parameters.

Multimedia Model (512 Byte packets)	**Total Packets Generated**	**Total Packets Dropped**	**Total Packets Lost**
No mobility	48828	0	0
Medium mobility	43014	30	1812
High mobility	40978	89	6821

TABLE 1: Packet information vs. *mobility* condition

Table 1 depicts packet information regarding total packets which were generated, dropped and lost at a multimedia-based IEE 802.11b network, using the DV routing protocol over various *mobility* schemes. According to this table the average rates of dropped and lost packets are 4.28% and 16.86% for medium and high *mobility* conditions respectively.

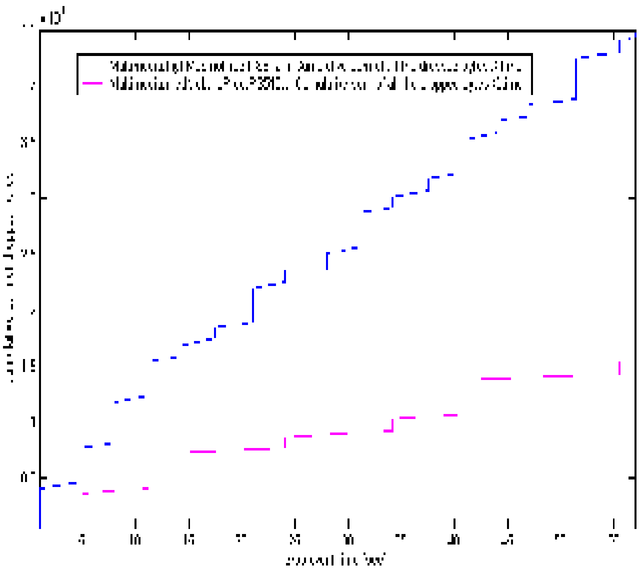

Fig.2 *Cumulative sum* of dropping bytes vs. *simulation time*

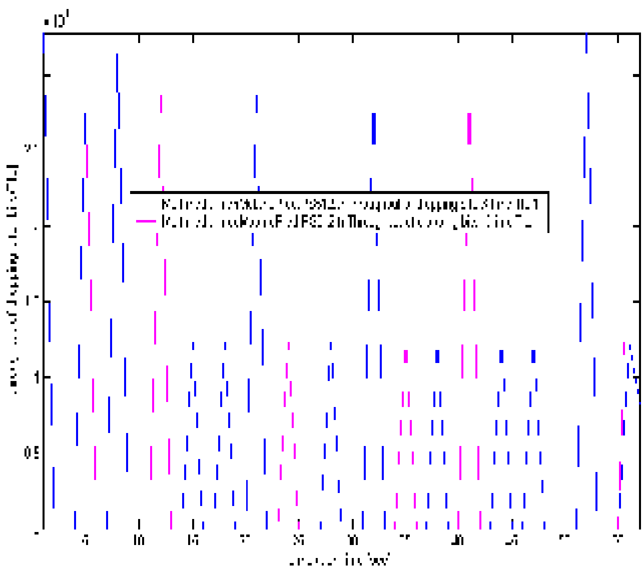

Fig.3 *Throughput* of dropping bits vs. *simulation time*

Figures 2 and 3 represent the *cumulative sum* and *throughput* of dropping bytes/bits at all *receive* and *drop nodes*. It is noticed that the rate of dropping packets ranged from tolerable to considerable at *medium* and *high mobility* setups respectively. The sharp peaks in figure 3 correspond to the events of link failures, which temporally coincide with the "delta-increments" in figure 2.

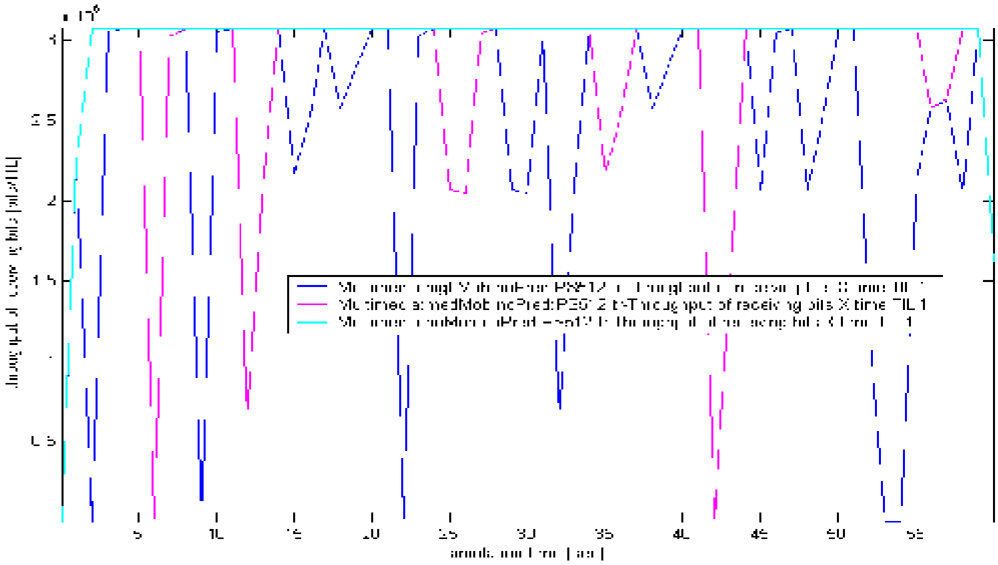

Fig.4 *Throughput* of receiving bits vs. *simulation time* under various *mobility* setups

Figure 4 depicts the *average throughput* of receiving packets at all *sink nodes* expressed in bps (bits per second) over the DV routing protocol at the test-bed multimedia-based network model. 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. We may also notice that in the "no mobility" setup, there exists a 2.5 (approximately) time interval before the throughput of receiving bits reaches its sustained value of 3 Mbps: this is owing to packet propagation delays and the time required by the nodes to accumulate the initial routing information by exchanging control packets at the beginning of the simulation.

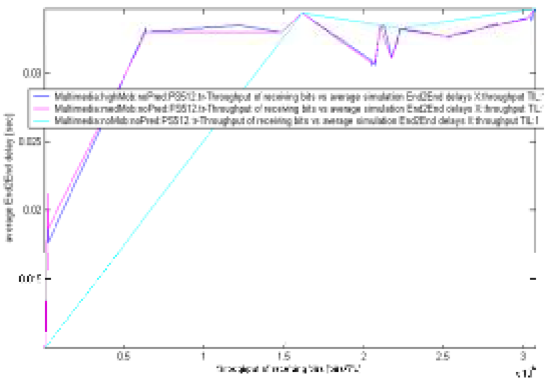

Fig. 5 *Throughput* of receiving bits vs. *End to End Simulation Delays*

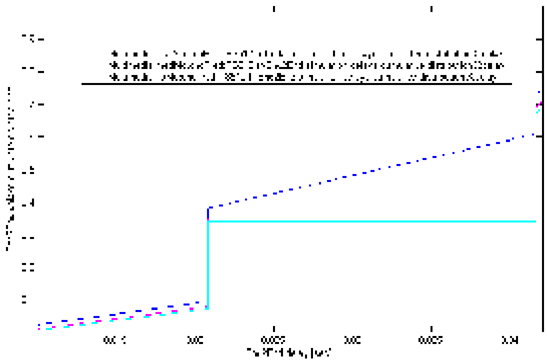

Fig. 6 *End to End Simulation Delays* vs. *Cumulative Distribution*

Finally figure 6 illustrates the *End to End Simulation Delays* vs. *Cumulative Distribution* on a multimedia-based network model using the DV routing protocol, while the figure 5 represents the *throughput of receiving bits* versus *End to End Simulation Delays,* under various *mobility* patterns. As expected, the end-to-end delay is small when the network has low amounts of traffic but increases when the amount of traffic rises. This can be observed in all mobility configurations and can be attributed to queuing delays in intermediate nodes. We may also notice that the cumulative delay in Fig. 6 for the medium mobility setup is only marginally smaller than the "no mobility" setup. This can be explained by considering that (a) links remain down for a small period of time and (b) network links have a capacity of 10 MBps, while the offered load is only 3 Mbps, thus the network has enough capacity to compensate for the link down time, if the number of failures is small. On the contrary, when the number of failures increases, more packets are delayed in the network queues.

CONCLUSIONS AND FUTURE WORK

In this paper an extensive performance evaluation of a wireless multimedia-based model over a generic distance-vector protocol conducted under various *mobility* schemes. The performance analysis was applied to a (4-G) network such as IEEE 802.11b providing significant conclusions. We observed that *the throughput of receiving packets* deteriorated from tolerable (4.28%) to considerable (16.86%), under medium and high *mobility* configurations respectively. Thus, for video streaming applications, the queuing and propagation delay and the number of dropping packets on the delivery of the critical data would have a very observable visual effect on the final quality, making the viewing of such data trying and sporadic. Consequently, the use of mobility prediction is required in order to anticipate topology changes and perform rerouting prior to route breaks. Future work will include not only different *mobility* setups, but also performance related issues, such as prediction, and QoS.

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