IMPROVING PERFORMANCE OF A WIRELESS MULTIMEDIA TRAFFIC-ORIENTED NETWORK THROUGH PREDICTION OF ROUTING

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Abstract: Wireless Local Area Networks (WLANs) have developed into a viable technology to support multimedia traffic and are expected to support multimedia services with guaranteed Quality of Service (QoS) for diverse traffic types (video, audio, and data). In this paper, we consider the incorporation of prediction into a generic distance-vector routing protocol for WLANs, evaluate the performance of the resulting routing scheme. Our study considers the enhancement of Distributed Bellman-Ford algorithm, which is a widely used algorithm, and assesses the effectiveness of the enhanced version on top of a fourth generation system (4-G). In order to compare the performance of the standard protocol against that of the prediction-enhanced version, we gather metrics for the two most important network performance factors, namely packet throughput and delay under different mobility and traffic conditions, using the simulation environment of NS-2. Both medium- and high-mobility configurations have been considered in this study.

Key words: Performance Evaluation, Distance Vector Protocol, Routing Information Protocol, Mobile Ad-hoc Networks, Mobility, Multimedia.

1. INTRODUCTION

Ad hoc networks are presently enjoying unprecedented research interest, and are expected to provide opportunities for utilization of network applications in new future demands. There is also an increasing demand for wireless multimedia networks due to the attractiveness of providing network services to communicate using any type of media without any geographical restrictions. 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 tansitions 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.

The majority of traditional routing protocols in packet-switched networks are able to be classified as either Distance-Vector (DV) protocols or Link-State (LS) protocols [6]. In either case, the routing protocols typically specify that each node makes periodic advertisements to supply current routing information to its neighbours. A neighbour is subsequently able to calculate routing paths to network nodes based on the received information. Moreover, the node can also incorporate the information it has received into its own advertisements. Both algorithm classes allow a host to find the next hop neighbour that a packet must be sent to, in order to reach its final destination via the "shortest path". The shortest path is usually in terms of the number of hops; however, other suitable cost measures such as link utilization or queuing delay can also be used. In routing protocols 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.

In the case of LS protocols, the advertisements can contain information about every known link between other routing agents in the network. Prominent example of LS protocols is the Open Shortest Path First (OSPF) protocol [14]. Using OSPF, a node that obtains a change to a routing table or detects a change in the network, immediately multicasts the information to all other nodes in the network in an attempt to maintain routing tables in different nodes synchronized. OSPF optimizes the route update process, as compared to RIP, since only changes to the routing table of each node are broadcasted and not its entire table. It 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 (since moving nodes may enter or exit the wireless protocol range and thus the corresponding links change their states to up or down, respectively), 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 inappropriate for wireless ad hoc networks with limited *bandwidth*, especially when these exhibit *medium or high mobility rates* and potentially include a considerable number of nodes.

Mobile Ad-hoc networks can also be grouped based on the time that routing information is updated. Under this classification scheme two routing protocol classes, namely Proactive Routing Protocols (PRP) and Reactive Routing Protocols (RRP) [12] can be identified. Destination Sequenced Distance Vector (DSDV) [15] is a Proactive routing protocol that solves the major problem associated with the DV routing of wired networks. The DSDV protocol requires each mobile station to advertise to each of its current neighbours, its own routing table (for instance, by broadcasting its entries). The entries in this list may change fairly dynamically over time, so the advertisement must be made often enough to ensure that every mobile computer can almost always locate every other mobile computer. In addition, each mobile computer agrees to relay data packets to other computers upon request. At all instants, the DSDV protocol guarantees loop-free paths to each destination. Dynamic Source Routing (DSR) [16] is a reactive protocol. It computes the routes when necessary and then maintains them. Source routing is a routing technique in which the sender of a packet determines the complete sequence of nodes through which the packet has to pass; the sender explicitly lists this route in the packet's header, identifying each forwarding "hop" by the address of the next node to which to transmit the packet on its way to the destination host. Furthermore, converged approaches such as hybrid routing protocols [17] have been proposed..

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] – include provisions to 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.

With the introduction of packet-switched 2.5 and 3-G systems a whole new range of mobile data services is possible. New types of systems providing advanced services in specific locations are being developed as a complement to cellular systems. 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. 4-G has been defined as a completely new fully IP-based integrated system and network for both wired and wireless networks as well as computers, and communication technology. Thus it will be capable to provide such high-speed, high bandwidth indoor and outdoor environments (e.g. 802.11b/g standards for 11Mbps and 54 Mbps respectively) with end-to-end QoS and high-security, offering any kind of services at any time as per user requirements, anywhere with seamless interoperability, always on, affordable cost and one billing. 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 IEEE 802.11b based network model over both *medium and high 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 model can also be uniformly applied to several representative networks such as IEEE 802.11g providing a basis for fair comparison. In our study, we compared the performance metrics of a wireless multimedia traffic-oriented network enhanced through the incorporation of prediction against the classical model without any prediction into the routing protocol. The cases considered in this study are as follows:

- *medium mobility*, where a medium amount of links fail and restore during the experiment period
- *medium mobility* with prediction: same as above, with the incorporation of prediction into the routing protocol
- *high mobility*, where a large amount of the links fail and restore
- *high mobility with prediction*: same as above with the incorporation of prediction into the routing protocol

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 with prediction. Section 3 presents the results of our performance analysis, which has been conducted through simulation experiments, while section 4 provides the concluding remarks.

2. **THE MODEL ANALYSIS**

Figure 1 represents a multimedia traffic-oriented network, employing the IEEE 802.11b standard for node-to-node communication, modelled by 9 nodes with 3 sources, 3 sinks, 1 gateway, and 2 more nodes for incorporating prediction into the routing protocol. The use of prediction of routes and links as described by Su et al.

[18] focuses in the reduction of generating excess overheads, which is a major problem with routing protocols. 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 modelling and simulation of larger networks.

The main goal of the simulation and performance analysis presented in this paper is to investigate the potential issues related to route maintenance and link failures under different *mobility* configurations, as well as their impact on performance. The rationale behind the introduction of prediction to the routing protocol is to overcome serious performance degradation due to the *mobility* situations, and guarantee QoS.

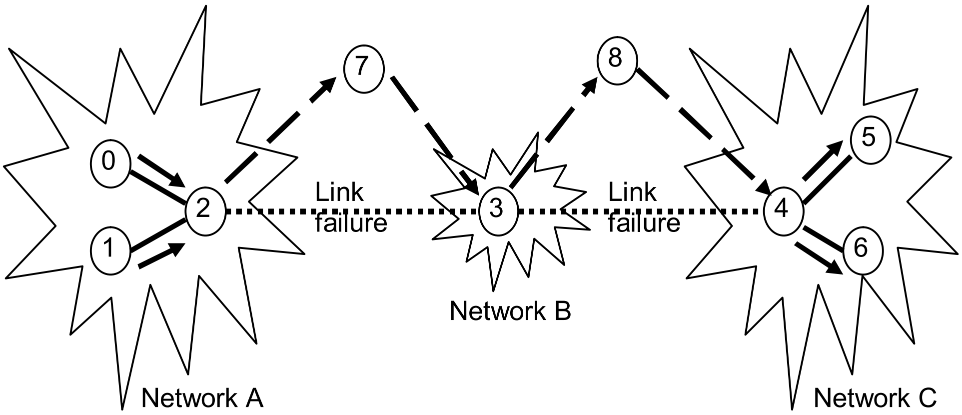

Fig.1. Multimedia-based network with prediction under link failures among boarder routers

As shown in figure 1, node 0 from network A can communicate with node 5 of network C via the routing path 0→2→7→3→8→4→5 during the link failures among border routers, where only a small number of packets are dropped or lost. The use of prediction aims at improving the network's overall performance, considering the two most important network performance factors, namely *packet throughput* and *delay*. Real-time services such as VoIP (Voice over IP) and video streaming are relatively restricted with delay compared with non real-time services (also called *best effort services*) such as web browsing and FTP data transfer. 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 with the incorporation of prediction into the routing protocol, where multimedia services are roughly categorized with data rate requirements and delay sensitivity.

- A nine *node* multimedia-based network model was evaluated, 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 supported by other two nodes (7 and 8) for alternative routing in the case of link failures among border routers.
- 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 0.002 sec (or 500 packets per second).
- The *packet size* was fixed to 512 Bytes incorporating a 2 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].
- Two different *mobility* settings were implemented. 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. From the simulation results, it was determined that this time was sufficient since the system had reached a stable state.

3. 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 two mobility conditions, namely *medium mobility* and *high mobility*, 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, which is the default value of advertInterval variable [10] for the distance-vector protocol used by simulator, 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 to 32 in order to determine the validity of a route. The following performance and operation metrics were collected:

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

TABLE 1: Packet information vs. mobility condition

Multimedia Model	**Total Packets Generated**	**Total Packets Dropped**	**Total Packets Lost**
Medium mobility	86,929	62	3,535
Medium mobility with prediction	100,861	62	35
High mobility	82,124	207	18,685
High mobility with prediction	106,728	206	135

Table 1 represents the numbers of total generated, dropped and lost packets over a multimedia-based IEEE 802.11b network, under two different *mobility* configurations with or without the incorporation of prediction into the routing protocol. Because all node communications are based on a drop-tail routing scheme, a packet gets dropped when the receiving queue is full. Consequently, in *high mobility* setup, where more congestion events occur due to the growing probability of link failures, the total *number of dropped packets* is greater than the one of *medium mobility* setup. Similarly, the total *number of lost packets* which contains only the packets dropped from the TCP connection is proportional to the time of link-failures and thus to *mobility* setup. According to this table, it is clear that the use of prediction into the routing protocol decrease dramatically the total numbers of *lost packets* at both *medium* and high *mobility* setups. *Dropped packets*, on the other hand, appear not to be affected in absolute numbers; however we must note that in the setups employing prediction substantially more packets are generated (16% more in the *medium mobility* setup and 29% more in *the high mobility* setup), thus the *packet dropping rate* is considerably smaller when prediction is employed.

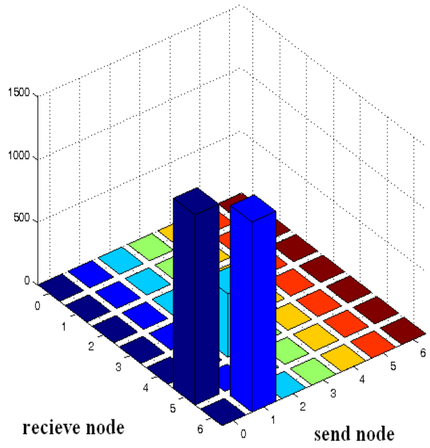

Fig.2. Number of lost packets under medium mobility

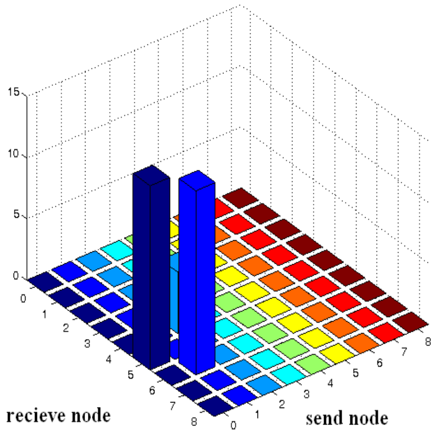

Fig.3. Number of lost packets under medium mobility with prediction

Figures 2 and 3 depict the numbers of *lost packets* at each receiving node over a *medium mobility* setup without or with prediction into the routing protocol respectively. It is worth noting that the use of prediction cut down 99% the number of *lost packets* at each node (observe the different scales on the y-axes).

Similarly, figures 4 and 5 represent the numbers of *lost packets* at each receiving node over a *high mobility* setup without and with prediction into the routing protocol respectively. According to figures 2 and 4, the fivefold number of *lost packets* (18,685) for the *high mobility* setup against those of the *medium mobility* one (3,535) at the case of using no prediction comes along with the greater time of link-failures. Nevertheless, it was found that the use of prediction cut down again 99.3% the *packet losses*.

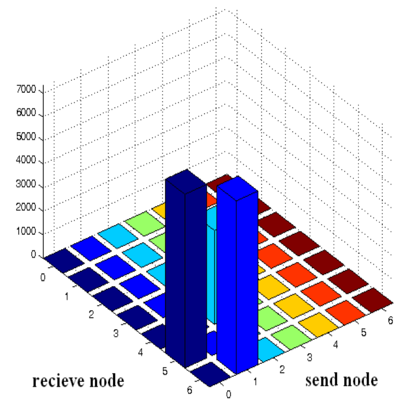

Fig.4. Numbers of lost packets under high mobility

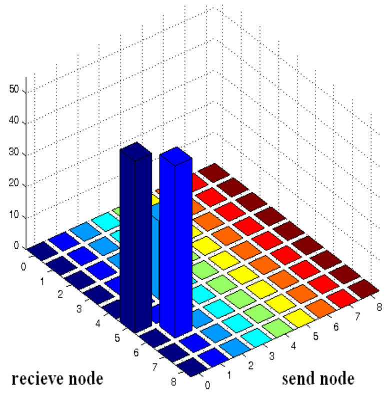

Fig.5. Numbers of lost packets under high mobility with prediction

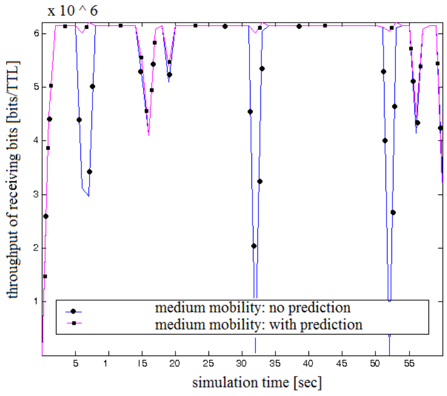

Fig. 6. Throughput of receiving bits vs. simulation time under medium mobility setup

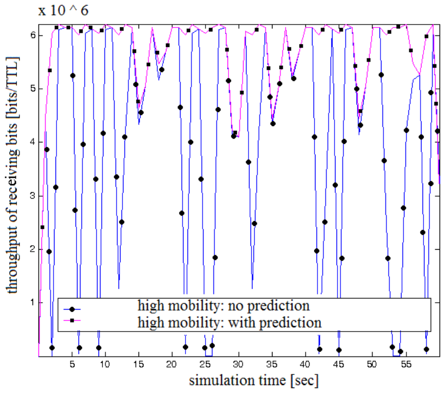

Fig. 7. Throughput of receiving bits vs. simulation time under high mobility setup

Figures 6 and 7 depict the *average throughput* of receiving packets at all *sink nodes* expressed in bps (bits per second) over the test-bed IEEE 802.11b multimedia-based network model for *medium* and *high mobility* setups respectively. In each diagram, metrics for both schemes one without and the other with prediction into the routing protocol are shown. The sharp *performance drop*s at both *mobility* setups are owing to link failures, but the incorporation of prediction into the routing protocol helps the protocol to quickly recover from the effects of failure and exploit the *bandwidth* of alternate routes. On the contrary, in the absence of prediction mechanisms link failures have higher recovery times and more severe impact on the network's performance. In the *high mobility* setup, where more link failures occur, the *average throughput* is expectedly less than in the case of the *medium mobility* setup.

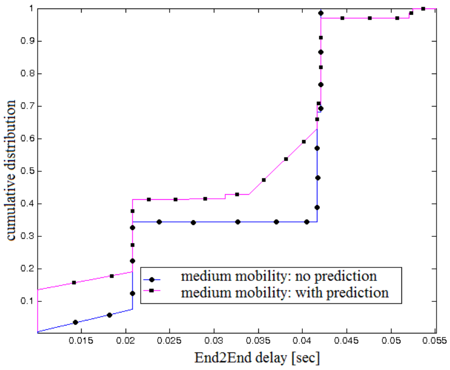

Fig. 8 End to End Simulation Delays vs. Cumulative distribution under medium mobility setup

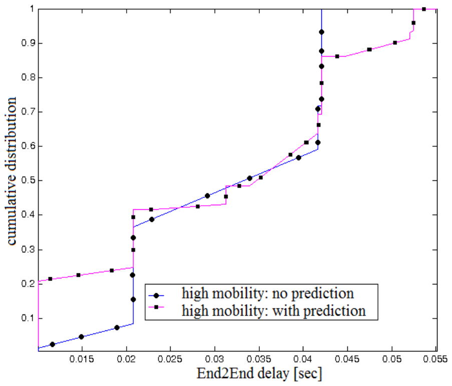

Fig. 9 End to End Simulation Delays vs. Cumulative distribution under high mobility setup

Figures 8 and 9 illustrate the *End to End Simulation Delays* vs. *Cumulative Distribution* on an IEEE 802.11b multimedia-based network model for *medium* and *high mobility* setups respectively with or without the incorporation of prediction into the routing protocol. When prediction is employed, packets have smaller *end-to-end delays*, since alternative routes are quickly exploited and thus packets spend less times in queues in the events of link failures. It is thus seen that under the *medium mobility* setup, the protocol with no prediction serves only 8% of the packets with *a delay* of 0,021 sec (these are packets originating from node 2 and having node 4 as their destination; the *delay* of 0,021 sec is the optimal one for these packets, accounting for two link propagation *delays* [2 * 10 msec] plus the *transmission delay* [0,00078125 sec, rounded to 0,001 sec]), while in the case that prediction is employed, the percentage of packets served with optimal *delay* rises up to 19%. When prediction is employed, 45% of the total packets have and *end-to-end delay* of less than 0,035 sec and 69% of the total packets have and *end-to-end delay* of less than 0,042 sec; with no prediction, the corresponding percentages are 36% and 67%. The advantage of the prediction scheme is clear; although it appears that the distribution percentages for high *delays* (time corresponding to four transmission slots) converge, we must recall that the prediction scheme serves 16% more packets (since more packets are generated in overall), while it also successfully serves an additional 4% of packets, which are lost when the routing scheme does not include prediction. Similar remarks can be made for the *high mobility* setup.

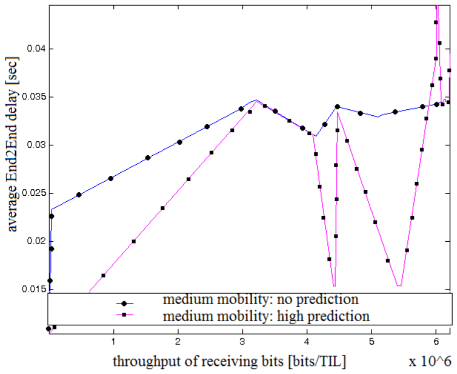

Fig. 10 Throughput of receiving bits vs. End to End Simulation Delays under medium mobility setup

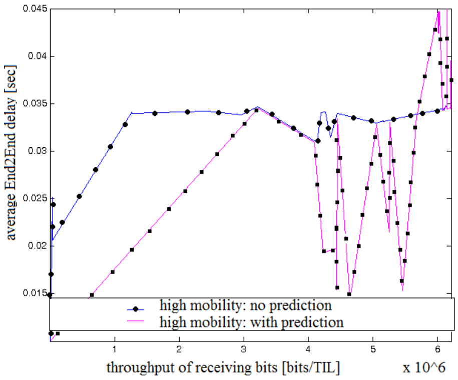

Fig. 11 Throughput of receiving bits vs. End to End Simulation Delays under high mobility setup

Finally figures 10 and 11 represent the *throughput of receiving bits* versus *End to End Simulation Delays,* on an IEEE 802.11b multimedia-based network model for *medium* and *high mobility* setups respectively with and without the incorporation of prediction into the routing protocol. The *throughput* is measured as bits per time interval length (TIL), which was set to 1 sec. From these diagrams we can see that the incorporation of prediction in the protocol leads to smaller *delays* to achieve the same *throughput*, which is generally expected taking into account the results depicted in fig. 6 and fig 7. What is worth commenting in these figures is that the *average delay* appears to rise in the area between $5.7 \mathrm{x} 10^6$ and $6.2 \mathrm{x} 10^6$ bits/sec, which is due to the fact that many packets having been alternatively routed due to link failures (and thus traverse routes with additional hops and are further penalized with the time to detect the link failure and recover from it) are mostly (> 90%) accumulated in this area. Most of these packets are discarded in the setup with no prediction and are therefore not considered in the graph.

4. 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 medium and high mobility scheme. The performance analysis was applied to a (4-G) network such as IEEE 802.11b providing a number of noteworthy conclusions. First, we observed that the number of lost packets in the case with no prediction rises from *tolerable* (4%) in the *medium mobility* configuration to *considerable* (22.7%) in the *high mobility* configuration. In the same case (no prediction), both the *end-to-end delay* and the *network throughput* appear to be considerably affected by link failures. Taking these into account, streaming media presentations over networks not employing prediction will be problematic and the final media quality will be considerably degraded. The introduction of prediction, which allows the network to anticipate topology changes and perform rerouting prior to route breaks, is found to alleviate these problems, almost eliminating lost packets and improving *throughput* and *end-to-end delay* . Future work will include different *mobility* setups, network node count and subnet participation, and different traffic patterns, taking into account mixtures of traffic with different QoS requirements such as streaming audio and video, web browsing and file transfer.

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