Pessimistic Backoff for Mobile Ad hoc Networks

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Abstract

Backoff algorithms have been introduced to solve the problem of collisions over networks. In the case of MANETs, extra point had to be taken into account while developing backoff mechanisms as part of the Media Access Control (MAC). During the process of developing backoff algorithms, many solutions have been proposed. The proposed mechanisms have suggested using certain behaviours to increase the Contention Window (CW) to avoid future transmission failures. In this paper, a new backoff for MANETs is suggested. In the new Pessimistic Linear-exponential Backoff (PLEB), a combination of two increment behaviours is introduced. Results show that the new backoff significantly improve total network throughput and reduce average packet delay.

Keywords: MANET, MAC, Backoff, throughput, Average delay

1. Introduction

Since their emergence in the 1970s, wireless networks have become increasingly popular in the world of computer research. This is particularly true within the past decade, which has seen wireless networks being adapted to enable mobility. There are currently two variations of mobile wireless networks [1], infrastructure and ad hoc wireless networks. Wireless networking increases availability and allows rapid

deployment of wireless transceivers in a wide range of computing devices such as PDAs, laptops and desktop computers [4]. In their early stages, wireless networks came as a result of the technological advances and extensions of LAN model as detailed in 802.11 standard [5].

According to the literature of research on backoff algorithms, many modified backoff mechanisms have been suggested [2,3,7]. A backoff timer has to be at some point between what is a considered long or short backoff time. The main two increment schemes used for CW sizes are either a linear increment [7] or an exponential one [5]. Exponential backoff mechanisms have shown failure to achieve adequate network throughput and have caused long delays over the network. The well known example of these backoff mechanisms is the standard BEB implemented in the IEEE 802.11 network protocol. On the other hand, linear increment of CW sizes produces slower expansion of CW size. However, the linear increment does not allow adequate time before retransmission. The Linear Multiplicative Increase Linear Decrease backoff (LMILD) is an example of the linear increment behaviour.

This paper suggests a new backoff algorithm which aims to improve the performance of a MANET in terms of network throughput and average packet delay. In the new suggested algorithm, the exponential backoff is combined with linear increment behaviour. Although the backoff period needs to be incremented after a transmission failure, the increment needs to avoid infinite extension of the contention window size while preventing too short Backoff periods. This paper introduces a new backoff algorithm which employs a combination of the linear and exponential increments. The combination of the two increment behaviours intends to merge the advantages of the two behaviours. By using the linear part, the proposed algorithm targets reducing network delay. The use of the exponential increments aims to produce adequate lengths of backoff times in order to improve network throughput. The simulation results presented later in this chapter reveal that the new suggested backoff mechanism improves both total network throughput and average packet delay under the assumption that contentions do not resolve in a short period of time.

This paper is structured as follows. Section 2 discusses related work. Section 3 introduces the new backoff algorithm. Section 4 describes the set up of experiments. Section 5 reports performance results and analyses network. Finally section 6 concludes the paper and outlines some future directions for this research.

2. Related Work

Z. Haas and J. Deng [6] have been active in the field of backoff mechanisms. In [6] Haas and Deng proposed The Linear Multiplicative Increase and Linear Decrease

(LMILD) backoff for use with the IEEE 802.11 Distributed Coordination Function. According to the LMILD scheme, colliding nodes multiplicatively increase their contention windows, while the other nodes overhearing the collisions increase their contention windows linearly. After successful transmissions, all nodes decrease their contention windows linearly. Preliminary study has shown the LMILD scheme out-performs the standard Binary Exponential Backoff (BEB) scheme deployed in the IEEE 802.11 MAC over a wide range of network sizes.

3. The Pessimistic Linear Exponential Backoff (PLEB) Algorithm

The new proposed backoff algorithm in this paper is referred hereafter as the Pessimistic Linear Exponential Backoff (PLEB). This algorithm assumes that a transmission failure is due to congestion in the network. This congestion could be the result of a high traffic rate or a larger number of nodes present in the network. PLEB works on the premise that congestion is not likely to be resolved in the near future. Therefore, as a first response to a transmission failure, PLEB exponentially increases the contention window size. An exponential increment forces a longer waiting time before trying the next transmission. However, after a number of exponential increments, PLEB starts to increase the timer linearly instead of the exponential increment in order to avoid increasing backoff more excessively.

In general, the basic functionality of PLEB aims to a less dramatic growth of the contention window size towards the maximum value allowing nodes to perform more attempts to access the channel after a reasonably affordable backoff time. Figure 1 shows the basic functionality of PLEB.

Figure 1 Pessimistic Linear/Exponential Backoff Algorithm

```
Step 0: Set BO to initial value
Step 1: While Bo ≠0 do
            For each time slot
                If channel is idle then BO=BO -1
Step 2: Wait for a period of IDFS then  Send
        If (sendFailure) then
            if ( numberOfBackoffs <= N)  then
                CW =CW *2
            Else
                CW = CW + T
            Go to step 1
Stop
```

4. Experiment setup

In order to assess the performance of PLEB, this paper compares the performance against LMILD algorithm.

Table 4.1: Summary of the parameters used in the simulations of PLEB algorithm

Parameter	Value
Transmitter range	250 meters
Bandwidth	2 Mbps
Simulation time	900 seconds
Pause time	0 seconds
packet size	512 bytes
Topology size	1000×1000 m^2
Number of node	10,50,100
Maximum speed	1,4 and 10 m/s

Three different values have been used for each of the factors considered in this research: namely, the number of nodes, mobility speed, and traffic load. The number of nodes has been set to 10, 50 and 100 nodes. In the case of mobility speed, this research uses a speed of 1 m/s, 4 m/s and 10 m/s. Moreover this work uses CBR traffic rates of 1 packet/s, 20 packets/s and also 100 packets/s in the simulations conducted.

5. Results and analysis

In this section, network performance is measured in terms of the total network throughput and average packet delay.

Total Network Throughput

Simulation results show that PLEB does not achieve higher network throughput compared to LMILD, for a network of size 10 nodes. This is not surprising since a network with such a small number of nodes is an ideal environment for LMILD. Firstly, with fewer nodes, it is easier for LMILD to update the backoff timer at each node as collisions occur in the network. Secondly, a network with a few nodes results in few collisions since there are fewer nodes to contend for channel access. Therefore, using PLEB for this size of network is not better than LMILD because of the extra delay introduced by the exponential quick-response of PLEB.

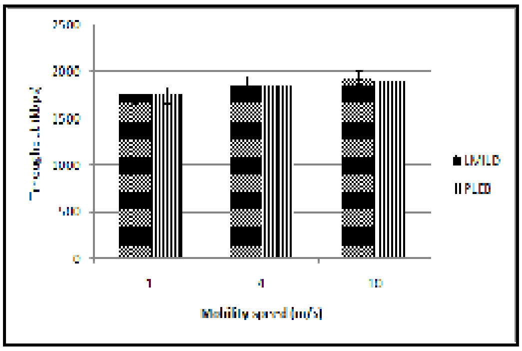

Figure 2 – Network speed vs. Network throughput in PLEB and LMILD for 10 nodes and traffic rate of 1 packet/s

Figure 2 depicts the throughput levels of PLEB against LMILD for a network of size 10 nodes and a traffic rate of 1 Packet/s. As seen in this figure, the levels of throughput are indicating that PLEB has the same performance levels as LMILD.

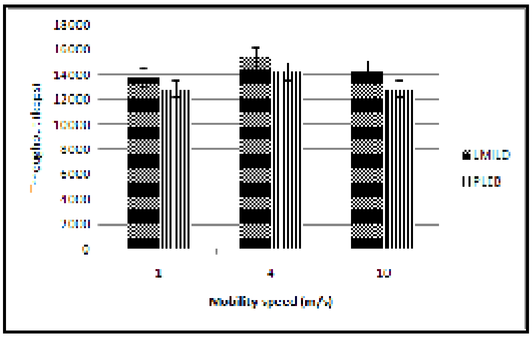

Figure 3 - Network speed vs. Network throughput in PLEB and LMILD for 10 nodes and traffic rate 20 packets/s

Figure 3 presents the throughput results when the traffic load is relatively moderate, which this work considers to be the rate of 10 Packets/s. The first piece of information that this figure provides in addition to previous figures is that increasing the traffic load here has reversed the performance gap between the PLEB and LMID algorithms in favour of the latter as the mobility speed increases. Moreover, it is noticeable that both algorithms perform better with low node mobility speed.

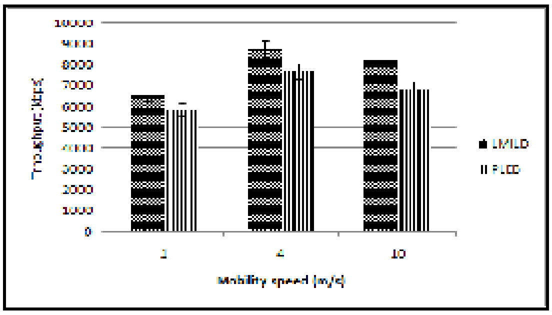

Figure 4 - Network throughput for 10 nodes, traffic rate of 100 packet/s

An interesting observation in Figure 4 is that the gap between the two algorithms is larger as the speed increases. Considering the basic functionality of PLEB suggests the possibility of this gap is caused by using a certain change point between the Linear and the Exponential increment behaviours of PLEB. It is worth studying to examine this change point in order to gain a better understanding and to further improve the performance of PLEB.

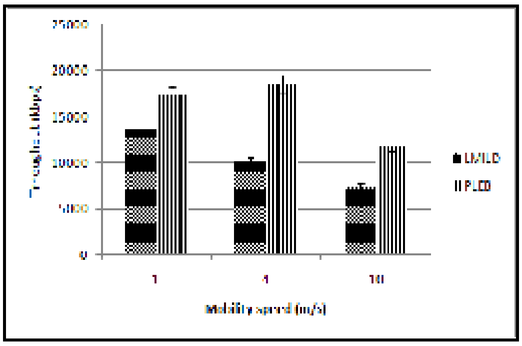

Figure 5 - Network throughput for 50 nodes, traffic rates of 1 packet/s

When the number of nodes increases, the result is a relatively better environment for PLEB. After increasing the number of nodes in the network to 50 nodes, PLEB starts to significantly outperform LMILD. As seen in Figure 5, the improvement is as high as 45% compared to LMILD. As mentioned earlier, a higher number of nodes provide a better environment for PLEB to function best. However, Figure 4 also shows that both PLEB and LMILD suffer from degradation in performance at higher mobility speeds. Even with the higher number of nodes tested here; medium mobility speed is still the best environment for PLEB compared to lower or higher speed values. Figure 6 represent throughput under 10 packets per second.

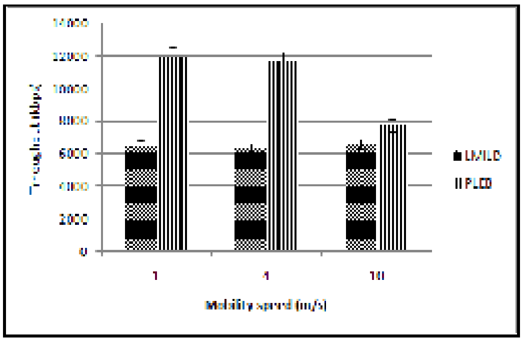

Figure 6 - Network throughput for 50 nodes, traffic rate 20 packet/s

As predicted in the previous graph, Figure 6 shows that the total network throughput decreases when the network traffic increases to 20 packets/s. Such a decrease indicates that the length of backoff times introduced by the two backoff algorithms becomes an obstacle in the way of delivering data messages to destination nodes. Figure 7, shows that increasing the traffic rate to 100 packets/s causes more decrease in network throughput.

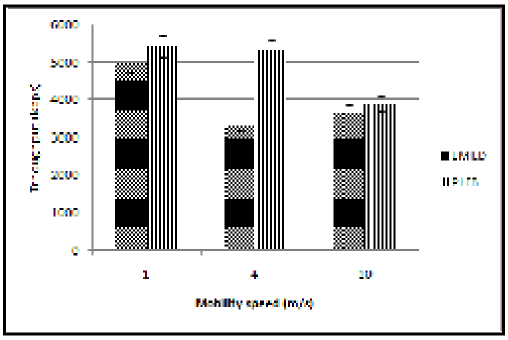

Figure 7 - Network throughput for 50 nodes, traffic rate of 100 packet/s

When introducing the challenge of larger network sizes, in terms of number of nodes, the tested networks form a relatively difficult task for backoff algorithms. In this category, the performance of PLEB is put for test under the highest values of the three factors used in this research. Performance levels are different depending on mobility speed at this network size.

In the case of Low mobility speed, a high congestion leads to PLEB achieving better performance. Lower mobility allows using longer backoff times without having a high risk of redundant idle time leading to a node leaving transmission range before the backoff timer expires. Moreover, having a large number of nodes increases the incompleteness of knowledge needed by LMILD about collisions happening over the network.

On the other hand, higher speed reduces the chance of a successful transmission after an exponential backoff timer expires due to the threat of a node leaving transmission range and breaking the link to the destination or the next hop in case the current destination is not the final destination of the packet.

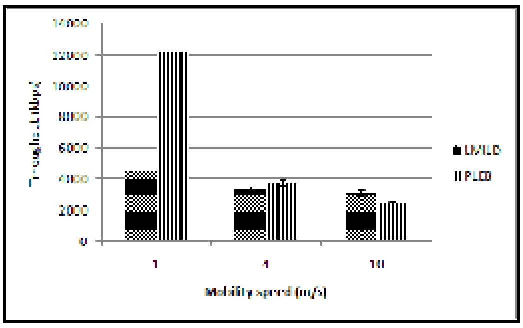

Figure 8 - Network throughput for 100 nodes, traffic rate of 1 packet/s

As shown in Figure 8, at a traffic rate of 1 packet per second, PLEB achieves higher throughput level with low mobility speed. However, as the speed increases, PLEB has a slightly higher performance at medium speed and lower throughput is achieved at high mobility speed.

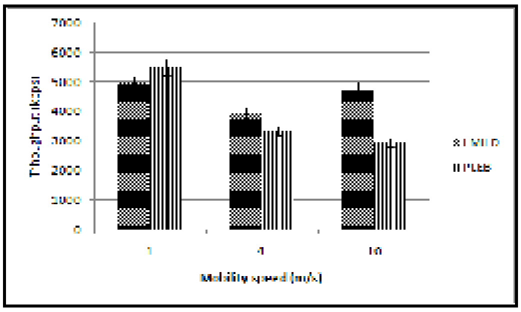

Figure 9 - Network throughput for a network of 100 nodes, traffic rate of 20 packet/s

The next set of figure plots results for even higher traffic rates. At this stage, a traffic rate of 20 packets/s is analysed. Figure 9 demonstrates that higher mobility speeds are still not the best environment for PLEB to achieve high network throughput. When high mobility speed is involved, LMILD has a better accessibility to more nodes over the network. Therefore, it is easier to gather information needed about colliding nodes.

The last figure for this network size, Figure 10 does not show any different behaviour of the algorithms evaluated. The same conclusions of PLEB having higher throughput under slow mobility is noticed here. However, in spite of the higher performance of LMILD at high speeds, the performance levels are higher for PLEB with medium speeds assuring that medium speed mobile networks form a good environment for PLEB to perform.

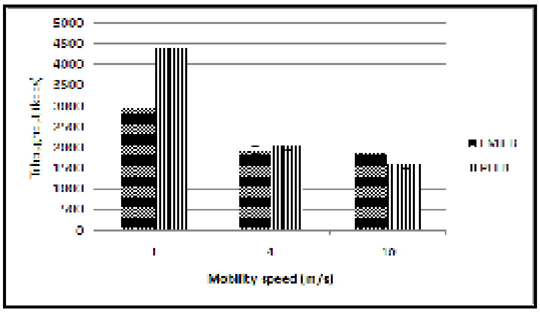

Figure 10 - Network throughput for 100 nodes, traffic rate of 100 packet/s

Average Packet Delay

In this section, the measurements of the average packet delay are presented using the same set of experiments discussed for the total throughput. Beginning with a small number of nodes, PLEB and LMILD appear to have a huge difference in levels of performance. The low average packet delay levels reported for PLEB is due to the fewer number of CW size expansion caused by the small number of nodes and the low traffic rate. On the other hand, the knowledge gathered by LMILD is accumulated from all neighbouring nodes. The results of a network under 1 packet/s are shown in Figure 11.

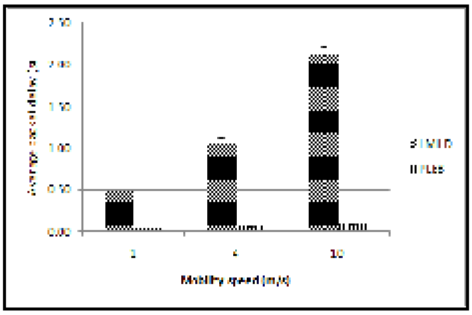

Figure 11 - Average packet delay for LMILD and PLEB in a network of 10 nodes and traffic rate of 1 packet/s

As the traffic rate increases, the small number of nodes provides a better environment for LMILD since information gathering is performed for smaller number of nodes. However, PLEB still has the significantly lower average packet delay.

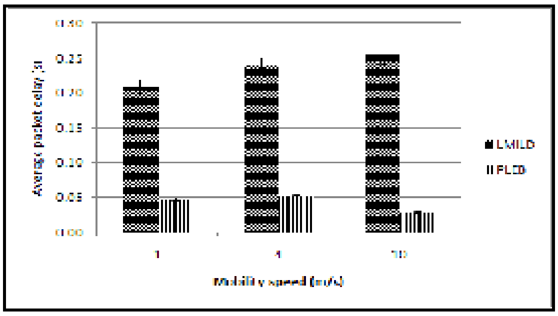

Figure 12 Average packet delay for LMILD and PLEB in a network of 10 nodes and traffic rate of 20 packet/s

Figure 12 shows that average packet delay caused by LMILD increases with traffic rate where stays at the same levels for PLEB. As the traffic increases, PLEB still achieves lower average packet delay compared to LMILD. Figure 4.14 presents average packet delay for 100 packets/s.

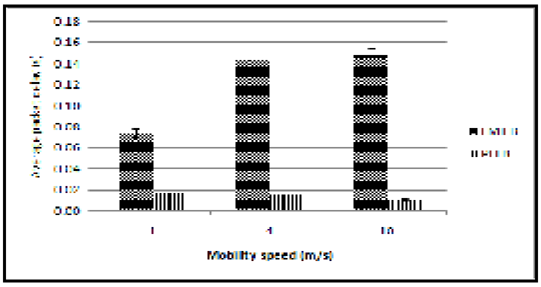

Figure 13 Average packet delay for LMILD and PLEB in a network of 10 nodes and traffic rate of 100 packets/s

For networks of medium size, that is 50 nodes, a low traffic rate is a better environment for PLEB to achieve a lower average packet delay. With a longer time between the arrivals of messages to the sending queue of source node, the exponential backoff deployed by PLEB provides adequate waiting time before transmissions with a small possibility of congestions caused by a large number of ready-to-send packets. Figure 14 introduces this result for a network with traffic rate of 1 packet per second.

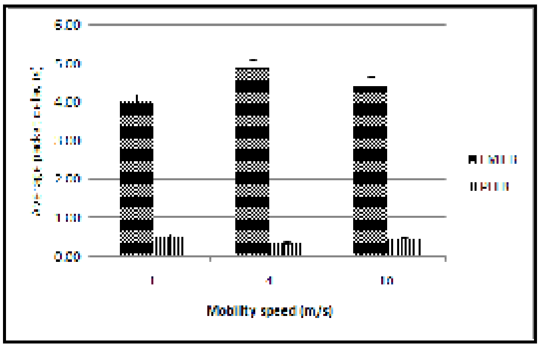

Figure 14 Average packet delay for LMILD and PLEB in a network of 10 nodes and traffic rate of 1 packet/s

The same observations are made for networks with 20 packets/s. These are presented in figures 15.

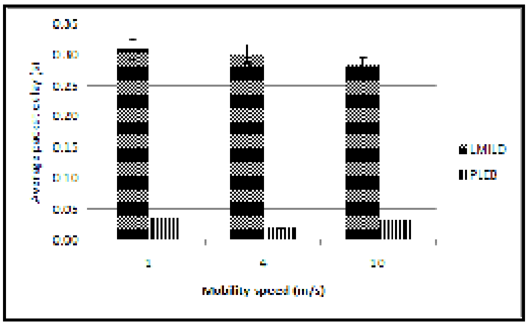

Figure 15 Average packet delay for LMILD and PLEB in a network of 50 nodes and traffic rate of 20 packet/s

When more traffic is injected into the network, the network idle time caused by PLEB is balanced by the higher number of ready-to-send packets over the network. This is results in a considerable reduction in average packet delays of PLEB and LMID. Figure 16 demonstrates the reduction of delay for PLEB and LMILD for a network of 100 packets / second.

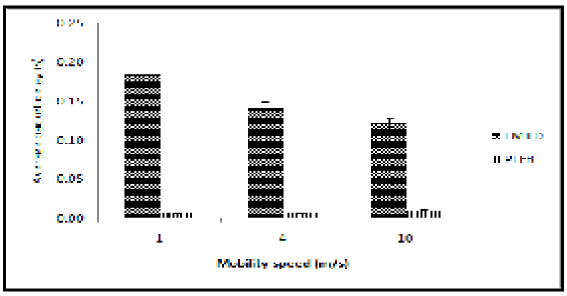

Figure 16 Average packet delay for LMILD and PLEB in a network of 50 nodes and traffic rate of 100 packets/s

For networks of a large number of nodes, 100 nodes in this work, PLEB significantly reduces average packet delay in comparison with LMILD. However, PLEB causes a higher network delay at low mobility speed in comparison with medium and high speeds. When the traffic rate is low, congestion over the network is unlikely to be resolved during the first few transmission failures when nodes are moving at a low speed, which is 1 m/s. However, higher speeds increase the possibility of resolving congestions through the discovery of new routes and change of hop order. This explains the reduction of average packet delay for LMILD with increased mobility speed. Figure 17 demonstrates this observation for a network of 100 nodes under a traffic rate of 1 packet per second and a speed of 10 m/s.

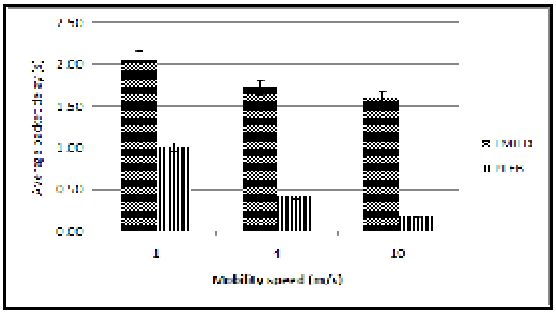

Figure 17 Average packet delay for LMILD and PLEB in a network of 100 nodes and traffic rate of 1 packet/s

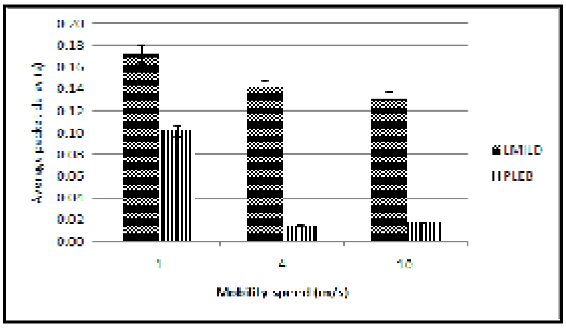

Figure 18 Average packet delay for LMILD and PLEB in a network of 100 nodes and traffic rate of 20 packets/s

When a heavy traffic load, (e.g. 20 packet/s), is applied to a large network of 100 nodes, PLEB shows a better performance in terms of the average network delay. As revealed in Figure 18, a high traffic rate is a cause of high contention levels in the network, providing the perfect environment for PLEB to achieve less average delay when compared to LMILD. The same results of Average packet delay for a network of 100 nodes and traffic rate of 100 packets/s as shown in figure 19.

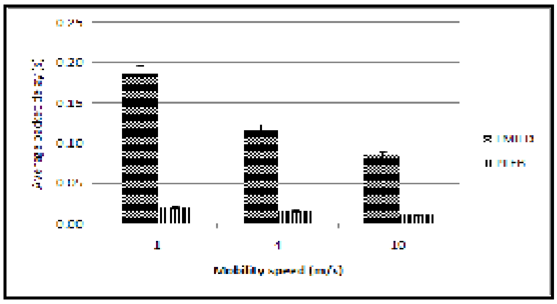

Figure 19 Average packet delay for LMILD and PLEB in a network of 100 nodes and traffic rate of 100 packets/s

6. Conclusions

In this paper, a new backoff algorithm, referred to as the Pessimistic Linear Exponential Backoff (PLEB), has been introduced. PLEB is a combination of exponential and linear increment behaviours. In order to evaluate the performance of PLEB, this chapter has compared its performance against the existing Linear Multiplicative Increase Linear decrease (LMILD) algorithm. Simulation results have shown that PLEB achieves a lower performance, compared to LMILD, for a network of size 10 nodes.

When the number of nodes increases, PLEB provides a better performance than MLIMD. A large numbers of nodes (e.g. 50 nodes and over) makes it more difficult for LMILD to be able to update backoff timers after each collision due to the increased collision rate. Moreover, PLEB achieves better performance with low mobility speed. On the other hand, the performance advantage of PLEB is reduced with high mobility speed as this reduces the chance of a successful transmission after an exponential backoff timer expires. This is due to fact that when nodes move with a high speed there is high chance that a node leaves transmission range and thus breaks the link to the destination or the next hop in case the current destination is not the final destination of the packet.

As for average packet delay, PLEB has not shown an improvement when used with small and medium size networks. However, results have shown significant improvements on average packet delay when PLEB is implemented for large network sizes especially when combined with high traffic rate and mobility speed.

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