Fragmentation Analysis For Scalable Wireless Local Area Networks

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Abstract: Wireless networks are being deployed widely to provide network connectivity without requiring the web of physical wires. A collection of a small number of workstations connected using a wireless network forms a wireless local area network (WLAN) that follows the IEEE 802.11 standard. In a WLAN, the communication takes place using packets whose sizes may vary and have a significant impact on the delay incurred during transmission. In this regard, fragmentation may play a vital role in reducing the delay for efficient transmission across the network.

This paper analyzes the performance of WLANs with respect to the packet fragmentation. We simulate three network scenarios having 4, 8 and 12 wireless workstations respectively. The scenarios are simulated using OPNET IT Guru Academic Edition v 9.1 while incorporating a peer-to-peer (P2P) based communication model for each scenario. We compare the performance of non-fragmented and fragmented communication in terms of network delay and throughput. Our results show that the fragmentation minimizes the delay and increases the throughput, however its impact is highly dependent on the size of the underlying network.

Keywords: Wireless Networks, Fragmentation, Network Delay, Network Scalability, P2P Networks.

1. INTRODUCTION

Wireless networks connect devices through access points at small distances to make them communicate without any physical cables encompassing the entire network. These networks follow the IEEE 802.11 specification [1] in order to operate at recommended communication speeds. The deployment of wireless networks is becoming ubiquitous and is considered to be an effective source to facilitate data communication at any place within a large covered region. Just like wired networks, the wireless networks also follow the networking standards in order to ensure efficient data transmission.

The performance of a network is evaluated using several metrics specified by the quality of service (QoS) [2-6] that describes the minimum standards to be achieved during data transmission. There are several factors that impact the QoS with the most important being the *network delay* (or just delay). The packets from source to destination reach at various intervals with varying delays. For networks running real-time applications (with the streaming video or telephony communication), the delays deteriorate the performance of the applications. An effective network always aims at providing QoS through an efficient and reliable delivery of data packets across the network. Similarly, another metric called *throughput* represents the rate of packet delivery and is used for evaluating the network performance. An efficient network should therefore have a small network delay and a high throughput.

While transmitting data in wireless networks, the packet sizes may vary. The transmission of large data packets may not be efficient and increases the delay of transmission [7]. To minimize the delay, the packets may be fragmented into smaller sizes so that they might be transmitted efficiently. The *fragmentation* [8-10] therefore impacts the delay and is considered to be an effective technique for an efficient and reliable delivery of data packets in wireless networks.

In this paper, we evaluate the impact of fragmentation with respect to various sizes of wireless networks. To accomplish that, we use various scenarios each with different number of wireless workstations communicating in a peer-to-peer fashion. The scenarios implement fragmented and non-fragmented data communication. We simulate our network scenarios using OPNET IT Guru Academic Edition v 9.1 [11]. The results are compared in terms of the overall network delay incurred during transmission.

The remaining part of the paper is organized as follows. Section 2 describes succinctly the fragmentation mechanism and its implementation in wireless networks. The experimental configuration is provided in Section 3. Section 4 presents and analyzes the performance results obtained from our simulation,

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and is followed by the conclusion and future work in Section 5.

2. FRAGMENTATION IN WIRELESS NETWORKS

Fragmentation mechanism as described in IEEE 802.11 standard allows conversion of data packets into small parts called fragments with each fragment representing an independent entity to be transmitted across the network. The unicast fragments (for single destination) are sent from source to destination and are re-assembled to produce the actual packet at the destination. Subsequently, the packet may be processed by other layers. The broadcast fragments are not allowed by the 802.11 standard as they could significantly increase the network traffic and consequently result in worsening the network performance.

A fragment consists of a frame header, a check sequence and other relevant information used to identify the location of the fragment within the data packet. The communication of fragments takes place until the *More* field in the header contains a zero value. As long as it contains the value 1, the packet re-assembling continues [10].

Since the data packets become smaller due to fragmentation, the collisions occurrence also reduces thereby improving the performance of data transmission in the network. In order to fragment packets, a threshold value is specified so that only the packets with size larger than the threshold are fragmented instead of all the packets.

The fragmentation is expected to improve the performance of a network, however it comes at a cost that may be detrimental for the network. The overhead of splitting a packet into smaller fragments and re-assembling them may not always be beneficial. We therefore perform a quantitative evaluation of the impact of fragmentation in wireless networks while taking into account different sizes of the wireless networks.

3. EXPERIMENTAL SETUP AND CONFIGURATION

We have used different scenarios to analyze the network performance with fragmented and non-fragmented data transmission in wireless networks. Figure **1** shows a local area network with 4 wireless workstation nodes (peers) each of (built-in) type *wireless_wkstn_adv (fix)*. This network represents a logical scenario that is used in 2 physical scenarios corresponding to fragmented and non-fragmented communication respectively. As we have three logical scenarios to represent wireless networks with 4, 8 and 12 clients respectively, we obtain 6 physical scenarios. For each physical scenario, the simulation is set to run for 300 seconds.

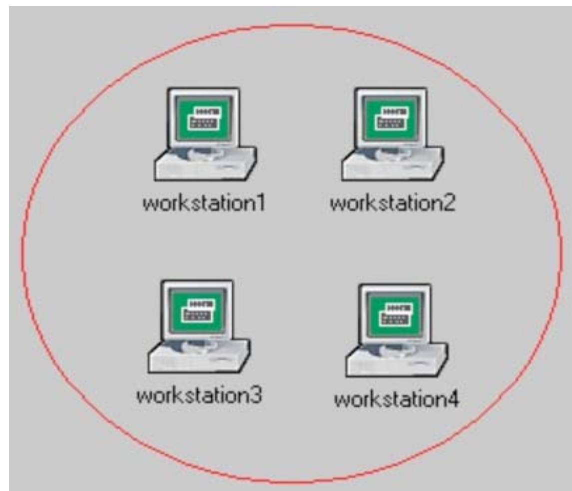

Figure 1: A logical scenario with 4 wireless workstations.

The inter-arrival time for the packets is configured to be 0.01 seconds, whereas the packet size is set to be 2048 bytes. The data rate for each scenario is set to be 2Mbps. Other parameters used for simulating the wireless network scenarios are given in Table **1**.

4. PERFORMANCE RESULTS

Figure **2** shows the results obtained for the delay incurred for logical scenario-1 having 4 wireless workstations. The fragmented transmission has an

Table 1: Configuration of Parameters and their Values Used for Experimentation

Parameter	Value (~MB)	Parameter	Value (~MB)
Destination	Random	Bandwidth	1000 KHz
Start Time	Constant - 2	Buffer Size	1024000 bytes
ON time	Exponential-100	Large Packet	20
OFF time	Exponential-1	Reception Power	7.33E-14

average delay of 15.96 seconds, whereas the non-fragmented transmission has an average delay of 17.99 seconds. Consequently, the fragmented communication performs 11.33% better than the non-fragmented communication.

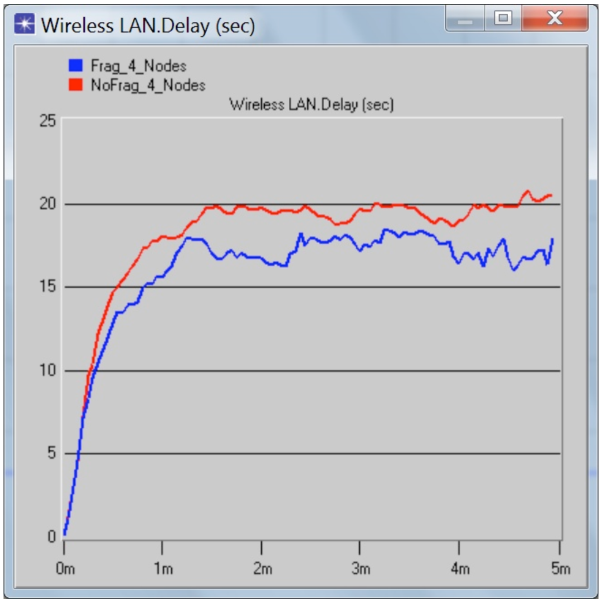

Figure 2: Delay for WLAN with 4 workstations having fragmented and non-fragmented configurations.

Similarly, the results for scenario-1 with 4 wireless workstations are given in Figure **3**. The fragmented and non-fragmented communications achieve throughput of 42184.2 and 37012.43 bits/second respectively. The fragmented communication therefore produces 13.97% improvement in throughput over the non-fragmented communication.

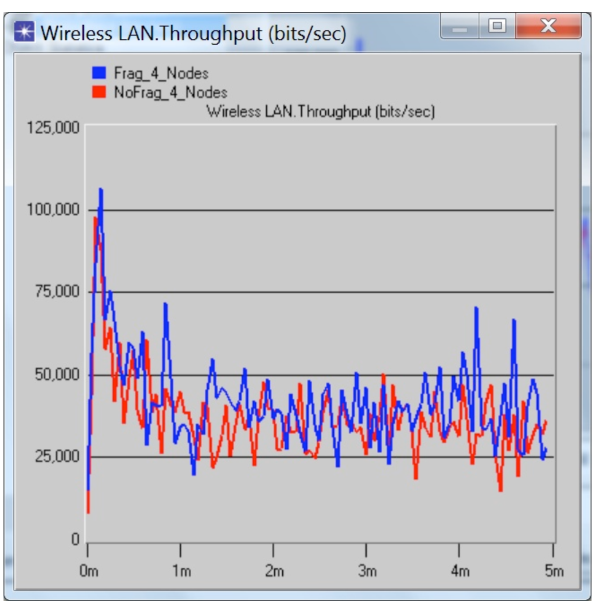

Figure 3: Throughput for WLAN with 4 workstations having fragmented and non-fragmented configurations.

The results of delay and the throughput for logical scenario-2 having 8 wireless workstations are given in Figure **4** and Figure **5** respectively. As shown in Figure **4**, the average delay incurred for fragmented communication has the value of 24.17 seconds, whereas for the non-fragmented communication the average delay is 26.69 seconds. The fragmented communication therefore performs 9.45% better than the non-fragmented communication. As shown in Figure **5**, the fragmented communication attains a throughput of 11634.72 bits/second. In contrast, the

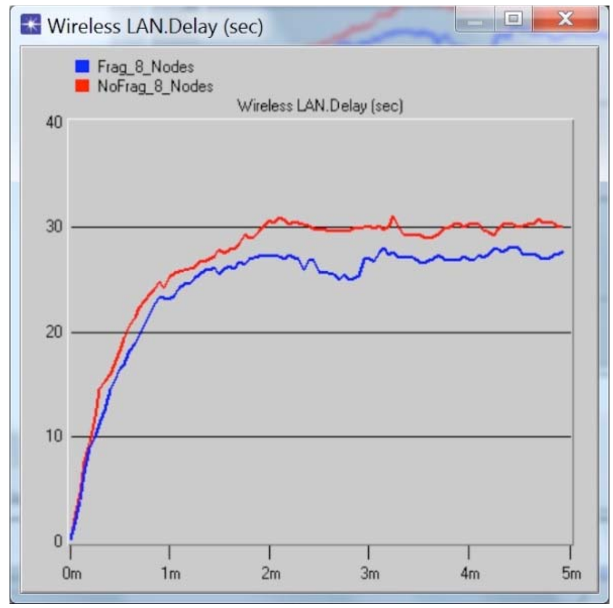

Figure 4: Delay for WLAN with 8 workstations having fragmented and non-fragmented configurations.

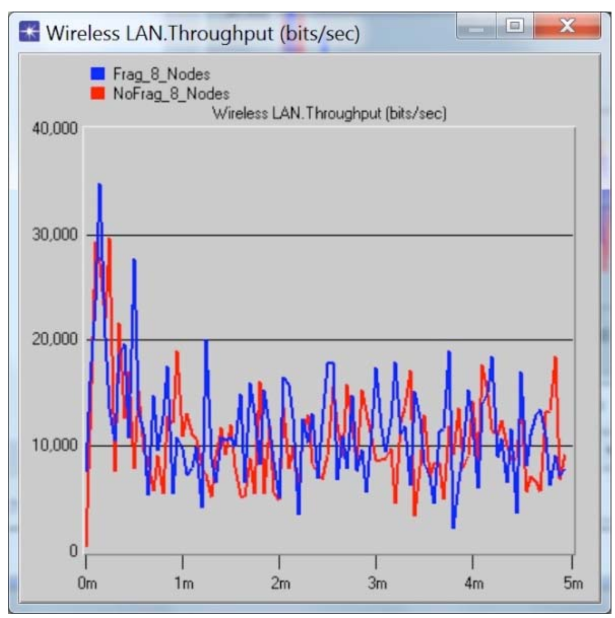

Figure 5: Throughput for WLAN with 8 workstations having fragmented and non-fragmented configurations.

non-fragmented communication achieves a throughput of 10776.96 bits/second. Consequently, the fragmented communication has a performance improvement of 7.96% over the non-fragmented communication.

Figure **6** shows the results obtained for the delay incurred for logical scenario-3 having 12 wireless workstations. The fragmented transmission has an average delay of 27.25 seconds, whereas the non-fragmented transmission has an average delay of 29.19 seconds. Consequently, the fragmented communication performs 6.64% better than the non-fragmented communication.

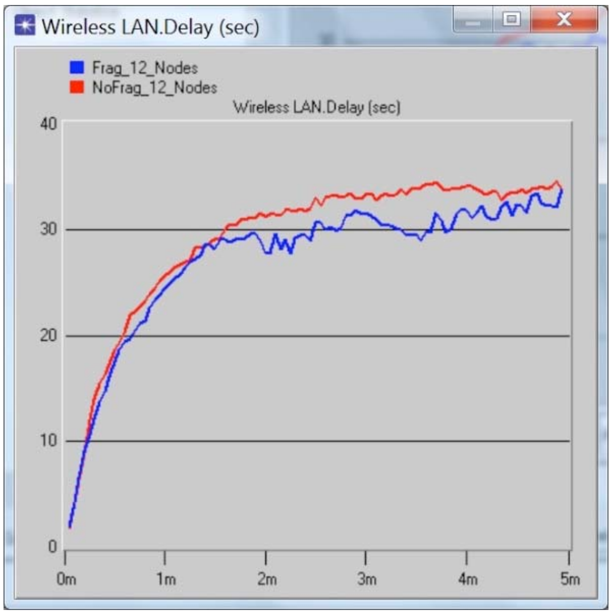

Figure 6: Delay for WLAN with 12 workstations having fragmented and non-fragmented configurations.

Similarly, the throughput results for logical scenario-3 with 12 wireless workstations are given in Figure **7**. The fragmented and non-fragmented communications achieve throughput of 6490.56 and 13352.56 bits/second respectively. The fragmented communication therefore produces 51.39% improvement in throughput over the non-fragmented communication.

Overall, the fragmented communication produces an average delay of 23.81 seconds, whereas the non-fragmented communication has an average delay of 25.73 seconds. The fragmented communication therefore performs almost 7.48% better than the non-fragmented communication. Similarly, for the throughput, the fragmented communications attains an average of 20103.16 bits/second. In contrast, the non-fragmented communication attains an average throughput of 20380.78 bits/second, thereby producing

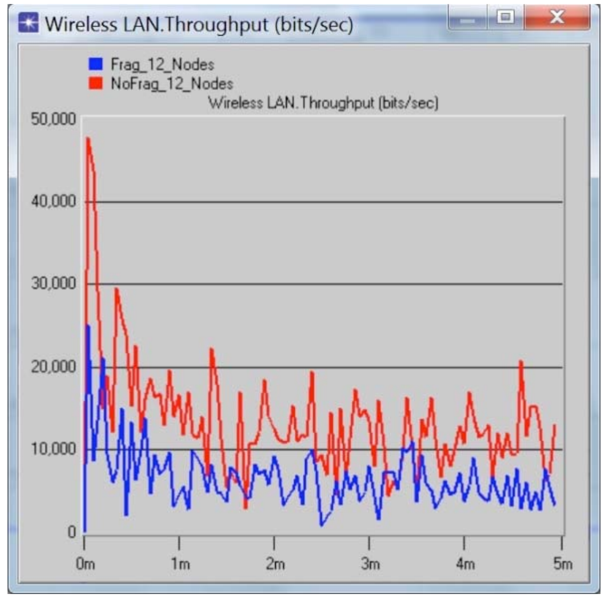

Figure 7: Throughput for WLAN with 12 workstations having fragmented and non-fragmented configurations.

an improvement of 1.38% over the fragmented communication.

With an increase in the number of workstations, there is a linear decline in the performance improvement obtained by fragmented communication in terms of the delay incurred. This implies the fact that the fragmented communication is better and produces a significant impact only for a small number of workstations. Similar is the case of throughput, where we find that the non-fragmented communication performs better in comparison with the fragmented communication for large sizes of wireless networks. The performance degradation in both the metrics (delay and throughput) is due to the overhead of activities (splitting and re-assembling of data packets) performed for fragmentation. The overhead of fragmentation increases with an increase in the number of workstations as a large number of data packets are being transmitted over the network. Consequently, the performance of the network deteriorates.

5. CONCLUSION AND FUTURE WORK

This paper evaluates the performance of the fragmented and non-fragmented data transmission in wireless networks with regards to the scalability. The number of workstations in a wireless network impacts the performance of these data transmission strategies. We have simulated wireless networks with 4, 8 and 12 workstations each communicating with all others in a peer-to-peer fashion.

Our simulation results show that for a small size of a wireless network, the fragmented data transmission outperforms the non-fragmented transmission. We have used the metrics of the network delay (seconds) and the throughput (bits/second) for evaluating the performance. For sizes of 4, 8 and 12 workstations in a WLAN, the fragmented communication has an improvement of 11.33%, 9.45% and 6.64% respectively in terms of the network delay incurred during transmission of data. However, there is a gradual decrease in the performance improvement implying that the increase in size of a WLAN deteriorates the performance of fragmentation as there is a large amount of overhead involved in splitting packets into multiple fragments and re-assembling them at the destination.

Similar to the delay results, there is a decrease in the performance of the fragmented communication in terms of the throughput obtained. Although for WLANs with 4 and 8 workstations, the fragmented communication performs 13.97% and 7.96% better than the non-fragmented communication, the performance of the fragmented communication deteriorates by 51.67% in comparison with the non-fragmented communication when there are 12 workstations in the wireless network.

As future work, we intend to perform a comparative analysis of the wireless networks with regards to the RTS/CTS (Request to Send / Clear to Send) data exchange used in conjunction with the fragmented communication. Both the approaches aim at minimizing the collisions and computing the impact of their combination can be useful for building large wireless networks that are reliable and more efficient.

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