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Novel Data Link Layer Encoding Scheme for Multi-hop Wireless Mesh Network

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Abstract

Wireless Mesh Network (WMN) provides multi-hop and multi-path communication by deploying network nodes in form of mesh topology and grasps the attention of research community and industry due to its features like self-healing and self-organizing etc. In multi-hop networks, bandwidth efficiency degrades with the increase in number of intermediate nodes. In this paper, we present a novel encoding scheme at data link layer with the characteristic of cut-through switch. By using the proposed technique, we can increase throughput by reducing re-transmissions in the network. We have verified our proposed method by simulation in NS3. The simulation results indicate that in-spite of high interference, we can achieve improved throughput and less delay with proposed model.

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Keywords: Wireless Mesh Network; DLL Encoding; MAC Layer Encoding;

1. INTRODUCTION

Wireless technology is used for multiple applications due to key benefits. Different variants of IEEE 802.11 are widely available and are very popular in use. The ongoing research in Ad-hoc Networking[8 3 11 5] focuses on military and some specialized civilian applications. The users are more interested in general purpose applications such as on-line gaming or multimedia applications[4]. Thus, bandwidth and internet connectivity is of high priority. Wireless Mesh network (WMN) provides both the functionality of infrastructure and Independent Basic Service Set (IBSS) mode. Mesh nodes may act as a relay station and can communicate directly without involving a base station[6]. However, proprietary solutions[19] provided by different organizations often have four types of nodes i.e. Stations (STAs), Mesh Access Point (MAP), Mesh Point (MP), and Mesh Portal (MPP). STAs get association with MAP which also has MP functionality where MP acts as a relay station. MPP connects a mesh network to the Internet and it also has MP

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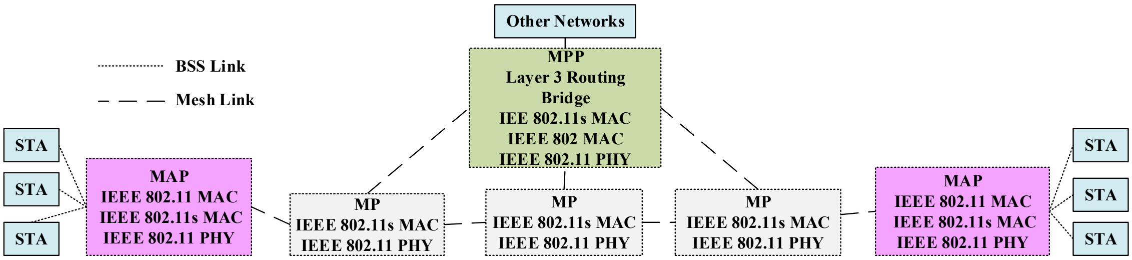

Fig. 1. Architecture of MWN with Protocol Stacks on Each Node

functionality. The IEEE 802.11s[1] protocol architecture is shown in Figure 1 for multihop. In-spite of having rich connectivity of the network, a node can be a bottle-neck due to relay functionality. In a dense environment nodes may face the issue of channel access due to weak signal strength and interference. Sometimes, the package has to be cut down at the last intermediate node, in-spite of the successful traversing of it on previous hops. In this scenario, re-transmission adds more delay. To overcome these problems, we propose a new model, which will help to reduce re-transmission attempts by disseminating redundant copies of frame and restoring it at the destination. Ultimately, it will reduce delays. For our model, we use a special feature of cut-through switch. Instead of waiting for reception of the whole packet, a cut-through switch forwards the frame as received. We combined this feature with multi-path WMN to get better results.

The rest of this paper is coordinated as follows: Section 2 will give overview of already proposed techniques in the literature. Section 3 will describe the proposed modification in MAC layer and its data unit. Section 4 will discuss the simulation of the proposed technique with current MAC layer and Section 5 will conclude the proposed research and give future directions.

2. LITERATURE REVIEW

In a WMN, traffic is aggregated at the portal nodes which introduces congestion and load balancing issue in the network. Some solutions were proposed to solve these issues, but most are generic. The ultimate goal of each proposed models is the efficient network resource utilization with minimal overhead. In[10], the authors proposed a modification in Ad-hoc On-demand Distance Vector (AODV) for multipath, called Ad-hoc On-demand Multi-path Distance Vector (AOMDV) and claimed better performance than the AODV. In[9], the proposed protocol showed the benefits of alternate path when the best available path is congested. The authors in[16], the proposed algorithm for end-to-end fairness of each running flow and a similar problem is discussed in[2]. In[12], a routing protocol is proposed for load balancing and it discussed that single path introduces greater packet loss in the network and showed greater improvement in throughput using simulation. The authors in[13] proposed a clustering algorithm for efficient route discovery and minimizing interference at the cost of greater control overhead. In[15], an architecture of multi-channel, multi-hop wireless ad-hoc network was proposed, and concluded that it increases good-put of network eight times as compared to a conventional network. Another optimized framework was proposed in[14] for opportunistic routing in WMN by taking advantage of the broadcast nature of wireless network. It also claimed 20- 200% increase in throughput as compared to single path routing and several times to the most recent opportunistic routing protocol like MAC independent Opportunistic Routing (MORE). In[18], the proposed opportunistic routing protocol used uni-cast with promiscuous mode of listening instead of broadcast and claimed a better throughput as compared to other routing protocols such as MORE, DOMR. In[20], the author discussed that in an opportunistic routing protocol, each node in the network needs to be configured for opportunistic routing behavior. The authors in[7] discussed opportunistic routing in wireless networks, explained wireless inherent characteristic of the broadcast can be utilized for improvement of network performance and revealed the fundamental idea of opportunistic routing and its issues to help the research community. In[17], the authors proposed a modification to improve link quality. The authors proposed a modification in Optimized Link State Routing (OLSR) mechanism and claimed that if ETX and OLSR are combined with long and short-term metrics, the new proposed mechanism always selects the highest throughput link for communication. This paper also discussed that this can help to reduce energy consumption of mesh routers.

Considering multiple algorithms and routing protocols in such scenarios where a network have the problems of greater error rate due to interference, we require a technique which can help in recovering a frame from error and also reduce delay. To get the advantages of multi-path multi-hop network, we propose a new model which not only helps in recovering a frame at the destination node, but also reduces re-transmissions and delay.

3. PROPOSED MODEL

Consider a scenario shown in Figure 2 (a), where each node is connected with all its neighboring nodes. Suppose 'S' node wants to communicate with 'D' node. Multiple routing paths exist between them. In this particular scenario, 'S' requires a minimum 4 hops to reach 'D'. Suppose 'S' chooses three best routing paths to forward three redundant copies of data packets to 'D'. Therefore, if some of the bits are corrupted on the intermediate node due to noisy channel, then the intermediate node will discard that frame. Thus, source node re-transmits the frame until a correct packet is received at the destination. In the proposed model, we use the new feature of cut-through switches. By using this, intermediate nodes start forwarding frame bits before receiving the whole frame. In this case, in-spite of some part of frame being corrupted, intermediate node forwards it. Thus, the source node sends redundant copies using multiple paths and the destination recovers the original copy by applying a respective algorithm on all received copies. To determine the corrupted part of the frame, the data part of the frame is divided at into number of chunks, and merged again in the same part of frame, but added a Cyclic Error Check (CRC) code in each chunk. Now, at the destination node these data chunks are validated by using CRC and restored to the original packet. This phenomenon is shown in Figure 2 (b), where the intermediate nodes are used to transmit redundant copies. As it is discussed, the

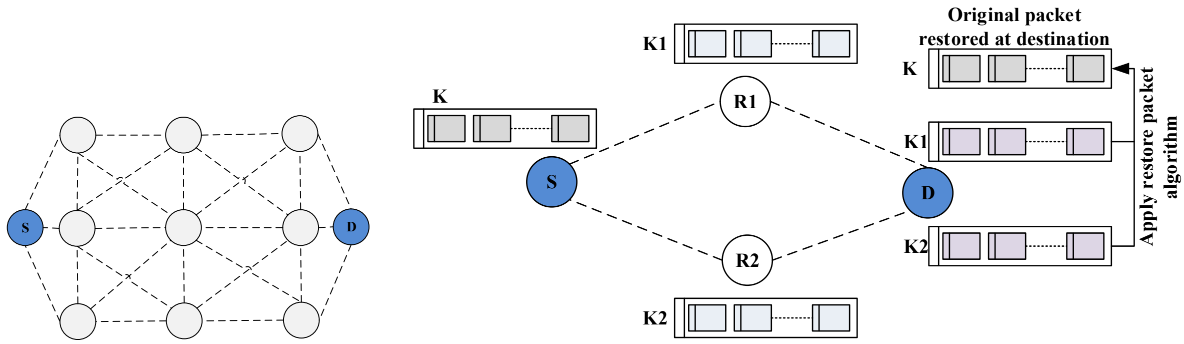

Fig. 2. (a)Example for Proposed Model; (b)Proposed System's Basic Mechanism;

proposed system model combines two features to get maximum benefits of it, i.e. it uses the broadcast characteristic of the wireless medium, and cut-through switches feature in multi-path, multi-hop wireless network. Our modified protocol follows a basic mechanism for transmitting frames from source to destination node. Figure 2 (b) shows the flow of system model, where source node 'S' transmits a frame with little modification in frame structure. When multiple copies of a transmitted frame are received at Data Link Layer of the destination node 'D', the destination node computes the CRC of the included chunks in the frame. Here, the destination node extracts the valid packet by combining valid received chunks and hands over to Network layer. The flow of algorithm is as follows:

1. Apply an algorithm to generate equal size chunks of payload at source node with header containing data validity code i.e. CRC
2. Encapsulate generated chunks in the payload of the frame with updated header where the header must contain total number of chunks, size (assume equal size) and each chunk must include CRC
3. Apply CRC algorithm on header of frame and intermediate nodes forward frame as received
4. Apply algorithm to restore original frame using redundant copies at destination

4. SIMULATION AND RESULTS ANALYSIS

Network simulator 3(NS3) provides the support for IEEE 802.11s. We implemented the proposed algorithm implemented in NS-3.14 and the simulation was carried out for considering multiple simulation scenarios and parameters on Fedora core 19 Platform. We considered the IEEE 802.11s standard with constant position mobility module RTS/CTS disable mode. We used on-off application over UDP transport protocol, and evaluated different scenarios by changing the number of nodes from 9 to 64 and application data rates from 100 to 300 Kbps. In our scenarios, data rates were of 100, 200 and 300 Kbps. We arranged network nodes in such a way that we can get multiple paths for data transmission. Therefore, a grid topology is used where the number of nodes increase in both dimensions i.e. $m \times n$ where m and n represent the number of nodes on X-axis and Y-axis respectively. The distance between nodes was 170m. For comparative analysis, we considered multiple simulation scenarios to evaluate the effect of application data rate on throughput, and end-to-end delay for our proposed protocol. We compared our proposed model with the IEEE 802.11s and considered mesh grid topology, in which half of the nodes in the network transmit data randomly. To make it more realistic, we selected the number of source and destination nodes at the run time. Only those nodes which have data to transmit try to access a channel. To observe the effect of application data rate on throughput, we considered different data rates and network typologies. The graphs in Figure 3 represent the data rate effect on throughput for changed application data rate with different nodes density. In these graphs, the x-axis represents number of nodes in network, while the y-axis represents throughput of the network.

Figure 3 (a) shows that by increasing the number of nodes, we get more available paths. Thus, we observed greater

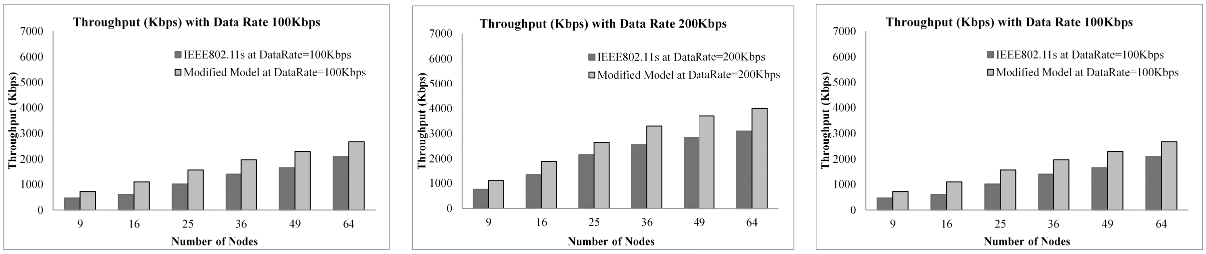

Fig. 3. Throughput with data rate (a) 100Kbps; (b) 200Kbps;(c) 300Kbps;

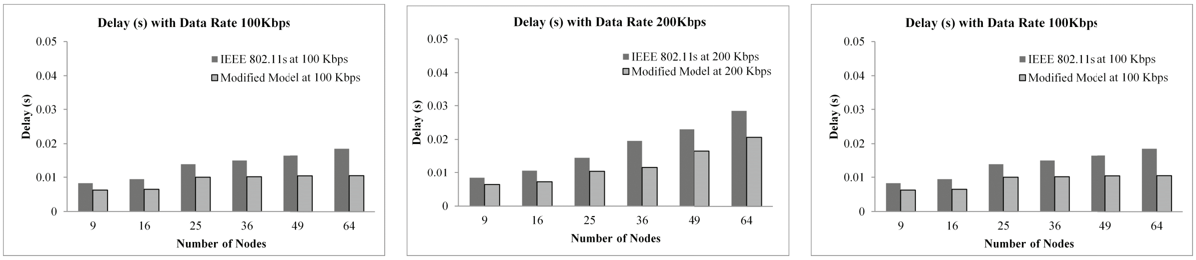

Fig. 4. Delay with data rate (a) 100Kbps; (b) 200Kbps;(c) 300Kbps;

throughput in case of the modified model as compared to the standard protocols. When we increased the data rate, we get better results for the proposed model. The graphs shown in Figure 3 (b) and 3 (c) represent the same trend, but with a data rate of 300Kbps in case of proposed model. We observed that with the increase of number of nodes, throughput line shows logistic growth. Both graph bars show that the proposed model performs better than the existing standard. Figure 4 shows the trend of end-to-end delay in different scenarios. In Figure 4(a) an application data rate of 100 Kbps is considered. We changed the number of nodes in the grid topology and observed the results. The graph observed less delay in case of the modified model. Because packets do not wait due to re-transmission if they are lost. Similar results are shown in Figure 4 (b) and 4 (c) for higher data rates. In each scenario, the proposed model performs better than the existing standard.

5. CONCLUSION

Traffic patterns of Internet data usage show that users are more interested in interactive sessions rather than static sessions. Among the evolving technologies, WMN is a one of the wireless technology which provides high bandwidth with mobility support. In wireless scenarios, packet loss is generally caused due to wireless communication issues like interference, errors and shared channel characteristics. Our study addressed this problem and proposed a novel encoding technique at data link layer that exploits broadcast characteristics of wireless medium. Our proposed cut-through switching characteristic adds the advantage of reducing delay in the network. We implemented this technique implemented in NS3 simulator and evaluated the throughput and end-to-end delay. The results show that the modified model performs better than existing standard in terms of greater throughput and less delay. For future work, we will evaluate our proposed model with the already proposed techniques for throughput, delay and packet lost.

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