A Sufficient and Scalable Multicast Routing Protocol in Wireless Mesh Networks
MeshSPT (Shortest Path Tree algorithm for wireless Mesh network)

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ABSTRACT

The accelerated progress in wireless technologies and the increasing growth of the Internet, wireless networks, especially Wireless Mesh Networks (WMNs) are going through an important evolution .In a WMN, designing efficient and scalable multicast protocol still a major task for researchers. In this work, we propose a protocol named MESHSPT (Shortest Path Tree algorithm for wireless Mesh network) for efficient and scalable multicast routing inside the mesh backbone of a WMN. The MESHSPT protocol builds source-based trees based on the network topology. It prevents flooding and employs an effective mechanism to prevent the implosion and exposure problems when a tree is constructed and when nodes join and leave. Our simulation results show that the MESHSPT protocol outperforms existing protocols such as ODMRP (On-Demand Multicast Routing Protocol), MNT (Minimum Number of Transmissions) in terms of throughput, and end-to-end delay.

Keywords

Wireless Mesh Network, Multicast, Routing Protocol, MNT (Minimum Number of Transmissions), MESHSPT (Shortest Path Tree algorithm for Wireless Mesh Network).

1. INTRODUCTION

Wireless Mesh Networks (WMNs) [1, 2] form a new class of networks that has emerged recently. Major components of a WMN include wireless mesh routers, wireless mesh hosts, and access points (or gateways) that act both as Internet routers and wireless mesh routers. The mesh routers in a WMN are stationary; they form the wireless mesh backbone, which provides multi-hop connectivity from mesh hosts to either other mesh hosts or the Internet via access points. The mesh hosts can be stationary or mobile; they can form a wireless local area network (LAN) or a mobile ad-hoc network (MANET), and communicate with the outside world via connections to the mesh routers. A WMN is dynamically self-organized and self-configured with nodes in the network automatically establishing and maintaining mesh connectivity among themselves. This feature brings many benefits to WMNs such as low installation cost, large-scale deployment, reliability, and self-management. WMNs are promising for providing Internet access to remote areas. They can provide large coverage area, reduce dead-zones in wireless coverage, and lower costs of backhaul connections for base stations. Their promise of rapid deployability and reconfigurability makes them suitable for important applications such as disaster recovery, homeland security, transient networks in convention centers, hard-to-wire buildings such as museums, unfriendly terrains, and rural areas with high costs of network deployment.

2. RELATED WORKS

In this section, we review the existing multicast routing protocols for Internet, MANETs, and WMNs. IP router to router multicast protocols used in the Internet such as MOSPF [8] are not suitable for wireless environments. In wireless networks, bandwidth is a scarce resource and wireless links are more error-prone than their wired counterparts. Proposed protocols for wireless mobile ad hoc networks such as ODMRP [19] do not work efficiently in WMNs because they assume nodes are mobile while mesh routers are static. Mechanisms designed to deal with node mobility such as periodic route refreshment by flooding or beacon exchange would create a lot of unnecessary overheads in WMNs. Although these protocols have been proposed and successfully implemented for MANETs. In the field of multicasting in Wireless Mesh Networks, Ruiz et al. [20] use minimum number of transmissions as a link cost metric and demonstrate that the problem of finding a MNT tree in a WMN is also NP-Complete. Nguyen et al. [22] quantify the performance differences of minimum cost trees (MCTs, e.g. MST/MNT) and shortest path trees (SPTs) in WMNs. experimental results show that SPTs offer significantly better performance to multicast flows than MCTs. Chou et al. [23] extend the SPT and MNT algorithms to provide a pair of paths between the sender and each receiver for more reliable delivery. Yuan et al. [24] propose a cross-layer optimization framework that balances the supply of link capacities at the physical layer and the demand of network flows at the network layer in order to find high throughput paths, we refer also to Multicasting in Wireless Mesh Networks: Challenges and Opportunities [25].

3. MULTICAST ROUTING APPROACHES

There are two fundamental multicast routing approaches: shortest path trees (SPTs) [3] and minimum cost trees [3] (MCTs: MST (Minimum Steiner Tree) and (Minimum Number of Transmission)). The goal of SPT algorithms is to construct a tree rooted at the sender and spanning all the receivers such that the distance between the sender and each receiver along the tree is minimum. As a result, the SPT algorithms normally minimize the end-to-end delay as well [3]. The two most commonly used algorithms for computing SPTs are those of Bellman-Ford and Dijkstra [4]. To compute an SPT, we apply the point-to-point shortest path algorithm repeatedly, once for each sender- receiver pair. SPTs by definition are per sender. Therefore, for many-to-many multicast, separate trees must be computed, one for each sender. Unlike the SPT algorithms, which aim at minimizing the distance (or cost) from the sender to each receiver, the goal of MCT algorithms is to minimize the overall cost of the multicast tree. MCT algorithms for multicast routing are based on the minimum Steiner tree problem, which is NP-complete. Thus several heuristics have been proposed to compute approximate Steiner trees , for example, the 2-approximation heuristic proposed by Kou et al [5]. and the 11/6-approximation algorithm by Zelikovsky [6]. The total cost of a Steiner tree is less than the total cost of a corresponding SPT, by definition of Steiner trees. However, the maximum distance between the sender and any receiver in a Steiner tree is typically longer than that in an SPT. This means that the average path length in a Steiner tree is more than that in an SPT. Due to the complexity of computing Steiner trees in a distributed manner. MCT algorithms for multicast routing are based on the minimum number of transmission tree problem, which is NP-complete also and the mean path lengths given by the MNT algorithms are longer than those given by the SPT algorithm. The majority of the multicast routing protocols used in the Internet today are based on SPTs, such as Distance Vector Multicast Routing Protocol (DVMRP) [7], and Multicast Open Shortest Path First (MOSPF) [8]. The reason is that SPTs are easy to implement and offer minimum end-to-end delay, a desirable quality-of-service parameter for most real-life multicast applications.

4. PROPOSED APPROACH

4.1 Motivations

Most of the existing work on WMNs concentrates on the issues of unicast routing and channel assignment when multiple channels are being used [9, 10, 11, 12], network architectures [13, 14], performance evaluation and analysis [15, 16], and network capacity analysis [17]. In this thesis, we focus on providing multicast services in WMNs. Not much research on multicast in WMNs has been done.

Multicast is a form of communication that delivers information from a source to a set of destinations simultaneously in an efficient manner; the messages are delivered over each link of the network only once (excluding retransmissions) and only duplicated at branch points, where the links to the destinations split. Important applications of multicast include distribution of stock quotes, billing records, software, and newspapers; audio/video conferencing; distance education; and Internet games.

4.2 Contributions

Specifically, we propose solutions to the following problem. we design a protocol named MESHSPT (Shortest Path Tree algorithm for WMNs) for efficient and scalable multicast routing inside the mesh backbone of a wireless mesh network. This multicast protocol build based on shortest path tree from the source to the destination which gives lower End – to – End delay and longer throughput, These matrices are the aiming in the real projects.

4.3 The Proposed Multicast Routing Protocol

The MESHSPT protocol uses the network topology information to build a shortest path multicast tree, which is rooted at the sender and spanning to all receivers. Unlike DVMRP or MOSPF, MESHSPT does not flood the network when the multicast tree is being constructed or when nodes join and leave the multicast group. The MESHSPT employs effective mechanisms to prevent the implosion and exposure problems during the tree construction process and when members join and leave. If several receivers join the multicast group at about the same time, the Join Requests would overwhelm the source. This problem is commonly termed as the implosion problem. Sending a Join Reply to each individual receiver would require a large amount of processing and transmission overhead for the source. A more efficient alternative is to let the source multicast a Join Reply that will reach all these receivers. However, this multicast approach may result in the exposure problem; the Join Reply may reach receivers or forwarding nodes that do not need it. When the sender is a mesh host, the AP serving the sender and receivers residing in the same WMN join a multicast tree rooted at the sender.

the MESHSPT works as follows:

- Before source S of a multicast group G starts the session, S sends (unicasts) a message to its AP to register with the information (G, S). The AP serving S then broadcasts the group information (G, S) to the other APs in the WMN, if any.
- When a receiver R wants to join group G, it sends a request to its AP to ask for the ID of the source of group G. The AP then replies with the group information (G, S).
- On receiving the information (G, S), receiver R computes the shortest path p from S to R based on the topology information, and sends a Join Request to source S along the path p. Note that all the nodes on this path will come up with the same route since they have the complete network topology and use the same algorithm for computing the route.
- When source S receives the Join Request, it sends a Join Reply to R using the shortest path p from S to R. All the nodes on this path will set a forwarding flag that indicates that they are now forwarding nodes of the multicast group G.
- Source S sends the data packets, and only the forwarding nodes of group G will forward the data packets received from S.

To solve the implosion and exposure problems [18], each forwarding node on the paths between the source and receivers sets up a boolean flag called replied which is associated with multicast group (G, S). When a node N receives a Join Request for source S for the first time, it sets the flag replied to FALSE, and then forwards the Join Request to the source. Before N receives a Join Reply, if another Join Request from another receiver arrives, node N simply discards this Join Request since the value of its flag replied is FALSE, which indicates that it has already forwarded one to the source earlier. This suppression mechanism prevents the implosion problem at branch points and at the source. After node N receives a Join Reply from the source, it sets the flag replied to TRUE, and transmits (multicasts) the Join Reply to its downstream neighbors. The flag replied set to TRUE indicates that a path from S to N has been established. Thus if node N receives a Join Request from a new receiver after replied is set to TRUE, it will not forward the Join Request to the source, but instead creates a Join Reply itself and transmits (multicasts) this Join Reply to its downstream neighbors. This mechanism eliminates unnecessary traffic overhead that would have incurred by the Join Request and a subsequent Join Reply on the path between N and S, and minimizes the workload of source S. The flag replied is also used to solve the exposure problem. When a node N receives a Join Reply, if its flag replied is FALSE then N forwards the Join Reply to its downstream neighbors; otherwise (i.e., replied = TRUE), N discards the Join Reply since it has already received one, and the path from S to N has been established. (Note that if a new Join Request reaches node N and its replied = TRUE, N will send back a Join Reply for this Join Request without involving the source as explained above).

5. EXPERIMENTAL RESULTS

In this section, we compare MESHSPT with ODMRP [19], and MNT [20] in terms of, throughput, end-to- end delay. ODMRP is a popular multicast routing protocol for wireless mobile ad hoc networks. It creates a forwarding mesh between the sender(s) and receivers. We compare MESHSPT with ODMRP to show that tree-based routing algorithms are in general more suitable for WMNs than mesh-based routing algorithms. MNT is a routing algorithm proposed for WMNs to compute multicast trees that minimize the number of transmissions. We compare MESHSPT with MNT to show that shortest-path multicast routing trees typically have better performance in WMNs than minimum-cost trees in terms of throughput and end-to-end delay.

Our experiments were carried out using Glomosim [21], a network simulator for wireless networks. We implemented the complete MESHSPT protocol in Glomosim.

We use the following metrics to measure the performance of the multicast protocol:

Average end-to-end delay (EED): The end-to-end delay of every packet received at every receiver is recorded; the average over all the packets received is then computed.

Average throughput: Throughput is defined as the total amount of data a receiver r actually receives divided by the time between receiving the first packet and the last packet. The average taken over all the receivers is the average throughput of the multicast group, assuming that each group has one sender.

Our simulations model a medium-size network of 100 mesh routers placed in a 2000m × 2000m terrain, and a large network of 300 mesh routers placed in a 3000m × 3000m terrain. We use the terms “router” and “node” interchangeably. The nodes are distributed uniformly over the sub-areas within a terrain, and the nodes within a sub-area are randomly placed in that sub-area. There are no network partitions throughout the simulation. Each simulation executes for 600s of simulation time. Multiple runs with different seed numbers are conducted for each experiment and collected data are averaged over those runs. All nodes are equipped with an 802.11b radio with a bandwidth of 11 Mbps and a nominal range of 250 meters. As MAC layer protocol we use the 802.11. Traffic model is constant bit rate (CBR). The data packet size is 512 bytes. The size of the queue at every node is 50 Kbytes. All senders and receivers (unicast and multicast) are randomly selected.

5.1 MESHSPT vs ODMRP

Figure 1 (100 nodes) and Figure 2 (300 nodes) show the performance of MESHSPT and ODMRP as the network traffic load varies. When the traffic load is low, both have similar throughputs; ODMRP incurs slightly longer packet delay than MESHSPT. This is due to fact that ODMRP uses periodical flooding to refresh the routes. When the traffic load is high, MESHSPT provides much better performance than ODMRP because the forwarding mesh of ODMRP consumes more bandwidth than the MESHSPT tree. This results in more channel contention and congestion in the network, and thus lower throughput and longer end-to-end delay.

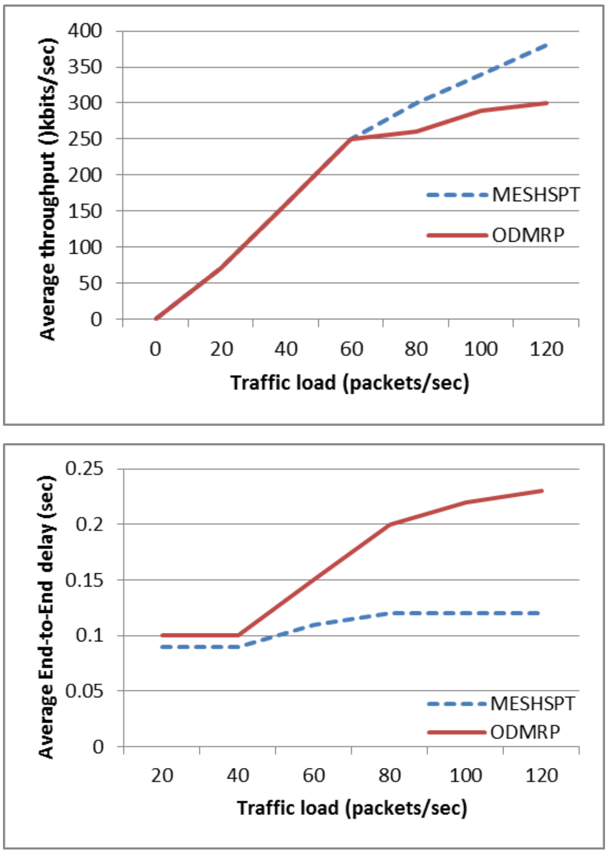
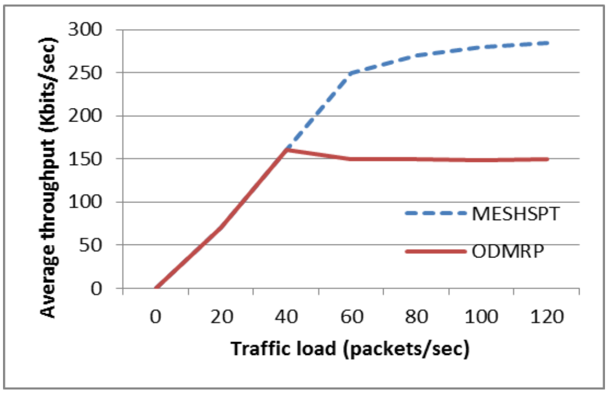
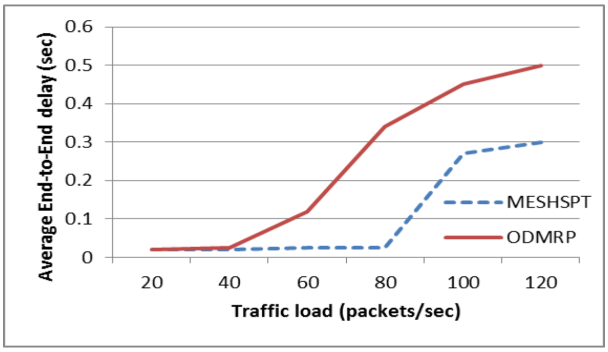


Figure 1: MESHSPT vs. ODMRP: functions of traffic load, one sender, 10 receivers, network of 100 nodes

Figure 3 (100 nodes) and Figure 4 (300 nodes) illustrate the performance of MESHSPT and ODMRP as the number of receivers varies. When the number of receivers is small, both have similar throughputs and end-to-end delays. However, when the number of receivers is large, MESHSPT gives much better performance than ODMRP in terms of throughput and end-to-end delay. The reason is that the forwarding mesh and periodic flooding in ODMRP consume more bandwidth, resulting in more network congestion and contention, and thus lower throughput and longer packet delay.





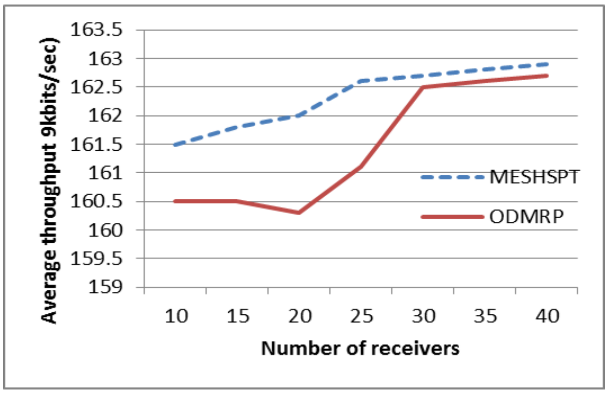


Figure 2: MESHSPT vs. ODMRP: functions of traffic load, one sender, 30 receivers, network of 300 nodes

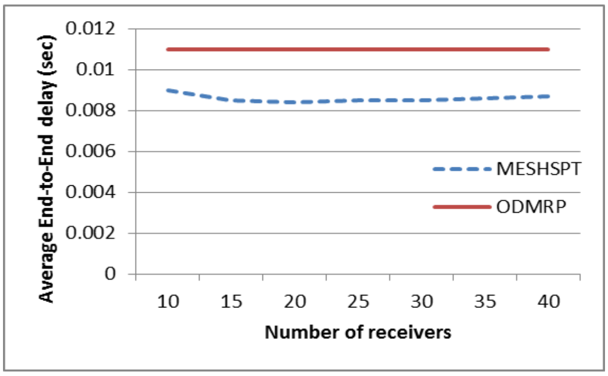


Figure 3: MESHSPT vs. ODMRP: functions of number of receivers, one sender, traffic load = 40 pkts/s, network of 100 node

Figure 5 (100 nodes) and Figure 6 (300 nodes) illustrate the performance of MESHSPT and ODMRP as the number of senders varies. When the number of senders is small, both have similar throughputs and end-to-end delays. However, when the number of senders is large, MESHSPT gives much better performance than ODMRP in terms of throughput and end-to-end delay. The reason is that the forwarding mesh and periodic flooding in ODMRP consume more bandwidth, resulting in more network congestion and contention, and thus lower throughput and longer packet delay.

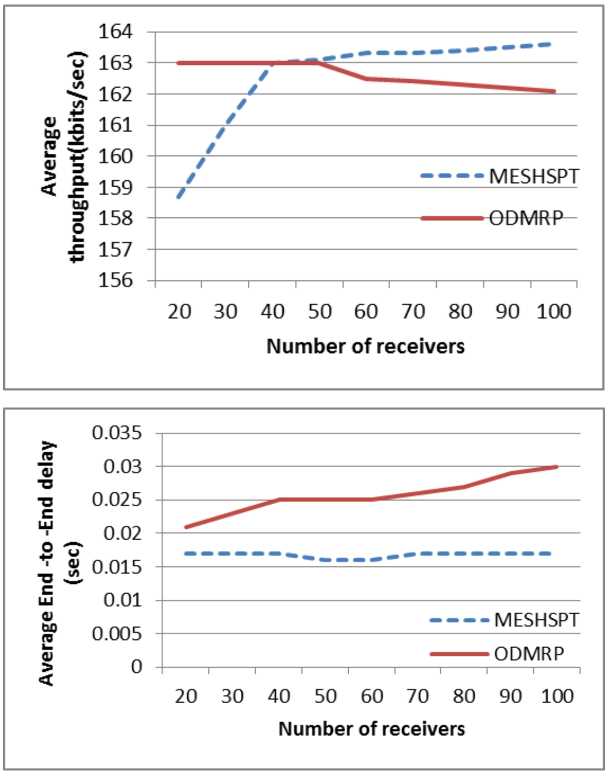


Figure 4: MESHSPT vs. ODMRP: functions of number of receivers, one sender, traffic load = 40 pkts/s, network of 300 nodes

5.2 MESHSPT vs MNT

In this experiment, we compare MESHSPT, MNT in terms of throughput, end-to-end delay. In this set of experiments, all the multicast senders and receivers join the multicast group at the beginning of the session and stay until the end of the session. In the network of 100 nodes, we examined two multicast groups having 20 and 40 receivers respectively, as illustrated in Figures 7 and 8. When the traffic load is light (under 30 packets/s), the performance of the MESHSPT, the MNT is comparable with respect to throughput. When the traffic load is moderate or high, the MESHSPT tree outperforms the MNT in all cases, and the difference can be significant. The reason is due to longer path lengths of the MNT. The longer the path a packet has to travel, the higher its chance of getting damaged or lost due to collision and/or congestion, especially under high traffic load. The average end-to-end delays incurred by the MESHSPT trees are also the lowest thanks to shorter source-to-destination paths.

In the larger network of 300 nodes, the performance differences between the MESHSPT tree and the MNT is even more pronounced, as illustrated in Figures 9, which show the results of one multicast groups having 40 receivers. In other words, given the same multicast group size, as the network size increases, the performance gain of MESHSPT over MNT also increases. The reason is that the larger the network, the bigger the difference in path length between the MESHSPT and the MNT as mentioned

Studying and comparing simulation results shows using MESHSPT protocol which is based on Shortest Path Tree causes much more performance of network.

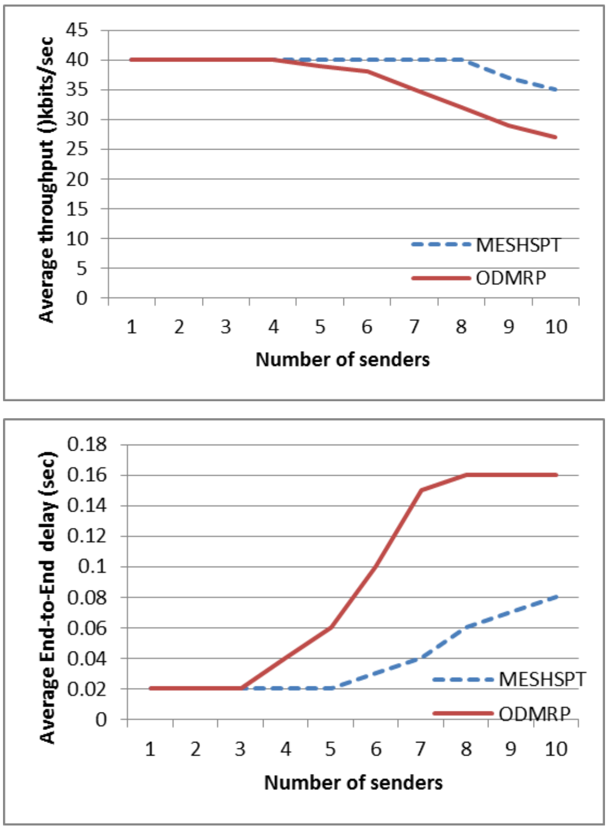
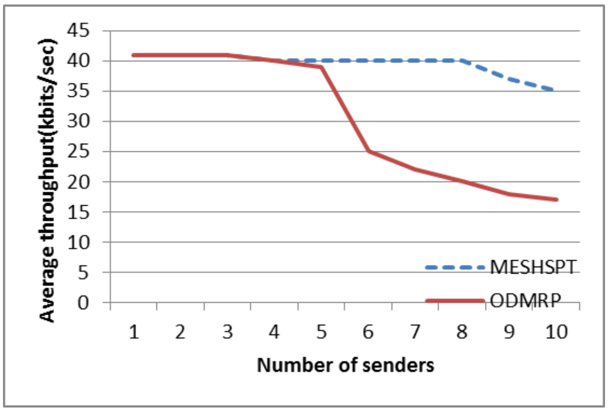


Figure 5: MESHSPT vs. ODMRP: functions of number of senders, 40 receivers, traffic load = 10 pkts/s per sender, network of 100 nodes



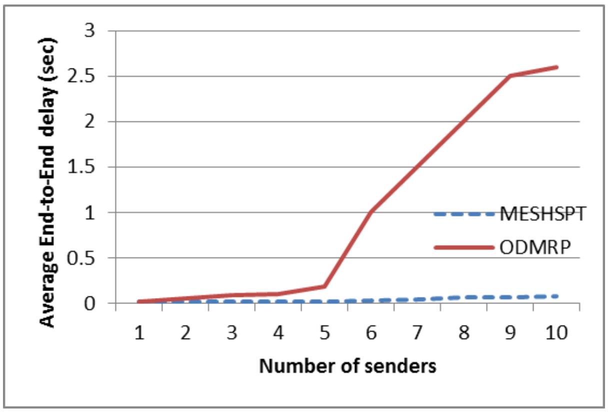


Figure 6: MESHSPT vs. ODMRP: functions of number of senders, 40 receivers, traffic load = 10 pkts/s per sender, network of 300 nodes

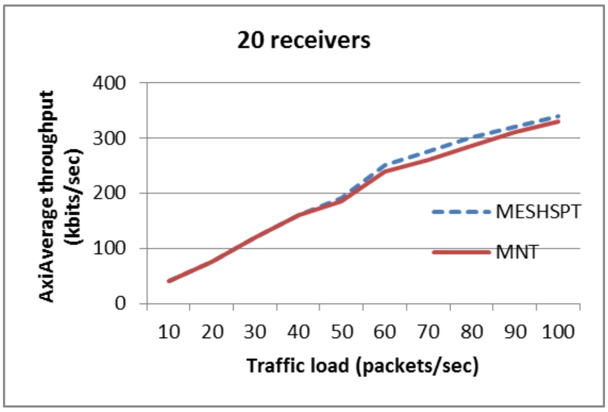
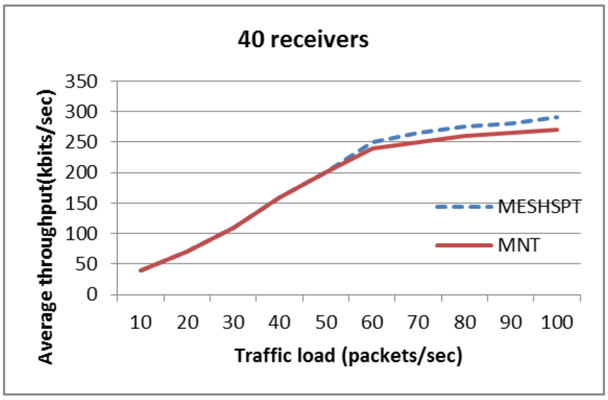


Figure 7: MESHSPT vs.MNT: functions of traffic load, one sender, 20 receivers, network of 100 nodes



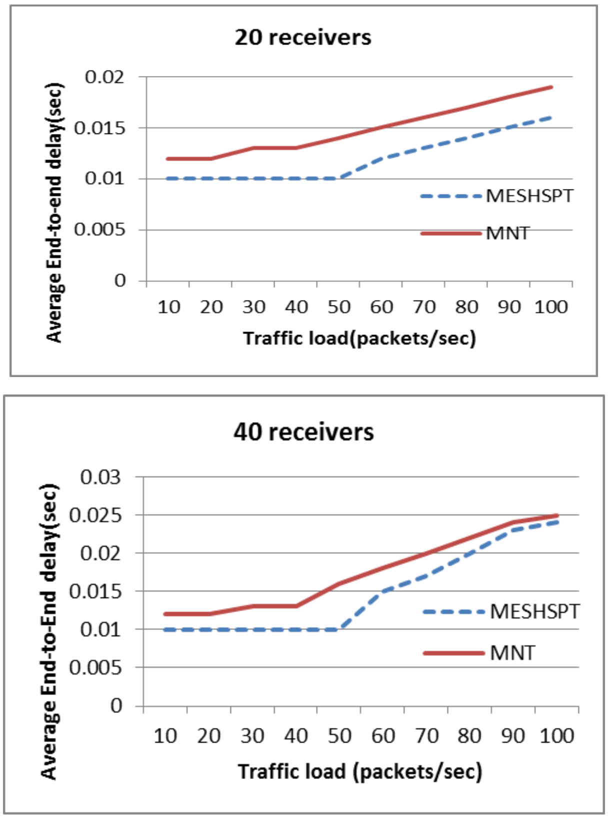


Figure 8: MESHSPT vs. MNT: functions of traffic load, one sender, 40 receivers, network of 100 nodes

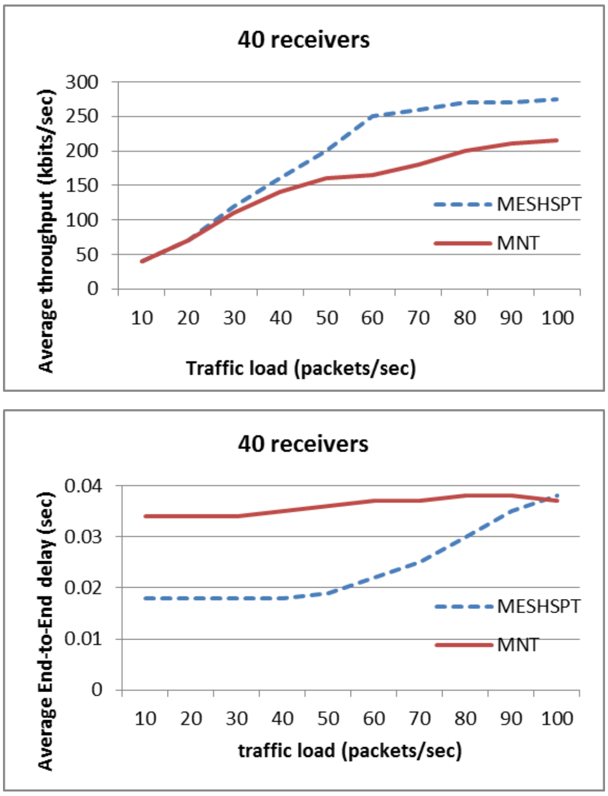


Figure 9: MESHSPT vs. MNT: functions of traffic load, one sender, 40 receivers, network of 300 nodes

6. CONCLUSION

In this work, we propose an efficient and scalable protocol for multicast routing in the mesh backbone of a WMN. The MESHSPT protocol builds source-based trees based on the network topology. It prevents flooding and employs effective mechanisms to prevent the feedback implosion and exposure problems during the tree construction process and while joining / leaving the group.. Our simulation results show that the MESHSPT protocol functions efficiently for WMNs.

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