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Performance characteristics of OLSR and AODV protocols in Wireless Mesh Network

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Abstract— A wireless mesh network (WMN) is a communications network made up of radio nodes organized in a mesh topology. Wireless mesh networks often consist of mesh clients, mesh routers and gateways. The mesh clients are often laptops, cell phones and other wireless devices while the mesh routers forward traffic to and from the gateways which may but need not connect to the Internet. The coverage area of the radio nodes working as a single network is sometimes called a mesh cloud. Wireless mesh networks can be implemented with various wireless technology including 802.11, 802.15, 802.16, cellular technologies or combinations of more than one type. AODV is a very popular routing protocol for MANETs. It is a reactive routing protocol. OLSR is a popular proactive routing protocol for wireless ad hoc networks.

I. INTRODUCTION

The most obvious advantage of wireless networking is mobility. Wireless network users can connect to existing networks and are then allowed to roam freely. A mobile telephone user can drive miles in the course of a single conversation because the phone connects the user through cell towers. Initially, mobile telephony was expensive. Costs restricted its use to highly mobile professionals such as sales managers and important executive decision makers who might need to be reached at a moment's notice regardless of their location. Mobile telephony has proven to be a useful service, however, and now it is relatively common in the United States and extremely common among Europeans. Wireless networks typically have a great deal of flexibility, which can translate into rapid deployment. Likewise, wireless data networks free software developers from the tethers of an Ethernet cable at a desk. Developers can work in the library, in a conference room, in the parking lot, or even in the coffee house across the street. Commonly available equipment can easily cover a corporate campus; with some work, more exotic equipment, and favorable terrain, you can extend the range of an 802.11 network up to a few miles.

II. Comparison between Wireless Ad Hoc and Mesh Networks

The major categories in the multi-hop wireless networks are the ad hoc wireless networks, WMNs, wireless sensor networks, and hybrid wireless networks. This paper mainly focuses on WMNs. Ad hoc wireless networks are mainly infrastructure-less networks with highly dynamic topology. Wireless sensor networks, formed by tiny sensor nodes that can gather physical parameters and transmit to a central monitoring node, can use either single-hop wireless communication or a multi-hop wireless relaying. Hybrid wireless networks utilize both single & multi-hop communications simultaneously within the traditionally single-hop wireless networks such as cellular networks and wireless in local loops (WiLL).

A wireless mesh network can be seen as a special type of wireless ad-hoc network. A wireless mesh network often has a more planned configuration, and may be deployed to provide dynamic and cost effective connectivity over a certain geographic area. An ad-hoc network, on the other hand, is formed ad hoc when wireless devices come within communication range of each other. The mesh routers may be mobile, and be moved according to specific demands arising in the network. Often the mesh routers are not limited in terms of resources compared to other nodes in the network and thus can be exploited to perform more resource intensive functions. In this way, the wireless mesh network differs from an ad-hoc network, since these nodes are often constrained by resources.

Issue	Wireless Ad Hoc Networks	Wireless Mesh Networks
Network topology	Highly dynamic	Relatively static
Mobility of relay nodes	Medium to high	Low
Energy constraint	High	Low
Application characteristics	Temporary	Semipermanent or permanent
Infrastructure requirement	Infrastructureless	Partial or fully fixed infrastructure
Relaying	Relaying by mobile nodes	Relaying by fixed nodes
Routing performance	Fully distributed on-demand routing preferred	Fully distributed or partially distributed with table-driven or hierarchical routing preferred
Deployment	Easy to deploy	Some planning required
Traffic characteristics	Typically user traffic	Typically user and sensor traffic
Popular application scenario	Tactical communication	Tactical and civilian communication

Table 1: Difference Between Ad Hoc Wireless networks and Wireless Mesh Networks

III. Routing Protocols

This section will describe selected routing protocols for wireless multihop networks as an illustration of the general concepts of routing protocols as well as some special routing protocols for wireless mesh networks. A comprehensive overview of all routing protocols cannot be done due to limited space.

Ad hoc On-demand Distance Vector Routing Protocol (AODV)

AODV is a very popular routing protocol for MANETs. It is a reactive routing protocol. Routes are set up on demand, and only active routes are maintained. This reduces the routing overhead, but introduces some initial latency due to the on-demand route setup. The advantage of AODV is that it creates no extra traffic for communication along existing links. Also, distance vector routing is simple, and doesn't require much memory or calculation. However AODV requires more time to establish a connection, and the initial communication to establish a route is heavier than some other approaches. AODV uses a simple request-reply mechanism for the discovery of routes. It can use hello messages for connectivity information and signals link breaks on active routes with error messages. The routing information has a timeout associated with it as well as a sequence number. The use of sequence numbers allows detecting outdated data, so that only the most current, a variable routing information is used. This ensures freedom of routing loops and avoids problems known from classical distance vector protocols, such as counting to infinity.

The source node S broadcasts a route request (RREQ) throughout the network In addition to several flags, a RREQ packet contains the hop-count, a RREQ identifier, the destination address and destination sequence number, and the originator address and originator sequence number.

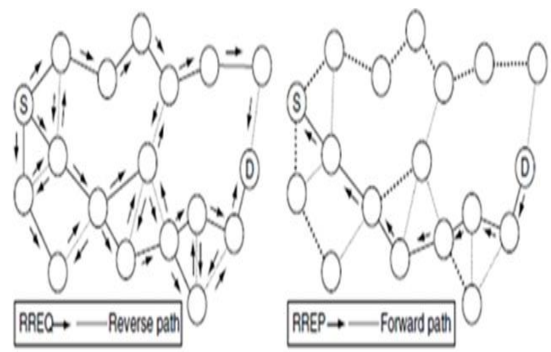

Figure 1: AODV route discovery: route request (left) and route reply (right)

When a node receives a RREQ packet, it processes as follows:

• The route to the previous hop from which the RREQ packet has been received is created or updated.

• The RREQ ID and the originator address are checked to see whether this RREQ has been already received. If yes, the packet is discarded.

• The hop-count is incremented by 1.

• The reverse route to the originator, node S, is created or updated.

• If the node is the requested destination, it generates a route reply (RREP) and sends the RREP packet back to the originator along the created reverse path to the source node S.

• If the node is not the destination but has a valid path to D, it issues a RREP to the source depending on the destination only flag. If intermediate nodes reply to RREQs, it might be the case that the destination will not hear any RREQ, so that it does not have a back route to the source. If the gratuitous RREP flag is set in the RREQ, the replying intermediate node will send a gratuitous RREP to the destination. This sets the path to the originator of the RREQ in the destination.

• If the node does not generate a RREP, the RREQ is updated and rebroadcast if TTL ≥ 1.

On receipt of a RREP message, a node will create or update its route to the destination D. The hop-count is incremented by one, and the updated RREP will be forwarded to the originator of the corresponding RREQ. Eventually, the source node S will receive a RREP only if the path is available to the destination. The buffered data packets can now be sent to the

destination D on the newly discovered path.
In case of link failure the node before the broken link checks first whether any active route is using the broken link. If this was not the case, nothing has to be done. If there have been active paths, the node may attempt local repair. It sends out a RREQ to establish a new second half of the path to the destination. The node performing the local repair buffers the data packets while waiting for any route replies. If local repair fails or has not been attempted, the node generates a route error (RERR) message. It contains the addresses and corresponding destination sequence numbers of all active destinations that have become unreachable because of the link failure.

Optimized Link State Routing Protocol (OLSR)

OLSR is a popular proactive routing protocol for wireless ad hoc networks. It has been developed at INRIA and has been standardized at IETF. OLSR uses the classical shortest path algorithm based on the hop-count metric for the computation of the routes in the network. Since link-state routing requires the topology database to be synchronized across the network, OSPF and IS-IS perform topology flooding using a reliable algorithm. Such an algorithm is very difficult to design for ad-hoc wireless networks, so OLSR doesn't bother with reliability; it simply floods topology data often enough to make sure that the database does not remain unsynchronized for extended periods of time. However, the key concept of OLSR is an optimized broadcast mechanism for the network-wide distribution of the necessary link-state information. Each node selects the so-called multipoint relays (MPRs) among its neighbors in such a way that all 2-hop neighbors receive broadcast messages even if only the MPRs rebroadcast the messages. The forwarding of broadcast messages by MPRs only can significantly reduce the number of broadcast messages. Figure 2 shows an example where the number of broadcast messages is reduced by half.

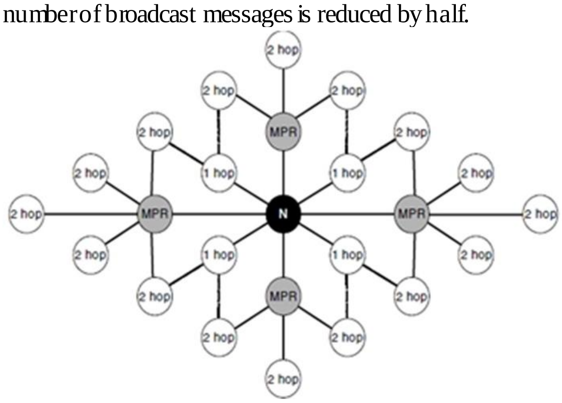

Figure 2: Multipoint relay selection in OLSR

OLSR proposes a simple heuristic for the MPR selection in which is described below, but other algorithms are possible.

- N: Neighbors of the node.

- N2: The set of 2-hop neighbors of the node excluding (i) nodes only reachable by members of N with willingness WILL_NEVER, (ii) the nodes perform the computation, and (iii) all the symmetric neighbors: the nodes for which there exists a symmetric link to this node.

- D(Y): Degree of 1-hop neighbor Y 2 N, which is the number of symmetric neighbors of Y excluding all members of N and excluding the node performing the computation

- Step 1: Start with an MPR set consisting of all members of N with willingness =
WILL_ALWAYS

- Step 2: Calculate D(Y), for all Y 2 N

- Step 3: Add to the MPR set those nodes in N, which are the only nodes to provide reachability to a node in N2

- Step 4: Remove the nodes from N2 which are now covered by a node in the MPR set

- Step 5: While there still exist nodes in N2 which are not covered by at least one node in the MPR set:
For each node in N, calculate the reachability, i.e., the number of nodes in N2 that are not yet covered by at least one node in the MPR set, and which are reachable through this 1-hop neighbor.
Select as an MPR the node with highest willingness among the nodes in N with nonzero reachability. In case of a tie, select the node that provides reachability to the maximum number of nodes in N2. In case of multiple nodes providing the same amount of reachability, select the node as MPR whose D(Y) is the greatest. Remove the nodes from N2 that are now covered by a node in the MPR set

- Step 6: As an optimization, each node Y in the MPR set can be checked for omission in increasing order of its willingness. If all nodes in N2 are still covered by at least one node in the MPR set excluding node Y, and if the willingness of node Y is smaller than WILL_ALWAYS, then node Y may be removed from the MPRset.

The OLSR routing table that contains entries for all reachable destinations in the mesh network (proactive routing protocol) is computed from the link set, neighbor set, 2-hop neighbor set, and topology set with a classical shortest path algorithm (e.g., Dijkstra algorithm). If any of the above sets has changed, the routing table has to be recalculated. Furthermore, it might be useful to send a hello or TC message to propagate the change of the topology immediately.
OLSR can also deal with multiple (OLSR) interfaces at a node. Such a node selects the address of any one of its interfaces as the main address and periodically broadcasts multiple interface declaration (MID) messages. MID messages distribute the relationship between the main address and other interface addresses. Obviously, a node with only a

single OLSR interface does not have to send MID messages.
In a wireless mesh network, some degradation in throughput might be expected over five or six hops. Channel interference could result in lower throughput if the nodes are too close to each other or if the power is too high for the area. WMN routing protocols should select paths based on observed latency and wireless environment as well as other performance factors, resulting in the best possible throughput across the network.

IV. Simulation Evaluation

We performed simulation experiments using the 802.11s MAC protocol available in standard wireless library of QualNet 5.0. We developed Multi Channel xTDMMAC Wireless Mesh Networks. The bit rate for each channel is 2 Mbps and the transmission range of each node is approximately 250 m. Each source node generates and transmits constant bit rate (CBR) traffic. We ran each simulation for 80 seconds of simulated time. Each data point in the results is the average of 30 replications with different random seeds. Unless otherwise specified, the packet size was 512 bytes and the packet arrival rate from each node was 50 Packets/s. Simulation experiments were performed for both single-hop and multiple-hop network scenarios. For the single-hop network simulations, all nodes were within each the transmission range of all other nodes, thus every source node can reach its destination node in a single hop. For each scenario, half of the nodes were data sources and the other half were data destinations. We considered both stationary and mobile ad hoc networks for the multiple-hop network scenario. In the simulation of stationary nodes, nodes were randomly placed in a 1500 m by 1500 m square area and did not move. The random waypoint model was used for mobility with a pause time of 30-seconds and a maximum node speed of 10 m/s. The developed scenario is implemented successfully.

Performance Characteristics of routing protocols (OLSR, AODV)

A. Performance Evaluation of Throughput capacity.

Figure 5, depicts a scatter plot comparing throughput for multi-hop bi-directional flows obtained, by applying the OLSR and AODV routing algorithm to the multi channel TDM MAC protocol. It is easily observable from the figure that the throughput capacity of OLSR (Pro-active routing) protocol is very much better than AODV (Reactive routing). The variation in the overall throughput process depends on the number of hops in between the mesh source address and mesh destination address. The variations also depend on the number of receiving (RX), and transmitting (TX) channels per a slot in a TDM structure. For e.g. nodes 10 to 20 have a heavy full duplex traffic flow per node, so that the throughput is considerably low on that region. The nodes from 30-35 are located at 3 hop distance, this results into their throughput degradation as expectedly.

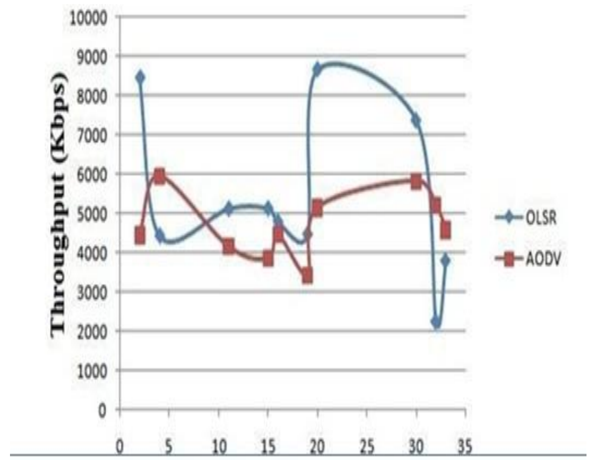

Figure 3: xTDM MAC Throughput of OLSR and AODV

B. Packet Loss Ratio

We consider a chain topology of four nodes and evaluate the performance of the packets transmitting successfully in parallel from the gateway node to the downstream network nodes. Figure 6, shows the difference in packet loss in OLSR and AODV for xTDMMAC protocol. We observe that the average loss rates of OLSR achieves higher successful delivery ratio than AODV. The number of successful delivery of packets in AODV is almost 0, and the average packet loss ratio is more in AODV than compared with OLSR.

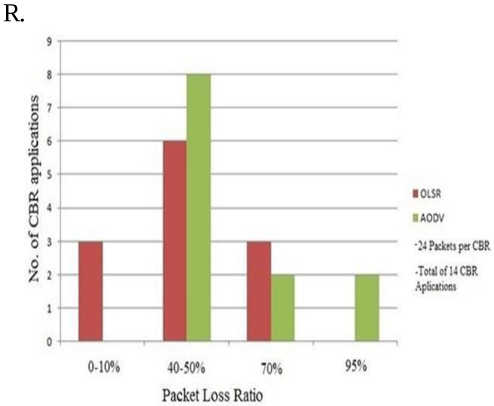

Figure 4: Packet loss ratio in between OLSR and AODV

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C. Mesh Management Statistics collected by 802.11s

Figure 5 shows difference in between the number of association requests enqueued for sending to mesh neighbors and the number of association requests received from mesh neighbors.

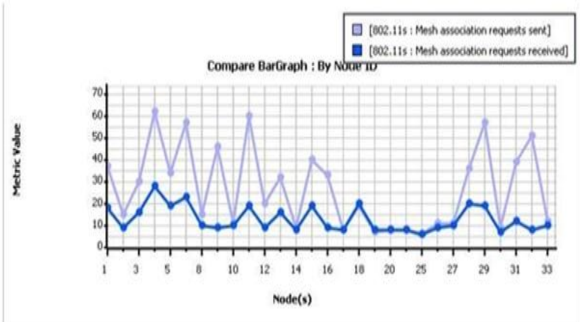

Figure 5: Comparison in graphs of mesh association requests

V. CONCLUSION

We evaluated the performance characteristics of AODV and OLSR routing algorithms. The simulation results show that proactive routing protocols have best performance ratio than reactive protocols for multi channel systems. We compared the mesh link status announcements forwarded and received for all mesh nodes with different hop count, the analysis of the graph proved that the designed mesh scenario is behaving in a proper way as per the 802.11s standard.
Thus we can say that if the Throughput and Packet loss ratio results of these Protocols (OLSR and AODV) are implemented by using a programmable wireless platform on real time will provide a milli-level accuracy results.

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