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Performance Modeling of MANET Interconnectivity

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The proliferation of mobile wireless computing devices and the increasing usage of wireless networking have motivated substantial research in mobile ad hoc networks (MANETs). In addition, much has also been done to link autonomous MANETs to the Internet, and as MANETs become more prevalent, the need to interconnect multiple MANETs becomes increasingly important too. However, direct interconnection of MANETs has rarely been studied. In this paper, we first report an experimental study on the performance of interconnected MANETs running two different routing protocols, viz., the Ad hoc On-Demand Distance Vector (AODV) and Optimized Link State Routing (OLSR) protocols, which represent the two major categories, and show that with the use of multiple gateways, it is possible to viably interconnect multiple networks running different MANET routing protocols. We then follow with a simulation study to evaluate the performance in large networks, which not only validates the scalability of the proposed scheme, but also helps to identify various problems that were not apparent in small experimental networks.

KEY WORDS: Interconnectivity; Mobile ad hoc networks (MANETs); AODV; OLSR.

1. INTRODUCTION

A mobile ad hoc network (MANET) consists of mobile nodes coming together to form a network without the support of dedicated routers and base stations, and communicate with one another over multi-hop wireless links. Due to the dynamic nature of MANETs, traditional routing protocols designed for wired networks fare poorly in such environments. There are mainly three general categories of MANET routing protocols, namely, proactive, reactive and hybrid [1].

In proactive routing protocols, every node in the network maintains a route to every other node in the network at all times. Examples of proactive routing protocols include OLSR [2] and TBRPF (Topology Dissemination Based on Reverse-Path Forwarding) [3]. In reactive routing protocols, every node in the network maintains a route to another node only if it needs to transmit data packets to that node. AODV [4] and DSR (Dynamic Source Routing) [5] are well known examples of such protocols. Hybrid routing protocols try to exploit the advantages of both categories. Generally, every node maintains a route to every other node in its locality at all times and a route to a node outside its locality only when it needs to send data packets to that node. Examples of hybrid routing protocols include ZRP (Zone Routing Protocol) [6] and CBRP (Cluster-Based Routing Protocol) [7].

Different MANETs exhibit different characteristics, such as node mobility, size of the network and traffic patterns [8]. Consequently, there is no single ad hoc routing protocol that will perform well under different network conditions. Therefore, it is not

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inconceivable for different networks to deploy different routing protocols based on the desired network requirements and policies. As MANETs become more prevalent, besides connecting them to wireless or fixed backbone networks like the Internet, the need to interconnect multiple MANETs becomes increasingly important too. However, interconnection of MANETs has rarely been studied.

In the Internet, different routing protocols, such as OSPF and BGP, can coexist because the Internet utilizes a hierarchical routing system [9]. Intra-autonomous system routing protocols, such as RIP and OSPF, are used to maintain routing tables for nodes in the same region while inter-autonomous system routing protocols, such as BGP, are used to maintain routing tables between different regions. However, this arrangement requires nodes in the same region to share a common network prefix and the routing tables in the Internet must always be up to date. When a node moves to another region, it either has to obtain another IP address or mobile IP has to be used.

In a MANET, nodes usually do not have to share a common network prefix. In proactive MANET routing protocols, the routing tables are complete and up to date as the nodes share routing information periodically. In reactive protocols, the routing tables are incomplete as a routing entry to a destination is only added and maintained when needed. The problem to address is how to manage and update the routing tables of nodes in reactive and proactive ad hoc networks so that they can communicate with one another without using mobile IP or any common network prefix.

In this paper, we first report an experimental study on the performance of interconnected MANETs running two different routing protocols, viz., AODV and OLSR, which represent the two major categories. We then use simulations to study the performance in larger MANETs, which not only provides a proof of the scalability of our scheme, but also helps to identify various problems that were not apparent in small experimental networks.

In the next section, we provide a brief description of the two protocols used in our study and the motivations behind our research efforts. In Section 3, we provide an overview of related work. Next, we describe the mobile gateway (MGW) architecture used in our study in Section 4, and the mechanisms used for inter-network routing of packets in Section 5. In Section 6, we illustrate the operation of the system in some typical scenarios. Testbed setup and experimental study results are presented in Section 7. This is followed by simulation results and analysis in Section 8, and conclusions in Section 9.

2. BACKGROUND AND MOTIVATION

The Internet Engineering Task Force (IETF) has identified five protocols as representative of the many that have been proposed, viz., reactive protocols AODV, DSR and DYMO [10], and proactive protocols OLSR and TBRPF.

AODV makes use of destination sequence numbers to ensure loop freedom at all times, and designed to respond quickly to changing link conditions in MANETs. Route Request (RREQ), Route Reply (RREP) and Route Error (RERR) are the basic control messages used in AODV. The RREQ message is used by a node to initiate a route discovery to the destination. The destination node or a node with a route to the destination uses a RREP to reply to the source. RERR messages are used to invalidate routes that are unusable due to link breakages. HELLO messages are also used to provide connectivity information. These are RREP packets with their Time-To-Live (TTL) set to 1, and broadcast locally to all nodes within the vicinity of any particular node. A node uses HELLO messages only if it is part of an active route.

OLSR uses multipoint relays (MPRs) to reduce the transmission of control messages, making it suitable for large MANETs where the network node density is high. Multiple Interface Declaration (MID), HELLO, Topology Control (TC) and Host and Network Association (HNA) are the basic control messages used in OLSR. A MID message advertises any multiple interface of the node. HELLO messages are used for link sensing between neighbouring nodes. TC messages enable nodes to construct the routing table by knowing routes to all possible destinations in the network. HNA messages are used to provide OLSR nodes with external routing information from other non-OLSR networks.

Different protocols have been designed with different assumptions and to meet different requirements. Hence, each is expected to perform ideally in the target network scenario that it is designed for. As the scope of MANET deployment expands, it is likely that the communication between a pair of nodes span multiple network domains. Since mobile devices in general are memory constrained; it would also be impractical for mobile nodes to have many different routing protocols simultaneously loaded to handle

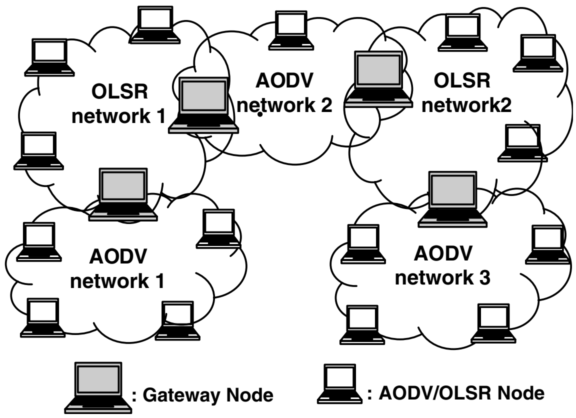

Fig. 1. Multiple interconnected network scenario.

data traffic carried by different routing protocols. Therefore, it would be more viable to deploy a gateway to interconnect nodes in different types of networks using different MANET routing protocols. In our study, AODV and OLSR are used to demonstrate the connectivity between two different ad hoc routing protocols. A typical interconnected network is shown in Figure 1.

3. RELATED WORK

While much research has initially focused on protocols and algorithms for autonomous MANETs, it soon became obvious that MANETs need to be connected to the Internet in order to be useful. The efforts in the IETF provide some good proposals for MANET–Internet connectivity. In [11], MANET nodes first need to obtain a globally routable address from an Internet gateway, after which it can communicate with other nodes in the Internet. Foreseeing that there will be a significant demand for globally routable addresses as well as other advanced features like security and quality of service, the proposal is based on IPv6. Another approach is to extend the existing IP routing protocols to cover MANETs [12,13]. Performance studies on key components like Internet gateway discovery, addressing and handover schemes have also been extensively studied [14,15]. There has been a few efforts to interconnect MANETs via some form wireless ad hoc infrastructure network, e.g. IS-MANET project [16] but they do not address the problem at the routing layer and thus our proposed scheme complements these efforts. To the best of our knowledge, the direct interconnection of MANETs, which is the focus of this paper, has not received much attention.

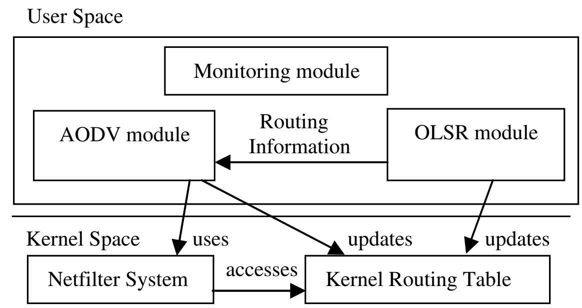

Fig. 2. Mobile gateway (MGW) architecture.

4. MOBILE GATEWAY ARCHITECTURE

To interconnect MANETs running different protocols, e.g. AODV and OLSR in this study, a MGW is needed. This MGW is loaded with both protocols and some changes to the protocols are needed to enable communication between multiple MGWs. However, pure AODV or OLSR nodes that do not act as gateways to other networks remain unchanged. Figure 2 illustrates the MGW architecture. As an optimization feature to improve the power efficiency of the MGW, the monitoring module listens for routing packets in the network and loads the OLSR module when there are surrounding OLSR nodes or unloads the OLSR module when there are no OLSR routing packets heard after a fixed time (set to a multiple of NEIGHB_HOLD_TIME), so that unnecessary control messages are not transmitted. The AODV module is always loaded since there are no additional routing messages incurred if there are no neighbouring AODV nodes.

5. INTER-NETWORK ROUTING MECHANISMS

5.1. Processing of Routing Messages in AODV

When a MGW receives a RREQ, it first determines whether it has a path to the requested AODV node or whether it is the MGW for the OLSR node. If it has a path to the destination node, it will send a RREP to the sender. If the destination in the RREQ is a pure OLSR node, the MGW will have to keep track of the destination sequence number on behalf of the OLSR node, to ensure correct operation of the AODV protocol. If the MGW does not have a path to the destination, it will have to rebroadcast the RREQ to other AODV nodes and unicast the RREQ to other MGWs, enabling it to traverse OLSR networks. The discovery of other MGWs is achieved by broadcasting HNA messages into the OLSR network, which is described in the next section.

When a MGW receives a RREP, it will create a forward route to the source of the RREP, and forward the RREP to the next hop of the reverse route. Similarly, the broadcasting of RERR messages will have to be modified. In AODV networks, RERR messages are unicast if there is only one predecessor or broadcast if there are more than one predecessor. However, if the node is a MGW, RERR messages will be unicast to every predecessor node that is a MGW.

5.2. Broadcasting of HNA Messages in OLSR

Under normal circumstances, an OLSR node that does not have a routing table entry for the destination of the data packet will simply drop the packet. However, the destination may be an AODV node or an OLSR node that is separated by AODV networks, so the OLSR node will send the data packets to the nearest MGW. Then, the MGW will need to initiate route discovery on behalf of the OLSR node. In order to advertise the MGW's connectivity to other AODV nodes as well as OLSR nodes which are separated by AODV networks, the MGW will broadcast HNA messages indicating that it is the default gateway for the OLSR nodes in the network. In the case of an OLSR node receiving HNA messages from multiple MGWs, the nearest MGW will be selected. These HNA messages also enable an MGW to discover other MGWs in the same OLSR network so that any RREQ can be unicast to these MGWs.

5.3. Processing of Data Packets

When the MGW receives a data packet, it will determine whether the packet is destined for an OLSR node, AODV node or MGW. This is done by searching the OLSR routing table as it has complete information about the OLSR network. For a data packet from an AODV node or another MGW, and the destination is not found, a RERR will be sent back to the sender. For a data packet received from an OLSR node, and the destination is not found, it will buffer the data packets and send a RREQ to initiate a route discovery process on behalf of the OLSR node. If no RREP is received after RREQ_RETRIES, then it will send an ICMP Destination Unreachable message back to the OLSR node.

5.4. Tunneling of Data Packets

Since an OLSR node has no route entry to other nodes (AODV nodes or OLSR nodes separated by AODV networks) other than the OLSR nodes in its own network, data packets have to be routed through a tunnel using IP encapsulation [17] between two MGWs. The original source address of the data packet will be replaced by the address of the source MGW while the destination address of the data packet will be replaced by the address of the destination MGW. When the data packet reaches the end of the tunnel, the original source and destination addresses of the data packet will be restored.

6. GATEWAY OPERATIONS

6.1. Single Gateway Operation

Figure 3 illustrates the route discovery process from an OLSR node to an AODV node interconnected by a single MGW. In this situation, the OLSR node will send all the data packets to the MGW which will initiate route discovery on behalf of the OLSR nodes. After a route is discovered, the buffered data packets are forwarded.

Figure 4 illustrates the route discovery process from an AODV node to an OLSR node. In this situation, the MGW will send a RREP on behalf of OLSR nodes. After the AODV node receives the RREP from the MGW, it will send the data packets to the MGW which will then forward the data packets into the OLSR network.

6.2. Multiple Gateways Operation

Figure 5 illustrates the route discovery process from an AODV node to another AODV node in different AODV networks which are separated by an OLSR network. Two rounds of RREQs are needed to reach the destination as the first RREQ will only travel two hops while the second RREQ will travel four hops. Data packets are sent to the MGW only after the route to the OLSR destination node has been discovered.

Figure 6 illustrates the route discovery process from an OLSR node to another OLSR node in different OLSR networks which are separated by an

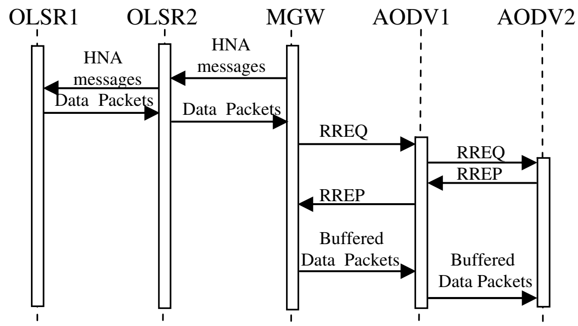

Fig. 3. Route discovery: OLSR1 → AODV2

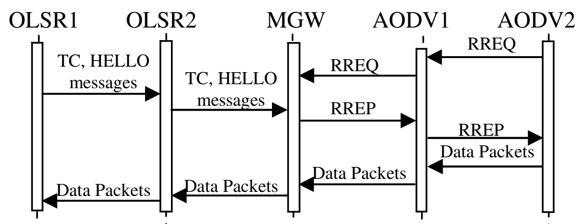

Fig. 4. Route discovery: AODV2 → OLSR1.

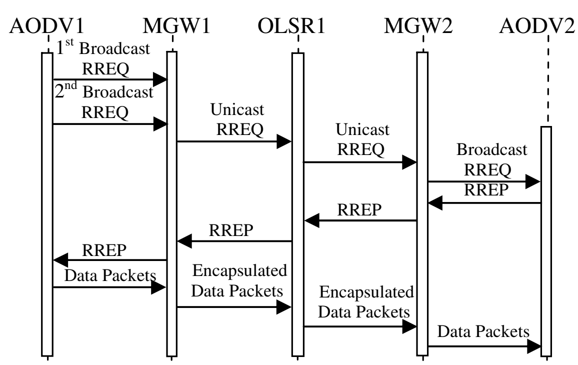

Fig. 5. Route discovery: AODV1 → AODV2.

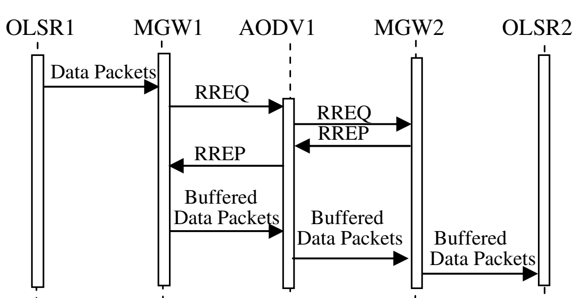

Fig. 6. Route discovery: OLSR1 → OLSR2.

AODV network. Unlike the previous scenario, the MGW buffers the data packets from the OLSR source node even before the route to the destination is found.

7. TESTBEDS AND PERFORMANCE ANALYSIS

7.1. Testbed Setup

To test the implementation of the algorithm for multiple gateways operation, a testbed consisting of five mobile nodes are set up using AODV [18] and OLSR [19] as routing protocols. The different testbed configurations are shown in Table 1. All the nodes are equipped with Red Hat Linux 8.0/9.0 with kernels 2.4.16/2.4.20. The program 'iptables' is used to simulate the lack of connectivity between nodes to create a multiple-hop ad hoc network.

To test the ability to handle mobility of MGWs, the testbed shown Figure 7 is used. In the tests, OLSR1 will resume communication with AODV1 even if either one of the two MGWs moves out of the network. This increases the reliability of the network as either of the MGW can continue to provide connectivity even if one of the MGWs moves out of range.

7.2. Performance Evaluation

Figure 8 shows the 1st packet Round Trip Time (RTT) delay for the 1st data packet to travel to the destination and back to the source for various node configurations with data packets originating from Node 1. This includes any delay due to route discovery process as well as ARP (Address Resolution Protocol) requests. For the pure AODV network, the route discovery times for the AODV network are not proportional to the number of hops as the AODV protocol uses expanding ring search for RREQ messages. The range for the first RREQ is two hops while for the second RREQ is four hops. This expanding ring search helps to reduce the number of RREQs if the destination node is near the source node but increases route discovery time if the destination node is many hops away from the source node. The first packet RTT delay for pure OLSR networks is insignificant as it is a link state routing protocol and the delays are mainly due to ARP requests. For the test beds with MGWs interconnecting AODV and OLSR networks, the first packet RTT delay times are low if the MGW knows of routes to OLSR nodes but high if the MGW has to do route discovery.

Figure 9 illustrates the RTTs of PING packets from Node 1. These RTTs include transmission, processing and queuing delays. In most cases, the RTTs are proportional to the number of hops. From

Table 1. Various configurations of testbed setup

Testbed	NODE 1	NODE 2	NODE 3	NODE 4	NODE 5
Pure AODV	AODV1	AODV2	AODV3	AODV 4	AODV5
Pure OLSR	OLSR1	OLSR2	OLSR3	OLSR 4	OLSR5
Single MGW	AODV1	AODV2	MGW1	OLSR 1	OLSR2
Multiple MGWs 1	AODV1	MGW1	OLSR 1	MGW2	AODV2
Multiple MGWs 2	OLSR1	MGW1	AODV 1	MGW2	OLSR2

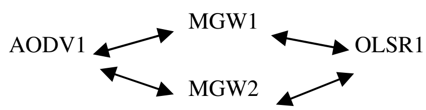

Fig. 7. Testbed of 2 MGWs connecting AODV and OLSR networks.

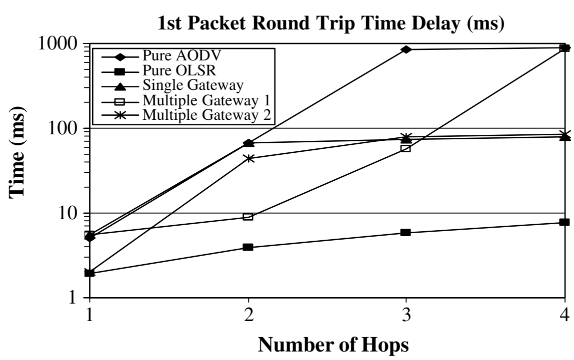

Fig. 8. 1st Packet RTT Delays.

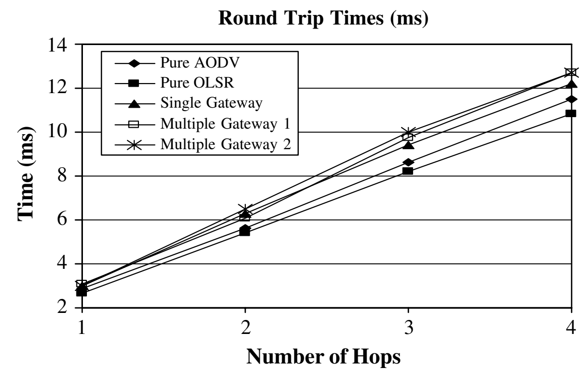

Fig. 9. Round Trip Times.

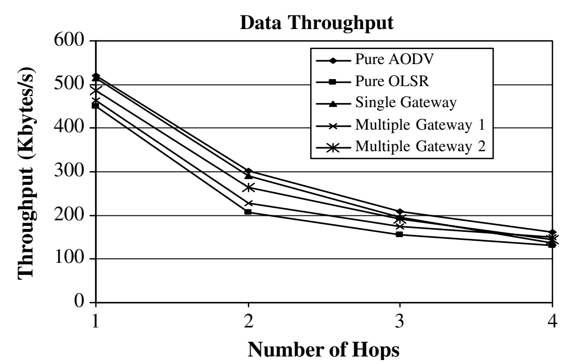

Fig. 10. Data throughput.

the tests conducted, some processing delays at the MGW resulted in about 20% increase in RTTs.

Figure 10 illustrates the data throughput using FTP. Default parameter values in the implementations of AODV and OLSR are used, and the higher throughput for the pure AODV network does not indicate that the performance of an AODV network is better than that of an OLSR network. For the various gateway configurations, the data throughput lies between the pure AODV and pure OLSR network, indicating that our gateway implementations do not negatively affect the performance of the network.

8. SIMULATION RESULTS AND ANALYSIS

In the previous section, through testbed implementations, we demonstrated that our scheme is able to work for heterogeneous networks without much compromise to the performance of the network. However, our performance evaluation was based on a simple string topology with small number of nodes and hops from the destinations. In this section, we extend our implementation studies by simulating the scheme over larger networks to validate its scalability.

8.1. Simulation Environment

We perform our simulations on Qualnet [20], which provides a simulation platform for large, wireless networks. A terrain size of 1500×1500 m is used throughout our simulations. Nodes are randomly deployed according to one of the following layouts (Figures 11–13):

To simulate data traffic, CBR (Constant Bit Rate) connections are set up between variable number of nodes and destinations. Each CBR source sends 3000 packets at regular intervals of 100 ms, and each packet contains 512 bytes of data. To allow the topology of OLSR to stabilize, data traffic commences only after the initial 100 s of simulation time.

The IEEE 802.11 standard is used as our underlying MAC (Medium Access Control) protocol and the maximum available bandwidth of the shared channel is 2 Mbps. Each simulation scenario is also run with a few seed numbers and all measurements are averaged to minimize any arbitrary randomness.

8.2. Performance Metrics

We analyze the performance of our scheme according to the following metrics:

- End-to-end delay – average time taken to transmit a data packet from the source to the destination.
- Throughput – average number of bits transmitted per second.
- Normalized routing overhead – total number of control packets transmitted as a ratio of the total number of data packets transmitted; this measures the efficiency of the protocols and/or schemes.

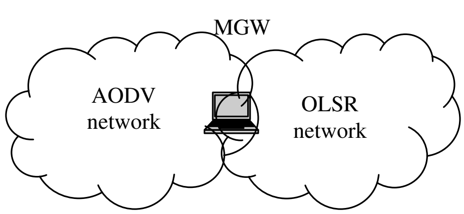

Fig. 11. One AODV network and one OLSR network connected via a single MGW.

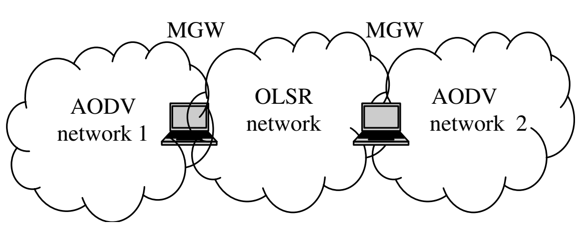

Fig. 12. Two AODV networks connected via multiple MGWs.

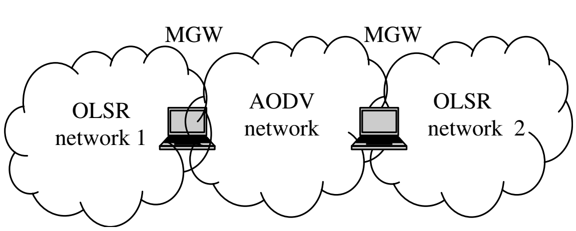

Fig. 13. Two OLSR networks connected via multiple MGWs.

For each set of experiments, we also compare the performance of the scheme against AODV and OLSR networks that do not contain any gateways, which we denote as "pure AODV" and "pure OLSR" networks, respectively.

8.3. AODV → OLSR via single MGW

Using the network topology as shown in Figure 11, we simulate varying number of traffic sources from the AODV network to the OLSR network via a single MGW. A network size of 101 nodes is used in our simulations. In the single MGW scenario, this comprises 50 AODV nodes, 50 OLSR nodes and a single MGW that is positioned in the centre of the terrain. Figures 14–16 show the comparative results of our schemes against that of pure AODV and pure OLSR networks.

In Figure 14, the pure AODV network experiences shorter end-to-end delay than the pure OLSR network, although the latter already has forwarding information available in its routing table and thus does not need to undergo the route discovery and route establishment phase as like AODV. The phenomenon can be explained by the fact that OLSR emits periodic control packets (such as MID, HELLO, TC and HNA messages), which can collide with the data packets and cause retransmissions, resulting in longer delays. In our scheme with a single MGW, the delay is longer because the AODV source node needs to find a route to the specific MGW (which is placed in the centre of the terrain for our simulation purposes) before it can send data packets to the destination. If it had been a homogeneous network (i.e. using the same routing protocol), the source node(s) may actually be able to discover shorter paths to the destination(s) without going

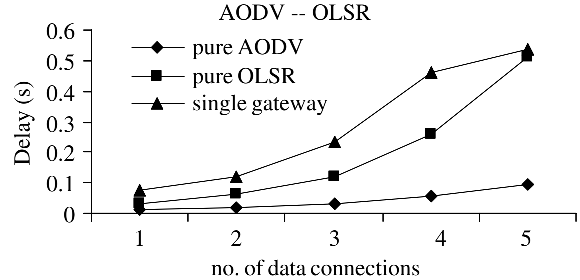

Fig. 14. Average delay of packets from AODV → OLSR network.

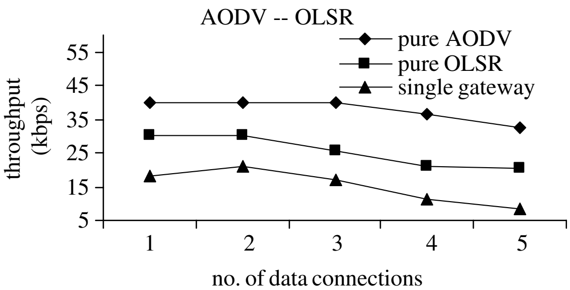

Fig. 15. Throughput from AODV → OLSR network.

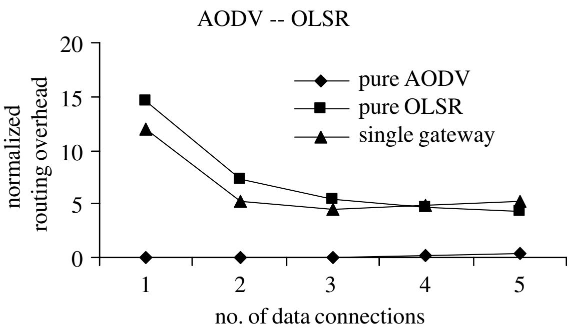

Fig. 16. Normalized routing overhead from AODV → OLSR network.

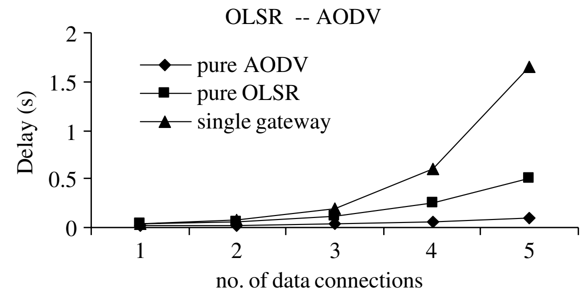

Fig. 17. Average delay of packets from OLSR → AODV network.

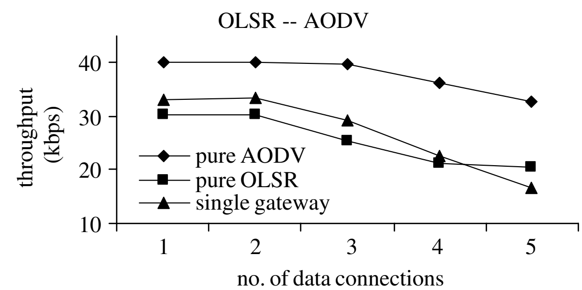

Fig. 18. Throughput from OLSR → AODV network.

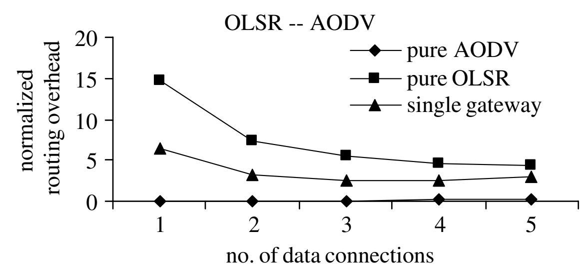

Fig. 19. Normalized routing overhead from OLSR → AODV network.

through the MGW, thus reducing the average end-to-end delay. The increased delay caused by data packets having to go through the MGW (which may be located far away from the source node) may actually lead to lowered throughput, as shown in Figure 15. However, since there is a mixture of OLSR and AODV nodes in the network with a single MGW, the normalized routing overhead is lower than that of the pure OLSR network, as can be seen in Figure 16. In general, OLSR nodes have higher routing overheads because of the periodic control packets that are being transmitted throughout the network lifetime. AODV will incur overhead only when there is data traffic to be sent.

8.4. OLSR → AODV via single MGW

In this scenario, varying numbers of traffic connections are established from OLSR nodes to AODV nodes in a network with a topology similar to that in Figure 11. In the scenario with a single MGW, we use a total of 50 AODV nodes and 50 OLSR nodes that are connected via a MGW.

Figures 17 and 18 show the average delay and throughput of the three network configurations. At low traffic loads, the variance of the delay between these three network configurations is not significant. At higher traffic loads, it becomes apparent that the single MGW is overloaded with traffic as all the data has to be buffered at the MGW before they can be forwarded to their destinations, resulting in increased delay and lowered throughput. Generally though, the single MGW provides performance that lies between a pure OLSR network and a pure AODV network. As shown in Figure 19, with the use of a single MGW, the normalized routing overhead is lesser than that of pure OLSR because lesser nodes transmit periodic broadcasts.

8.5. AODV → OLSR → AODV

In the topology shown in Figure 12, we simulate a total of 25 OLSR nodes and 50 AODV nodes

(25 nodes in each AODV network). Data connections are set up from AODV network 1 to AODV network 2 such that traffic has to pass through the two MGWs that interconnect these three networks.

Figure 20 shows the average end-to-end delay of the data packets in the network. At low traffic loads, the delay of the scenario with MGWs is longer than the pure OLSR network, because two route discovery and maintenance processes are required: (i) from the AODV source node to the MGW; and (ii) from the second MGW to the AODV destination node.

Throughput is lower than both the pure AODV and pure OLSR networks, as shown in Figure 21, because of the contention at the MGWs. This effect can be alleviated with the use of multiple, strategically positioned MGWs in the network, which can also be utilized for load balancing purposes. There is also lesser normalized routing overhead (see Figure 22) because the AODV nodes in the network need not broadcast periodic control messages as like the OLSR nodes.

8.6. OLSR → AODV → OLSR

The topology shown in Figure 13 is used, where two OLSR networks (each of which comprises 25 nodes) are connected to an AODV network (with 25 nodes), via multiple MGWs. Data traffic is sent from OLSR network 1 to OLSR network 2 by passing the two MGWs. As shown in Figure 23, the delay for the network with multiple MGWs is generally lower than that of a pure OLSR network for high traffic loads (more than three data connections). With increased data packets in the network, there is more contention for accessing the shared communication channel, especially in OLSR networks that make use of periodic control messages. At low traffic loads, the pure OLSR network is able to provide shorter end-to-end delay because the nodes already have available routes to the destinations.

Figure 24 shows the throughput performance of the network with multiple MGWs in comparison with the pure OLSR and pure AODV networks. Generally, the use of MGWs causes the data packets to take longer paths because they have to pass through the MGWs. This also increases the load and contention at the MGWs, resulting in the lowered throughputs.

The normalized routing overhead is shown in Figure 25. Since the network with multiple MGWs comprise both AODV nodes and OLSR nodes, less periodic control packets are transmitted from the network, resulting in better efficiency than the pure OLSR network.

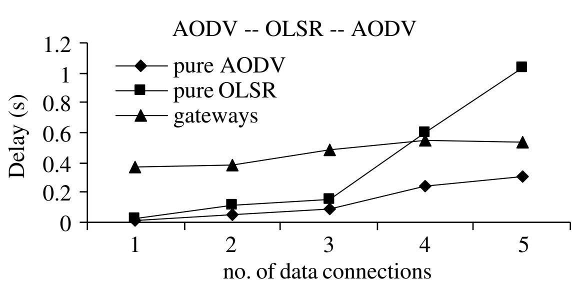

Fig. 20. Average delay of packets from AODV → OLSR → AODV network.

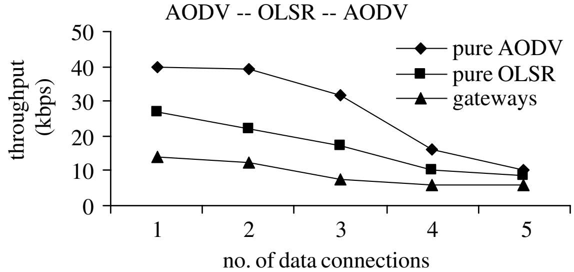

Fig. 21. Throughput from AODV → OLSR → AODV network.

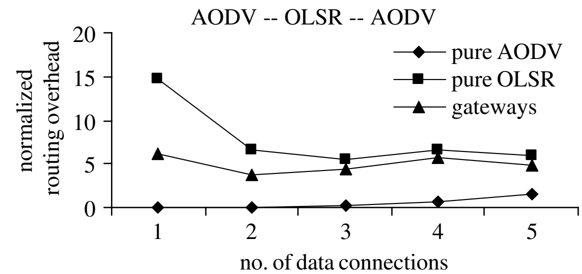

Fig. 22. Normalized routing overhead from AODV → OLSR → AODV network.

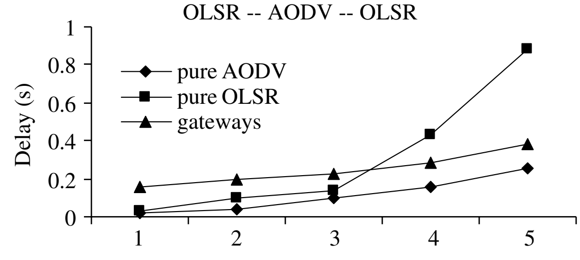

Fig. 23. Average delay of packets from OLSR → AODV → OLSR network.

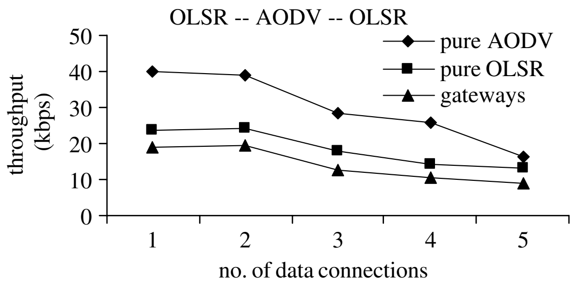

Fig. 24. Throughput from OLSR → AODV → OLSR network.

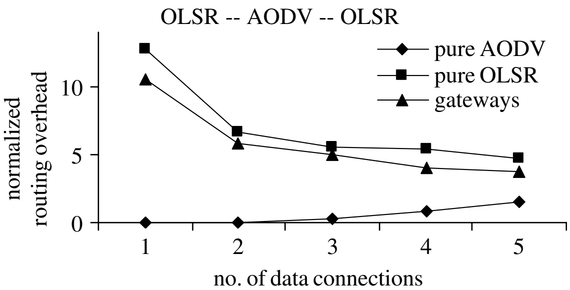

Fig. 25. Normalized routing overhead from OLSR → AODV → OLSR network.

8.7. Overall Analysis of Implementation and Simulation Results

From our implementation results and simulation results, there are a few key differences and issues that need to be highlighted. In the simple string topology that was used for our experimental studies, the performance of the scheme was generally in between that of the pure OLSR and pure AODV network, because it is essentially a hybrid between these two networks. However, in our simulation studies, which comprise of larger nodes with more than 50 nodes, the performance of the scheme with MGWs is generally slightly poorer than that of both pure AODV and pure OLSR networks.

The main reason behind this phenomenon is that in our simulation studies, only one MGW is placed between each type of network. This increases the load and contention at the MGW, thereby degrading the network performance slightly. In the experimental setup, very light traffic loads are used; therefore the performance of the scheme is better than a pure OLSR network.

To tackle this problem, multiple MGWs can be used to interconnect any two different networks, such that traffic flowing through them need not always go through the same MGW. This helps to do load balancing and shorten the lengths of routes through the MGWs, thus improving the performance of the network. While the role of a node as a MGW is fixed, the discovery of such a "default" MGW to serve other nodes (pure AODV or pure OLSR) is dynamic. This can help to improve the robustness of the scheme, because even with the failure of one or more MGWs, other MGWs can be used to route data traffic in between heterogeneous networks.

9. CONCLUSION

This study has achieved the following objectives:

- Interconnectivity of AODV and OLSR protocols, which represent the two main classes of MANET protocols
- Compatible with current AODV [17] and OLSR [18] implementations on Linux
- Seamless roaming experience for the wireless nodes as the MGW to the node is discovered dynamically
- Automated configuration of routing protocols with dynamic loading/unloading of protocols by MGWs
- The MGW architecture can be utilized for mobile entities to provide dual protocol stack capability
- Extends the area of operations of ad hoc networks.

The experiments have been carried out with a small number of nodes primarily for functional verifications, while the performance evaluation of the MGW in larger MANETs has been done using simulations.

The aim of this study is to ensure that the performance of the network does not degrade due to the MGW design. However, it is inevitable that the overall network performance may suffer due to the increased traffic in the MGW's locality, which then justifies the need for multiple MGWs to be deployed in order to distribute the inter-network traffic. In wired networks, a router can have multiple subnets connected to it without mutual interference and the performance of the inter-network routing is closely linked with the router architecture design. However, in wireless networks, proper network topology design is critical especially when shared contention-based medium access technologies are used.

We aim to support all the ad hoc routing protocols (AODV, OLSR, TBRPF, DSR and DYMO [10]) selected by IETF as this will enable seamless roaming for end-users via automated detection/selection of the routing protocols. As part of future work, we will also study the performance of the scheme in mobile networks. Furthermore, with the increasing interest in wireless mesh networks which utilizes a combination of different access as well as networking technologies, the interconnectivity of different ad hoc routing protocols will become a key enabling technology.

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