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Performance comparison of ADOV and OLSR routing protocols in realistic network scenarios

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Abstract. Many routing protocols have been proposed to efficiently discover paths from a source node to a destination node in a mobile ad hoc network. In this paper, we compare the performance of two well-known routing protocols: the ad hoc on demand distance vector routing protocol (AODV) and the optimized link state routing protocol (OLSR). Existing work has studied the routing protocols under idealistic settings where the network sizes are small and all the nodes function properly. Our work addresses realistic settings where some nodes may be faulty resulting in the degradation of the performance of routing protocols. Our simulations consider large network sizes with several nodes. We compare the performance of the two routing protocols using the QualNet network simulator. Our results show that AODV outperforms OLSR in terms of packet delivery ratio and the average routing overhead.

Keywords: ad hoc networks, routing protocols, faulty nodes

1. Introduction

A mobile ad hoc network (MANET) is a network of wireless mobile nodes which co-operate to maintain network connectivity and exchange information. MANETs are very useful in cases where wired network installation is infeasible such as battlefields and buildings with no previous network cabling. In a MANET, the nodes must act co-operatively as routers that can relay data packets from a source node to a destination node. MANET is a self configuring network of mobile nodes that could form an arbitrary topology. The nodes have the ability to move randomly and organize themselves in an arbitrary manner. Hence, the topology of the network may change rapidly and unpredictably. MANETs have become very popular because of their military and civilian applications. MANETs have several important features such as bandwidth constrained links, energy constrained operation, and limited network security.

Several routing protocols have been proposed for mobile ad hoc networks. In this paper, we present a performance comparison of AODV and OLSR routing protocols. Although these protocols have been compared by several researchers, our work addresses the performance comparison of the protocols in realistic network settings. The two main contributions of this work are:

- Performance comparison of two well-known routing protocols on networks with a large number of nodes using the recent version of the QualNet network simulator.
- Analysis and performance comparison of the routing protocols in the presence of faulty nodes. This is a significant improvement over existing work where nodes were considered ideal.

The rest of the paper is organized as follows. In Section 2, we describe the related work in routing protocol design for MANETs. Section 3 describes the AODV and OLSR routing protocols. Section 4 describes the various features of the QualNet network simulator. In section 5, we describe the node mobility model, the node fault model, and the performance metrics. Section 6 describes our simulations and presents a discussion of the results obtained. Section 7 summarizes the contributions of our work.

2. Related Work

Routing protocols can be divided into two categories: table driven (proactive) and on-demand (reactive). Table driven protocols enforce mobile nodes to maintain tables with route information from every node to every other node in the network. Two well- known table driven routing protocols are: the destination sequenced distance vector protocol (DSDV) and the optimized link state routing protocol (OLSR). The table driven protocols differ in the mechanisms used for data propagation when the topology of the network changes. Table driven protocols are not suitable for large scale networks where the network topology changes rapidly due to node mobility. A detailed description of table driven routing protocols is presented in [1].

The on demand routing protocols do not maintain global routing information for the whole network. A route discovery process is initiated only when a source node intends to transmit data to a destination node. The protocols include route maintenance mechanisms which store the routing information until sources do not need that information or until routes become invalid. Ad hoc on demand distance vector routing protocol (AODV) is a reactive protocol widely used in MANETs. In AODV, a route discovery process is initiated by source nodes only when the source nodes that desire to transmit data to a destination node do not have a valid route. A detailed description of ADOV is presented in [2].

Recently, several researchers have analyzed the performance of routing protocols in MANETs. Abolhasan et. al [1] have presented a comprehensive review of several proactive and reactive routing protocols in ad hoc networks. In [3], the performance of AODV is compared with statistics based routing protocol (SBR). The results in [3] show that SBR outperforms AODV in networks with high mobility and small number of data sinks. However, the routing overhead generated by SBR is much higher compared to AODV. Haerri et al. [4] compared the performance of AODV and OLSR in vehicular ad hoc networks under realistic mobility patterns. Their study concluded that OLSR outperforms AODV in urban environments in terms of routing overhead and end to end delay. Hsu et al. [5] have compared several on demand routing protocols using QualNet simulator. They have validated the results obtained by QualNet against network and traffic configuration generated from field exercises. Their results demonstrate that QualNet simulations can accurately model real world scenarios with good correlation on end to end statistics such as throughput and delay. In [6], Brinda et al, have compared the performance of AODV and DSR by using the group mobility model. The group mobility has applications in military where the commander and soldiers form a logical group. Their work demonstrated that AODV outperforms DSR with constant bit rate traffic while DSR has a lower routing overhead. Ade and Tijare [7] have compared the performance of AODV, OLSR and DSR in MANETs. Although their results are insightful, their work does not consider large scale networks and the effect of network density and mobility speeds on the performance of the routing protocols. In [8], the authors have considered quality of service routing in OLSR. They have developed heuristics that allow OLSR to find the maximum bandwidth path. Their simulations showed that the heuristics improved the performance of OLSR in the static network scenario and are optimal for the ad hoc network.

Mueller et al. [9] have examined the issues of multipath routing in MANETs. Multipath routing enables the discovery of multiple paths between a source and destination. This increases the reliability of data transmission and provides fault tolerance. Although their work provides interesting insights into multipath routing, they have not addressed the interaction of multipath routing with the transport layer. Caro et al. [10] have proposed a hybrid algorithm called AntHocNet for routing in MANETS. Their algorithm combines reactive path setup with proactive path probing using ant colony optimization framework. Their results show that AntHocNet outperforms AODV for different evaluation criteria. Although their algorithm is interesting, their simulations were based on sparse networks and they have not examined the behavior of the algorithms for dense ad hoc networks.

The work studied by various researchers [5-8] discussed above have failed to address realistic network scenarios with large number of nodes in which some nodes may be faulty. Our work provides a comprehensive performance comparison by incorporating faulty nodes and realistic network sizes and mobility speeds in our simulations. We use the fault model provided by QualNet network simulator to model faulty node behavior. Our results provide interesting insights about the behavior of the protocols in the presence of faulty nodes that refuse to forward packets to the destination.

3. MANET Routing Protocols

Several routing protocols have been proposed for successful packet transmission in mobile ad hoc networks [1]. Table driven routing protocols enforce mobile nodes to maintain tables with route information from every node to every other node in the network. The most popular table driven protocol is OLSR. The on-demand protocols perform route discovery only when the source has a data packet to transmit to the destination. AODV is a widely used reactive routing protocol. In this section, we describe the two routing protocols: OLSR and AODV. A detailed description of these protocols is presented in [2, 11].

3.1 Optimized Link State Routing

Optimized link state routing is a proactive routing protocol in which the routes are always available when needed. In OLSR, topological changes in the network cause the flooding of topological information to all available hosts in the network. To reduce overhead in the network, OLSR uses multipoint relays (MPR). MPR is used to reduce flooding by avoiding multiple broadcasts in some regions of the network. OLSR uses two kinds of control messages: hello and topology control. Hello messages are used to discover information about the link status and the neighbors of the host. Topology control messages are used for broadcasting information about the neighbors of a node which includes the MPR selector list.

3.2 Ad hoc On Demand Distance Vector Routing

AODV is a reactive routing protocol in which the routes are created and maintained only when needed. The routing table stores information about the next hop to the destination and a sequence number that indicates the freshness of the received information. The protocol performs route discovery using two control messages: route request (RREQ) and route reply (RREP). A RREQ message is broadcasted when the source does not have a valid route to the destination. The RREQ packet contains the source and destination sequence numbers, the source and destination addresses and the hop count. The RREQ packet is either forwarded or replied with a route reply (RREP) message. If a node that receives the RREQ packet is the destination or has a valid route to the destination, it unicasts a RREP packet back to the source. Otherwise, the RREQ packet is broadcasted with an incremented hop count. All nodes monitor their neighboring nodes. When a node in an active route gets lost, a route error message is transmitted to notify the neighboring nodes about the loss of a link.

4. QualNet Network Simulator

For our simulations, we used the QualNet network simulator version 5.0.2 [12]. QualNet has the ability to perform simulations for networks with large number of nodes within a reasonable computational time. QualNet provides several attractive features such as:

- Efficient implementation of various well known routing protocols such as AODV, DSR, DSDV, and OLSR at the routing layer.
- Detailed physical layer capabilities such as channel fading, shadowing, and directional antennas.
- Implementation of various MAC protocols such as IEEE 802.11e, CSM-CA and ALOHA.

In QualNet, there are a variety of simulation parameters that can be set at various layers of the network. A large number of statistics is also collected at each layer. QualNet also provides an animator written in Java for demonstration purposes. At the end of the simulation run, QualNet analyzer provides the simulation results in various categories for each level of the open systems interconnection model. For our work, we are interested in statistics such as the number of packets received and the routing overhead at the network and application layers.

5. Simulation Setup

In this section, we describe the traffic, mobility, and node fault models used for our simulations. We also present a description of the performance metrics used for comparing AODV and OLSR routing protocols.

5.1 Traffic and Mobility Models

The traffic sources are continuous bit rate (CBR). The data packet is chosen to be 1024 bytes in length and the channel bandwidth is 2 Mbps. The mobility model is random waypoint model. In this model, a node moves with a randomly chosen speed uniformly distributed between 0-20 m/s.

5.2 Node Fault Model

In QulaNet, node interfaces can have static or dynamic faults. In our work, we use static faults to model the anomalous behavior of a node. A static fault causes a node interface to be unavailable at a pre-determined time for a pre-determined length of time. Static faults have user specified start and end times. In QualNet, the faults are described in a fault configuration file that specifies the IP address of the node which is faulty and the start and end times of the fault. In this model, the node remains faulty between the start and end times and the MAC address of the node interface comes up again after the end time.

5.3 Performance Metrics

We compare the performance of the routing protocols based on two metrics:

- Average packet delivery ratio: This metric is defined as the ratio between the number of data packets successfully delivered to the destination and the number of packets transmitted by the source.
- Average routing over head: This represents the number of bytes required by the routing protocols to construct and maintain their routes.

6. Simulation Results and Discussion

In our simulations, 200 nodes were randomly placed in a 300m×300m rectangular field. The source destination pairs were chosen randomly from the set of network nodes and are the same for the duration of the entire simulation. We run ten trials of each simulation run and the results presented are averages over the ten trials. Each simulation is run for 200 seconds. The rest of the section is organized as follows. In section 6.1, we investigate the effect of node mobility on the performance of AODV and OLSR for a fixed number of faulty nodes in the network. Section 6.2 describes the effect of varying the number of faulty nodes on the performance of the routing protocols.

6.1 Effect of Node Mobility on Protocol Performance

To examine the effect of node mobility, we randomly choose 10% of nodes in the network as faulty. We then vary the mobility of the source node from 5 to 50 m/s. Figure 1 shows the performance comparison of AODV and OLSR in terms of the packet delivery ratio. We observe that with increase in the speed of the node, the packet delivery ratio decreases. AODV performs much better than OLSR especially for higher node mobility. Since AODV performs route discovery only on demand, it is better equipped to discover broken links and changes in the network topology due to node mobility. On the other hand OLSR maintains routing table at each node and the routing entries may become invalid when a node reaches out of the transmission range of its neighbors due to mobility. This explains the significant difference in the PDR of both protocols for higher node mobility.

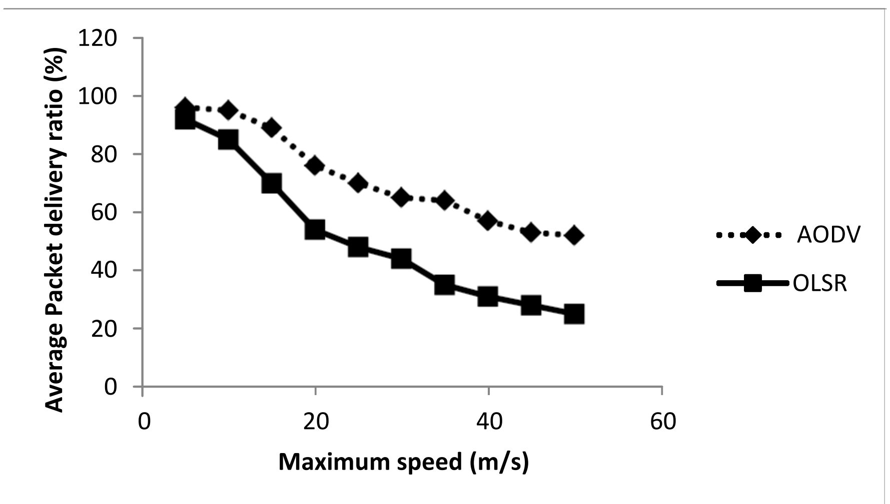

Fig. 1. Comparison of AODV and OLSR in terms of packet delivery ratio for various node speeds

Figure 2 shows the average routing overhead for AODV and OLSR. We observe that the average overhead for AODV remains relatively the same for various node speeds. However, the overhead for OLSR decreases with increase in maximum node speed. This decrease results from errors in multipoint relay set calculations which reduces the number of topology control messages that are forwarded. We also observe that OLSR generates a much higher overhead than AODV especially when the nodes have lower speed. In networks with low mobility, OLSR is able to distribute the topology information using control messages to the whole network. This minimizes the errors in multipoint relay set calculations at the cost of an increase in routing overhead.

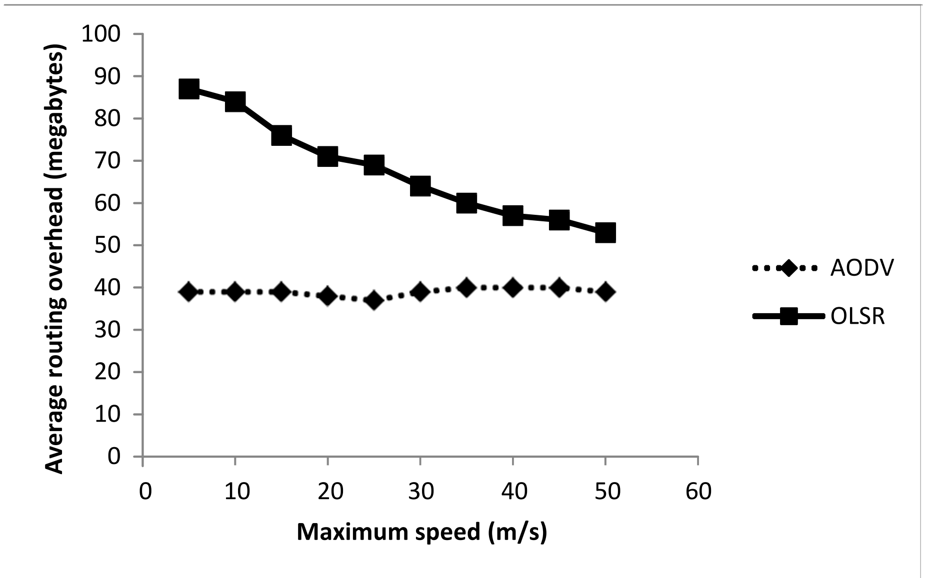

Fig. 2. Variation of average routing overhead with node speed for AODV and OLSR

6.2 Effect of Faulty Nodes on the Performance of the Protocols

In this section, we describe the simulation results obtained by varying the number of faulty nodes in the network. The mobility of the source node was set to 10 m/s throughout the experiment and the number of faulty nodes was varied from 5 to 30 percent of the total number of nodes in the network. The results presented are averages over 10 trials. The source destination pairs were chosen randomly from the set of network nodes and are the same for the duration of the simulation.

Figure 3 shows the variation of packet delivery ratio with the percent of faulty nodes in the network. We observe that AODV outperforms OLSR. This is evident as the number of faulty nodes in the network increase. When more nodes in the network become faulty, many of the routing table entries maintained by OLSR become invalid. This explains the decrease in the PDR for OLSR. Since AODV performs route discovery on demand, it is more robust to the number of faulty nodes in the network.

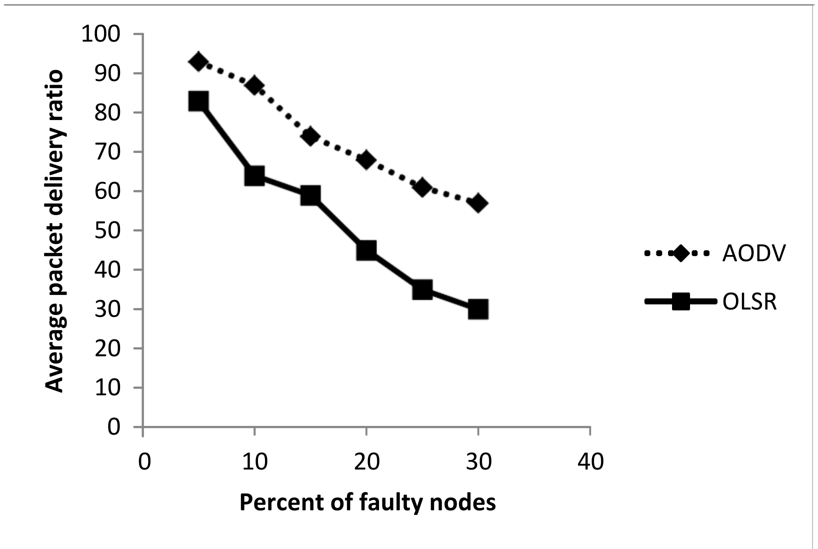

Fig. 3. Effect of faulty nodes on PDR for OLSR and AODV

Figure 4 shows the variation in routing overhead with the percent of faulty nodes for AODV and OLSR. We observe that the routing overhead increases with the number of faulty nodes for both protocols. OLSR has a significantly higher overhead compared to AODV. For AODV, the routing overhead increases very rapidly with increase in number of faulty nodes. In AODV, the destination node replies with a single RREP per route discovery. With the increase in number of faulty nodes, the probability of not receiving a RREP packet also increases due to several faulty nodes being unavailable. If the RREP is not received another RREQ is sent up to a maximum RREQ retries. This results in the increase in number of control packets transmitted for successful route discovery. On the other hand in OLSR, with increase in faulty nodes the protocol is unable to distribute topology information using control messages to the whole network. Hence, the routing overhead does not increase rapidly with increase in number of faulty nodes.

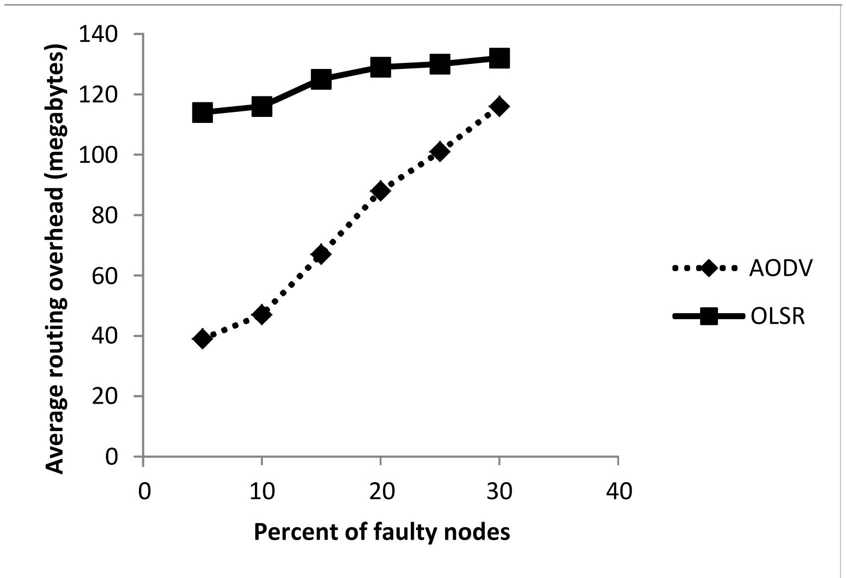

Fig. 4. Effect of faulty nodes on the routing overhead of AODV and OLSR

7. Conclusions

In this work, we compared the performance of AODV and OLSR in large scale mobile ad hoc networks. Although these protocols have been studied by several researchers, our work modeled the network using a very realistic setting where nodes were modeled as exhibiting faulty behavior. Our simulations showed some very interesting results in terms of two metrics: packet delivery ratio and routing overhead. We observed that AODV performs better than OLSR in terms of successfully delivering packets to the destination. The performance improvement was very significant with increase in the node mobility. We also observed that AODV outperforms OLSR in terms of the average routing overhead. OLSR generates a much higher overhead especially in networks with a lower mobility speed. Our results indicate that the choice of one protocol over another is dependent upon the reliability of the network and the parameters of interest to the system designer. Our future work will investigate the behavior of other routing protocols such as DSR and DSDV in the presence of faulty nodes. We also plan to examine the performance of the protocols in terms of the end to end delay.

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