A Comparative Study of MANET Routing Protocols

Mona N. Alslaim

Haifaa A. Alaqel

Soha S. Zaghloul

Department of Computer Science
King Saud University
Riyadh, KSA

432203899@student.ksu.edu.sa

433203589@student.ksu.edu.sa

smekki@ksu.edu.sa

***Abstract*— Mobile Ad-Hoc Network (MANET) is a collection of wireless mobile hosts forming a temporary network without the aid of any stand-alone infrastructure or centralized administration. Due to the mobility of the nodes in the network, these nodes are self-organizing and self-configuring. Not only they act as hosts, but also they function as routers. They direct data to or from other nodes in the network. In MANETs, routing protocols are necessary to find specific paths between the source and the destination. The primary goal of any ad-hoc network routing protocol is to meet the challenges of the dynamically changing topology. Therefore, an efficient route between any two nodes with minimum routing overhead and bandwidth consumption should be established. The design of these routing protocols is challenging due to the mobility and the dynamic nature of the mobile ad-hoc networks. MANET routing protocols are categorized into two types: proactive and reactive. In this paper, the MANET characteristics and challenges are highlighted. In addition, the previously mentioned categories of routing protocols, proactive and reactive, are explored. Moreover, a comparison is conducted between three protocols; namely, DSDV, DSR and AODV in terms of both properties and performance. Finally, a critical analysis is performed on some papers that discussed routing in MANET.**

Keywords*— MANET; Proactive Routing; Reactive Routing; DSDV; DSR; AODV

I. INTRODUCTION

Recently, wireless networks and mobile devices gained a wide popularity. This led to the significant increase of mobile ad-hoc networks in the last few years. Accordingly, MANETs became one of the most prevalent areas in research. The ability of this type of networks to operate anywhere and anytime made it adaptable in many new applications.

All manuscripts must be in English. These guidelines include complete descriptions of the fonts, spacing, and related information for producing your proceedings manuscripts. Please follow them and if you have any questions, direct them to the production editor in charge of your proceedings (see author-kit message for contact info).

In general, there are two communication approaches for wireless mobile nodes. Here they are:

- *Infrastructure-based* wireless mobile networks: these are based on the cellular concept. They rely on a good infrastructure support. Mobile devices communicate with an access point, such as a base station, which in turn is connected to a fixed network infrastructure.
- *Infrastructure-less:* MANETs belong to this type of communication. It consists of a collection of wireless dynamic nodes that form a network. The nodes exchange information without using any pre-existing fixed network infrastructure.

In the infrastructure-less approach, all nodes cooperate with each other to forward packets; thus extending the limited transmission range of each node's wireless network interface. Each node may forward traffic unrelated to its own use, and therefore be a router [2]. Each node in a MANET is free to move independently in any direction, and therefore changes its links to other devices frequently. Due to the dynamic nature of the MANETs, routing protocols should be efficient enough to satisfy the network's requirements.

This paper is organized as follows: Section 2 explores the background about MANETs. Section 3 enumerates MANETs applications. Section 4 exposes the challenges faced in MANETs. Section 5 details the MANETs routing protocols. Section 6 conducts a comparative study between the routing protocols in terms of their characteristics and performance. Finally, Section 7 concludes the paper.

II. BACKGROUND

A mobile ad-hoc network (MANET) is a self-configuring infrastructure-less network of mobile devices connected by wireless communication. They are characterized by the following criteria:

- *Dynamic topology:* Nodes are free to move arbitrarily, meaning that the network topology, which is typically multi-hop, may change randomly and rapidly at unpredictable times [3].
- *Bandwidth-limited and fluctuating capacity links:* wireless links, by nature, have substantially lower capacity as compared to their hardwired counterparts. Besides the throughput of a wireless communication in a real environment is often much lower than a radio's maximum transmission rate. This is due to the existence of multiple negative effects such as fading, noise and interference conditions [2].

ISBN: 978-1-4799-3166-8 ©2014 IEEE

- *Low power and resource:* Mobile nodes are likely to rely on batteries. Therefore, the primary design criteria should be energy conservation [4].
- *Constrained physical security:* mobile wireless networks are more likely to be vulnerable to physical security threats than are fixed cable nets. For example, there is an increased possibility of eavesdropping, spoofing, and denial of service attack that should be carefully considered [2].
- *Decentralized network control:* the decentralized nature of network's control in MANETs supports extra robustness against the single points of failure found in centralized approaches [2].

III. MANETs Applications

Due to their flexible nature, MANETs are used in many applications such as [4]:

- Sensor Networks for environmental monitoring
- Rescue operations in remote areas
- Remote construction sites
- Emergency operations
- Military battlefield
- Civilian environments
- Law enforcement activities
- Commercial projects

IV. Challenges in MANETs

- *Routing:* since the topology of the network is constantly changing, the issue of routing packets between any pair of nodes becomes a challenging task. Furthermore, multicast routing even imposes a bigger challenge because the multicast tree is no longer static. This is due to the random movement of nodes within the network. Routes between nodes may potentially contain multiple hops. Therefore, the design of the protocol becomes even more complicated [1].
- *Power Consumption:* the routing protocol should take into consideration the limited power resource of the mobile wireless nodes. In other words, the routing protocol should be efficient and energy-aware [2].
- *Internetworking:* a MANET may be interconnected with a fixed network. Therefore, the routing protocol should take into consideration the coexistence of other routing protocols designed for fixed networks [3].
- *Security and Reliability:* In addition to the common vulnerabilities of wireless connection, an ad hoc network has its particular security problems due to nasty neighbor relaying packets. The feature of distributed operation requires different schemes of authentication and key management. Furthermore, wireless link characteristics introduce reliability problems, because of the limited wireless transmission range, the broadcast nature of the wireless medium (e.g. hidden terminal problem), mobility -induced packet losses, and data transmission errors [1].
- *Quality of Service (QoS):* Providing different quality of service levels in a constantly changing environment imposes a further challenge [3].

V. Routing Protocols

Several MANETs routing protocols are proposed in the literature. These may be broadly classified into two types as [8]:

- *Table Driven or Proactive Protocols:* In this type of protocols, each node maintains one or more tables containing routing information to every other node in the network. All nodes keep on updating their routing tables to maintain the latest view of the network. DSDV is an example of such protocols.
- *On Demand or Reactive Protocols:* In this type of protocols, routes are created only when required. In other words, when a packet is to be transmitted from a source to a destination, it invokes the route discovery procedure. The route remains valid till either the destination is reached or the route is no longer needed. Some of the existing on demand routing protocols are: DSR and AODV.
- This paper emphasizes on DSDV, DSR and AODV routing protocols since it was proven that these are the best suited for Ad Hoc Networks. The next subsections describe the basic features of these protocols.

A. Destination-Sequenced Distance-Vector (DSDV)

The Destination-Sequenced Distance-Vector (DSDV) routing algorithm is an improvement of the classical Bellman-Ford routing algorithm. The basic idea is that each mobile station maintains a routing table that contains all available destinations, the corresponding number of hops to reach that destination and a sequence number assigned by the destination node. The sequence number is used to distinguish stale routes from new ones and thus avoid the formation of loops. So, the update is both time-driven and event-driven. The routing table may be updated either by a full dump or by an incremental update. A full dump sends the whole routing table to the neighbors. Therefore, many packets may be spanned in such update mode. On the other hand, only the entries that have a metric change since the last update are broadcast. Accordingly, such update must fit in a packet. If there is space in the incremental update packet then those entries may be included whose sequence number has changed. When the network is relatively stable, incremental updates are sent to avoid extra traffic and full dump are relatively infrequent. In a fast-changing network, incremental packets can grow big so full dumps will be more frequent [6].

1) DSDV Advantages

- Guarantees no loop.
- Guarantees the freshness of routing information in the routing table by using the sequence number.
- Avoids extra traffic by using incremental updates.
- Maintains the best path only to every destination. Therefore, the space of the routing table is reduced.

2) DSDV Limitations

- The required periodic updates messages impose a big overhead. Therefore, it is not effective in large networks.
- Does not support multipath routing.
- Waste of bandwidth due to the needless advertising of routing information even if there is no change in the network topology.

B. Ad Hoc on-Demand Distance Vector Routing (AODV)

AODV uses traditional routing tables, one entry per destination. This is in contrast to DSR, which can maintain multiple route cache entries for each destination. Without source routing, AODV relies on routing table entries to propagate an RREP back to the source and, subsequently, to route data packets to the destination. AODV uses sequence numbers maintained at each destination to determine freshness of routing information and to prevent routing loops. All routing packets carry these sequence numbers. An important feature of AODV is the maintenance of timer-based states in each node, regarding utilization of individual routing table entries. A routing table entry is expired if not used recently. A set of predecessor nodes is maintained for each routing table entry, indicating the set of neighboring nodes which use that entry to route data packets. These nodes are notified with RERR packets when the next-hop link breaks. Each predecessor node, in turn, forwards the RERR to its own set of predecessors, thus effectively erasing all routes using the broken link. In contrast to DSR, RERR packets in AODV are intended to inform all sources using a link when a failure occurs. Route error propagation in AODV can be visualized conceptually as a tree whose root is the node at the point of failure and all sources using the failed link as the leaves [5][6].

1) AODV Advantages:

- Very effective in highly dynamic networks.
- Since the information of stale routes expire after a specific time, AODV requires less space as compared to other reactive routing protocols.
- Supports multicasting.

2) AODV Limitations:

- AODV lacks an efficient route maintenance technique since routing information is always obtained on demand.
- Like DSR, AODV suffers from high route discovery latency.
- As DSDV, a big overhead is imposed on the routing protocol due to the large number of control overheads. These are necessary to send route reply messages for single route request.

C. Dynamic Source Routing (DSR)

Dynamic Source Routing (DSR) is an Ad Hoc routing protocol based on the theory of source-based routing rather than table-based. This protocol is source initiated. This is particularly designed for use in multi hop wireless ad hoc networks of mobile nodes. Basically, DSR protocol does not need any existing network infrastructure or administration. This allows the network to be completely self-organizing and self-configuring. This protocol is composed of two essential parts of route discovery and route maintenance. Each node maintains a cache to store recently discovered paths. When a node needs to send a packet to another node, it first checks its entry in the cache. If it is there, then it uses that path to transmit the packet. In addition, it appends the source address to the packet. If the entry does not exist in the cache, or it is expired (because of being idle for a long time), then the sender broadcasts a route request packet to all neighbors asking for a path to the destination. The sender will be waiting till the route is discovered. During the waiting time, the sender can perform other tasks such as sending/forwarding other packets. As soon as the route request packet reaches any of the neighboring nodes, the latter looks for the destination in its corresponding cache. If the route information to the destination is known, then the neighbor node sends back a route reply packet to the sending node; otherwise the same route request packet is broadcast.

When the route is discovered, the sender starts transmission on the discovered route. Also, an entry is created in the corresponding cache. In addition, the node maintains the entry's age information in order to decide whether the cache line is fresh or not. When any intermediate node receives a data packet, it first checks whether the packet is meant for itself or not. If it is meant for itself (i.e. the intermediate node is the destination), the packet is received; otherwise, the same packet is forwarded using the path appended to the data packet.

Since in Ad hoc network, any link might fail anytime. Therefore, the route maintenance process constantly monitors the status of the network. A notification is sent to the relevant nodes in case of any failure in the path. Accordingly, the nodes change the entries of their route cache [7].

1) DSR Advantages:

- By using the cache, the route discovery overhead is reduced.
- Supports multipath routing.
- Does not require any periodic beaconing or hello message exchanges.

2) DSR Limitations:

- Not effective in large networks.
- Packet size keeps on increasing with route length because of source routing.

- Suffers from the high latency encountered in route discovery.

VI. Comparative Study

This section provides a comparative analysis of routing protocols previously described. Comparison is conducted in terms of both characteristics and performance. The metrics used in the performance analysis include the following [9]:

- *Packet Delivery Ratio:* this is the ratio of the data packets delivered to the destinations to the total number of packets.
- *Average end-to-end Delay:* this is the average amount of time taken by a packet to go from a source to a destination. This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC and propagation and transfer times.
- *Packet Loss:* this is the measure of the number of packets dropped by the routers.
- *Routing Overhead:* this is the ratio of the total number of the routing packets transmitted to data packets.

A. Analysis of Characteristics

Table 1 summarizes the differences between the most important characteristics of the three routing protocols.

B. Analysis of Performance

- *Packet delivery ratio:* in case of low mobility, all three protocols deliver a large percentage of the packets. This may reach 100% when there is no node motion. Under high mobility simulation, Both AODV and DSR perform better than DSDV [10].
- *Number of nodes* in the network should also be taken into consideration. DSR performance is indirectly proportional to the number of nodes in the network. The upper limit of DSR is two hundred nodes. DSDV outperforms both DSR and AODV with larger number of nodes. On the other hand, the performance of AODV is consistently uniform.

TABLE I. ROUTING PROTOCOLS CHARACTERISTICS

Characteristic	DSDV	DSR	AODV
Loop free	Yes	Yes	Yes
Multicasting	No	Yes	No
Distributed	Yes	Yes	Yes
Periodic broadcast	Yes	No	Yes
QoS Support	No	No	No
Routes maintained in	Route table	Route cache	Route table
Route cache/table timer	Yes	No	Yes
Reactive	No	Yes	Yes
Proactive	Yes	No	No

- *Average end-to-end delay:* DSDV gives the highest average end-to-end delay of packets delivery as compared to both DSR and AODV.
- *Packet Loss (or dropped):* Packet loss is defined as the difference between the number of packets sent by the source and received by the sink. The routing protocol forwards the packet to destination if a valid route is known; otherwise, the packet is buffered until a route is available. If the buffer is full the packet is dropped. Also, if the buffered packet exceeds a threshold value of time in the buffer without being sent, it is dropped. DSR demonstrates the least number of lost packets as compared to both AODV and DSDV. On the other hand, DSDV shows the maximum packet losses in case of varying speed. AODV has more packet losses than DSDV when the number of nodes is greater than 50.
- *Routing overhead:* This is the ratio of the total number of the routing packets to the number of data packets as calculated at the MAC layer. DSR has a lowest routing load as compared to both AODV and DSD. This is explained by the followed aggressive caching strategy to reply to all requests reaching the destination from a single request cycle. On the other hand, AODV suffers from a lot of routing control packets. Therefore, the routing overhead is higher than the other two protocols. DSDV routing overhead is negligible. However, it suffers from less route stability as compared to AODV.

VII. Conclusion

In this paper, a comparative study is conducted between on-demand (DSR and AODV) and table-driven (DSDV) routing protocols in terms of both characteristics and performance. The performance metrics used are the packet delivery ratio, the average end-to-end delay, the number of dropped packets, the routing overhead, the nodes mobility and the increasing number of nodes in the network.

As a conclusion, DSR outperforms the other two protocols in ordinary situations. However, DSDV is better in more stressful situations. Therefore, practically speaking, it is better to use DSDV as it has the best performance in situation similar to the real life situation.

References

[1] K. S. Umesh, S. Mewada, L. Iaddhani, and K. Bunkar. "An overview and study of security issues & challenges in mobile ad-hoc networks (MANET),". International Journal of Computer Science and Information Security, 9(4), pp. 106—111, 2011.

[2] S. Kumar, and J. Kumar. "Comparative analysis of proactive and reactive routing protocols in mobile ad-hoc networks (MANET)," Journal of Information and Operations Management, 3(1), pp. 92—95, 2012.

[3] S. Karthik, S. Kannan, V. P. Arunachalam, T. Ravichandran, and M. L. Valarmathi. "An investigation about performance comparison of multi-hop wireless ad-hoc network routing protocols in MANET," International Journal of Computer Science Issues (IJCSI), 7(3), pp. 35—41, 2010.

[4] S. Tamilarasan. "A comparative study of multi-hop wireless ad-hoc network routing protocols in MANET," International Journal of Computer Science Issues (IJCSI), 8(5), pp. 176—184, 2011.

[5] R. Bansal, H. Goyal, and P. Singh. "Analytical study the performance evaluation of mobile ad hoc networks using AODV protocol," International Journal of Computer Applications, 14(4), pp. 34 – 37, 2011.

[6] K. Kunavut. "Performance Evaluation of Routing Protocols for Heterogeneous Mobile Ad Hoc Networks," In 10th International Conference on Telecommunication and Information Technology (ECTI-CON), pp. 1 – 6, 2013.

[7] S. Taneja, and A. Kush. "A survey of routing protocols in mobile Ad-hoc networks," International Journal of Innovation, Management and Technology, 1(3), 279-285, 2010.

[8] F. Lee. "Routing in mobile Ad-hoc networks: protocol design," Prof. XinWang (Ed.), ISBN: 978-953-307-402-3, 2011.

[9] K. Lego, P. K. Singh and D. Sutradhar. "Comparative study of Ad-hoc routing protocol AODV, DSR and DSDV in mobile Adhoc NETwork," Indian Journal of Computer Science and Engineering, 1(4), pp. 364 – 371, 2010.

[10] S. Shah, A. Khandre, M. Shirole and G. Bhole. "Performance evaluation of Ad-hoc routing protocols using NS2 simulation," Mobile and Pervasive Computing (CoMPC), pp. 167 – 171, 2008.