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An Investigation on Performance Analysis and Comparison of Proactive and Reactive Routing Protocols in Mobile Ad-Hoc Network

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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. Mobile ad-hoc networks are self-organizing and self-configuring multihop wireless networks where the structure of the network changes dynamically. This is mainly due to the mobility of nodes. The nodes in the network not only acts as hosts but also as routers that route data to or from other nodes in network. In mobile ad-hoc networks a routing procedure is always needed to find a path so as to forward the packets appropriately between the source and the destination. The main aim of any ad-hoc network routing protocol is to meet the challenges of the dynamically changing topology and establish a correct and an efficient communication path between any two nodes with minimum routing overhead and bandwidth consumption. The design problem of such a routing protocol is not simple since, an ad-hoc environment introduces new challenges that are not present in fixed networks. A number of routing protocols have been proposed for this purpose like Ad-Hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Destination-Sequenced Distance Vector (DSDV). In this research, we study and compare the performance of the following three routing protocols AODV, DSR and DSDV.

Key words: On demand, table driven, DSR, AODV, DSDV, ad-hoc, MANET

INTRODUCTION

The Internet Engineering Task Force (IETF) created a Mobile Ad hoc Network (MANET) working group to standardize IP routing protocol functionality suitable for wireless routing application within both static and dynamic topologies with increased dynamics due to node motion and other factors. The vision of ad-hoc networks is wireless internet where users can move anywhere anytime and still remaining connected with the rest of the world. The mobile ad-hoc network is characterized by energy constrained nodes, bandwidth constrained links and dynamic topology. In real-time applications such as audio, video and real-time data, the ad-hoc networks need for Quality of Service (QoS) in terms of delay, bandwidth and packet loss is becoming important. Providing QoS in ad-hoc networks is a challenging task because of dynamic nature of network topology and imprecise state information. Hence, it is important to have a dynamic routing protocol with fast re-routing capability which also provides stable route during the life-time of the flows. Generally, there are two distinct approaches for enabling wireless mobile units to communicate with each other.

Infrastructure-based: Wireless mobile networks have traditionally been based on the cellular concept and relied on good infrastructure support. Here, mobile devices communicate with access points like base stations connected to the fixed network infrastructure.

Infrastructure-less: In Fig. 1 infrastructure less approach, the mobile wireless network is commonly known as a Mobile Ad-hoc Network (MANET). A MANET is a collection of wireless nodes that can dynamically form a network to exchange information without using any pre-existing fixed network infrastructure. The infrastructure

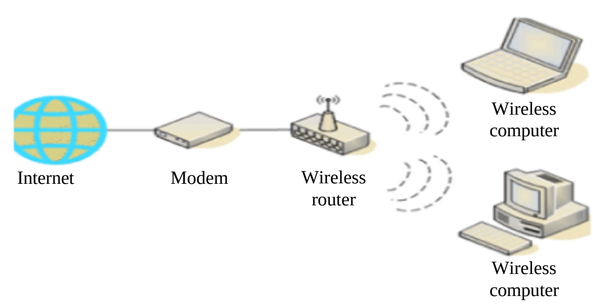

Fig. 1: MANET approaches

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less approach is increasingly becoming a very important part of communication technology because in many contexts information exchange between mobile units cannot rely on any fixed network infrastructure but on rapid configuration of a wireless connections on the fly.

MENT characteristics: The fundamental difference between fixed networks and MANET is that the computers in a MANET are mobile. Due to the mobility of these nodes, there are some characteristics that are only applicable to MANET. Some of the key characteristics are described by Karthik *et al*. (2008c).

Dynamic network topologies: Nodes are free to move arbitrarily, meaning that the network topology which is typically multi-hop may change randomly and rapidly at unpredictable times.

Bandwidth constrained links: Wireless links have significantly lower capacity than their hardwired counterparts. They are also less reliable due to the nature of signal propagation.

Energy constrained operation: Devices in a mobile network may rely on batteries or other exhaustible means as their power source. For these nodes, the conservation and efficient use of energy may be the most important system design criteria.

The MANET characteristics: Described above imply different assumptions for routing algorithms as the routing protocol must be able to adapt to rapid changes in the network topology.

Applications of MANET: There are numerous scenarios that do not have an available network infrastructure and could benefit from the creation of an ad hoc network (Basagni *et al*., 2004).

Rescue/emergency operations: Rapid installation of a communication infrastructure during a natural environmental disaster that demolished the previous communication infrastructure.

Law enforcement activities: Rapid installation of a communication infrastructure during special operations.

Commercial projects: Simple installation of a communication infrastructure for commercial gatherings such as conferences, exhibitions, workshops and meetings.

Educational classrooms: Simple installation of a communication infrastructure to create an interactive classroom on demand.

Military battlefield: Ad-hoc networking would allow the military to take advantage of commonplace network technology to maintain an information network between the soldiers, vehicles and military information head quarters.

Commercial sector: Emergency rescue operations (like fire, flood, earthquake, etc.) must take place where non-existing or damaged communications infrastructure and rapid deployment of a communication network is needed.

Local level: Ad-hoc networks can autonomously link an instant and temporary multimedia network using notebook computers or palmtop computers to spread and share information among participants at a e.g., conference or classroom.

LITERATURE REVIEW

Several researchers have done the qualitative and quantitative analysis of ad-hoc routing protocols by means of different performance metrics. They have used different simulators for this purpose.

Broch *et al*. (1998) in their research have compared the DSDV, TORA, DSR and AODV protocols using ns-2 simulator. The simulation was done with 50 nodes with varying pause times.

The results were obtained for the metrics: packet delivery ratio, routing overhead, number of hops taken by the packet to reach the destination. Das *et al*. (2000) evaluated the DSR and AODV on-demand routing protocols with three performance metrics : packet delivery fraction, average end-end delay and normalized routing load with varying pause times.

They have used ns-2 simulator. Based on the observations, recommendations were made as to how the performance of either protocol can be improved. Raju and Garcia-Luna-Aceves (2000) in their research have compared WRP-Lite a revised version of wireless routing protocol with DSR.

The performance parameters used are end-end delay, control overhead, percentage of packets delivered and hop distribution. The evaluation of the performance metrics was done with respect to varying pause time. It was observed that WRP-lite has much better delay and hop performance while having comparable overhead to DSR.

FEATURES OF MANET

Some of the salient features that describe the MANET clearly are (Karthik *et al*., 2008a):

Dynamic network topology: Since, the nodes are mobile, the network topology may change rapidly and unpredictably and the connectivity among the terminals may vary with time.

Autonomous terminal: In MANET, each mobile terminal is an autonomous node which may function as both a host and a router (to perform switching functions).

Multi hop routing: When delivering data packets from a source to its destination (i.e., only when the nodes are not directly linked), the packets should be forwarded via one or more intermediate nodes.

Distributed operation: Since, there is no background network, the control and management of the network is distributed among the terminals.

Light-weight terminals: In most cases, the MANET nodes are mobile devices with less CPU processing capability, small memory size and low power storage. Such devices need optimized algorithms and mechanisms that implement the computing and communicating functions.

Challenges faced in MANET: Regardless of the attractive applications, the features of MANET introduce several challenges that must be studied carefully before a wide commercial deployment can be expected. These include (Schiller, 2003).

Internetworking: The coexistence of routing protocols for the sake of internetworking a MANET with a fixed network in a mobile device is a challenge for the mobility management.

Security and reliability: An ad-hoc network has its particular security problems due to e.g., nasty neighbor relaying packets. Further, wireless link characteristics introduce also 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.

Routing: Since, the topology of the network is constantly changing, the issue of routing packets between any pair of nodes becomes a challenging task. Most protocols should be based on reactive routing instead of proactive.

Quality of Service (QoS): Providing different quality of service levels in a constantly changing environment will be a challenge.

Power consumption: For most of the lightweight mobile terminals, the communication-related functions should be optimized for less power consumption.

Performance metrics of MANET: The following metrics are considered for simulating and analyzing the performance of routing protocols and characteristics of MANET (Karthik *et al*., 2009b; Corson and Macker, 1999).

Jitter: Jitter describes standard deviation of packet delay between all nodes.

Throughput: The throughput metric measures how well the network can constantly provide data to the sink. Throughput is the number of packet arriving at the sink per milliseconds.

Power consumption: The total consumed energy divided by the number of delivered packet.

Packet Delivery Ratio (PDR): PDR is the ratio of the number of packets successfully received by all destinations to the total number of packets injected into the network by all sources. The PDR is a number between 0 and 1.

Average packet delay: It is sum of the times taken by the successful data packets to travel from their sources to destination divided by the total number of successful packet. The average packet delay is measured in seconds.

Average hop count: It is the sum of the number of hops taken by the successful data packets to travel from their sources to destination divided by the total number of successful packets. The average hop count is measured in number of hops.

Node Expiration Time (NET): It is the time for which a node has been alive before it must halt transmission due to battery depletion. The node expiration is plotted as number of nodes alive at a given time for different point in time during the simulation.

End-to-end delay: The average time interval between the generation of a packet in a source node and the successfully delivery of the packet at the destination node. It counts all possible delays that can occur in the source and all intermediate nodes including queuing time, packet transmission and propagation and retransmissions at the MAC layer. The queuing time can be caused by network congestion or unavailability of valid routes.

ROUTING PROTOCOLS IN MANET

There are different criteria for designing and classifying routing protocols for wireless ad-hoc networks. For example what routing information is exchanged; when and how the routing information is exchanged when and how routes are computed etc.

Proactive vs. reactive routing: Proactive schemes determine the routes to various nodes in the network in advance, so that the route is already present whenever needed. Route discovery overheads are large in such schemes as one has to discover all the routes. Examples of such schemes are the conventional routing schemes, Destination Sequenced Distance Vector (DSDV) (Karthik *et al*., 2008b). Reactive schemes determine the route when needed. Therefore, they have smaller route discovery overheads.

Single path vs. multi path: There are several criteria for comparing single-path routing and multi-path routing in ad hoc networks. First, the overhead of route discovery in multi-path routing is much more than that of single-path routing (Karthik *et al*., 2006). On the other hand, the frequency of route discovery is much less in a network which uses multi-path routing since, the system can still operate even if one or a few of the multiple paths between a source and a destination fail. Second, it is commonly believed that using multi-path routing results in a higher throughput.

Table driven vs. source initiated: In table driven routing protocols, up-to-date routing information from each node to every other node in the network is maintained on each node of the network. The changes in network topology are then propagated in the entire network by means of updates. Destination Sequenced Distance Vector Routing (DSDV) and Wireless Routing Protocol (WRP) are two schemes classified under the table driven routing protocols head. The routing protocols classified under source initiated on-demand routing, create routes only when desired by the source node (Karthik *et al*., 2009a). When a node requires a route to a certain destination, it initiates what is called as the route discovery process. Examples include DSR and AODV.

Destination-Sequenced Distance Vector (DSDV) routing protocol: DSDV is a table-driven routing scheme for ad-hoc mobile networks based on the Bellman-Ford algorithm. It was developed by Perkins and Royer (1999).

The main contribution of the algorithm was to solve the routing loop problem. Each entry in the routing table contains a sequence number, the sequence numbers are generally even if a link is present; else, an odd number is used. The number is generated by the destination and the emitter needs to send out the next update with this number. Routing information is distributed between nodes by sending full dumps infrequently and smaller incremental updates more frequently (Charles and Bhagwat, 1994). A comparison of the characteristics of the above three ad hoc routing protocols DSDV, DSR, AODV is shown in Table 1 property comparison of DSDV, DSR and AODV.

Dynamic Source Routing (DSR) Protocol: DSR is a routing protocol for wireless mesh networks. It is similar to AODV in that it forms a route on-demand when a transmitting computer requests one. However, it uses source routing instead of relying on the routing table at each intermediate device. Determining source routes requires accumulating the address of each device between the source and destination during route discovery. The accumulated path information is cached by nodes processing the route discovery packets. The learned paths are used to route packets (Johnson and Maltz, 1996). This protocol is truly based on source routing whereby all the routing information is maintained (continually updated) at mobile nodes. It has only 2 major phases which are route discovery and route maintenance. Route reply would only be generated if the message has reached the intended destination node.

Ad-hoc On Demand Distance Vector (AODV) routing protocol: AODV is capable of both unicast and multicast routing. It is a reactive routing protocol, meaning that it establishes a route to a destination only on demand. In contrast, the most common routing protocols of the Internet are proactive, meaning they find routing paths independently of the usage of the paths. AODV is as the name indicates, a distance-vector routing protocol. AODV avoids the counting-to-infinity problem of other distance-vector protocols by using sequence numbers on route updates, a technique pioneered by DSDV (Charles and Bhagwat, 1994).

Table 1: Property comparison of DSDV, DSR and AODV

Protocol property	DSDV	DSR	AODV
Loop free	Yes	Yes	Yes
Multicast routes	No	Yes	No
Distributed	Yes	Yes	Yes
Unidirectional link support	No	Yes	No
Multicast	No	No	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

PERFORMANCE RESULTS OF AODV, DSR, DSDV

The Fig. 2 are the performance analysis of the routing protocol with respect to different metric considered. The x-axis shows the number of nodes and the y-axis shows the metric considered. In terms of packet delivery ratio (Fig. 2), DSR performs well when the number of nodes is less as the load will be less. However, it is performance declines with increased number of nodes due to more traffic in the network. The performance of DSDV is better with more number of nodes than in comparison with the other two protocols.

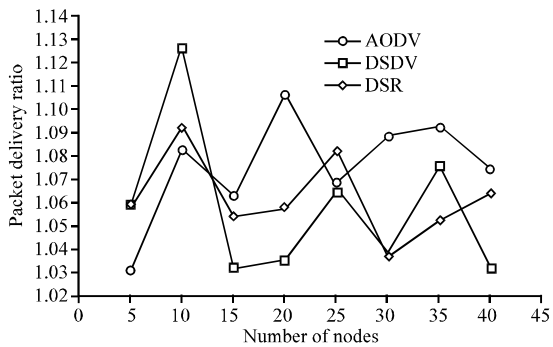

Fig. 2: Packet delivery ratio for AODV, DSR, DSDV

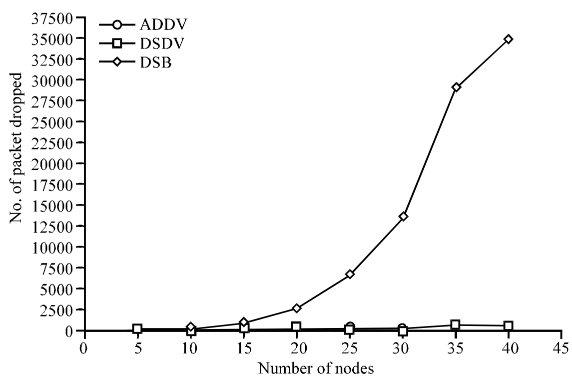

Fig. 3: Dropped packets for AODV, DSR, DSDV

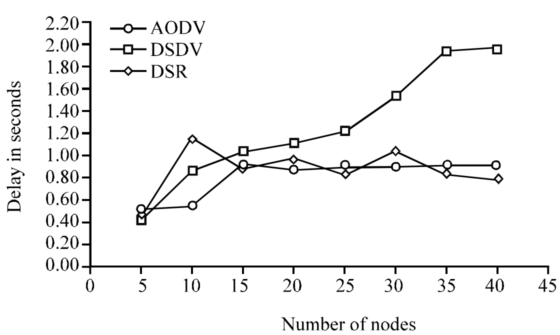

Fig. 4: No. of nodes

The performance of AODV is consistently uniform. In terms of dropped packets (Fig. 3), DSDV's performance is the worst. The performance degrades with the increase in the number of nodes. AODV and DSR performs consistently well with increase in the number of nodes. For average end-to-end delay (Fig. 4), the performance of DSR and AODV are almost uniform. However, the performance of DSDV is degrading due to increase in the number of nodes the load of exchange of routing tables becomes high and the frequency of exchange also increases due to the mobility of nodes.

CONCLUSION

It is difficult for the quantitative comparison of the most of the ad-hoc routing protocols due to the fact that simulations have been done independent of one another using different metrics and using different simulators. In this study, we have presented comparison studies about On-Demand (DSR and AODV) and table-driven (DSDV) routing protocols. The comparison indicate that the performance of the two on demand protocols namely DSR and AODV is superior to the DSDV in conformance with the research done by other researchers. It is also observed that DSR outperforms AODV in less stressful situations, i.e., smaller number of nodes. AODV outperforms DSR in more stressful situations. The routing overhead is consistently low for DSR and AODV than in comparison with DSDV especially for large number of nodes. This is due to the fact that in DSDV the routing table exchanges would increase with larger number of nodes. The comparison also indicate that as the number of nodes in the network increases DSDV would be better with regard to the packet delivery ratio but it may have considerable routing overhead. As far as packet delay and dropped packets ratio are concerned, DSR/AODV performs better than DSDV with large number of nodes. Hence for real time traffic, AODV is preferred over DSR and DSDV. For less number of nodes and less mobility, DSDV's performance is superior. A general observation is that protocol performance is linked closely to the type of MAC protocol used. In conclusion, the design of the routing protocol must take into consideration the features of the lower layer protocols.

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