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A Comparision Study of Common Routing Protocols Used In Wireless Ad-Hoc Networks

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Abstract: The aim of this study is to analyze and compare performance of both reactive and proactive Mobile Ad hoc Networks (MANETs) routing protocols using different environments. Wireless networks are divided into two types: infrastructure and ad hoc network. In wireless ad hoc networks each node can be a sender, router and receiver, so these types of network are less structure compared to infrastructure network. Therefore wireless ad hoc networks need special routing protocols to overcome the limitations of wireless ad hoc networks. Wireless ad hoc networks routing protocols can be categorized into two types: reactive (on demand) routing protocols and proactive routing protocols. In proactive routing protocols the nodes periodically send control messages across the network to build routing table. Different routing protocols have been simulated using GloMoSim (Global Mobile Information system simulation) library and PARSEC compiler. Five multi-hop wireless ad hoc network routing protocols have been simulated to cover a range of design choices: Wireless Routing Protocol (WRP), Fisheye State Routing (FSR), Dynamic Source Routing (DSR), Ad hoc On-demand Distance Vector (AODV) and Location Aided Routing (LAR). The protocols are evaluated in different environments to investigate performance metrics. Performance metric includes the following aspects: packets deliver ratio, end-to-end delay and end-to-end throughput.

Keywords: Ad hoc routing protocols, AODV, DSR, FSR, GloMoSim, LAR, MANETs, protocols simulation**,** WRP

INTRODUCTION

With the wide spread of new group wireless communication technology, small group size and high performance computing and communication devices have been arose in daily life and computing industry.

Wireless networks can be divided into two types, infrastructure and infrastructure less networks (ad hoc). Infrastructure type needs all the mobile devices to communicate directly to an Access Point (AP) or base station (Wang *et al*., 2005). Infrastructure-less networks or ad hoc networks have no access point or bridge; all nodes are able to communicate dynamically in an arbitrary manner. Nodes of these networks can be sender, receiver or intermediate node. Since nodes are moving rapidly and forwarding packets for each other, so a suitable routing protocol is necessary to make the routing decisions. Currently there are many proposals for routing protocols in wireless ad hoc networks to solve some limitations.

Ad hoc networks are used in emergency operations, meetings or conventions to share information and data acquisition operations in inhospitable terrain, disaster recovery and automated battlefields as wireless ad hoc networks don't need central administration or infrastructure (Indrayan, 2006). Wireless ad-hoc networks are characterized by the following issues (Biskupski *et al*., 2007):

- No infrastructure is provided
- Spontaneity and low radio bandwidth
- Mobility and frequent topology change
- Short contact time between nodes
- Large network and high number of nodes
- High error rate
- Limited bandwidth and battery lifetime
- Loop free Routing and minimum control overhead

The main point in most of Routing protocols which are proposed for mobile ad hoc wireless networks is the routing strategy. With the advent of GPS (Global Positioning System), protocols making use of node location information have been proposed recently. With the knowledge of node position, routing can be more effective at the cost of overhead required to exchange location information. Location-Aided Routing (LAR) is one of the routing protocols that make use of node location (Ko and Vaidya, 1998).

Many routing protocols that are based on node location have been proposed, but there is a lack of

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comparisons between the different location routing protocols (Abolhasan *et al*., 2004; Royer and Toh, 1999). Some simulation studies of these routing protocols evaluated have been presented in Broch *et al*. (1998), Jörg (2003) and Johansson *et al*. (1999). Wireless Routing Protocol (WRP), Dynamic Source Routing (DSR), Ad hoc On Demand desistance Vector (AODV), Location Aided Routing (LAR) and Fisheye State Routing (FSR) have been examined in this study.

Perkins *et al.* (2003) have investigated the performance of two on-demand ad hoc routing protocols: AODV and DSR. The research is based on simulations as well. The NS2 simulator was used. Realistic physical and link level models were utilized (Das *et al*., 2001). Three key performance metrics were evaluated: Packet delivery fraction, average end-to-end delay of data packets and normalized routing load.

Johansson *et al.* (1999) studied three different routing protocols: DSDV, DSR and AODV, their work is also based on simulations. However they decided to do two kinds of simulations: ones for random scenarios and others for three different realistic scenarios.

The main objectives of this study concentrate on studying the performance of the tested routing protocols at different conditions, these conditions represent the different scenarios that mobile wireless ad hoc networks may face in real applications.

AD HOC ROUTING PROTOCOLS

Routing is the process of finding an optimal path from source to destination. Many researches divide routing protocols into two categories as (Royer and Toh, 1999):

- **Table-driven routing protocols:** Each node keeps one or more routing tables that hold routing information to every other node in the network. All nodes update these tables frequently to update view of the network.
- **On-demand routing protocols:** These protocols create a route on demand to build route table. When a source wants to send to a destination, it invokes the route discovery mechanisms to find the path to the destination. The route remains valid until the route is no longer needed.

Desired properties: Wireless ad hoc routing protocols should have the following characteristics to fulfil wireless ad hoc networks properties (Cisco Systems Inc., 2000):

Optimality and dynamic topology: Refers to the capability of the routing protocols to choose the best route.

Distributed operation: The protocol should not be dependent on a centralized controlling node.

Loop freedom and multiple routes: The routing protocol should guarantee the routes supplied are loop free.

Rapid convergence: Routing protocol must be agreed by all routes.

Bidirectional/unidirectional links: Routing protocol should be able to execute on both bidirectional and unidirectional links.

Protocol comparisons: Table 1 summarizes the complexities of all above-mentioned protocols using four criteria: storage complexity, control packet size, time complexity and communication complexity (Royer and Toh, 1999; Corson and Ephremides, 1995; Toh, 1997).

Table 2 summaries key characteristics and properties of the simulated protocols.

Sophisticated routing protocols use multiple metrics to select best route, while shortest path (path length) represents number of hop count, or the minimum sum of the cost associates with each link traversed. Network topology denotes the structure of network or the way of nodes connected.

Update scheme (update period) takes the values “periodical”, “event-driven” or “hybrid”. For example, when a link on a route is broken, route maintenance is activated, which is called Route Re-Construction (RRC).

SIMULATION ENVIRONMENT

Simulation tools are effective devices to measure network metrics as these device reduce cost and can measure different environments in a simple manner. There are several different simulation packages that can be used for mobile ad hoc network simulation, a survey of the commonly used simulators: OPNET, NS2, QualNet and GloMoSim (Cavin *et al*., 2002). Global Mobile Information System Simulator (GloMoSim) is a scalable simulation environment for large wireless and wire line communication networks [http://pcl.cs.ucla.edu/projects/glomosim/]. GloMoSim

Table 1: Time complexity of routing protocols

Protocol	Storage complexity	Time complexity	Control packet size complexity	Communication complexity
WRP	O (N*A)	O (D)	O (N+A)	O (N)
FSR	O (N*A)	O (D)	Determined by fisheye	O (N)
DSR	O (D)	O (2D)	O (D)	O (2N)
AODV	O (D_d)	O (2D)	O (D_d)	O (2N)
LAR	O (N^2)	O (2D)	O (D)	O (2N)

N: Total number of nodes in the network; A: The average number of adjacent nodes (neighbors); D: The diameter of the network (the maximum number of nodes in the longest path); D_d: The number of maximum desired destination

Table 2: Summary of protocols characteristics

Protocols	WRP	FSR	DSR	AODV	LAR
Routing strategy	Distance vector	Link state	On-demand	On-demand	Location based
Network topology	Flat	Hierarchical	Flat	Flat	Flat
Route selection metric	Shortest path	Shortest path	Shortest path	Freshest and shortest path	Shortest path, location
# routes	Single	Single/multiple	Multiple	Multiple	Multiple
Loop-free	No (temporary)	Yes	Yes	Yes	Yes
Periodic messages	Hellos	Hellos route entries	None	None	None
Updates triggered by:	Event, time	Time	Event	Event	Time
Flooding packets	None	None	Route Request messages (RREQs)	Route Request messages (RREQs)	Route Request messages (RREQs)
Routes in data	No	No	Source route	Source route	Source route
Need for Global Positioning System (GPS)	No	No	No	No	Yes

Table 3: Summary of simulation parameters

Parameter	Value
Channel bandwidth	2 Mbit/sec
Transmitter range	200 m
Environment size	1000×1000 m
Speed of node	0-20 m/sec
Simulation time	500 sec
Traffic type	Constant Bit Rate (CBR)
Network size	Medium sized
Number of nodes	50
Pause time	3 sec
Packet size	512 bytes
Packet rate	5 packets/sec
Number of flows	40

is capable for simulating networks with up to thousand nodes that are connected by different models. GloMoSim is a loosely coupled layered network simulator where different functionalities are implemented at different layers (Cloran, 2004). GloMoSim supports different protocols such as: AODV, DSR, Fisheye, LAR1, ODMRP and WRP that represents the basic of this paper comparison.

SIMULATION MODEL AND METHODOLOGY

The simulator for evaluating routing protocols was implemented within the GloMoSim library [http://pcl.cs.ucla.edu/projects/glomosim/]. The GloMoSim library is a scalable simulation that uses the parallel discrete event simulation capability provided by PARSEC (Bagrodia *et al*., 1998). This study simulated a modeled network of 50 mobile hosts, which are placed randomly in a 1000×1000 m simulation area. Radio propagation range for each node was 200 m and channel capacity was 2 Mbps. There were no network partitions throughout the simulation. Multiple runs with different seed numbers were conducted for each scenario then the collected data was averaged over those runs to increase the accuracy of gathered data.

Simulation parameters: The simulation parameters that have been used for the mobility simulation are shown in Table 3.

Mobility model: Fifty Nodes move around in a rectangular region of size 1000×1000 m according to a mobility model. The nodes have a constant radio range of 200 m. Nodes are constantly moving, thus producing a load on the routing protocol. For the randomized simulations we have varied the maximum speed in the interval 0 to 20 m/sec corresponds the speed of a vehicle, which will lead to a high mobility. All simulations were run for 500 simulated sec.

Besides, in all node movement scenarios, a node chooses a destination and moves in a straight line (Fig. 1) towards the destination at a speed uniformly distributed between 0 m/s and some maximum speed to reach its destination with a pause time before choosing another random destination, the x-axis and y-axis in Fig. 1 represent the pause time which is measured by second. This process is repeated. This is called the random waypoint model (Camp *et al*., 2002).

Traffic model: The same communication pattern is used for all mobility simulations. The traffic pattern consisted of 40 CBR sources that started at different times over UDP with random source and destination pairs. Each generator produces a data packet of 512 bytes each at the rate of 5 packets/sec. All of these parameters were set in the Glomosim application configuration file.

Simulation metrics: Different performance metrics were used to evaluate the performance of the tested routing protocols. These metrics involve the following performance parameters:

- P**acket delivery ratio:** It represents the ratio between the total of number of packets that should be received by CBR client to the/total number of packets that are sent by corresponding CBR server.
- **Average end-to-end delay of data packets**: It represents the difference between the generation time by CBR client and the receiving time by the CBR server.
- **The average end-to-end throughput:** It represents the ratio of the total number of packets that reach their destination, to the total number of packets sent by the source.

The first metric is the most important for best-effort traffic (Corson and Macker, 1999). Since, packet delivery ratio describes the loss rate that will be seen by the transport protocol, which in turn affects the maximum throughput that the network can support. While, average end-to-end delay of data is an important issue for real time applications. These metrics characterize both the completeness and correctness of the routing protocol (Broch *et al*., 1998). These metrics are not completely independent. For example, lower packet delivery fraction means that the delay metric is evaluated with fewer samples. In contrast, the longer the path lengths, the higher the probability of a packet drops. Thus, with a lower delivery fraction, samples are usually biased in favor of smaller path lengths so produced less delay (Corson and Macker, 1999).

SIMULATION RESULTS

The distance vector based protocol WRP, the link state based protocol FSR, the on-demand routing protocol DSR, AODV and location based protocol LAR are simulated in a common wireless network simulation platform (Nuevo, 2004).

Different speeds have taken been taken with ten number of seeds, then these results are averaged. After the calculation of the whole mobility speeds for all tested routing protocols, we take the average for each node at each metric and then calculate the Mean for all nodes. After that, we take the Median for all Means that we produced. Therefore, we could see the consistency and enhancement of the results of the simulation.

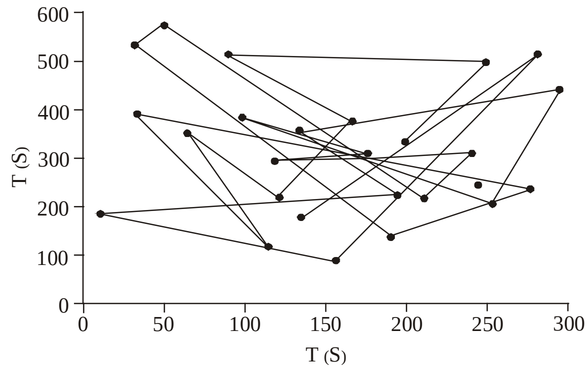

Fig. 1: Traveling pattern of a mobile node using random waypoint mobility (Camp *et al*., 2002)

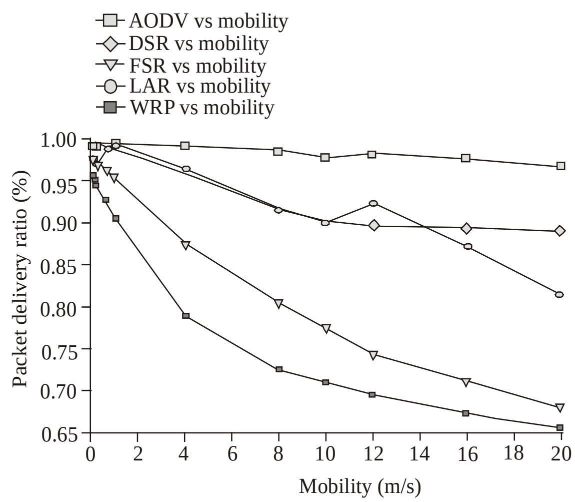

Fig. 2: Packet delivery ratio vs. mobility

Figure 2 highlights the packet delivery ratio of five protocols. All protocols performed well under low mobility rates, but some of them become less effective as the mobility speed increases since congestion increases with the increase of mobility speed leading to a degrade in performance metrics. This result satisfies with the results that are found by different researches (Sung-Ju *et al*., 2002; Josh *et al*., 1998).

On-demand routing protocol AODV is the superior and robust with mobility. It has a delivery rate of 98% regardless of node mobility and network load. DSR and LAR perform quite well. At low network load and regardless of mobility, they have a delivery rate of 95%. In highly mobile situations, route requests control packets may be broken when the source sends data or even when Route Replies are being returned back to the source. Since, each source needs to draw a path from source to the desired destination through having a route request and route reply procedures.

Thus, it is found from simulation results that the delay resulting from discovering routes plays an important role in the degradation performance of routing protocols at high mobility speed. Since LAR is an improvement of basic DSR, but DSR performs much better than LAR. Since, DSR has several optimization features that are not implemented in LAR. In addition, the location information used by LAR may be out-of-date when nodes move at high speeds.

FSR was sensitive to mobility. It performs well at low node mobility, but the performance of FSR degrades at high mobility speed. Update messages in FSR are time-triggered only, i.e., there are no event-triggered updates messages. Additionally, routes to remote destinations become less accurate at high mobility speeds. As a result, some of the link-state imprecise information is kept in route tables. This problem can be solved by shortening the periodic update interval, but at the cost of excessive routing overhead, so update message should be selected accurately depending on different time intervals.

WRP routing protocol simulation results have the worst performance compared to other tested routing protocols, especially at high mobility speeds. It performs poorly when nodes are dynamically moved with different speeds. As nodes move faster, link connectivity changes more often and more update messages are triggered. For each triggered update, neighboring nodes are required to send back an acknowledgment, so this will add more control overhead. However, more temporary loops will be formed as the network will view convergence slowly, with many changes needing to be absorbed and propagated. Loops, triggered updates and ACKs created an enormous amount of packets, contributing further to collisions, congestion, contention and packet drops.

Figure 3 highlights the average end-to-end delay of the five tested routing protocols. All protocols performed well under low mobility rates, but most of them the delay performance degrades as the mobility speed increases. AODV shows the minimum delay characteristics. Under low mobility, DSR has a low end-to-end delay, but with high mobility, delay increases 4 to 5 times because of route caching. In FSR, end-to-end delay increases with increasing mobility since FSR uses periodic broadcasts.

LAR which is a reactive routing protocol approach further reduces control traffic of DSR by restricting the propagation of flood packets. However, no route can be obtained by the protocol in situations where no link is available in the limited flooded areas or when location information is obsolete. More delays are expected when constructing routes in those circumstances. Even though LAR can utilize knowledge of location to reduce path discovery overhead and can predict changes.

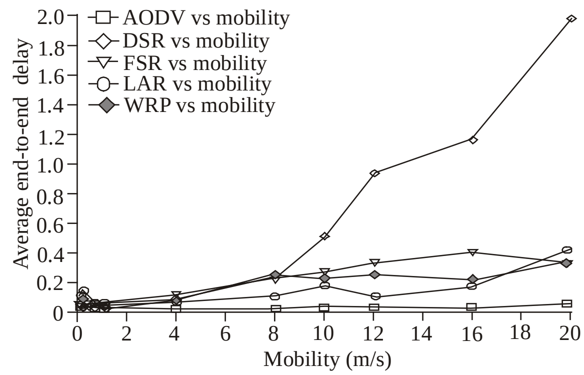

Fig. 3: Average end-to-end delay vs. mobility

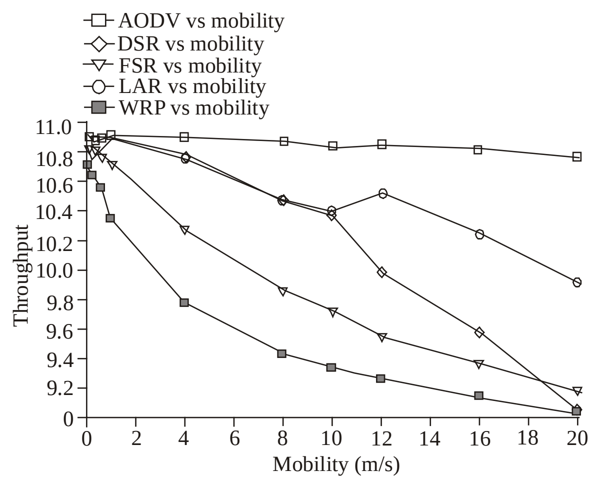

Fig. 4: End-to-end throughput vs. mobility

WRP has the worst delay characteristics because WRP is a proactive routing protocol and WRP shows slow response time to changes in topology. Although WRP exhibits low delay when transmitting packets at low mobility, but many packets are dropped due to invalid routes (and while new (valid) routes are being propagated through the network). As load is increased, delay increases, but with higher mobility, the situation is even worse.

It is clear from the previous studies that speed has inverse effect on average end to end delay, as increasing the speed will increase packets collisions, the simulated results in this study satisfies with the previous studies (Novatnack *et al.*, 2005).

Figure 4 highlights the end-to-end throughput of five protocols. All protocols performed well under low mobility rates, but most of them show throughput degradation as the mobility speed increases. At low mobility, the throughput of On-demand routing protocols AODV, DSR and LAR is unaffected of the mobility, it stays constant at the same rate of throughput. At higher mobility, the throughput of

AODV is stayed unaffected of the mobility and the throughput of DSR and LAR decreased when the mobility increases. But LAR is the superior in this evaluation; since it uses specialized location information to limit the amount of network flooding that occurs. Since DSR uses source routing, it send only a few protocols specific packets, but each data packets has some overhead due to routing information carried. So the result for LAR is slightly better that for DSR.

FSR performs well when there is no mobility, regardless of network load. At low mobility the protocol still performs well. At higher mobility (>1 m/s) the throughput drops considerably (60% at 2 m/s), from this point, the throughput decreases more slowly so that at 10 m/s it is still at 40%.

The throughput of WRP is acceptable at low mobility. But the throughput of WRP decreases more and more as the mobility increases. WRP performs poorly and fails at higher mobility conditions. WRP performs well only for very slow changing network topologies.

CONCLUSION AND FUTURE WORK

Mobility speed has a reverse effect on the reactive and proactive routing protocols, since the tested performance of each metric in each tested routing protocol degraded as mobility rates increased, but AODV was the most robust to the speed. DSR and LAR reactive routing protocols are highly effective and efficient in most of the tested scenarios. LAR and DSR have also exhibited a good performance also when mobility is high. Extra delay in acquiring routes, though, makes them less attractive in delivering real-time traffic. LAR further improved an on-demand protocol by using location information, but produced more overhead in location information exchange.

In summary, every protocol has its advantages and drawbacks depending on the tested scenarios. However there are many issues that could be subject to further studies. Number of nodes could be increased to observe its impact on the performance of for ad hoc routing protocol. More routing protocols, for instance TORA, ZRP and DREAM could be simulated in order to gain a more in-depth performance analysis of the ad hoc routing protocols.

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