Comparative study and Performance Analysis of FSR, ZRP and AODV Routing Protocols for MANET

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ABSTRACT
A mobile adhoc network (MANET) is autonomous, self-organizing and self-configuring network with the capability of rapid deployment in response to application needs. Each host is equipped with a CSMA/CA (carrier sense multiple access with collision avoidance) transceiver. The mobile characteristic of mobile network creates the scenario of multihop, where the packets originated from the source host are relayed by several intermediate hosts before reaching the destination. Routing is the process of finding a path from a source to destination among randomly distributed routers. In this paper hybrid routing protocol called Zone Routing Protocol (ZRP), Fisheye State Routing Protocol (FSR) and Ad Hoc On-Demand Distance-Vector Protocol (AODV) are examined. The comparative characteristic study and performance analysis is presented using performance metrics throughput, end-to-end delay packet delivery ratio is presented using network simulator Qualnet 5.0.2.

General Terms
Algorithms, Performance, Experimentation

Keywords
Adhoc networks; wireless networks; CBR, routing protocols; route discovery; simulation; performance evaluation; MAC, IEEE 802.11.

1. INTRODUCTION
Today, mobile adhoc networks (MANETs) have been widely adopted in many applications. A typical MANET is composed of a group of mobile wireless nodes which cooperate among themselves for packet forwarding in a multihop fashion. A MANET is distributed, dynamic and self-organized without any centralized administration. The dynamic nature of MANETs provides special challenges beyond those in standard data networks. In such networks, each mobile node operates not only as a host but also as a router [3], forwarding packets for other mobile nodes in the network that may not be within direct wireless transmission range of each other. Each node must cooperate dynamically establish routing among themselves.

Each node participates in an ad hoc routing protocol that allows it to discover "multi-hop" paths through the network to any other node. Some applications of the possible uses of ad hoc networking include students using laptop computers to participate in an interactive lecture, business associates sharing information during a meeting, soldiers relaying information for situational awareness on the battlefield, and emergency disaster relief personnel coordinating efforts after a hurricane or earthquake.

In this paper hybrid routing protocol called Zone Routing Protocol (ZRP) and Fisheye State Routing Protocol (FSR) are examined. The performance analysis based on performance metrics throughput, end-to-end delay and packet delivery ratio is presented by using Qualnet 5.0.2 [15].

2. ROUTING PROTOCOLS: CLASSIFICATION IN BRIEF
Routing is the process of finding a path from a source to some arbitrary destination on the network. The broadcasting [3] is inevitable and a common operation in ad-hoc network. It consists of diffusing a message from a source node to all the nodes in the network. Broadcast can be used to diffuse information to the whole network. It is also used for route discovery protocols in ad-hoc networks. The routing protocols are classified as follows on the basis of the way the network information is obtained in these routing protocols.

2.1 Proactive or Table-driven routing protocol
Proactive protocols, also called table driven, continuously evaluate the routes within the network, so that when a packet needs to be forwarded the route is already known and can be immediately used. Table driven protocols maintain consistent and up to date routing information about each node in the network. These protocols require each node to store their routing information and whenever there is a change in network topology, the updating has to be made throughout the network.

For example

1. Destination sequenced Distance vector routing (DSDV) [13]
2. Fisheye State Routing (FSR) [6]

2.2 Reactive or On-demand routing protocol

Reactive routing protocols, also called on demand, invoke a route determination procedure only on demand. A node wishing to communicate with another node first seeks for a route in its routing table. If it finds one the communication starts immediately, otherwise the node initiates a *route discovery* phase. Once a Route has been established, it is maintained until either the destination becomes inaccessible (along every path from the source), or until the route is no longer used, or expire.

For example

1. Ad-Hoc On-demand Distance Vector (AODV) [4]

2. Dynamic Source Routing (DSR) [10][5]

2.3 Hybrid Protocols

This type of protocols combines the advantages of proactive and of reactive routing. The routing is initially established with some proactively prospected routes and then serves the demand from additionally activated nodes through reactive flooding. The choice for one or the other method requires predetermination for typical cases. The features of such algorithms are:

1. Depends on amount of nodes activated.
2. Reaction to traffic demand depends on gradient of traffic volume.

For example

1. Temporally ordered routing algorithm (TORA) [17]

2. Zone Routing Protocol (ZRP) [18]

These classes of routing protocols are reported but choosing best out of among them is very difficult as one may be performing well in one type of scenario the other may work in other type of scenario [12][11][1][[20]

3. ZONE ROUTING PROTOCOL (ZRP)

Zone Routing Protocol (ZRP) [18], a hybrid routing, is suitable for a wide variety of mobile ad-hoc networks, especially those with large network spans and diverse mobility patterns.

In ZRP, for every node a zone is defined with single configurable parameter n hops from it. This parameter is also called zone radius. It uses sequence number for messages to discover loopfree routes. ZRP uses three different route discovery protocols

Intrazone Routing Protocol (IARP) [7]

Interzone Routing Protocol (IERP) [8]

Bordercast Resolution protocol [19]

3.1 Intrazone Routing Protocol (IARP)

The proactive Intrazone Routing Protocol (IARP) is used to maintain the local topology. The IARP is derived from globally proactive link state routing protocols that provide a complete view of network connectivity.

3.2 Interzone Routing Protocol (IERP)

Interzone Routing Protocol (IERP) is very similar to classical route discovery protocols. An IERP route discovery is initiated when no route is locally available to the destination of an outgoing data packet. The source generates a route query packet, which is uniquely identified by a combination of the source node's address and request number. The query is then relayed to a subset of neighbors as determined by the bordercast algorithm called Bordercast Resolution protocol. Bordercast, is used to reduce the number of redundant forwarding in route discovery of interzone routing protocol.

3.3 Routing Zone and Maintenance

Each node proactively maintains routes within a local region (referred to as its routing zone). Knowledge of the routing zone topology is leveraged by the ZRP to improve the efficiency of a globally reactive route query/reply mechanism. The proactive maintenance of routing zones also helps in improving the quality of discovered routes, by making them more robust to changes in network topology. The ZRP can be configured for a particular network by proper selection of a single parameter, the routing zone radius.

Choosing an appropriate routing zone is very important for this protocol. Large routing zones are preferred when demand for routes is high and/or the network consists of many slowly moving nodes. In the extreme case of a network with fixed topology, the ideal routing zone radius would be infinitely large. On the other hand, smaller routing zones are appropriate in situations where route demand is low and/or the network consists of a small number of nodes that move fast relative to one another. In the "worst case", a routing zone radius of one hop is best, and the ZRP defaults to a traditional reactive flooding protocol.

4. FISHEYE STATE ROUTING (FSR)

Fisheye State Routing (FSR) [6] is a multilevel with Scope technique, table driven routing protocol for adhoc network. It is designed to reduce routing overheads in large and fast dynamic changing network. The link state updates are periodically broadcasted with specific frequency as per its scope method. The whole network is divided into different scopes based on the hop distances from a specific node. The nodes within this distance range are called in inner scope and rest treated to be in outer scope. The link states updates are propagated to neighbor at different frequencies. The information is transmitted at higher frequency to inner scope nodes and lower frequency for farther neighbors. Thus closer the nodes have more accurate link state updates. It makes route progressively more accurate on which packets are transmitted. Thus, FSR leads to major reduction in link overhead caused by routing table updates. It enhances scalability of large, mobile ad hoc networks.

It is suitable for fast changing topology as it do not trigger any control message when link is broken. The failed links are not being included in the next distance scope of fisheye state message exchange. The periodical table updates and sequence number maintains the fresh and loop-free links in dynamic mobile network.

The following are the advantages of FSR.

* Simplicity
* Usage of up-to-date shortest routes
* Robustness to host mobility
* Exchange Partial Routing Update with neighbors

5. ADHOC ON-DEMAND DISTANCE-VECTOR PROTOCOL (AODV)

The Ad Hoc On-Demand Distance-Vector Protocol (AODV) [4] is a distance vector routing for mobile ad-hoc networks. AODV is an on-demand routing approach, i.e. there are no periodical exchanges of routing information.

The protocol consists of two phases:

i) Route Discovery, and
ii) Route Maintenance.

5.1 Route Discovery

A node wishing to communicate with another node first seeks for a route in its routing table. If it finds one the communication starts immediately, otherwise the node initiates a *route discovery* phase. The route discovery process consists of a route-request message (RREQ) which is broadcasted. If a node has a valid route to the destination, it replies to the route-request with a route-reply (RREP) message. Additionally, the replying node creates a so called *reverse route* entry in its routing table which contains the address of the source node, the number of hops to the source, and the next hop's address, i.e. the address of the node from which the message was received. A lifetime is associated with each reverse route entry, i.e. if the route entry is not used within the lifetime it will be removed.

5.2 Route Maintenance

The second phase of the protocol is called *route maintenance*. It is performed by the source node and can be subdivided into:

i) source node moves: source node initiates a new route discovery process,

ii) destination or an intermediate node moves:

A route error message (RERR) is sent to the source node. Intermediate nodes receiving a RERR update their routing table by setting the distance of the destination to infinity. If the source node receives a RERR it will initiate a new route discovery. To prevent global broadcast messages AODV introduces a local connectivity management. This is done by periodical exchanges of so called HELLO messages which are small RREP packets containing a node's address and additional information.

6. CHARACTERISTIC SUMMERY OF ZRP, FSR AND AODV

ZRP, FSR and AODV protocols are studied and their characteristics are summarized using different metrics in the tabular format in table 1.

Table 1. Characteristic Summery of ZRP, AODV & FSR

Protocol	**Zone Routing (ZRP)**	**Fisheye State Routing (FSR)**	**Adhoc On-demand Distance Vector (AODV)**
Category	Hybrid	Table-driven	Reactive
Metrics	Shortest path	Scope range	Newest route, shortest path
Route Recovery	Start repair at failure point	Notify source	New route, notify source, local repair
Route repository	Interzone, intrazone tables	Routing table	Routing table
Broadcasting	Simple	Simple	Simple
Loop freedom maintenance	Sequence number	Sequence number	Sequence number
Multiple paths	Yes	Yes	No
Communication Overhead	Medium	Low	High
Feature	Routing range defined in hops	Updates are localized	Only keeps track of next hop in route

7. SIMULATION SETUP

The Qualnet 5.0.2 simulator is used for the analysis. The animated simulation is shown in figure 1. The IEEE 802.11 [9] for wireless LANs is used as the MAC layer protocol. The 54 nodes are placed uniformly over the region of 1500mx1500m. In the scenario UDP (User Datagram Protocol) connection is used and over it data traffic of Constant bit rate (CBR) is applied between source and destination. The random waypoint model of mobility model is used in a rectangular field. The multiple CBR application are applied over different source and destination nodes. The simulation parameters are shown in Table 2.

7.1 Performance Metrics

Throughput: Throughput is the average rate of successful data packets received at destination. It is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second.

End-to-End Delay: A specific packet is transmitting from source to destination and calculates the difference between send times and received times. Delays due to route discovery, queuing, propagation and transfer time are included in the delay metric.

Packet Deliver Ratio (PDR): The (PDR) is defined as the ratio between the amount of packets sent by the source and received by the destination.

Jitter: Jitter is the variation of the packet arrival time. In jitter calculation the variation in the packet arrival time is expected to be low. The delays between the different packets need to be low for better performance in ad-hoc networks. It becomes a matter of concern if it is more than the threshold value, which is different for data, voice or video transmission services.

First Packet Received Time: It is the time at which first packet is received at the destination successfully.

Transmission time: It is the time taken between receiving of last and first packet successfully.

Routing via IERP: In ZRP when the route between two nodes placed in two different zone is not available then the packet is routed with the help of IERP.

Table 2. Simulation Parameters

Parameter	Value
Area	1500mX1500m
No. of Nodes	54
Channel Frequency	2.4 Ghz
Data rate	2.Mbps
Path Loss Model	Two Ray Model
Mobility Model	Random-Way Point
Packet size	512 bytes
Physical Layer Radio type	IEEE 802.11b
Antenna Model	Omni-directional

8. RESULTS & DISCUSSION

The Qualnet 5.0.2 network simulator has been used to analyze the parametric performance of Zone Routing Protocol (ZRP), Fisheye State Routing Protocol (FSR) and Ad Hoc On-Demand Distance-Vector Protocol (AODV). The metric based analysis is shown in figure 2 to figure 8.

Throughput: With the varying CBR data traffic the throughput is analyzed. The successful packet delivery at given nodes having number (ID) in an adhoc network is observed with increasing MAC based traffic load and mobility. It is found that AODV with least routing overhead uniformly performs better than FSR and ZRP but FSR performs better than ZRP because of its multilevel Scope technique and reduced routing traffic overhead in route discovery and maintenance. It is also observed that ZRP has not performed better than FSR due to zone method. The performance is shown in figure 2.

End-to-End Delay: When a packet is transmitted from source to destination it takes time to reach. This time includes different delay as described in its definition above. In this analysis it is observed as expected the delays are more for ZRP in comparison to FSR and AODV. These delays are incurred by the ZRP's IARP and IERP methods. The end-to-end delay of FSR and AODV is less because it has reduced routing overhead and queuing delay. The performance is shown in figure 3.

Packet Deliver Ratio: Performance is analyzed on this parameter and it is observed that FSR and AODV performs better than ZRP except at nodes 31, 36, 37 due to its low overheads. The ZRP and AODV performs better at these nodes as these low mobility nodes are in their source zone and also due to proactive maintenance of routing zones. On all other nodes PDR is better for FSR due to it scope technique and thus reduced traffic overhead. The results are shown in figure 4.

Jitter: Jitter, the variation of the packet arrival time, is an important metrics for any routing protocol. In this analysis it is found to vary. Initially it is low but for higher nodes ID than 37 it is high. The jitter for nodes 42,43,45,54 is high for both of the protocols due to larger distance between source and destination. In ZRP it is due to zone change and in FSR and AODV, it is due to higher frequency of propagation. The jitter results are shown in figure 5.

First Packet Received Time: The safe delivery of the first packet is faster with ZRP and AODV because destination nodes are in the same zone initially. With mobility they go away from source and packet required to move over multiple region and attributes to its lower throughput than FSR as shown in figure 6.

Transmission time: It is observed that transmission time of FSR protocol is least among them, because of its usage of up-to-date shortest routes. The transmission time for ZRP and AODV is same. It is shown in figure 7.

Routing via IERP: The mobility nodes are changing their zone from one zones to other and all the nodes in the topology are participating in the routing through IERP to reach any of the node. The packets are heavily routed through the node 13, 19, 26, 45, 47 and 51 as they are mostly on the boundaries of the zones in simulation time as shown in figure 8.

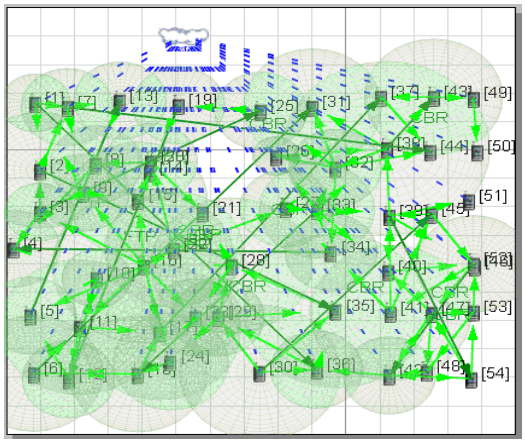

Figure 1. Snapshot of Simulation

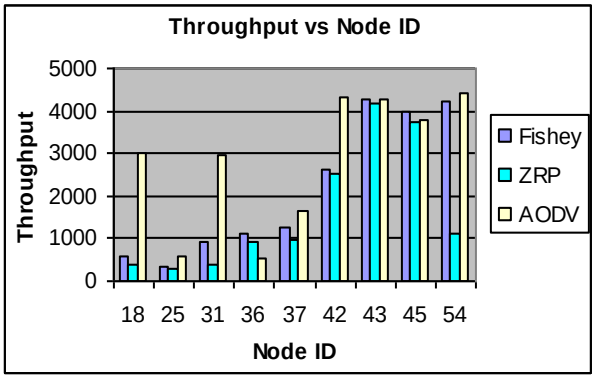

Figure 2. Throughput vs Node ID

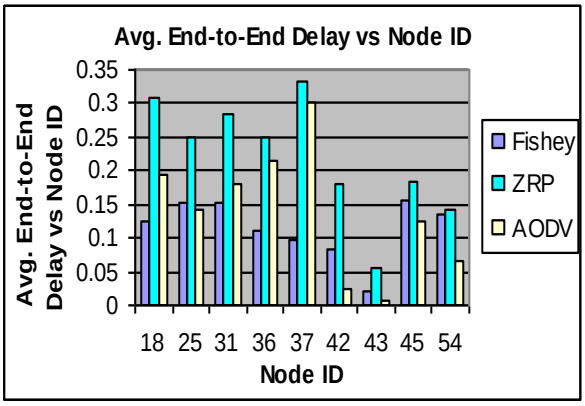

Figure 3. Avg. End-to-End Delay vs Node ID

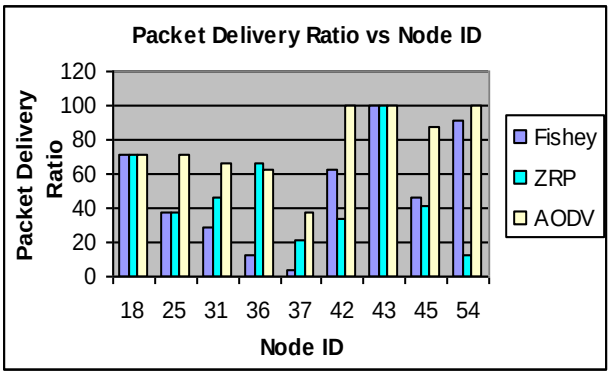

Figure 4. Packet Delivery Ratio vs Node ID

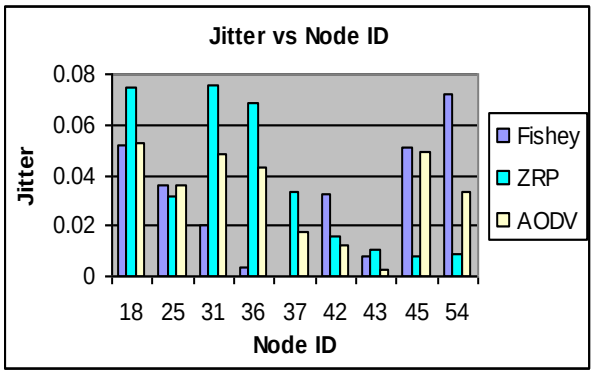

Figure 5. Jitter vs Node ID

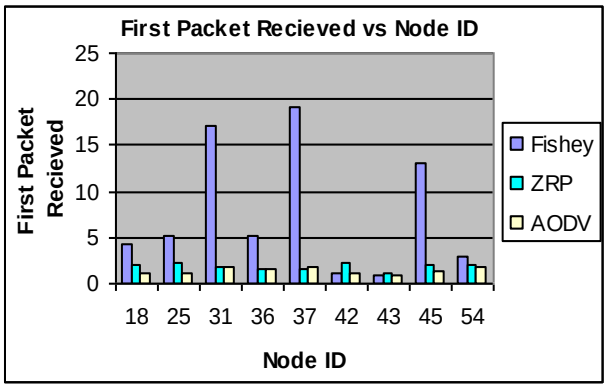

Figure 6. First Packet Received Time vs Node ID

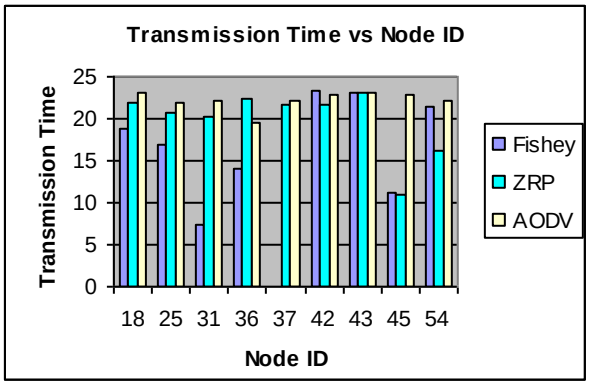

Figure 7. Transmission Time vs Node ID

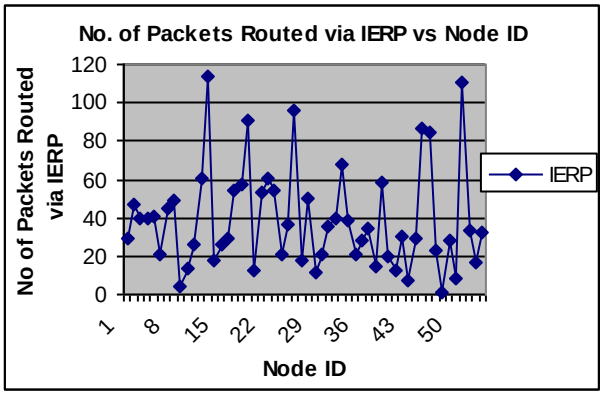

Figure 8. No. of Packets Routed via IERP vs Node ID

9. CONCLUSION

It is observed in the analysis that FSR and AODV outperform ZRP in general for all the scenarios due to its low overheads and multilevel scope technique. The reduced routing traffic overhead and only periodical propagation of link state information makes FSR suitable for the high mobile dynamic changing network topology and thus the throughput is good with the high mobility of nodes, similarly for the AODV also. The poor performance of ZRP is also because it doesn't have suitable mechanism to expire the expired routes. ZRP is suitable for the low mobility scenarios

and therefore the average end-to-end delay is also very high with high mobility. One of our future research works is to develop an efficient and optimized routing protocol with heavy mobility and routing overheads.

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