Performance comparison of ZRP Bordercasting using Multiple Unicasting vs Broadcasting

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ABSTRACT

MANET (Mobile Ad hoc Networking) is an ad hoc network formed by wireless mobile nodes without any fixed infrastructure. Each node can send, receive and forward data from other nodes. The volatile nature of wireless medium and mobility of nodes pose a great challenge for efficient routing in MANET. There are several routing protocols developed for MANET. ZRP (Zone Routing Protocol) is one of the hybrid MANET routing protocols. It combines proactive and reactive routing approaches for better scalability. In ZRP, the nodes build overlapping zones and maintain topology information of the nodes within their zone. The zone size is decided by zone radius which is defined as no. of hops. Proactive routing is used within the zone and reactive routing is used outside zone. ZRP uses bordercasting to efficiently control the flooding of reactive route queries in outward regions. Each forwarding node propagates the query to selected neighbors which lead to uncovered border nodes of the zone. Ad hoc networks commonly use single channel network. While using single channel network in ZRP, bordercasting can be done either using multiple unicasting or broadcasting.

This paper analyses and compares the impact of using multiple unicasting vs broadcasting on routing performance of ZRP, in single channel wireless network. Networking Simulator 2 (NS2) has been used for the simulations. The Qos parameters used for routing performance measurement were Packet delivery ratio (PDR), Average end-to-end delay, throughput and Normalized routing load (NRL). The simulation was done at high mobility by varying network size from small to large network. While using broadcasting, QD2 query control method was used to further control flooding of route queries to uncovered regions. The simulation results conclude that broadcasting is more performance efficient than multiple unicasting for bordercasting in ZRP.

General Terms

MANET, Mobile Ad hoc networking, ZRP, Zone routing.

Keywords

ZRP; Zone routing; MANET; Bordercasting; multiple unicasting; broadcasting; QD2; performance comparison.

1. INTRODUCTION

MANET (Mobile Ad hoc Networking) is an ad hoc network formed by mobile wireless nodes.

It does not require setting up any infrastructure. It is self-organizing and it can be set up spontaneously. Hence it is used widely in situations where prompt, ad hoc network is required.

The common applications of MANET include battlefield operations, disaster relief, habitat monitoring, vehicular area networks and social community networks [1] [2] [3].

Its connectivity varies over time. The mobility of nodes, limited energy and dynamic network conditions of wireless medium makes it challenging to perform efficient routing in MANET. Different kinds of MANET routing protocols have been developed for different scenarios and requirements.

Based on the routing approach, MANET routing protocols can be broadly classified as reactive, proactive and hybrid, as shown in Fig. 1 [1][2][3].

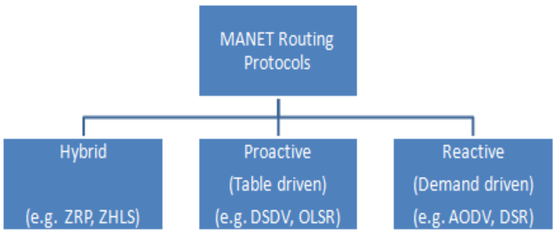

Figure 1: MANET routing protocols classification

1.1 Proactive protocols

These protocols proactively maintain routes to every other node by periodic/triggered routing updates, regardless of need for the given route now or in future. Each node maintains the complete picture of network topology. The updates regarding topology changes in direct neighborhood are propagated throughout the network using form of distance vector routing or link state flooding. The routes to the known destinations are calculated from these updates and maintained in routing table and hence it's called table-driven approach [2] [3].

Examples of such protocols include Destination-Sequenced Distance-Vector (DSDV), Wireless Routing Protocol (WRP), and Optimized Link State Routing (OLSR) etc. [1].

1.2 Reactive protocols

These protocols discover routes only when needed for data transfer, so called on-demand protocols [1] [2] [3]. When any node wants to send data to other node for which there is no active route available, then it discovers a route first and then initiates data transfer. The discovered route is maintained as long as the communication continues.

Examples of on-demand protocols include Dynamic Source Routing (DSR), and Ad hoc On-demand Distance Vector (AODV) [1][2].

1.3 Hybrid protocols

These protocols combine features of both reactive and proactive protocols to make it more scalable to different network sizes, node density and mobility conditions. Hybrid protocol uses hierarchical or multi-scope approach. Different type of routing is used at diff. hierarchical level or within different scope [2]. ZRP (Zone Routing Protocol) and Zone-based hierarchical link state (ZHLS) are examples of hybrid protocols [1] .

Proactive protocols are more suitable for low mobility, and small networks. Reactive protocols are more suitable for high mobility and large networks with low activity. Hybrid protocols aim to combine and balance features of both, thereby offering better scalability.

1.4 ZRP (Zone Routing Protocol)

ZRP (Zone Routing Protocol) is hybrid MANET routing protocol. Each node in the network to builds zone around it with neighbours up to certain hops. The size of the zone is restricted by zone radius which is no. of hops. The zones are overlapping [5] [6]. Each node maintains local topology knowledge within a zone by exchange of proactive updates with zone members. This can be used to find route, if the destination is within the zone. If destination is outside the zone then reactive routing is used to find a route, as shown in Fig. 2.

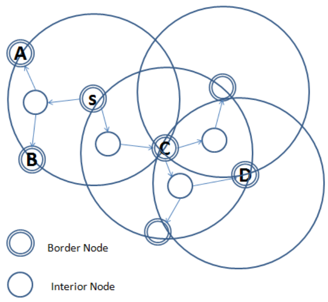

Figure 2: Zone Routing Protocol (ZRP)

The nodes which are at hop distance same as zone radius are called peripheral nodes or border nodes. The nodes at distance less than zone radius are called interior nodes. When there is no active route available, the node raises query and sends it to peripheral nodes. These nodes check if destination is within their zone, if so, it sends route reply back to source. If not, they forward the query further to their peripheral nodes, until destination is found OR TTL reaches zero [5].

ZRP is a framework protocol and allows any proactive/reactive protocols to be used as its components with some modifications [5] [6].

The protocol's architecture is organized into four main components: IntrAzone Routing Protocol (IARP), IntErzone Routing Protocol (IERP), Bordercast Resolution Protocol (BRP), and Neighbour Discovery Protocol (NDP) [6]. It is shown in Fig. 3.

IARP is a proactive component and can be implemented using techniques like link-state or distance-vector routing. The IARP aims to have updated topology information for all nodes within the zone. A node sends update of its neighbourhood topology changes, periodic and/or event triggered (link additions or losses) to other nodes within the zone.

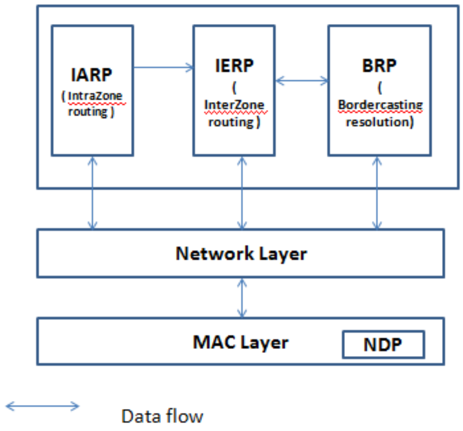

Figure 3: ZRP Architecture

The IERP is reactive component to discover the routes outside the zone on-demand. It performs route discovery and route maintenance. IERP component uses bordercasting to choose among neighbours to which query is forwarded [5].
Bordercast Resolution Protocol (BRP) performs bordercasting. It builds bordercast tree of node's peripheral nodes. If any of the peripheral nodes are interior nodes of last bordercast node then the node skips forwarding to those peripheral nodes, assuming those as covered. It builds bordercast tree using itself as a root and uncovered peripheral nodes as the leaves. Based on this tree, the next hops are decided to forward query further. Bordercasting helps to restrict flooding of queries away from the covered areas [6].
NDP is used by each node to discover their immediate neighbours. This can be provided at MAC layer OR it can be achieved at network layer using Hello messages. NDP transmits "HELLO" beacons at regular intervals [5] [6].

2. RELATED WORK

The authors, Zygmunt J. Haas et al. mentioned in [7][8], that reactive component of ZRP uses multicast based bordercasting to route queries through the network, away from the source towards uncovered regions, which is much more efficient, compared to blind broadcasting to neighbors, which is used in traditional reactive protocols. The bordercasting can be done by using either multiple unicasting or broadcasting. In bordercasting if node received a query through unicast message then it implies that, it is a forwarder of the query and it forwards the query further. If the node received a query via broadcast message, then it builds bordercast tree of last bordercasting (BC) node to check if it is a part of that tree. If so, it forwards the query further or otherwise it discards the query [7] [8].

Zygmunt J. Haas et al. further introduced query control methods for reactive component of ZRP in [9] to further restrict flooding of queries away from covered areas. QD1 (Query Detection 1), QD2 (Query Detection 2) and RQPD (Random Query Processing Delay) are suggested for query control. As shown in the Fig. 4, QD2 is query detection condition in which, a node overhears or detects broadcasted query for which it was not intended receiver (not on the receivers list or not a part of bordercast tree of last BC node). In this case, it treats all peripheral nodes of the zone, as covered, assuming that, some other node in the neighborhood would forward query to those nodes.

3. PROPOSED WORK

As of now, ad hoc wireless networks commonly use single channel networks. In single channel networks, the same channel is shared by node and its neighbors and hence if node broadcasts a query, it can be detected by all nodes within the range.

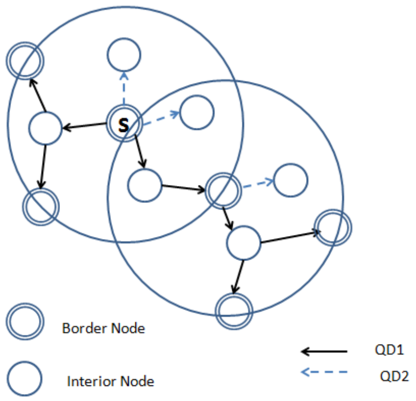

Figure 4: Query control QD1/QD2 in ZRP

If we use ZRP for single channel network, then we can implement bordercasting using either multicasting(multiple unicasting) or broadcasting.

In both cases, during bordercasting, each relay node builds its own bordercast tree and decides, to which neighbors it should forward the query further. Once neighbors are selected, if multiple unicast option was chosen, then it unicasts query separately to each neighbor by direct IP addressing. If broadcasting is chosen for query forwarding, then query is simply broadcasted which is received by all neighbors at once. However it is different from blind broadcasting. Only those receiving nodes, which are part of sender node's bordercast tree would forward the query further. This selection can be done at sender and explicit list of forwarders can be sent in the query OR at receiver's end, by building sender node's bordercast tree at and checking if it is a part of the tree.

The advantage of using broadcasting is that, it allows us save time and bandwidth by broadcasting a query message once only instead of repeated unicasts. Also, we can use QD2 query control method, which would help further to restrict query flooding to uncovered regions.

The disadvantage is that, if we use broadcasting, same query would be received multiple times by nodes and each time, each receiving node would need to forward query further to network layer where it would be checked if it is intended receiver OR if the query was received before and what should be done further with the query message. This would add considerable processing overhead for the nodes.

As a part of this research, ZRP protocol was implemented in NS2, as per author guidelines from latest ver. 4 of IETF draft for ZRP [7]. Then simulations were performed using single channel network, and details of that are given in the next section IV. ZRP bordercasting was implemented and simulated using both techniques: multiple unicasting as well as broadcasting (with explicit list of intended receivers). QD2 was implemented for broadcasting scenario. The experiment results are analyzed in section V.

4. SIMULATIONS

The research has been carried out using simulations on Network Simulator (NS2) version 2.35 on Ubuntu OS. The latest IETF version 2 of ZRP has been used as a framework to implement ZRP protocol. A fixed radius =2 was used for ZRP, which is found to be suitable for most scenarios. IARP uses link state routing with periodic and event triggered updates. IERP uses source routing with query control methods QD1, QD2 and RQPD. Network layer Hello messages are used for NDP. A single channel network is used for this simulation.

Random waypoint mobility model has been used to generate different mobility scenarios, as it is most commonly used for ad hoc networks simulations.

Network size was varied from 30 nodes to 200 nodes. For each scenario, few runs were performed and averages of values were taken as results. Table 1 summarizes simulations parameters used.

At first simulation runs were carried out by using multiple unicasting for IERP query transmission. Then same connection patterns and mobility scenarios were used to generate results for using broadcasting for IERP query transmission.

Table 1: Simulation parameters

Simulation Parameter	Value
Propagation model	Two-ray ground
Mobility Model	Random Waypoint
Simulation time	600 sec
Network Area	1000x1000 m
ZRP radius	2
Transmission radius	250 m
MAC Protocol	802.11
MAC Data rate	11 Mb/s
Carrier frequency	2.4 GHz
Antenna	Omnidirectional
Queue Type	DropTail/PriQueue
Max number of packets in Interface Queue	100
Traffic pattern	Constant Bit Rate (CBR)
Transport protocol	UDP
Packet size	512 Bytes
Constant Bit Rate (CBR)	4 pkts/sec
Maximum connections	50
Puase time	5 sec
Max Node speed	20 m/s
# of Nodes	30, 50, 75, 100, 150, 200

The metrics chosen for performance measurement were packet delivery ratio, throughput, Avg. delay and NRL (Normalized Routing Load).

5. RESULTS ANALYSIS

Fig. 5 gives Packet Delivery Ratio (PDR) of ZRP at different network sizes for both scenarios: multiple unicasting vs broadcasting.

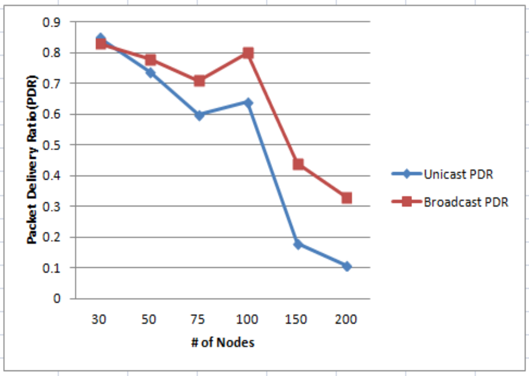

Figure 5: Packet Delivery Ratio vs. Network size

As shown in fig. 5 PDR drops significantly as network size (# of nodes) increases for both cases, specifically from 100 nodes onwards. This occurs due to increased node density leading to increased routing load and collisions. As ZRP uses flooding of link state proactive updates within zones, proactive routing load increases significantly with increase in # of nodes. However as noticed, using broadcasting with forwarder list for flooding of route queries reduces reactive routing load compared to using multiple unicasting. For each node at most one retransmission is required for a route query in case of broadcasting, whereas it needs multiple transmissions at each node for unicasting. Also broadcasting allows using QD2 query control scheme, which helps to further reduce retransmissions of route queries. Hence we can see some gain in PDR for broadcasting case.

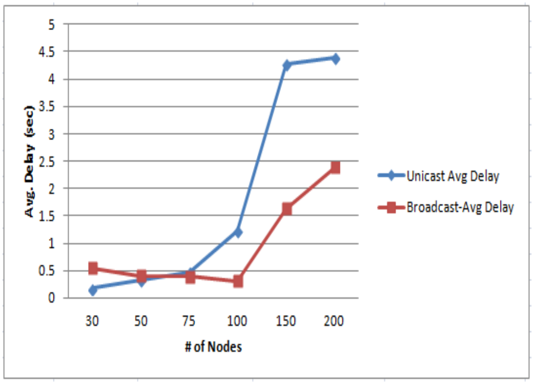

Figure 6: Average Delay vs Network size

As shown in Fig. 6, Avg. delay remains below 1 sec for both cases up to 100 nodes. For small networks unicasting or broadcasting is not making much difference from delay point of view. Above 100 nodes, as we increase no. of nodes, avg. delay increases significantly for both cases. This should be due to congestion resulting from heavily increased routing load. Again, broadcasting case demonstrates better performance in terms of reduced avg. delay compared to unicasting case, as we increase no. of nodes.

As shown in Fig. 7, throughput reduces for both cases as we increase network size. This attributes to increasing routing load and dropped packets and increase in avg. delay. However broadcasting case shows better throughput compared to unicasting, due to comparative gain in PDR and avg. delay.

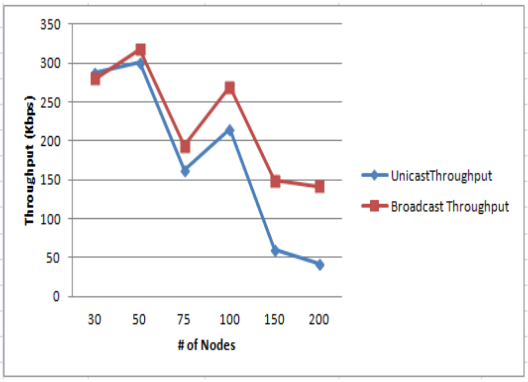

Figure 7: Throughput vs. Network size

Fig. 8 shows Normalized Routing Load (NRL) for different network sizes for unicasting and broadcasting. NRL increases drastically from 100 nodes onwards for Unicasting case. NRL also increases for broadcasting case, but the increase is not significant, due to reduction in route query retransmissions.

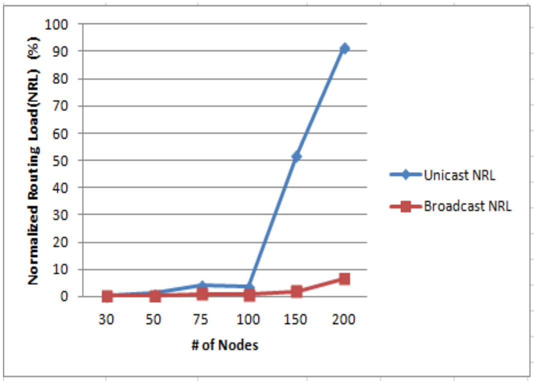

Figure 8: Normalized Routing Load vs. Network size

6. CONCLUSION

In this research, simulations were done for ZRP using multiple unicasting vs broadcasting as a method of bordercasting, for single channel networks. The results were compared for both cases. The results show that, for small networks sizes the difference in PDR, throughput and Avg. delay for both cases is not much. However as we increase network size, it increases node density. This results in significant increase in # of route query retransmissions and NRL for the case of multiple unicasting as compared to broadcasting. Its impact is seen in PDR, throughput and avg. delay metrics. PDR and throughput reduces and avg. delay increases much faster for multiple unicasting scenario compared to broadcasting. Hence, this research concludes that, for single channel networks with moderate to large network size, using broadcasting with QD2 query control for bordercasting is much more performance efficient than using multiple unicasting.

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