Efficient Query Propagation by Adaptive Bordercast Operation in Dense Ad Hoc Network

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Abstract

We designed the Adaptive Bordercast Resolution Protocol for efficient query propagation in a flat ad hoc network. The characteristic of Ad hoc networks like dynamic topology, network density causes asymptotic packet generation that results in degraded performance of routing protocols. The Bordercast Resolution Protocol (BRP) under Zone Routing Protocol (ZRP) outperforms flooding, albeit naïve query propagation technique. We can optimize the performance of bordercast operation by setting the optimal routing zone radius. In this paper, we present and examine the characteristics of new adaptive routing protocol based on the ZRP protocol. The results show that the cost of discovering the route by adaptive bordercast is better than the native bordercast resolution protocol

Key words:
Bordercast resolution protocol; Zone routing protocol; Dense Ad hoc network; Query propagation

1. Introduction

As Ad Hoc networks do not rely on existing infrastructure and self- organizing, they can be rapidly deployed to provide robust communication in a variety of hostile environments. This makes ad hoc networks very appropriate for a broad spectrum of applications ranging from providing tactical communication for the military and emergency response efforts to civilian forums such as convention centers and construction sites. With such diverse applicability, it is not difficult to envision ad hoc networks operating over a wide range of coverage areas, node densities, mobility patterns and traffic behaviors. This potentially wide range of ad hoc network operating configurations poses a challenge for developing efficient routing protocols. On one hand, the effectiveness of a routing protocol increases as network topological information becomes more detailed and up-to-date. On the other hand, in an ad hoc network, mobility may cause frequent changes in the set of communication links of a node requiring large and regular exchanges of control information among the network nodes. And if this topological information is used infrequently, the investment by the network may not pay off. Moreover, this is in contradiction with the fact that all updates in the wireless communication environment travel over the air and are, thus, costly in transmission resources.

Existing routing protocols for ad hoc networks can be classified either as proactive, reactive or hybrid. Proactive or *table driven* protocols 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. Examples of proactive protocols include OLSR [1], TBRPF [2], and WRP [3]. In contrast, reactive or *on-demand* protocols invoke a route determination procedure on an on-demand basis by flooding the network with the route query. Examples of reactive protocols include AODV [4], and DSR [5]. The on-demand discovery of routes can result in much less traffic than the proactive schemes, especially when innovative route maintenance schemes are employed. However, the reliance on flooding of the reactive schemes may still lead to a considerable volume of control traffic in the highly versatile ad hoc networking environment. Moreover, because this control traffic is concentrated during the periods of route discovery, the route acquisition delay can be significant.

This is due to at one time or another, either due to limited cache sizes, changes in the network that invalidating existing information, or the arrival of a new query for an unknown destination, each of routing protocols is forced to send a query into the network in search of a node or information about a node, information that might be available at some other, nearer nodes. Because it is a fundamental operation, efficient query propagation is, therefore, of significant importance when performance is considered.

Flooding is a frequently used, albeit naïve, query propagation protocol, whereby each node, upon receiving a query for the *first* time, merely rebroadcast it to all its neighbors, possibly with some jitter to reduce the probability of congesting the network. Reception of a previously seen query is ignored. Excluding failures, every node with a path to the source receives the query at least once and transmits it exactly at once. Truncating the flood by using an expanding ring (Such as TTL-based ring [6]), as is done. For example, in AODV, is merely a

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stop-gap measure that is useful only when the destination node or cached information happens to exist nearby.

By the flooding operation the cost of discovering a route within a flat ad hoc network in the absence of any information about the desired destination node except for its unique address. But BRP under ZRP framework uses bordercasting operation that can discover a route with cost proportional only to the area of the network, and independent of the number of nodes in the network (i.e., independent of the network density). Furthermore, at this is optimal; i.e., that this cost is a lower bound for any possible route discovery protocol that does not rely on additional information about the destination node. *bordercasting*, a query propagation protocol where a node resends the query to nodes at some distance away.

The bordercasting, which proposed as part of the *Zone Routing Protocol* (ZRP) framework [7], is, indeed, density-independent. For any given scenario, it is desirable for the BRP to operate as efficiently as possible. This is can be achieved through proper selection of the routing zone radius. In general, choosing the optimum routing zone radius requires an accurate model of the network and individual node behavior. Even with perfect knowledge of all network parameters, computation of the optimal routing zone radius is not straightforward.

In this paper, we analyzed the effective parameters like node density and number of nodes. We also proposed enhanced bordercast operation called ABRP, which can determine the optimal zone radius. We introduced optimal zone radius calculator that will determine the optimal zone radius for efficient bordercast operation.

2. OVERVIEW OF ZONE ROUTING PROTOCOL

Proactive routing uses excess bandwidth to maintain routing information, while reactive involves long route request delays. Reactive routing also efficiently floods the entire network for route determination. The Zone Routing Protocol (ZRP) [7] aims to address the problems by combining the best properties of both approaches. ZRP can be classed as hybrid reactive/proactive routing protocol. In an ad-hoc network, it can be assumed that the largest part of the traffic is directed to nearby nodes. Therefore, ZRP reduces the proactive scope to a zone centered on each node. In a limited zone, the maintenance of routing information is easier. Further, the amount of routing information that is never used is minimized. Still, nodes farther away can be reached with reactive routing. Since all nodes proactively store local routing information, route requests can be more efficiently performed without querying all the network nodes [8].

Despite the use of zones, ZRP has a flat view over the network. In this way, the organizational overhead related to hierarchical protocols can be avoided. Hierarchical routing protocols depend on the strategic assignment of gateways or landmarks, so that every node can access all levels, especially the top level. Nodes belonging to different subnets must send their communication to a subnet that is common to both nodes. This may congest parts of the network. ZRP can be categorized as a flat protocol because the zones overlap. Hence, optimal routes can be detected and network congestion can be reduced [9].The Zone Routing Protocol, as its name implies, is based on the concept of zones. A routing zone is defined for each node separately, and the zones of neighboring nodes overlap. The routing zone has a radius ρ expressed in hops. The zone thus includes the nodes, whose distance from the node in question is at most ρ hops.

ZRP refers to the locally proactive routing component as the IntrA-zone Routing Protocol (IARP). The globally reactive routing component is named IntEr-zone Routing Protocol (IERP). IERP and IARP are not specific routing protocols. Instead, IARP is a family of limited-depth, proactive link-state routing protocols. IARP maintains routing information for nodes that are within the routing zone of the node. Correspondingly, IERP is a family of reactive routing protocols that offer enhanced route discovery and route maintenance services based on local connectivity monitored by IARP, [10] [11]. The fact that the topology of the local zone of each node is known can be used to reduce traffic when global route discovery is needed. Instead of broadcasting packets, ZRP uses a concept called *bordercasting*. Bordercasting utilizes the topology information provided by IARP to direct query request to the border of the zone. The Bordercast Resolution Protocol (BRP) [12] provides the bordercast packet delivery service. BRP uses a map of an extended routing zone to construct bordercast trees for the query packets. Alternatively, it uses source routing based on the normal routing zone. By employing *query control* mechanisms, route requests can be directed away from areas of the network that already have been covered, [9].

In order to detect new neighbor nodes and link failures, the ZRP relies on a Neighbor Discovery Protocol (NDP) provided by the Media Access Control (MAC) layer. NDP transmits “HELLO” beacons at regular intervals.

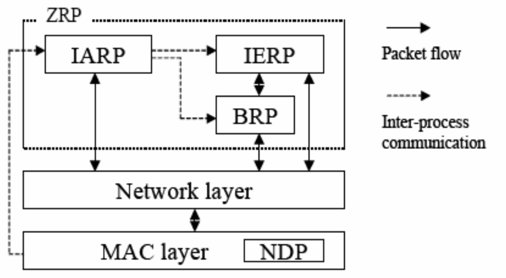

Fig.1 ZRP Components

Upon receiving a beacon, the neighbor table is updated. Neighbors, for which no beacon has been received within a specified time, are removed from the table. If the MAC layer does not include a NDP, the functionality must be provided by IARP [11]. The relationship between the components illustrated in Figure 1. Route updates are triggered by NDP, which notifies IARP when the neighbor table is updated. IERP uses the routing table of IARP to respond to route queries. IERP forwards queries with BRP. BRP uses the routing table of IARP to guide route queries away from the query source [12].

3. Routing Operation in ZRP

A node that has a packet to send first checks whether the destination is within its local zone using information provided by IARP. In that case, the packet can be routed proactively. Reactive routing used, if the destination is outside the zone [11]. The reactive routing process is divided into two phases: the *route request* phase and the *route reply* phase. In the route request, the source sends a route request packet to its peripheral nodes using BRP. If the receiver of a route request packet knows the destination, it responds by sending a route reply back to the source. Otherwise, it continues the process by bordercasting the packet. In this way, the route request spreads throughout the network. If a node receives several copies of the same route request, these are considered as redundant and are discarded [10, 11]. The reply is sent by any node that can provide a route to the destination. To be able to send the reply back to the source node, routing information must be accumulated when the request is sent through the network. The information is recorded either in the route request packet, or as next-hop addresses in the nodes along the path. In the first case, the nodes forwarding a route request packet append their address and relevant node/link metrics to the packet. When the packet reaches the destination, the sequence of addresses is reversed and copied to the route reply packet. The sequence is used to forward the reply back to the source. In the second case, the forwarding nodes records routing information as next-hop addresses, which are used when the reply is sent to the source. This approach can save transmission resources, as the request and reply packets are smaller [11].The source can receive the complete source route to the destination. Alternatively, the nodes along the path to the destination record the next-hop address in their routing table [11].

In the bordercasting process, the bordercasting node sends a route request packet to each of its peripheral nodes. This type of one-to-many transmission can be implemented as multicast to reduce resource usage. One approach is to let the source compute the multicast tree and attach routing instructions to the packet. This is called Root-Directed Bordercasting (RDB). Another approach is to reconstruct the tree at each node, whereas the routing instructions can be omitted. This requires that every interior node knows the topology seen by the bordercasting node. Thus, the nodes must maintain an extended routing zone with radius $2\rho -1$ hops. Note that in this case the peripheral nodes where the request is sent are still at the distance ρ. This approach is named Distributed Bordercasting (DB), [9]. The zone radius is an important property for the performance of ZRP. If a zone radius of one hop is used, routing is purely reactive and bordercasting degenerates into flood searching. If the radius approaches infinity, routing is reactive. The selection of radius is a tradeoff between the routing efficiency of proactive routing and the increasing traffic for maintaining the view of the zone.

3.1 Bordercast- Based Route Discovery

Like flooding, the bordercast protocol propagates the query across the entire network. However, while flooding attempts to iteratively relay the query to any neighbors that have not heard it yet, the bordercast protocol seeks to iteratively relay the query to any of its *border* nodes that have not seen the query yet. Thus, while all the neighbor nodes receive the query broadcast, not all of them need to retransmit it on its way to the border nodes.

If we consider the nodes within the zone to be a micro-ad hoc network with area, it is clear that the cost of propagating the query across the zone is a function of its area and not of the number of nodes within it. Therefore, because of the broadcasting nature of wireless communications, the bordercast protocol broadcasts the query to all its neighbors, but selects only a few to re-bordercast the message. The other neighboring nodes are silent recipients. It is important to understand that bordercasting does *not* actually attempt to deliver the query to every node within its zone. Rather, its objective is to relay the query only to any *border* nodes that have not yet received the query. The protocol still works correctly, because each node in the network maintains information about all the nodes within its zone and can answer queries about them or, at the very least, forward the query directly to the desired node. Thus, we say that a node is *covered*, if any node within its zone has received the query.

3.2 Bordercast Operation Example

Consider the network in Figure 2. The node S has a packet to send to node X. The zone radius is $\rho=2$. The node uses the routing table provided by IARP to check whether the destination is within its zone. Since it is not found, a route request is issued using IERP. The request is bordercast to the peripheral nodes (gray in the picture). Each of these searches their routing table for the destination.

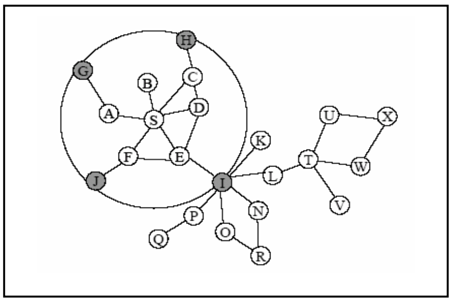

Fig.2 The routing zone of Node S

Node I does not find the destination in its routing table. Consequently, it broadcasts the request to its peripheral nodes, shown in gray in Figure 3. Due to query control mechanisms, the request is not passed back to nodes D, F and S.

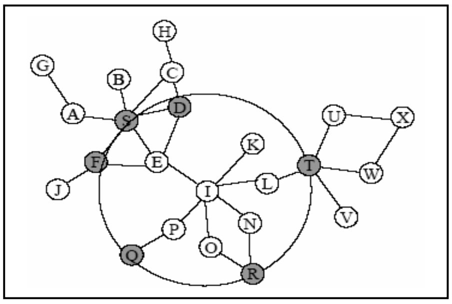

Fig.3 The routing zone of Node I

Finally, the route request is received by node T, which can find the destination in its routing zone, shown in Figure 4. Node T appends the path from itself to node X to the path in the route request. A route reply, containing the reversed path is generated and sent back to the source node. If multiple paths to the destination were available, the source would receive several replies.

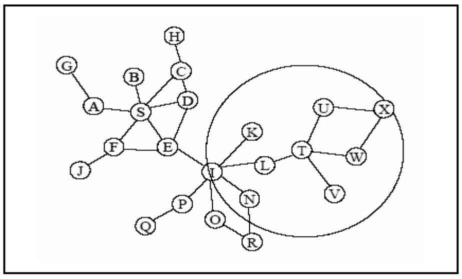

Fig.4 The routing zone of Node T

4. Architecture of Adaptive Bordercast Resolution Protocol

In this paper we propose an Adaptive Bordercast Resolution Protocol (ABRP) that can adapt to any given state of the dense network, using a unique approach in order to maximize efficiency and minimize packet loss and end-to-end delay.

We seek to enhance BRP in order to be able to adapt to any given state of the network, even in probable different network behaviors throughout the same network. The main purpose of the proposed algorithm is to set the optimal routing zone radius in order to enhance the performance of BRP with the use of optimal zone radius. The BRP (Bordercast Resolution protocol) provided by ZRP is much more effective if the zone is optimal and reactive based on the mobility and traffic state of the network in the area around the node.

Bordercast operation can be replacing the existing flooding-based query propagation protocol effectively. Our proposed enhanced bordercast (ABRP) will be more effective for its ability to determine the optimal routing zone radius using the node density and number of nodes as parameters.

ABRP work same as BRP as we seen earlier in above section but it will set automatically optimal zone radius. Optimal zone can help to lower the excess traffic from IARP & BRP during low node mobility and packet traffic periods, by selecting a larger zone radius. In high node mobility and packet traffic, ABRP will decrease zone radius in order to provide a better knowledge in the network around the node and a clear way to and from a border node for the route acquisition / response packet. By increasing the zone radius, the destination node may even be a new part of the zone. As the zone increases, reduced route acquisition times and lower bandwidth loss will result. The mechanism that decides whether to increase or decrease the zone radius called Optimal Zone Radius Calculator is shown in Figure 5. In this Calculator mobility* operation left to future work.

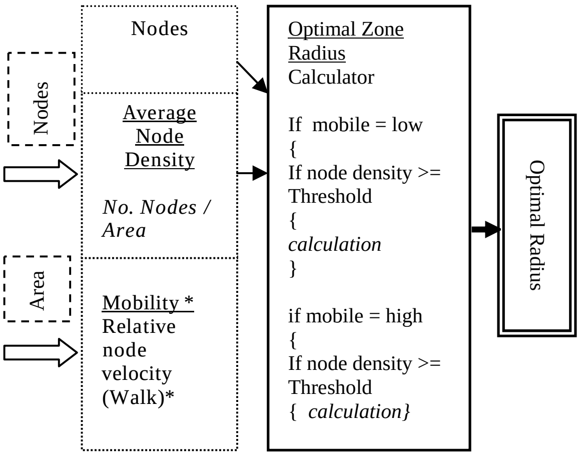

Fig.5 Optimal Zone Radius Calculator

4.1 Impact of Node Density and Number of Nodes

Node density is an important deciding factor for Zone routing radius. If the density is high means setting larger routing radius has efficient effect on routing because it covers lot of nodes inside the zone.

Suppose the density of nodes is low than setting a larger zone routing radius is no impact rather it even cause worst performance. During this type of topology, setting the lower zone radius is more efficient. Therefore in our proposed model, which means ABRP, works on the factor node density is vital. Other one factor is number of nodes, this also important factor. As the network, size grows whether it is low density or high density affects the performance of query propagation.

4.2 Setting Optimal Zone Radius

Setting the optimal zone radius is still a research problem. As we said earlier, in our case (Dense network) we take node density and number of nodes as important parameters to determine the optima zone radius for bordercast operation. This research [13] concluded that setting zone radius to two hops. This research also concluded that setting a higher zone radius results in little bordercast improvement and substantially increase the cost of zone maintenance, especially at higher network densities.

There is other reason to have a larger zone, including proactive route maintenance and a high rate of route requests relative to the rate of link changes(i.e., mostly stationary network).

Therefore, from this above observation we defined zone radius 2 as a base optimal zone radius. However, to find up most optimal zone radius, we derived the result from other work [8]. In this research they conducted various experiment for IARP & IERP traffic with different zone radius and different node density. Analyzing the result, we taken the Zone radius 4 is more apt than other zone radius.

For the highest optimal zone radius we took value 4. From this analysis, we concluded that the range of the optimal zone routing radius is between 2 and 4.

4.3 Determine Threshold Value

In this proposed algorithm the important parameter is Threshold. By the Threshold value we able to determine the Optimal Zone Radius. Threshold actually value of optimal node density. We determined the value of threshold from a research [8]. In the research “Determining the optimal for ZRP” [8] they perform various experiment using different node-neighbor and also discovered radius within 4-7 hops were vital. So averagely node-neighbor or node density 6 is worthy value to choose. The result shows that node density 6 produces an optimal result on various criteria [8]. We take node density 6 as a balanced node density We choose that value for criteria to fix Optimal Zone Radius, this value not only suitable for Route discovery but also traffic control for IARP & IERP and Route failure rate traffic during node velocity.

So the performance of Bordercast operation under ZRP will improve by configured for particular network through adjustment of single parameter, the *routing zone radius*.

5. Performance Evaluation

The evaluation of adaptive bordercast was done using the SWANS simulator [14], because of its scalability property of being able to simulate very large networks. We measure the *unit* packet cost of a protocol, which is defined as the number of packets sent throughout the network to perform a single round or operation. The unit cost of the IARP protocols is the number of packets for the protocol to quiesce, such that every node has learned its complete zone state. IARP operation is provided by the Simulator’s component itself. Since the nodes begin with no information, this measurement represents the worst case (or, alternatively, the highest mobility case) for the protocol, which is when the information about *all* the zone links must be communicated. The unit cost of a bordercast operation is the number of packets transmitted to cover the entire network with a query. For any fixed density, both of these protocols grow linearly with the area of the network or, equivalently, linearly with the number of nodes in the network, since we keep the density constant.

We generate the network by placing wireless nodes randomly within a square area and increase the size in proportion to the number of nodes. Each network node is turned on at time $t=0$ with no information other than its unique address. The protocol stack at each node comprises a wireless radio, the 802.11b MAC, IPv4 network, UDP transport, and our test application components that generate traffic. Other relevant protocols, such as NDP, for example, have also been implemented as part of the simulation. Note that since the various protocols perform link-level broadcasts, the 802.11 collision avoidance and retransmission mechanisms do not play a role in these simulations.

However, each of the simulated protocol incorporates jitter to reduce the probability of congestion and is already resilient to point failures, either due to repetition (NDP) or due to a flooding-like behavior (IARP and BRP). The simulator accounts for signal interference, but neither for shadow fading nor for Raleigh fading. The following table explains the other simulation parameters.

Table 1: Simulation Parameters

Parameters	Values
Routing zone Radius (*R*)	2 (default) , 3, 4
Routing protocol	ZRP
Routing Sub protocol	BRP , ABRP
Number of nodes (n)	100…3000
Field [x axis meter, y axis meter]	300 , 300
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6. Results and Discussion

In the first experiment, which is showed in figure 6, we compare the performance of query propagation of flooding and bordercasting as a function of node density. Each point represents the average of at least 10 runs. The graph shows how a flooding-based propagation grows in proportion to the number of nodes, but that bordercast is density independent. In other words, adding more nodes to the network does not increase the cost of bordercasting.

The x-axis shows both the total number of nodes, as well as the network density in terms of the expected average number of neighbors per node. This number of neighbors is computed from the node density and the transmission radius. It matches the values reported by NDP in simulation. *R* is referred to as the zone radius

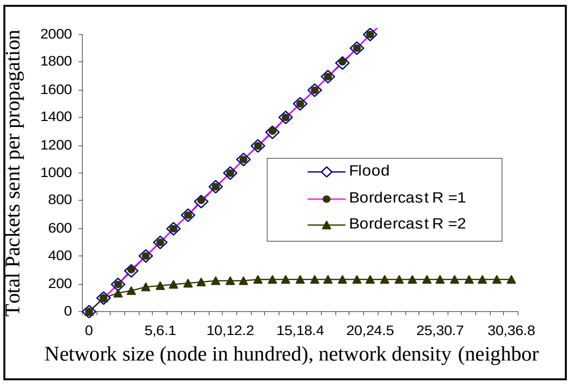

Fig.6 Bordercast vs. Flooding

Finally, we observe that by setting the zone radius to 1, the performance of bordercast degenerates to flooding. This is expected, since with $R = 1$ the border set becomes the neighbor set. In the figure the slight advantage of bordercast over flooding is merely an edge effect: edge nodes do not retransmit the query under the bordercast protocol, because all of their neighbors are already covered

In the second experiment, which we represent in figure 8, was performed for ABRP validity. As far we know that, the ABRP deals with setting the optimal zone radius for ZRP. Therefore, the following experiment is manually setting the zone radius for bordercast protocol. From this experiment result, we can check the validity performance of the ABRP.

Increasing the zone radius improves the performance of bordercast only minimally, as shown in Figure 7.

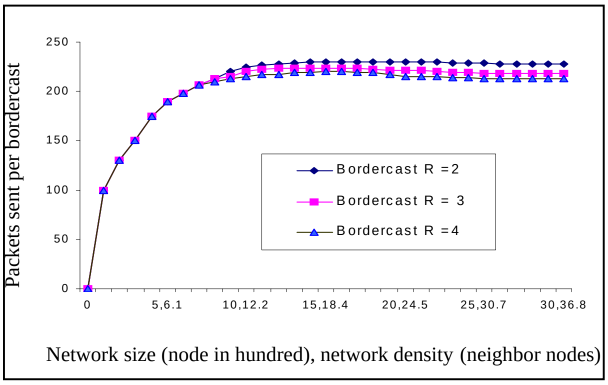

Fig.7 Bordercast with different radius

But there is little deviation in the graph (Figure 8). After the 1000 nodes the graph for both zone radius 3

& 4 slightly drop when compare to zone radius 2.This is due to the increase in zone, because it comprise more nodes than zone with radius 2. It shows that some propagation query reduced. From this we can conclude that when network grows with constant density and choosing higher radius can have effective query propagation. Effective query propagation here refers to reduced packet propagation.

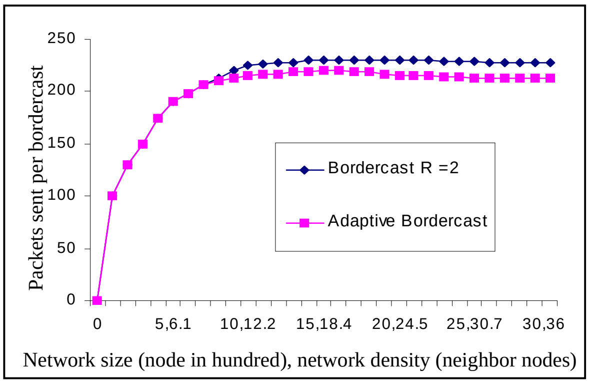

Fig.8 Adaptive Bordercast vs. Bordercast

The third experiment, which is shown in figure 8, it compares the performance of bordercast (BRP) operation & Adaptive bordercast (ABRP) operation. ABRP is our proposed idea; its shows result better than bordercast operation.

For bordercast operation, it used Routing Zone is 2 because previous research [7] says that radius 2 is optimal zone radius. But proposed method Adaptive bordercast (ABRP) result shows better performance than bordercast operation. This is due to the ABRP can set the optimal radius zone according to the node density and number of nodes. In the figure 9 when we analyze up to 1000 nodes packet sent by both bordercast (BRP) operation & adaptive bordercast (ABRP) operation is same because is due to the number of nodes. After 1000, nodes graph began to deviate because number of nodes increases and the density constant. Therefore, the zone can cover more nodes. The result shows better performance by adaptive bordercast operation than bordercast operation.

7. Conclusion and Future Works

The scalability of ad hoc networks – the ability to efficiently route and transmit packets across ad hoc networks as they grow in size – is a key research challenge. In this thesis, we analyzed the cost of discovering a route to some desired destination node using only its unique address.

We have presented the design of an adaptive bordercast protocol is an enhancement of bordercast protocol, a query propagation protocol and have proven that this is optimal. Bordercast protocol can improve the performance of many existing routing protocols in dense networks by replacing their flooding-based query propagation.

Our results also show that: adaptive bordercast operation outperforms the flooding and enhanced result with bordercast operation. Adaptive borderacast operation can detects the environment by using node density and number of nodes. Adaptive bordercast also set the optimal zone radius for routing. We have highlighted the importance of node density and number of nodes for determines the optimal zone routing radius.

In future bundle all ZRP protocols into a single protocol. The adaptive bordercast operation will implement instead of flooding in routing protocols like AODV and DSR for route discovery.

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