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Localized Routing in Mobile Ad hoc Networks

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ABSTRACT: Mobile Ad Hoc Networks (MANETs), one of OppNets technologies, have a high potential to be used for facilitating an extension for the Internet and a backup communication platform in disaster situation. However, a connection disruption due to node mobility and unreliable wireless links is possible to trigger a flooding operation of route repair process. ,is results in transmission delay and packet loss. The flooding of routing packets is an expensive operation cost in MANETs which affects network reliability and wastes limited resources such as network bandwidth and node energy. These are obstacles to practical implementation of MANETs in real-world environment. In this paper, we propose Low Overhead Localized Flooding (LOLF), an efficient overhead reduction routing extension based on Query Localization (QL) routing protocol. The purpose of this work is to control the propagation of routing packets in the route discovery and route repair mechanisms while incurring only a small increase in the size of control information in the packet.

KEYWORDS: MANET, DTN, RREP,RREQ Packets

I. INTRODUCTION

Depending on the network design, OppNets can provide temporary (or even permanent) infrastructure-less multihop communication. Many types of OppNets are widely discussed and proposed in the last decade, such as Mobile Ad Hoc Networks (MANETs) , Delay-Tolerant Networks (DTNs), Wireless Sensor Networks (WSNs), and Wireless Mesh Networks (WMNs). These types of networks have their own characteristics and are generally designed to use in a different situation. MANETs and DTNs are designed for mobile nodes while most of the nodes in WSNs and WMNs are almost stationary and mainly used in sensing and collecting environmental data.

This also includes real-time based applications, such as instant messaging and streaming application (VoIP, IPTV, and video conferencing). When looking at OppNets, there are two competitive technologies which have potential to support today's Internet activities for smart phone users, i.e., DTNs and MANETs. DTNs are designed for the situation that connection establishment is not possible, such as in low-density and high mobility networks where network partition always occurs. In contrast, MANETs are connection oriented communication using smart phones as relay nodes to create end-to-end path for continuous and reliable data transmission. Standard transport-level protocols (i.e., TCP and UDP) are compatible with MANETs without requiring any modification. Therefore, MANETs have the capability to support Internet applications relying on TCP/IP and can also be applied for temporary communication in a disaster situation or extension of the Internet.

Since nodes have limited bandwidth and rely on battery power, a node should send only necessary packets to save these important resources. However, the movement of nodes frequently breaks the communication path and causes a loss of data packets. This also triggers the exchange of routing packets in order to find a new path in MANETs. Ad Hoc On demand Distance Vector (AODV) is a well-known on demand routing. First, a source floods a Route Request (RREQ) packet. Then, the destination sends a Route Reply (RREP) packet back along the reverse path to the source. Then, the source can start sending data packets. Even though global flooding is the simplest way to discover a route to a destination, it causes excessive broadcast storm overhead, which directly affects the performance of OppNets. To prevent network-wide flooding, TTL (Time-To-Live) is used to limit flooding scope. The TTL value is decremented by one when a packet is forwarded and will be dropped when the value reaches zero. An initial TTL value will be determined according to specific conditions. The smaller the initial TTL value, the smaller the flooding scope.

Query Localization (QL) technique is based on the hypothesis that most routing protocols construct the shortest path (in hops) if possible. All relay nodes of the constructed path are in the direction of the destination. Therefore, in Query Localization, the routing packets are flooded on the basis of the most recently broken path. Based on this idea, Query Localization does not require a complex calculation. In spite of these advances, there are still opportunities for further enhancements to achieve better performance. Our method controls the dissemination of the RREQ packet while incurring only insignificant control information overhead. -is results in lowered overall routing overhead and less network congestion. Extensive simulations demonstrate that overall performance metrics are improved in our protocol. We choose to implement our method based on AODV due to its simplicity and its wide use by many researchers.

II. RELATED WORK

[1].In MANETs, Blocking-Expanding Ring Search (B-ERS), is proposed as an extension to the Expanding Ring Search (ERS). A special stop packet is used to eliminate the propagation of RREQ packets. When a source receives a RREP packet, it broadcasts a stop packet. This packet contains the RREQ originator address and a corresponding RREQ ID. The TTL value in the IP header is set to the hop count to the destination. Whenever a relay node receives a RREQ packet, it waits for a certain back-off delay before rebroadcasting the packet. During the back-off period, if the node receives a stop packet which contains a matched RREQ originator address and RREQ ID, it drops the RREQ packet.

[2].In original AODV, when a relay node detects a link breakage, it performs a route repair. If the hop count to the destination is not farther than max_repair_ttl, the relay node initiates a local repair mechanism. The data packets are buffered and the node, rather than the source, broadcasts a RREQ packet with a higher destination number to find a new route. Otherwise, the node sends a Route Error (RERR) packet back to its upstream nodes. When the source receives the RERR packet, it broadcasts a new RREQ packet.

In Multihop (MH) repair, the multihop neighbor information is used to find a bridge node to replace an unreachable next hop. Each node maintains a list of neighbors up to n hops. When there is a link breakage, the upstream node of the broken link sends a query to find neighbors (up to n hops) which can connect to the downstream node of the broken link. A scheme in modifies the RREQ packet to include both the unreachable next hop address and the destination address as targets to increase the opportunity to find a route to the destination. The target of the RREQ packet is the next 2-hop node of the broken link while TTL of the packet is set to 2 or 3 in order to reduce the scope of local repairs. Therefore, all relay nodes on the active route have to maintain the address of the next 2 nodes by appending the address of its previous hop to the forwarded RREQ and RREP packets in order to inform its next hop. In, the number of RREQ packets can be reduced by applying the Multipoint Relay (MPR) algorithm to avoid redundant broadcasts.

[3].Location-based routing models limit the number of flooding nodes by using location information. A special device such as Global Positioning System (GPS) receiver is required in every node to determine location information and velocity. In IBR-AODV, an overhearing technique is used to passively learn a route without creating additional overhead. In DSR over AODV (DOA), some selected intermediate nodes, called waypoint nodes, divide a route between a source and a destination into segments. DOA uses Dynamic Source Routing (DSR) for inter segment routing and uses AODV for intra segment routing. When the route breaks, the upstream node of the broken hop performs a small scope local repair to the waypoint node of the next segment (or the next two segments) instead of to the destination.

Node Caching (NC) allows only nodes which have recently forwarded any data packets to rebroadcast a RREQ packet. It assumes that these nodes are located in a better location than other dead-end nodes. Encounter-Based Routing (EBR) uses the history of rates of node encounters to determine an appropriate amount of message copies the node should forward. A number of data packets are distributed by a node which has a high potential to meet other many nodes.

[4].Dynamic Route Change Algorithm (DRCA) utilizes a Hello packet to perform path shortening. The recently used route entry (destination address, hop count, and sequence number) is attached to the Hello packet. When a relay node receives the Hello packet, if the attached destination sequence number is higher and the attached hop count is smaller than that of its routing table, the node changes its next hop to the Hello packet originator and updates the corresponding route entry with the new hop count and sequence number. DRCA can reduce path length, which reduces the number of forwarding packets and can be applied to repair a broken link.

[5].First, normal route discovery is performed. Then, an intermediate node recognizes whether it acts as a relay for any connection from the RREP packet. When the route is broken, the next route discovery's RREQ packets will each contain a counter, which is initially set to zero. When a node rebroadcasts the packet, the counter is incremented if the node is not a relay of the broken path. This is done by checking the source IP address in the IP header and the destination IP address in the AODV header of the received RREQ packet. Otherwise, the counter remains untouched (Path locality) or is reset to zero (Node locality). The number of hops of the recently broken path is used to steer RREQ packets toward a destination, preventing RREQ packets from being rebroadcasted back to a source. This results in lower routing overhead from a reduced number of RREQ packets.

[6].In Query Localization Optimization (QL-O), only the 1-hop neighbors of the recently broken route rebroadcast the RREQ packet. Figure 1 demonstrates the active route from source S to destination D (black node). Arrows illustrate nodes which have a route to destination D while dotted lines represent links between two nodes which are in the transmission range of each other. Each node in the active route (black nodes) broadcasts the routing information of destination D to its 1-hop neighbors (white nodes) periodically. As a result, the neighbors have a route to destination D. The next hop address is set to the node which originates the routing information. When source S starts route discovery, only the 1-hop neighbors which have recently had a route to the destination (white node: U, V, W, X, Y, and Z) rebroadcast the RREQ packet. In addition, each 1-hop neighbor can use the hop count information to decide if it is located nearer to or farther from the destination than the originator of the RREQ packet.

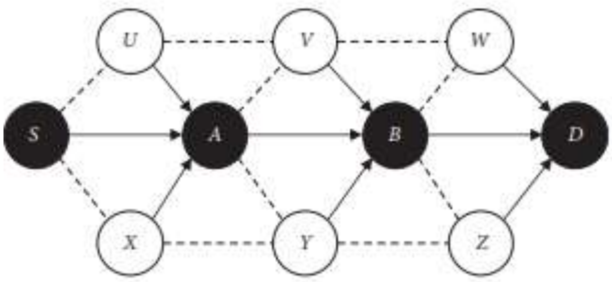

Fig 1 Route Construction of Query Localization Optimization

QL and QL-O mechanisms have a high potential for further enhancements in our proposed work. They can be used as an extension for existing on-demand routing protocols (i.e., AODV and DSR without requiring any complicated computation, promiscuous mode, and sensing devices for routing operation.

[7].Figure 2 shows the operations of LOLF when network topology changes. First, the link between nodes is detected from the link-layer acknowledgment and the hello packet mechanism. When route breakage is detected, the upstream node of the broken link chooses to repair the route locally or inform a source node. Then, the selected route establishment method is performed. Finally, the source node and new relay nodes will update their routing tables according to a RREP packet sent directly from the destination or from some nodes which has a fresher route to the destination. These operations are almost similar to AODV, except the route establishment mechanism including the route discovery at a source node and the local repair process at an intermediate node.

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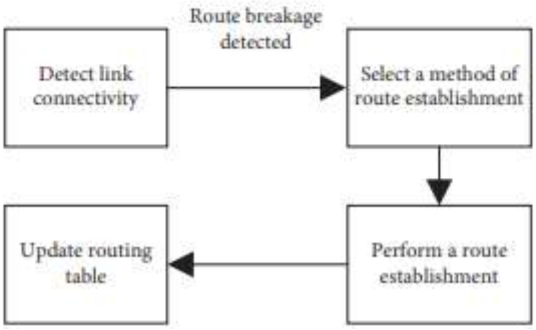

Fig 2 Operations of LOLF when network topology changes

[8].Figure 3 shows the overall operations when each packet arrives each node. The node decides which actions it should take for each received RREQ packets. The decision depends on information which is collected from previously received packets to determine if the node is located inside or outside the request zone. This method has a drawback in computational and space complexity. Each node has to process all incoming packet and record some information in the node's memory. However, this method is worthwhile to eliminate unnecessary RREQ packets. In the beginning, a source performs global flooding by broadcasting a RREQ packet to a destination in a similar way to AODV.

During this time, all relay nodes (including the source and the destination) start maintaining local connectivity by broadcasting Hello packets with TTL set to one. In order to maintain the request zone of the currently active route, each Hello packet is also aggregated with the list of only the destination addresses which have a valid_active state in the routing table (Figure 6). Other nodes which only have route entries created from a RREQ or Hello packet (valid state) are not being used for forwarding data packets.

[9].For each destination address, if the node does not have a usable route entry of the corresponding destination (either in the valid or valid_active state), this means that the node is located within the request zone of some active route to the destination. The node then sets the state of the corresponding route entry to in_zone and sets the initial lifetime of the state. If the route entry is already in in_zone state, only the lifetime is extended. When the lifetime expires, the state of the route entry is set to invalid to indicate that the node is no longer located within the request zone.

When the route breaks, the upstream node of the broken link chooses to perform local repair or inform the source node which depends on user configuration. The AODV specification defines that the intermediate node can perform local repair only if it is located no farther than max_repair_ttl hops away from the destination which is a static variable. However, this may not suitable in MANETs.

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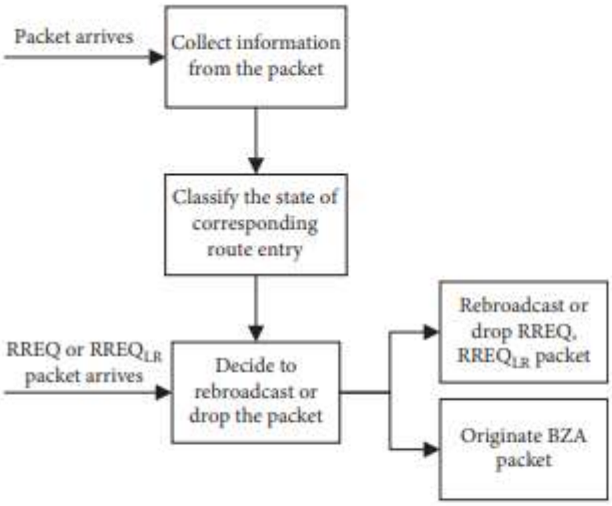

Fig 3 Overall operations of LOLF when packet arrives

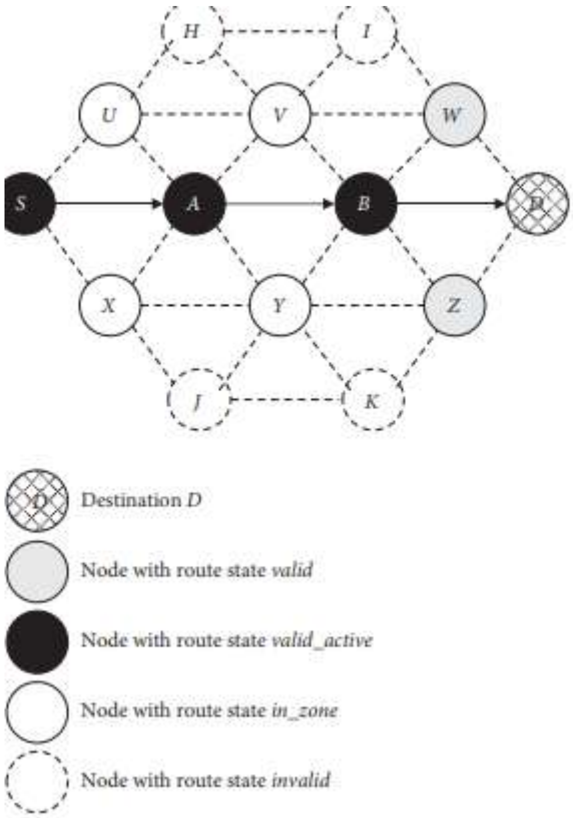

Fig 4 Expected request zone for RREQ originating from S to destination D

Destination	Next hop	Hop count	Seq. no.	Exp. time	State
D	*B*	2	2	10 s	valid_active

Figure 5: Routing table of node A created from the reception of RREP from destination D via node B.

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Destination	Next hop	Hop count	Seq. no.	Exp. time	State
D	—	—	—	4.5s	in_zone

Figure 6: Routing table of node U created from the reception of Hello from node A.

If none of the conditions is satisfied, it means that the node is not located within the request zone. In this case, it simply drops the RREQ packet. When the RREQ packet arrives at the destination, an RREP packet is sent back to the source. In addition, we simply employ Node Locality of Query Localization to expand the search area. Each RREQ packet contains a counter and a threshold, k. The counter is reset to zero if the RREQ packet is rebroadcast by a node in the request zone. Otherwise, the counter is incremented by one and the RREQ packet is dropped if the counter exceeds the threshold (k). In the first route discovery, the threshold is initially set to zero so that no RREQ packet leaves the request zone.

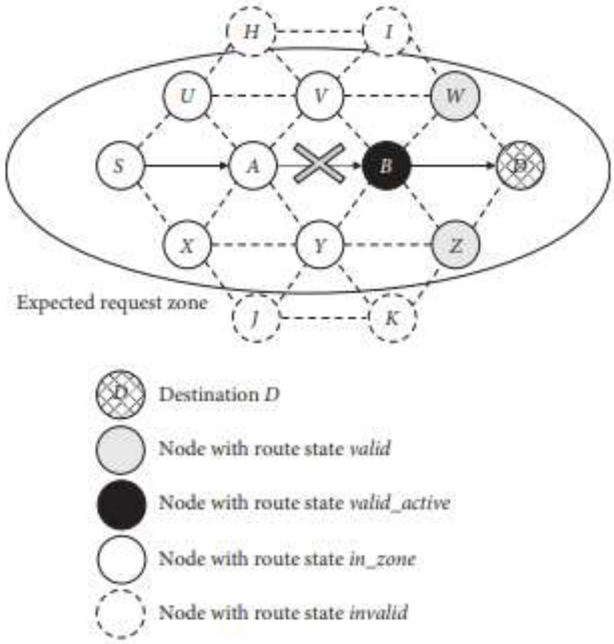

Figure 7: Expected request zone for RREQ originating from S to destination D.

Route Repair

[1].When the relay node attempts to perform local repair, the number of forwarding nodes should be kept minimum as much as possible. Assuming that route beyond node B is disconnected, the RREQ packets originating from node B should only be propagated in the local neighborhood of all downstream nodes of the broken link. The nodes located around the upstream nodes of the broken link should be pruned from the request zone.

[2].First, node B increases the sequence number of the destination and broadcasts an RREQ packet with a special local repair flag (denoted by RREQLR). When its one-hop surrounding nodes (i.e., nodes A, V, W, Y, and Z) receive the packet, they do not rebroadcast the packet immediately. Instead, each of them checks whether or not it is a predecessor node of the originator of the RREQLR packet.

[3].The BZA packet contains the address of the RREQLR originator, the address of the destination, and the ID of the dropped RREQLR packet. The purpose of the BZA packet is to have all nodes in the local neighborhood of the route to

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the source discard all RREQLR packets originating from the upstream node of the broken link (node B).

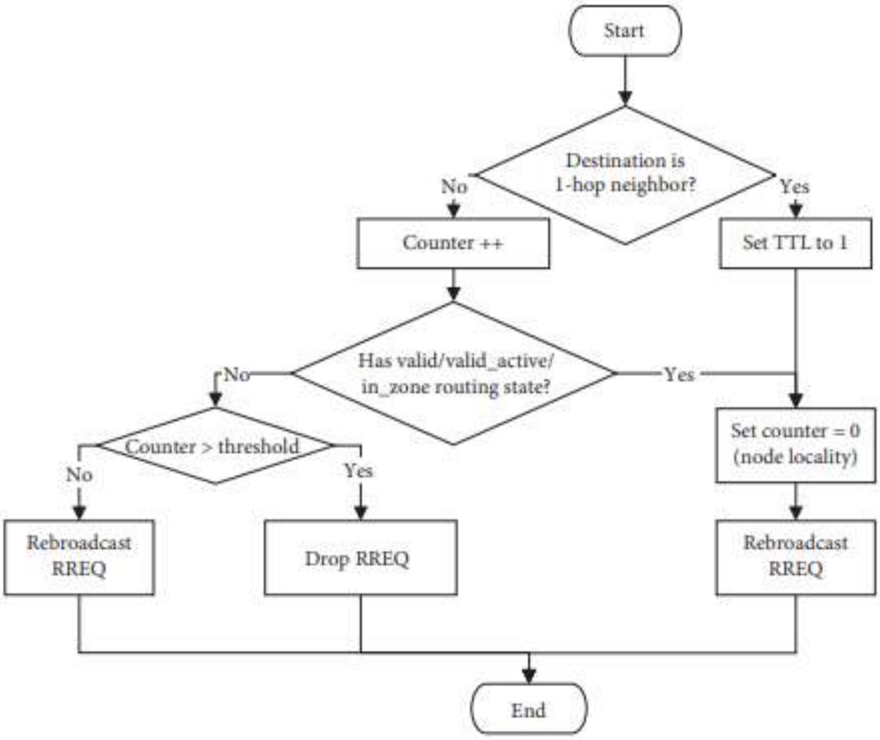

Fig 8 Flow chart of RREQ packet processing at the intermediate node.

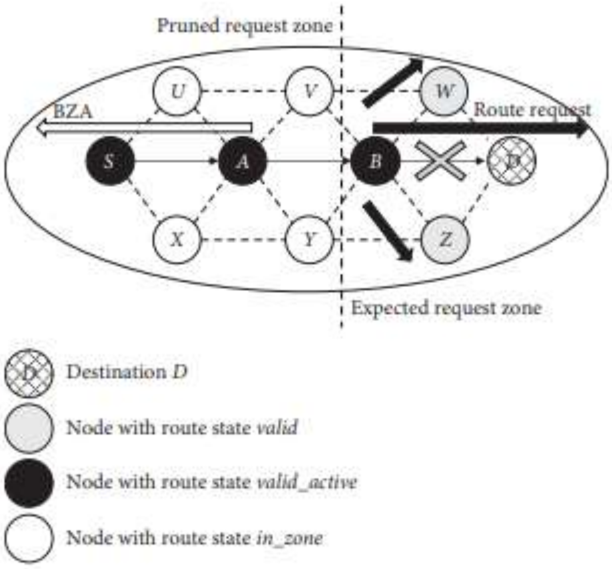

Fig 9 Expected request zone for RREQ packets originating from node B.

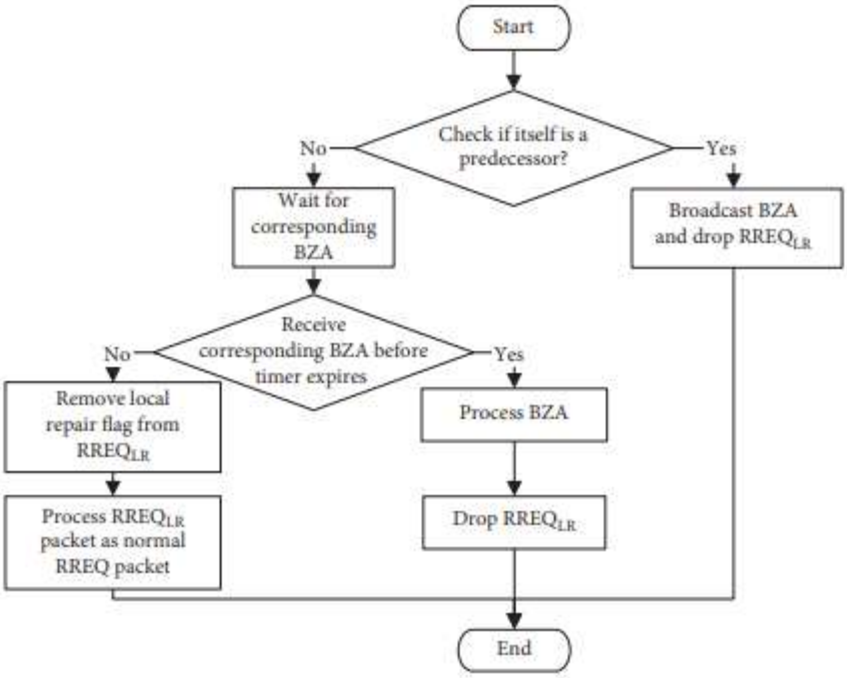

Fig 10 Flow chart of the RREQLR packet processing at the intermediate node

[4].In addition, an RREQ packet is also generated when the relay node performs local repair. Assume that node B, which is located l hops away from the destination, begins local repair. The intermediate node performs a normal flooding of RREQ packet during local repair in QL. -is results in a large number of the RREQ packets generated in the same level as AODV. In QL-O, the number of broadcast nodes includes all 1-hop neighboring nodes located in the transmission radius of the downstream node of the broken link (gray area).

[5].Our proposed method will reduce the number of RREQ packets incurred from route discovery and route repair to the same level as QL-O. The number of RREP and RERR packets is not significantly different in each protocol as these packets are sent by unicast (RREP packet) or directional broadcast (RERR packet) method while most routing overhead is overwhelmed by the flooding of RREQ packets.
Since QL-O periodically distributes the full routing information of its every active route to the destination (including the destination address, the destination sequence number, the number of hops to the destination, and the lifetime of the information), the size of Hello packet is increased by 104 bits per destination entry.

III. PERFORMANCE EVALUATION

Each node has an omni directional antenna which provides 250 meters transmission range and bidirectional communication. The Distributed Coordination Function (DCF) is used as the MAC layer with 2 Mbps radio bandwidth. The mobility model is Random Waypoint and the node's speed is uniformly selected from (1, 5) m/s. The pause time is set to zero so that a node moves continuously during the simulation. The simulation time is set to 600 seconds. The warm-up is performed for 300 seconds, and then sources start to send data packets for 300 seconds. The results were averaged from 20 trials with different mobility scenarios.

Normalized routing overhead

The ratio of the total size of transmitted routing packets (i.e. RREQ, RREQLR, RREP, RERR, Hello, and BZA packet) to the total size of delivered data packets. We represent the routing overhead in terms of size instead of the number of packets since each routing packet of different protocols carries additional data which increases the size of the packet.

Energy consumption

The average amount of energy consumed per node per delivered data packet after the simulations are finished.

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Packet delivery ratio
The ratio of the number of delivered data packets to the number of sent data packets.

End-to-end delay
The average amount of time to deliver data packets from source to destination.

Route establishment time
The average amount of time that nodes used to discover a valid route to destination.

There are two objectives in this simulation evaluation. In the first evaluation, we varied the number of nodes to show the performance of each protocol in different network densities. The number of nodes is varied from 100, 150, 200 to 400 nodes, and there are 15 sources sending four 512 bytes Constant Bit Rate (CBR) packets per second. In the second evaluation, we varied the number of CBR connections to evaluate each protocol in different congestion levels. -e number of connections is varied from 10, 12, 14 to 20 in the scenario that consists of 250 nodes in total. Each source also generates four 512 bytes CBR packets per second.

TABLE 1 SIMULATION PARAMETERS

Parameter	Value
Simulator	Network simulator 2
Simulation area	$1000 \times 1000\ m^2$
Simulation time	600 seconds
Transmission range	250 meters
Transmission rate	2 mbps
Mobility model	Random waypoint
Node's movement speed	Uniformly (1, 5) m/s
Pause time	0 second
Connection type	UDP/CBR
Data sending rate	4 packets/second
Data packet size	512 bytes
Number of simulation trials	20

]Performance with Varied Network Density

Due to the Omni directional flooding behavior, it is not surprising that AODV incurs high routing overhead in most network densities. All optimized schemes, QL, QL-O, and LOLF, generate less routing overhead than AODV. QLO is expected to achieve lower routing overhead because of the limited broadcast area of the RREQ packets. However, QL-O suffers from the large size of the Hello packet since it needs to add the routing information of the destinations. Our optimization to the broadcasting of RREQ and Hello packets can significantly reduce routing overhead in LOLF. The number of RREQ packets is significantly eliminated while only a small amount of overhead from the list of destinations in the Hello packet is added.

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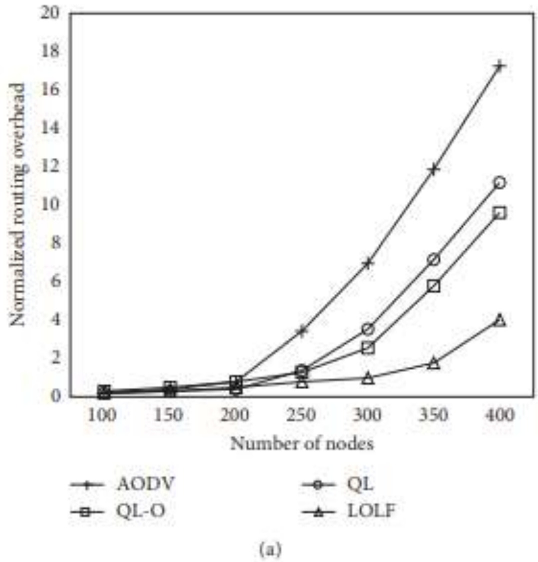

Fig 11 (a) Normalized routing overhead with different number of nodes.

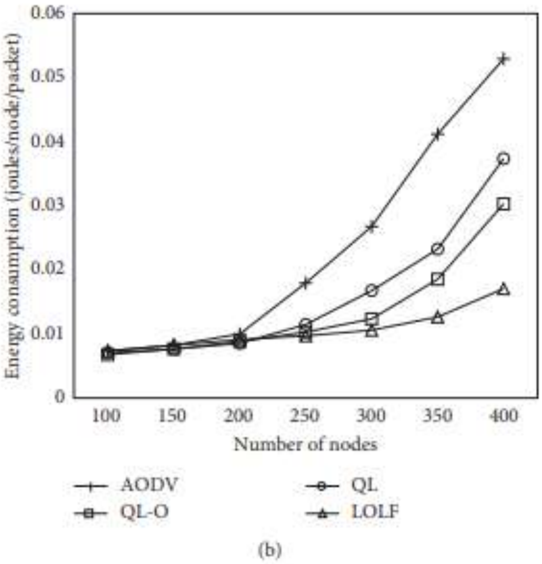

Fig 12 Energy consumption with different number of nodes

The average energy consumption per node per delivered data packet with a varied number of nodes. As the network size grows, the average energy consumption of all nodes increases. The energy consumption is the consequence of the radio transmission.

In LOLF, our protocol maintains lower average energy consumption than others which is the result of lower routing overhead. The amount of energy consumption of LOLF in the network with 400 nodes is 43.5% lower than QL-O.

Performance with Varied Number of Connections

The packet delivery ratio with various number of connections. As the traffic load increases, more data packets are lost due to network congestion. Both QL-O and LOLF have a higher packet delivery ratio since they have similar low routing overhead as previously exhibited.

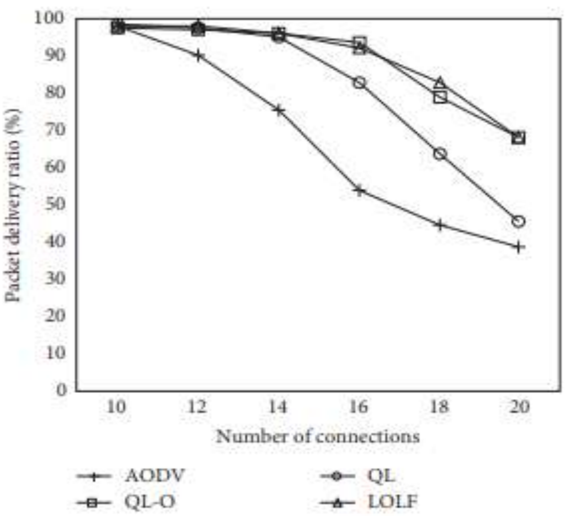

Fig 13 Packet delivery ratio with varied number of connections.

IV. CONCLUSIONS

MANET is an interesting opportunistic networking technology which can be applied for facilitating an extension for the Internet as well as backup communication system. In MANETs, routing overhead is a critical problem for practical implementation in real-world environment. -is paper proposes LOLF, a low overhead localized flooding protocol based on Query Localization (QL) and Query Localization Optimization (QL-O) to reduce routing overhead of AODV routing protocol. LOLF only adds a small amount of information to the Hello packet of AODV to prepare a local flooding area for each active route. We also present a technique to prevent reverse broadcast when performing local repair without having to maintain the hop count information for all nodes in the local flooding area. Simulation results show that our approach can reduce routing overhead significantly compared to other previous schemes and scales well in a large network.

LOLF achieves the out performance at the expense of a longer route establishment time since it minimizes message exchange and does not employ the route-caching mechanism via Hello packet. Consequently, its route establishment time is observed to be longer than that of QL-O but not significantly different from those of QL and AODV.

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