

Optimization in Route Discovery Delay for Integrated MANET with Internet using Extended AODV

Shalini Singh

Department of Electronics and Communication
Engineering
Graphic Era University, Dehradun, India

Rajeev Tripathi

Department of Electronics and Communication
Engineering, Motilal Nehru National
Institute of Technology Allahabad, India

ABSTRACT

The integration of the internet and ad hoc mobile host can be used to eliminate dead zones in the wireless network, and can also be used to extend the coverage of wireless networks. This paper utilizes extended Ad hoc On Demand Distance Vector (AODV) for interconnection of MANET with Internet. An approach is presented to reduce the search cost; such as route discovery delay (RDD) and routing overhead (RO) based on modification in TTL value for network wide search. Moreover, this paper not only simulates and compares the existing and proposed approach for optimization in search cost but also derive search strategies (i.e sequence of TTL values). We used a dynamic programming formulation with which optimal search strategies can be derived that minimizes the expected search cost associated with packet transmissions. Thus, the mathematical formulation justified the simulation results.

General Terms

MANET routing protocols, Expanding ring search, Network wide search.

Keywords

MANET, AODV, Extended AODV, Search strategy, Integrated network.

1. INTRODUCTION

An ad hoc network is generally viewed as stand - alone network, where communication is generally supported between mobile nodes in the network. The lack of connectivity to the wired infrastructure enables simple management and deployment, but limits the applicability of ad hoc networks to scenarios that require connectivity outside the ad hoc network [18]. It is also highly likely that a user of the network will have the need to connect to the Internet. To achieve this network interconnection, it is necessary to introduce an Internet Gateway that provides the link to external hosts. Thus, a gateway acts as a bridge between a MANET and the Internet and all communication between the two networks must pass through gateway.

This paper considers the problem of searching for a destination node by a source node in the route establishment procedures of an integrated wired cum wireless MANET networks [16, 18]. Many emerging networks and their applications are required to conduct cost effective and fast searches. A good search mechanism should have a short response time, i.e. the time it takes to find the destination, and should do so with minimal cost.

The Internet Engineering Task Force (IETF) has proposed several routing protocols for MANETs, such as Ad hoc On-Demand Distance Vector (AODV) [1], Dynamic Source

Routing (DSR) [2], Optimized Link State Routing Protocol (OLSR) [3]. However, these protocols were designed for communication within an autonomous MANET. The ad hoc routing protocol AODV [1] is one of the promising routing protocols and can be used to route packets between mobile nodes. However, it cannot provide Internet access to the mobile nodes because it does not support routing between a fixed network like the Internet and a mobile ad hoc network [12]. In the Internet draft "Global Connectivity for IPv6 Mobile Ad Hoc Networks" [9] a solution is presented where the AODV protocol is modified in such a way that it can route packets not only within a mobile ad hoc network, but also to a fixed, wired network. The extended AODV [10] implementation in NS2 [4] in accordance with the Internet draft "Global connectivity for IPv6 Mobile Ad Hoc Networks" [9] is used for simulation in this paper. With extended AODV, author utilized the network wide search and compares the performance with expanding ring search [17] for integrated MANET with fixed internet. For different simulation scenario, it is found that the use of network wide search provides the optimization in route discovery delay (RDD) time and routing overhead.

The remainder of this paper is organized as follows: Section 2 gives an overview of AODV and Extended AODV. Section 3 is about gateway discovery strategy. Section 4 gives the protocol stack for Internetworking. Section 5 provides metrics for analysis. In Section 6 provides the dynamic programming formulation and derivation of optimal search strategies [15]. Section 7 describes the simulation scenarios. In Section 8, results are presented and discussed. Section 9 finally, concludes this paper.

2. PROTOCOL DESCRIPTION

This section provides an overview of AODV, and also presents a solution, which is referred to as Extended AODV [5], where AODV is extended to provide Internet access for mobiles node in a MANET.

2.1 AODV

Ad Hoc On- Demand Distance Vector (AODV) [6] combines the features of Destination Sequenced Distance Vector (DSDV) and Dynamic Source Routing (DSR) protocols [2] However, AODV maintains route in a distribution fashion, as routing table entries. The AODV keeps routing table entries in the form of <destination, next hop, distance>. AODV incorporates timer – based routing table entries for destination in each node [7].

In AODV routing, when a source has data to transmit to a new destination, it broadcast a route request (RREQ) for that destination to its neighbors. RREQ packet contains the address of destination node, sequence number of destination

node, broadcasting sequence number, sequence number of source node, address of previous hop count. When an intermediate node receives RREQ information, and if it has a route to the destination in its routing table, then it would forward route reply (RREP) packet by the reverse routing. RREP containing address of source node, address of destination node, hop count and life time. The RREP is unicasted in hop – by – hop fashion to the source [8]. When the source receives the RREP, it record route to the destination and begins sending data. If multiple route replies are received by the source, the route with the shortest hop count and highest destination number is chosen. Highest the destination number means most latest the information about the destination route.

If the source does not receive any RREP before the RREQ timer expires, it broadcasts a new RREQ with an increased time to live (TTL) value. This technique is called expanding ring search [17] and continues until either a RREP is received or a RREQ with the maximum TTL value is broadcasted. Broadcasting a RREQ with the maximum TTL value is referred to as a network-wide search since the RREQ is disseminated throughout the MANET. If a source performs a network-wide search without receiving any corresponding RREP, it may try again to find a route to the destination, up to a maximum of RREQ_RETRIES times after which the session is aborted.

In case link break is detected the node at the upstream of route broken would broadcast RERR, which contains the address and sequence number of unreachable nodes to the neighbor nodes. As the route error propagates towards the source, each intermediate node invalidates route to unreachable destinations. When the source node receives the RERR, it invalidates the route and reinitiate route discovery.

2.2 Extended AODV

When a destination is a fixed wired node and a mobile node wish to communicate with it; firstly mobile node searches its routing table for route towards destination. If a route is found, the mobile node starts sending packets. Otherwise, the mobile node needs to begin route discovery process by broadcasting RREQ message as described in conventional AODV routing protocol.

When a RREQ message is received by an intermediate mobile node, an intermediate mobile node searches its routing table for a route towards the wired destination. If a route is found, the intermediate node would normally send a RREP back to the originator of the RREQ. But in that case, the source would think that the destination is a mobile node that can be reached via the intermediate node. It is important that the source knows that the destination is a fixed node and not a mobile node, because these are sometimes processed differently. But in extended AODV, this problem has been solved by preventing the intermediate node to send a RREP back to the originator of the RREQ if the destination is a wired node. Instead, the intermediate node updates its routing table and rebroadcasts the received RREQ message. To determine whether the destination is a wired node or not, an intermediate node consults its routing table. If the next hop address of the destination is a default route (see Table 1), the destination is a wired node. Otherwise, the destination is a mobile node or a gateway. Since neither the fixed node nor the mobile nodes in the MANET can reply to the RREQ, it is rebroadcasted until its TTL value reaches zero. When the timer of the RREQ expires, a new RREQ message is broadcasted with a larger

TTL value. However, since the fixed node cannot receive the RREQ message (no matter how large the TTL value is) the source will never receive the RREP message it is waiting for. This problem has been solved by letting the source assume the destination is a fixed node if a network wide search has been done without receiving any corresponding RREP. In that case, the source must find a route to a gateway (if it does not have one already) and send its data packets towards the gateway, which will forward them towards the fixed node [10].

It should be mentioned that when using the expanding ring search, a considerable route discovery delay (RDD) will occur if the destination is a fixed node. Modifying the parameters involved in the expanding ring search technique (such as TTL_START and TTL_THRESHOLD) can decrease the route discovery delay if the destination is a fixed node.

Gateway Operation: When a gateway receives a RREQ, it consults its routing table for the destination IP address specified in the RREQ message. If the address is not found, the gateway sends a RREP with an 'I' flag (RREP_I) back to the originator of the RREQ. On the other hand, if the gateway finds the destination in its routing table, it unicasts a RREP as normal, but may also optionally send a RREP_I back to the originator of the RREQ. This will provide the mobile node a default route although it has not requested it. If the mobile node is to communicate with the Internet later, the default route is already established, and another time consuming gateway discovery process can be avoided.

Routing Table Management: Another issue that must be taken into consideration is how the routing table should be updated after a network-wide search without receiving any corresponding RREP. Once the source has determined that the destination is a fixed node located on the Internet, it has to create a route entry for the fixed node in its routing table. The first entry of Table 1 tells the node that the destination is a fixed node since the next hop is specified by the default route. The second entry specifies which gateway the node has chosen for its Internet connection. The last entry gives information about the next hop towards the gateway. Table 1 shows the routing table of a mobile node after creating a route entry for a fixed node.

Table 1: The routing table of mobile node

| Destination Address | Next Hop Address |
|---------------------|------------------|
| Fixed node | Default |
| Default | Gateway |
| Gateway | IMN |

3. GATEWAY DISCOVERY

In order to evaluate the performance of extended AODV, another requirement is that how to set up configuration phase with gateways. This paper utilizes the configuration phase with the gateway is initiated by the mobile node (reactive method). The description of this mechanism is as follows:

3.1 Reactive Gateway Discovery

A mobile node initiates the reactive gateway discovery [19] to create or update a route to a gateway [11]. The mobile node broadcasts a RREQ with an 'I' flag (RREQ_I) to the ALL_MANET_GW_MULTICAST [5] address, i.e. the IP address for the group of all gateways in a MANET. Thus,

only the gateways are addressed by this message and only they process it. Intermediate mobile nodes that receive a RREQ_I are not allowed to answer it, so they just rebroadcast it. When a gateway receives a RREQ_I, it unicasts back a RREP_I which, among other things, contains the IP address of the gateway. The advantage of this approach is that control messages are generated only when a mobile node needs information about reachable gateways.

4. INTERNETWORKING

Whenever a mobile node is to send packets to a fixed network, it must transmit the packets to a gateway [9]. The protocol stacks involved during communication between a mobile ad hoc network and the fixed Internet node are shown in Figure 1. A gateway acts as a bridge between a MANET and the Internet. Therefore, it has to implement both the MANET protocol stack and the TCP/IP suite, as shown in the middle of Figure 1. Although the Figure 1 shows that all the layers are implemented for the gateway, it does not necessarily need all of the layers.

| Mobile Node | Gateway | | Internet Node |
|-------------|-------------|-------------|---------------|
| Application | Application | Application | Application |
| UDP | UDP | UDP | UDP |
| IP AODV | IP AODV | IP | IP |
| 802.11 MAC | 802.11 MAC | DATA LINK | DATA LINK |
| 802.11 PHY | 802.11 PHY | 802.11 PHY | 802.11 PHY |

Fig 1: Protocol Stack of nodes

5. PERFORMANCE METRICS

The following metrics for Integrated MANET are used for performance evaluation:

The *route discovery delay* (RDD) is defined as the time required receiving the first data packet by the destination.

The *routing overhead* (RO) is defined as the total number of routing packets transmitted during simulation. For packets sent over multiple hops, each transmission of packet (each hop) count as one transmission.

6. MATHEMATICAL FORMULATION FOR SEARCH STRATEGY

The objective is to derive and use the TTL-based controlled flooding of search strategies [14] that will minimize the cost of such searches, with the intention that they can be applied to wired and wireless networks.

For that, L denotes the minimum TTL value required to search every node within the network, and will also refer to L as the dimension or size of the network. Since we have assumed that the object exists, using a TTL value of L will locate the destination with probability 1.

The minimum TTL value required to locate the destination is denoted by X and also loosely refer to as the destination location. Note that X is an integer-valued random variable taking values between 1 and L such that $P_r(X \in \{1, 2, \dots, L-1, L\}) = 1$. We denote the cumulative distribution of X by $F(k)$. By definition $F(k) = P_r(X \leq k)$.

Similarly, the tail distribution of X is denoted by $\bar{F}(k)$, so that $\bar{F}(k) = 1 - F(k) = P_r(X > k)$. Note that $F(L) = 1$ and $\bar{F}(L) = 0$ for any X . For a given search strategy, u_i denote the TTL value used during the i -th round, and let $\mathbf{u} = [u_1, u_2, \dots, u_N]$ be a vector denoting the increasing sequence of N TTL (integer) values. The N -tuple \mathbf{u} represents a specific search strategy. For any sensible strategy must have $u_i < u_{i+1}$, for all $1 \leq i \leq N-1$. Note that in a specific search experiment, it is not necessary to use the entire sequence. However, in order to guarantee that the strategy \mathbf{u} will locate the destination with probability 1, it must be true that $u_N = L$. Also note that the value of N can vary between different policies.

A round of search with TTL value k with a search cost C_k . The goal is to find search strategies that will minimize the expected search cost, for a priori known distribution of nodes. This will refer to as the average cost measure or performance objective, and the corresponding strategies optimal average cost strategies.

6.1 Optimal Average Cost Strategies

This section used dynamic programming formulation, with which optimal strategies may be obtained. Consider destination location X with a tail distribution $\bar{F}(k)$, where $1 \leq k \leq L$, and a search strategy with TTL values $\mathbf{u} = [u_1, u_2, \dots, u_N]$. The total expected search cost using strategy \mathbf{u} is given by

$$J_X^{\mathbf{u}} = \sum_{i=1}^{N_u} C_{u_i} P_r(X > u_{i-1}) = \sum_{i=1}^{N_u} C_{u_i} \bar{F}(u_{i-1}) \quad (1)$$

where N_u is number of elements in the vector \mathbf{u} , C_{u_i} is the cost of searching with TTL value u_i and $u_0 = 0$. The search policy that minimizes this cost, denoted by \mathbf{u}^* , is thus

$$\mathbf{u}^* = \underset{\mathbf{u} \in U}{\operatorname{argmin}} J_X^{\mathbf{u}} = \underset{\mathbf{u} \in U}{\operatorname{argmin}} \sum_{i=1}^{N_u} C_{u_i} \bar{F}(u_{i-1}) \quad (2)$$

where U denotes the set of all admissible search strategies (TTL sequences), i.e., all vectors \mathbf{u} such that $u_i < u_{i+1}$ for all $1 \leq i \leq N-1$ and $u_N = L$. This minimization can be solved backward in time using standard dynamic programming techniques [13]. Specifically, the most recently used TTL value, denoted by n , as the information state. For convenience, $\bar{F}(j|n)$ denotes the conditional tail distribution of the destination given that the most recently used TTL value n did not locate the destination, i.e.,

$$\begin{aligned} \bar{F}(j|n) &= P_r(X > j | X > n) \\ &= \begin{cases} 1 & 1 \leq j \leq n \\ \bar{F}(j) / \bar{F}(n) & n+1 \leq j \leq L \end{cases} \end{aligned}$$

The following dynamic programming equations can be solved recursively for $1 \leq n \leq L-1$:

$$\begin{aligned} V(L) &= 0 \\ V(n) &= \min_{n+1 \leq l \leq L} \{C_l + \bar{F}(l|n)V(l)\} \end{aligned}$$

where the value function $V(n)$ is the minimum expected cost-to-go (over all choices of TTL values), given that the most recently used TTL value n did not locate the destination.

The initial condition $V(0)$ reflects the fact that using a TTL value of L ensures finding the destination and thus there would be no more remaining cost. Equation for $V(n)$, follows from the fact that after unsuccessfully searching with a TTL value of n , the remaining choices for TTL values are the integers from $n+1$ to L . Any such choice l incurs an

immediate search cost C_l plus an expected future cost if the destination is not located using l . Note that because $\bar{F}(j|n) = 0$ for any value of n , $V(L-1) = C_L$ for any search strategy. This agrees with the fact that if searching with a TTL value of $L-1$ is unsuccessful, then the only remaining option is to search with a TTL value of L .

Solving this set of equations backward, $V(n)$ will obtain for all n and determine the optimal TTL sequence \mathbf{u}^* . Finally $V(0)$ is the optimal (minimum) total expected search cost $\min_{u \in U} J_X^u$.

As an example, consider the special case where X is uniformly (discrete) distributed between 1 and L on a linear network. Therefore, $\bar{F}(l) = \frac{L-1}{L}$ for $1 \leq l \leq L-1$, and $\bar{F}(l|n) = \frac{L-1}{L-n}$ for $n \leq l \leq L-1$. Further assume that the search cost is linear, i.e., $C_k = \alpha k$ for TTL value k and some constant α . We can then calculate $V(L-2)$ as follows (noting $L \geq 2$):

$$\begin{aligned} V(L-2) &= \min_{1 \leq l \leq L} \{C_l + \bar{F}(l|L-2)V(l)\} \\ &= \min \left\{ C_{L-1} + \frac{C_L}{2}, C_L \right\} \\ &= C_L \cdot \min \left\{ \frac{L-1}{L} + \frac{1}{2}, 1 \right\} = C_L \end{aligned}$$

Repeating the above calculation, we can easily show that $V(n) = C_L$ for $n \leq l \leq L-1$, meaning that if using a TTL value of n fails to locate the destination, then it is optimal to next use a TTL value of L . Consequently the minimum total expected cost is

$$\begin{aligned} V(0) &= \min_{1 \leq l \leq L} \{C_l + \bar{F}(l)V(l)\} \\ &= \min_{1 \leq l \leq L} \left\{ C_l + \frac{L-1}{L} C_L \right\} \\ &= C_L \min_{1 \leq l \leq L} \left\{ \frac{l}{L} + \frac{L-1}{L}, 1 \right\} = C_L \end{aligned}$$

Therefore, the optimal search cost when X is uniformly distributed with linear search cost is C_L . The minimum can be obtained by either using an initial TTL value of L so that $\mathbf{u} = [L]$.

7. PERFORMANCE EVALUATION

The network simulator ns-2 (ns – 2.33) has been used for performance evaluation of extended AODV in Integrated MANET with fixed internet.

7.1 Simulation Scenario

The simulation scenario consists of two MANET domains and one wired domain. Each MANET domain consists of one gateway node and five mobile nodes. The wired domain consists of two fixed node. The topology is rectangular area with 2000 m length and 1000 m width. The pictorial representation of the topology is shown in Figure 2.

Simulation parameters are given in Table 2. The gateway node $GW(0)$ of MANET domain 1 is placed side of the area; its x, y coordinates in meters is (200, 1000). The mobile nodes of MANET domain 1, $MN_1(1)$, $MN_1(2)$, $MN_1(3)$ and $MN_1(4)$ are placed at a distance of 200; their x, y coordinates in meters are (200, 200), (200, 400), (200, 600) and (200, 800) respectively. The gateway node $GW(1)$ of MANET domain 2 is placed at x, y coordinates (200, 1000). The mobile nodes of MANET domain 2, $MN_2(0)$, $MN_2(1)$, $MN_2(2)$, $MN_2(3)$ and $MN_2(4)$ are placed at a distance of 200; their x, y coordinates in meters are (600,1), (600, 200), (600, 400), (600, 600) and (600, 800) respectively

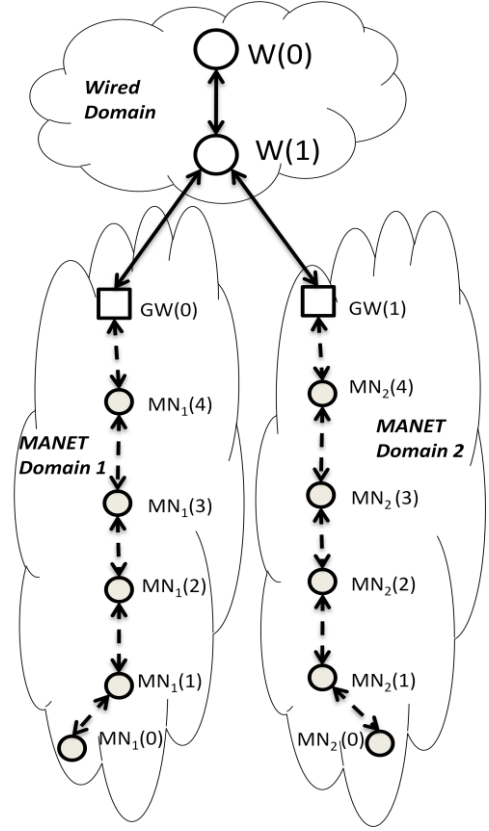


Fig 2: Simulation Scenario

Consider the first simulation scenario, when the mobile node $MN_1(0)$ is placed at different positions; x, y coordinate in meters are (200,900), (200,700), (200,500), (200,300) and (200, 100). These positions of mobile node $MN_1(0)$ are taken to have direct, 1 hop, 2 hop, 3 hop, and 4 hop communication with home domain gateway node $GW(0)$.

For second simulation scenario case, consider the mobile node $MN_1(0)$ is also placed at different positions; x, y coordinate in meters are (600,900), (600,700), (600,500), (600,300) and (600, 100). These positions of mobile node $MN_1(0)$ are taken to have direct, 1 hop, 2 hop, 3 hop, and 4 hop communication with foreign domain gateway node $GW(1)$.

Basically, the scenario used in this study, the source is mobile node $MN_1(0)$ of MANET domain 1 wishes to send data packets through gateway to fixed node $W(0)$ which is located on the internet.. The traffic was chosen to be Constant Bit Rate (CBR). The simulation run time is 10 seconds only as our focus is on initial route discovery delay time. As soon as route is established, the continuous communication takes place until any route break.

The transmission range is the maximum possible distance between two communicating mobile nodes. If the distance between two mobile nodes is larger than 250 meter they cannot communicate with each other directly.

All simulation scenarios is carried out to analyze the effect of different TTL values; while keeping the network diameter and other parameters are fixed in each scenario.

Table 2: Simulation Parameters

| Parameters | Value |
|---|-------------------|
| Mobile node Transmission range | 250 m |
| Topology size | 2000 m x 1000 m |
| Domain | 1 Wired, 2 MANET |
| Number of gateways in each MANET domain | 1 |
| Mobile Nodes in each MANET domain | 5 |
| Traffic type | Constant bit rate |
| Packet size | 512 bytes |
| Packet interval | 0.25 s |

8. SIMULATION RESULTS

Figure 3 shows the plot of route discovery delay (RDD) versus number of hops of source mobile node from gateway, when source mobile node $MN_1(0)$ stayed in MANET domain 1 and wishes to send data to the fixed wired node $W(0)$.

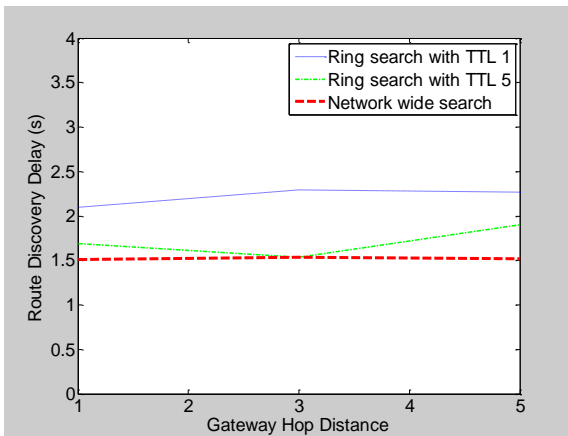


Figure 1: Route discovery delay (RDD) (source node in Home Domain)

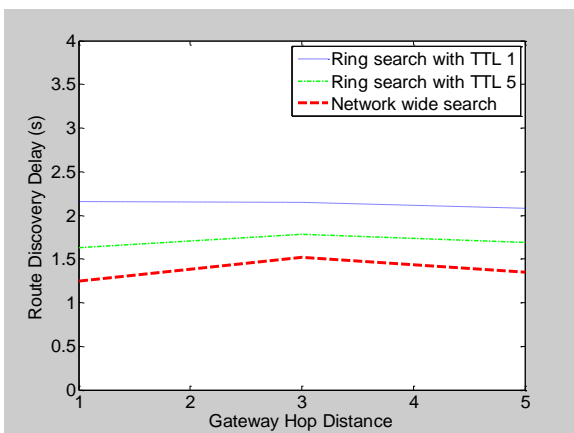


Figure 2: Route discovery delay (RDD) (source node in Foreign Domain)

It is clear that when expanding ring search is used with $TTL_START = 1, 5$; $TTL_INCREMENT = 2$ $TTL_THRESHOLD = 7$; the route discovery delay (RDD) is high. This is because; the source mobile node is needed to send multiple times RREQ across the network diameter; until the route to the destination is not found. But when network wide search used with TTL_START equal to network diameter while keeping other parameters same as previous; the route discovery delay (RDD) is less. This is because only one time the RREQ is broadcasted to entire network wide search without receiving any corresponding RREP for the destination node located in wired domain. Table 3 is for this same case, and it is clear that the route discovery delay (RDD) time is less by the use of network wide search mechanism. Figure 4 and Table 4 is based on the scenario when source mobile node $MN_1(0)$ of MANET domain1 moves from its home network to MANET domain 2 as foreign network, and wishes to send data to fixed node $W(0)$ located at internet. The amount in route discovery delay time (RDD) is almost similar to the case when source mobile node $MN_1(0)$ is in its home network. This is because of source mobile node $MN_1(0)$ uses gateway $GW(1)$ of MANET domain 2 for sending data to destination node $W(0)$ of wired domain.

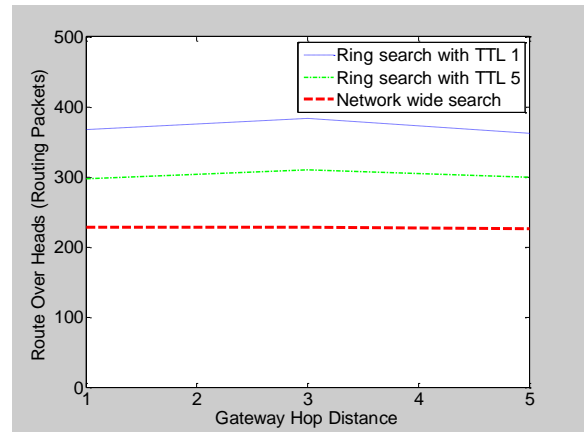


Figure 5: Routing overheads (RO) (source node in Home Domain)

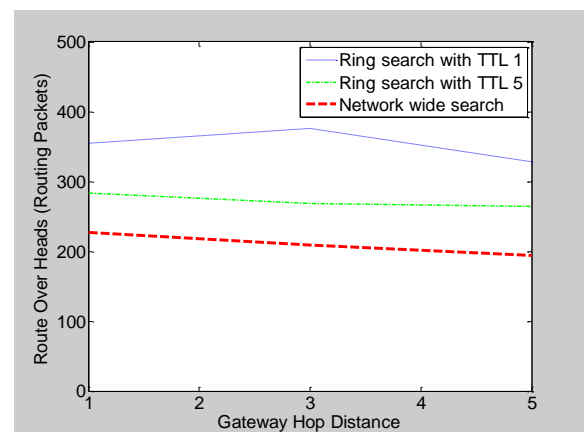


Figure 6: Routing overheads (RO) (source node in Foreign Domain)

Table 3. Route discovery delay (RDD) (source node in home domain)

| Search Type | RDD with 1 hop (Seconds) | RDD with 3 hop (Seconds) | RDD with 5 hop (Seconds) |
|-------------------------|--------------------------|--------------------------|--------------------------|
| Ring Search with TTL =1 | 2.10 | 2.29 | 2.27 |
| Ring Search with TTL =1 | 1.69 | 1.54 | 1.90 |
| Network wide search | 1.51 | 1.54 | 1.52 |

Table 4. Route discovery delay (RDD) (source node in foreign domain)

| Search Type | RDD with 1 hop (Seconds) | RDD with 3 hop (Seconds) | RDD with 5 hop (Seconds) |
|-------------------------|--------------------------|--------------------------|--------------------------|
| Ring Search with TTL =1 | 2.16 | 2.15 | 2.08 |
| Ring Search with TTL =1 | 1.63 | 1.78 | 1.69 |
| Network wide search | 1.25 | 1.52 | 1.35 |

Table 5. Routing overheads (RO) (source node in home domain)

| Search Type | RO with 1 hop (Bytes) | RO with 3 hop (Bytes) | RO with 5 hop (Bytes) |
|-------------------------|-----------------------|-----------------------|-----------------------|
| Ring Search with TTL =1 | 368 | 384 | 362 |
| Ring Search with TTL =1 | 297 | 310 | 300 |
| Network wide search | 228 | 228 | 226 |

Table 6. Routing overheads (RO) (source node in home domain)

| Search Type | RO with 1 hop (Bytes) | RO with 3 hop (Bytes) | RO with 5 hop (Bytes) |
|-------------------------|-----------------------|-----------------------|-----------------------|
| Ring Search with TTL =1 | 355 | 376 | 328 |
| Ring Search with TTL =1 | 283 | 269 | 264 |
| Network wide search | 227 | 209 | 194 |

Figure 5 and Table 5 shows that the routing overhead (RO) is reduced for network wide search compare to expanding ring search. Because of the use of network wide search, route to the fixed destination node is found by sending RREQ once; and hence, it consumes less link bandwidth. Although, with TTL_START =1, 5 which is the case of expanding ring search; requires more control packets to send for the determination of destination location. Thus the routing overhead (RO) is high in expanding ring search mechanism. Figure 6 and Table 6 shows the routing overhead (RO), when source mobile node $MN_1(0)$ move from MANET domain 1 to MANET domain 2. Again, routing overhead (RO) is reduced by the use of network wide search. Because mobile source node start sending data packets to fixed node through gateway GW(1) of MANET domain 2 and does not require any other additional routing control packets.

9. CONCLUSION

The Internet access of mobile nodes in a mobile ad hoc network is possible by the use of extended AODV ad hoc routing protocol. The simulation results prove that the proposed network wide search approach provides low route discovery delay (RDD) and routing overhead (RO) compared to the expanding ring search for integrated internet and mobile ad hoc network. By the use of dynamic programming approach, with which search strategies can be derived to minimize the search cost. The mathematical derivation for the class of TTL based search method also justifies the obtained simulation results for integrated MANET with internet. This

paper also concludes that there is no effect on the performance of extended AODV, whether the source mobile node uses the home domain gateway or foreign domain gateway to send the data packets to the wired domain.

10. REFERENCES

- [1] C. Perkins, E. M. Belding-Royer and S. Das. "Ad hoc On-Demand Distance Vector (AODV) Routing", Experimental RFC 3561
- [2] D. B. Johnson, D. A. Maltz, Y. Hu and J. G. Jetcheva. "The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR)". IETF Internet Draft, April 2003. Work in progress.
- [3] T. Clausen, P. Jacquet, A. Laouiti, P. Minet, P. Muhlethaler, A. Qayyum and L. Viennot. "Optimized Link State Routing Protocol". Experimental RFC 3626.
- [4] McCanne S.; Floyd S. ns Network Simulator. <http://www.isi.edu/nsnam/ns/>. Fall K; Varadhan K., and the VINT project. The ns manual.
- [5] Ali Hamidian, Ulf Körner and Anders Nilsson; "Performance of Internet Access Solutions in Mobile Ad Hoc Networks" Department of Communication Systems Lund University, Sweden
- [6] Mario Galgalj, "Performance Evaluation of AODV Routing Protocol; Real Life Measurement. LCA, EPFL. Alexander Zurkinden, SCC June 2003, <http://>

Icawww.epfl.ch/Publications/ Cagalj/ Zurkinden
 CH03.pdf.

- [7] WU Lijie, Qian Xuezhong, Dou Weijiang, "Routing protocols for prolonging network's lifetime based on AODV[J]". Computer Engineering and Applications, 2007, 43 (19).
- [8] Dan Yu and Hui Li, "A Model for Performance Analysis of a Mobile Ad Hoc Networks," Siemens AG, ICM N PG SP RC FR, Gustav- Heinemann – Ring 115, 81730 Munchen, Germany.
- [9] Wakikawa R.; Malinen J.; Perkins C.; Nilsson A.; Tuominen A.J. "Global Connectivity for IPv6 Mobile Ad Hoc Networks", IETF Internet Draft, November 2001. Work in progress.
- [10] A. Hamidian. "A Study of Internet Connectivity for Mobile Ad Hoc Networks in NS 2". Master's thesis. Department of Communication Systems, Lund Institute of Technology, Lund University. January 2003.
- [11] M. Bernard. "Gateway Detection and Selection for Wireless Multihop Internet Access". Master's thesis. Olching, Germany, May 2002.
- [12] H. Wu, C. Qiao, S. De and Q. Tonguz, "Integrated Cellular and Ad Hoc Relaying Systems": iCAR, IEEE Journal on Selected areas in Communications, Vol 19, No. 10, pp 2105 2115, Oct 2001
- [13] P.R. Kumar and P. Karaiya, Stochastic Systems: Estimation, Identification, and Adaptive Control, Prentice-Hall, Inc, 1986, Englewood Cliffs, NJ.
- [14] Z. Cheng and W. Heinzelman, "Flooding strategy for target discovery in wireless networks," Proceedings of the Sixth ACM International Workshop on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM 2003), Sept 2003.
- [15] N. Chang and M. Liu, "Revisiting the TTL-based controlled flooding search: Optimality and randomization," EECS Technical Report CGR 04-06, 2004, University of Michigan, Ann Arbor.
- [16] Habib M. Ammari, "A survey of current architectures for connecting wireless mobile ad hoc networks to the Internet", International Journal of Communication Systems Volume 20, Issue 8, August 2007.
- [17] D.N.Pham, V.D.Nguyen, V.T.Pham, N.T.Nguyen, X.Bacd, T.D.Nguyen, C.Kuperschmidt and T.Kaiser, "An Expanding Ring Search Algorithm for Mobile Ad-hoc Networks", IEEE International Conference on Advanced Technologies for communication, 2010.
- [18] J. J. Garcia-Luna-Aceves, Rolando Menchaca-Mendez, "PRIME: An Interest-Driven Approach to Integrated Unicast and Multicast Routing in MANETs", IEEE/ACM Transaction on Networking, VOL. 19, NO. 6, December 2011
- [19] A.J. Yuste A. Trivin~ E. Casilari F.D. Trujillo, "Adaptive gateway discovery for mobile ad hoc networks based on the characterisation of the link lifetime", IET Communication, 2011, Vol. 5, Iss. 15, pp. 2241–2249.