On Performance Analysis of AMBR Protocol in Mobile Ad Hoc Networks

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Abstract

Due to mobility of nodes in ad hoc networks, the most challenging issue is to design and to make sound analysis of a routing protocol that determines its robustness to deliver packets in low routing packet overhead. In this paper, we thoroughly analyzed the Adaptive Monitor Based Routing (AMBR) protocol by varying different parameters that affect a routing protocol to measure its performance. Analysis shows that it requires less routing control overhead comparing with other prevalent routing protocols. An improved analytical model is also presented in this paper. All these analyses firmly prove that AMBR is a sound and robust protocol in terms of flooding, routing overhead and hence, enhances reliability.

I. INTRODUCTION

An ad hoc network is a class of wireless systems that consists of independent mobile nodes communicating with each other over wireless links, without any static infrastructure such as base stations [1]. A communication session is achieved either through a single-hop radio transmission if the communication parties are close enough, or through relaying by intermediate nodes otherwise [2]. Since the nodes move randomly, the topology of the network changes with time. Dynamically changing topology and lack of centralized control make the design of an adaptive distributed routing protocol challenging [1]. Due to the limited spectrum, user’s mobility and power constraints, routing remains a challenge, particularly in wireless communication systems such as ad hoc networks. Several other challenges complicate routing, including scalability, routing efficiency, adaptation to wireless networks of various densities, and distribution [3].

In CBRP [4], problem with having explicit cluster heads is that routing through cluster heads creates traffic bottlenecks. In Landmark, LANMAR [5] and L+ [6], this is partially solved by allowing nearby nodes route packets instead of the cluster head, if they know the route to the destination. All of the above schemes have explicit cluster heads, and all addresses are therefore relative to these and are likely to have to change if a cluster head moves away [7]. DSDV [8], due to its periodic updates and flat routing tables, experiences very high overhead growth as the networks beyond 100 nodes, but nevertheless performs well in comparison with other protocols in the size ranges studied. AODV [9], due to its reactive nature, suffers from high overhead growth both as the size of the network, and the number of flows, grows. While AODV performs very well in small networks, the trend suggests that it is not recommendable for larger networks [7].

In this paper, a thorough analysis is performed on the Adaptive Monitor Based Routing (AMBR) [10] protocol to show its robustness by varying different parameters that affect most of the routing protocols. AMBR discovers and maintains routes in hierarchical and distributed fashion and locally repairs the broken link. The main motivation behind the proposed AMBR is to drastically cut down flooding, to substantially tame the routing overhead, to repair broken link locally in order to minimize the routing overhead, and to increase efficiency in packet movement in the ad hoc networks. In all analyzing cases, it is found that AMBR is a bandwidth efficient routing protocol as the routing overhead was drastically cut down.

In section II, we describe AMBR routing protocol in brief and in section III we describe, an improved analytical model. Simulation results are shown in section IV. Finally, section V concludes the paper.

II. AMBR ROUTING PROTOCOL

The original version of AMBR routing protocol is proposed in paper [10]. The AMBR protocol uses monitor which are nodes whose first hop connectivity
(total number of neighbors) acquire a predefined number over the whole network. If a node gets alive, it broadcasts “hello” message which is not periodic rather it is event driven. Any node, getting this message from another node should reply back to that node only (not a broadcast). According to this protocol if a node becomes a monitor, it will then broadcast a “new monitor” packet and all its covered nodes will accept it.

The AMBR protocol uses the following symbols:

- \( S \) = Source
- \( M \) = Monitor
- \( D \) = Destination

- \( DL_{\text{max}} \) = Maximum Depth Level
- \( A \rightarrow B \) = A sends data/message to B
- \( N(U) \) = Neighbor set of node U
- \( C(U) \) = Set of routes in the cache of node U
- \( M_{\text{source}} \) = Monitor connected to the source node
- \( NM(M) \) = Set of Neighbor Monitors of Monitor \( M \)
- \( ID(M_i,M) \) = Depth between the Monitor\( (M)\) and Monitor\( (M_i)\)

Total routing technique of the AMBR protocol is encoded in the following algorithm:

**AMBR Algorithm:**

```markdown
if \( D \in N(S) \) then
    \( S \rightarrow D \) //Directly connected
end if
else if \( D \notin N(S) \) and \( D \notin C(S) \) then
    \( S \rightarrow M \) // Send data to Monitor
    if \( D \in N(M) \) then
        \( M \rightarrow D \) //Route through Monitor
    end if
    else if \( D \notin N(M) \) then
        if \( D \in C(M) \) then
            \( M \rightarrow D \) // Send data through cache
        end if
        else if \( D \notin C(M) \) then
            call RouteFinder\( (M,M,S) \)
        end else if
    end else if
else if \( D \notin N(S) \) and \( D \in C(S) \) then
    while(!RouteBrokenDynamically)
        \( S \rightarrow D \) //Route in the cache of source
    end while
    if RouteBrokenDynamically then
        call RouteFinder\( (M,M,S) \)
    end if
end else if
```

**Function RouteFinder**\( (M_{\text{source}}, M, Source) \)

[This user defined function finds route between the \( M_{\text{source}} \) and the Monitor connected to the destination node]

\[
M \rightarrow NM(M)
\]

**end if**

**end else if**

III. ANALYTICAL MODEL

We assume that there are \( n \) nodes in the system, all the nodes have the same distribution of moving speed and direction and the same transmission range \( r \). We assume that:

1. The average route length between the source and destination is \( E_r \).
2. The duration of the packet arrival is an exponentially distributed with mean \( 1/\lambda \).
3. The time between location changes for each node is exponentially distributed with mean \( 1/\mu \).
4. All \( n \) mobile hosts in the network have the same transmission range \( r \).

Then, probability of a route is broken [1],

\[
P_B = \frac{\mu}{(\mu + \lambda)}
\]  

(1)

And the probability that a route is not broken is \((1 - P_B)\).

**A. Packet Routing Probabilities**

**Theorem 1.** The probability \( P_N \) that at least one of the \( E_N \) monitors able to route from source to destination is,
\[ P_N = 1 - (1 - (1 - P_B)^3)^E \]  \(2\)

**Proof.** Let the packet is sent from node \( A \) to \( C \), where \( C \) is not directly connected with \( A \). So, an on demand diagnosis approach invokes a monitor \( M \). The probability of \( M \) to find the desired route is \( \rho = (1 - P_B)^3 \). If \( E_N \) be the number of monitors in the network, then \( K \) be the number of nodes that want a route by monitor \( M \) is given by,

\[ P(K) = (E, C, k) \rho^k (1 - \rho)^{E_k - k} \]  \(3\)

Thus, the probability that at least one of the \( E_N \) monitors is able to route from source to destination is given by above.

B. **AMBR Probabilities**

**Theorem 2.** The probability \( P_R \) that a route discovery succeeds in AMBR protocol is,

\[ P_R = 1 - (1 - P_F)^{E_k} (1 - P_B)^{KE_s} \]  \(4\)

**Proof.** If \( k \) hops are counted in the case of a failure of route discovery without asking the monitors, then the probability that self diagnosis fails is,

\[ P_{F_0} = (1 - P_B)^K \]  \(5\)

Here, \( P_B \) be the probability that next desired node found. Again, the probability that total number of \( E_N \) monitors also fails to discover the route is,

\[ P_{F_1} = (1 - P_B)^{KE_s} \]  \(6\)

Then, the probability that the route recovery succeeds is,

\[ P_R = 1 - P_{F_0} P_{F_1} = 1 - (1 - P_B)^K (1 - P_B)^{KE_s} \]

**Theorem 3.** The probability that a packet is successfully routed by our protocol is,

\[ P_S = ((1 - P_{F_0})^{1/k})^{E_k} + (E_k - 1) (1 - P_{F_1})^{1/KE_s}(E_{k-1}) \]

\[ + (1 - P_B) [1 - (1 - P_B) (1 - P_B)^{KE_s} (E_{k-1})] \]  \(7\)

**Proof.** A packet arrives in one attempt if it passes along all links without being resent by the original host again. That means that an error does not occur along the whole route and an error occurs in one link and the recovery mechanisms are launched and give the result. Therefore, we have

\[ P_S = (1 - P_{F_0})^{1/k} E_k + (E_k - 1) (1 - P_{F_1})^{1/KE_s}(E_{k-1}) \]

\[ + (1 - P_B) [1 - (1 - P_B) (1 - P_B)^{KE_s} (E_{k-1})] \]  \(8\)

IV. **Simulations**

A. **Simulation Environment**

In order to analyze the performance of the proposed AMBR protocol, we run the simulation under the NS-2 testbed with a CMU wireless extension. The simulator parameters are listed in Table 1.

| Parameter | Value |
|-----------|-------|
| Simulator | NS-2 (Version 2.29) |
| Network Area | 1300m×1300m |
| Transmission Range | 250m |
| Bandwidth | 5kbps |
| Data Packet Size | 512 bytes |
| MAC Layer | IEEE 802.11 |

The network area is confined within 1300m×1300m. Each node in the network has a constant transmission range of 250m. Constant-bit-rate (CBR) traffic sources are used. The source-destination pairs are spread randomly over the network. Only 512 byte data packets are used. The movement pattern of each node follows the random way-point model. Each node moves to a randomly selected destination with a constant speed between 0 and maximum speed \( V_{max} \). When it reaches the destination, it stays there for a random period and starts moving to a new destination. Through out the simulation we calculate the total routing overhead per node.

B. **Affected Parameters [11]**

We consider the following parameters that affect the performance of a routing protocol:

1. **Network size (n).** The number of nodes in a network determines the density of the network. A dense network will cause more collision and contention.
2. Mobility of the node ($V_{\text{max}}$). The mobility of the node affects the performance of the routing operation. The faster the node moves, the higher is the possibility of the node to lose the information of the neighbors and the information of the monitor.

3. Pause time ($p$). At the start of the simulation each node waits for a pause time. It then randomly selects its destination and moves towards this destination with a speed randomly lying between 1 to $V_{\text{max}}$, where $V_{\text{max}}$ is the maximum speed of a node. Once the destination is reached, another random destination is targeted after a pause.

C. Results and Analysis

Sensitivity to Network Size. Figure.1 is the corresponding graph to the routing overhead versus network size where $V_{\text{max}}$ is 10 meters per second, (m/s), pause time is 10 second, Total simulation time is 200s and the data traffic load constant-packet-rate (CPR) is 10 packets per second (pkt/s).

We compare the routing overhead against AMBR, DSDV [8] and AODV [9] by varying the network size 80, 90, 100, 150, 200. From the graph it can be easily understood that the routing packet overhead of AODV, DSDV and AMBR increases as network size increases but increasing rate in the case of AODV and DSDV is much higher than the AMBR. Even in denser network (network size 200 nodes) the graph shows that the routing packet overhead of AMBR is much less comparing with the other two protocols.

Sensitivity to Mobility of the Node. Figure.2 represents the graph shows the effect of the node's mobility on the performance of routing operation. In this case, $n=100$, $p=10s$, total simulation time=200s and CPR=10 packets per second (pkt/s). This graph shows the routing control packet overhead for different mobility of nodes. Here, we vary the maximum speed of the nodes from 10 m/s to 50 m/s with an interval of 10 m/s.

V. CONCLUSION

In this paper, we performed a thorough analysis of AMBR protocol. From the analysis we found that AMBR is an efficient technique to route data from source to destination with a low routing cost. Firstly, we proposed an improved analytical model which illustrates the Packet routing probabilities and AMBR probabilities. Secondly, using NS-2 simulator and varying different affecting parameters we measured the
Routing overhead for AMBR including DSR-LRR, DSR, DSDV and AODV, and compared with each other. These thorough analyses show the inherent strength of the AMBR protocol and firmly determine that AMBR protocol is the most feasible protocol for the ad hoc networks.

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