CHAPTER 8

THEORETICAL ANALYSIS

8.1 INTRODUCTION

The network model that forms the basis for analysis is discussed in this chapter. The simulated results of the proposed protocol have been analyzed in detail and presented in the previous chapters. The protocol analysis is made much easier as we use many of the derived results from literature. The characteristics of the proposed protocol have been compared with that of other classes of protocols.

8.2 NETWORK MODEL

Let $A$ be the area of the network and $N$ be the number of nodes in the network. The nodes are uniformly and randomly distributed over $A$ with a standard probabilistic model of homogeneous Poisson point process.

It is also assumed that each source node initiates packets to randomly chosen destinations in the network. The expected length $\bar{L}$ for such traffic as derived in section 4.1 of Jingyang Li et al (2001) is

$$\bar{L} \cdot \frac{2\sqrt{A}}{3} \quad (8.1)$$
8.3 PERFORMANCE ANALYSIS

We analyze the proposed GRD-ARM with respect to the following parameters.

i) Number of control packets \( C \) involved in route Discovery.

ii) Delay involved in route discovery.

iii) Proof of reachability with controlled flooding.

iv) Number of RRPR packets involved in fixing up of link breaks.

v) Delay involved in repairing a broken link.

8.3.1 Control Packets in Route Discovery

Unlike AODV, in GRD-ARM every node that is identified to forward the RREQ will select the set of forwarding nodes dictated by the reachability parameter \( K \) as discussed in chapter 4. The range of values assumed in \( K \) is 2 to 7. Therefore a node can choose either one half or one seventh of its neighboring nodes depending on the randomly generated reachability value. Hence

\[
p \cdot \frac{1}{2} \text{ or } \frac{1}{3} \text{ or } \frac{1}{4} \text{ or } \frac{1}{5} \text{ or } \frac{1}{6} \text{ or } \frac{1}{7}
\]

\[
\cdot p \cdot 0.37
\]

and so the number of possible rebroadcast \( C \) is \( 0.37 \times (N - 2) \) on average in route discovery phase.
8.3.2 Delay involved in Route Discovery

The delay involved in discovering a path between the source and destination is directly proportional to the number of hops. Since the expected length is $\bar{L}$ and the transmission range of the node is $R$, the number of hops $H_c$ between the source and the destination can be computed as shown below.

$$H_c \cdot \frac{L}{R}$$ (8.2)

Substituting $\bar{L}$ from equation (8.1) in equation (8.2) in $H_c$ equation (8.3) is arrived as

$$H_c \cdot \frac{2\sqrt{A}}{3R}$$ (8.3)

Therefore delay involved in the route discovery is $2(H_c)$. In GRD-ARM, as the number of control packets generated during discovery phase is reduced largely, the delay incurred is closer to the theoretical delay. In AODV, even though the theoretical delay involved in route discovery is proved to be $2H_c$, this is highly increased in dense scenarios as the packet drops are higher due to superfluous flooding. The same was also seen through simulations results.

8.3.3 Reachability

A path between the end systems can be established successfully (if exist) only if at least few of the nodes can relay the RREQ packets. The Poisson point process is characterized by a property that the number of nodes in a region is a random variable depending only on the area of the region. Hence the number of nodes $x$ in a unit area follows a Poisson distribution. Therefore the probability that there are exactly $x$ nodes appearing in any region $\Psi$ of area $A$ is
where \( n \) is the total number of neighbors of a node in the network of \( N \) nodes. The probability that at least 1 node is present in the forwarding area can be computed using the equation (8.4) by substituting values for \( n = 20 \), \( R = 100 \) in an area of \( 500 \times 500\text{m}^2 \) as \( P(X = 1) = 0.4 \). This proves that the reachability is guaranteed if the network is not badly partitioned.

### 8.3.4 Number of Control Packets involved in Route Maintenance

It is known that a packet should pass through \( H_c \) number of hops from source to reach the destination. The probability of link break at any point is equally likely. A node that is likely to cause link break broadcast RRPR packet to its one hop neighbors. If \( n \) is the average number of neighbours then every node that is likely to cause link break will broadcast \( n \) number of RRPR packets. Therefore the average RRPR packets generated are

\[
RRPR_{\text{avg}} \cdot \frac{nH_c}{H_c} \cdot n
\]  

(8.5)

where \( n \) is the average number of neighbours, which can be computed by using the following equation

\[
n \cdot (N - 1) \cdot \frac{R^2}{A} \]  

(9.6)

In the traditional AODV, almost all \( N \) nodes in the network are involved in route maintenance. It is obvious that the superfluous flooding of AODV has been drastically reduced by the proposed GRD-ARM.
**Numerical Analysis:** For the following values assumed in various variable \( N = 100 \) nodes; \( R = 100 \) mts; \( A = 500 \times 500 \) m\(^2\) the average number of neighbouring nodes \( n = 12 \) nodes. On an average only 12 nodes of 100 nodes are involved in link break fixing. In AODV the number of nodes involved in fixing up a broken link is 98.

**8.3.5 Delay involved in Route Maintenance**

From the above discussion, it is learnt that only \( n \), a smaller number of nodes are intimated about the link break that is likely to occur. Of \( n \) communicated nodes all the \( n \) nodes check its neighbour table for itself to become a candidate for the bridge node. Applying binary search, every \( n \) node take a time of \( \log n \). Therefore total delay involved is \( n \log n \).

\[
\text{Delay}_{\text{Maint}} = n \log n
\]

From the above discussion and derivations, it is proved that the proposed GRD-ARM performs better in all aspects.

**8.4 COMPARISON OF UNICAST ROUTING PROTOCOLS**

Time complexity is defined as the time required for the number of steps to perform a protocol operation, and communication complexity is defined as the number of messages exchanged in performing a protocol operation. Route discovery in on-demand routing protocols usually occurs by flooding a route request message through bi-directional links or by piggy-backing the route in a route reply packet via flooding. Thus, DSR and AODV have relatively the same time complexity = \( O(2d) \) and communication complexity = \( O(2N) \). GRD-ARM routing protocol is based on the greedy technique, where in each step, a node chooses a set of farthest node at random, to forward messages. Thus, the time complexity needed for all nodes in a diameter of the network with size \( d \) is \( O(d) \), and the communication complexity is \( O(n \log n) \). Therefore, the proposed GRD-ARM routing
protocol is more efficient and scalable than flooding-based ad hoc routing protocols because of reduction in communication overhead. The reliability of GRD-ARM depends on the Reachability Parameter $K$.

The characteristics of proposed GRD-ARM protocol is compared with widely used unicast routing protocols and listed in Table 8.1.

**Table 8.1 Comparison of Characteristics of Unicast Routing Protocols**

<table>
<thead>
<tr>
<th>Performance Parameters</th>
<th>AODV</th>
<th>DSR</th>
<th>GRD-ARM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Complexity (Discovery)</td>
<td>O(2d)</td>
<td>O(2d)</td>
<td>O(2d)</td>
</tr>
<tr>
<td>Time Complexity (Maintenance)</td>
<td>O(2d)</td>
<td>O(2d) or 0(cache hit)</td>
<td>O(n log n)</td>
</tr>
<tr>
<td>Routing / Loop Free</td>
<td>Flat / Yes</td>
<td>Flat / Yes</td>
<td>Flat/Yes</td>
</tr>
<tr>
<td>Multicast Capability</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Beaconing Requirements</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Multiple Route Possibilities</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Route Reconfiguration</td>
<td>Erase Route, Notify Source</td>
<td>Erase Route, Notify Source</td>
<td>Localized and proactive</td>
</tr>
<tr>
<td>Route Maintained in</td>
<td>Route table</td>
<td>Route cache</td>
<td>Route Table</td>
</tr>
<tr>
<td>Routing Metric</td>
<td>Fresh and shortest</td>
<td>Shortest</td>
<td>Shortest Path</td>
</tr>
<tr>
<td>Scalability</td>
<td>BAD</td>
<td>FAIR</td>
<td>GOOD</td>
</tr>
<tr>
<td>Adaptability to topological changes</td>
<td>Strong</td>
<td>Weak</td>
<td>Strong</td>
</tr>
<tr>
<td>Routing Overheads</td>
<td>Very High in Dense Scenarios</td>
<td>Very High in Dense Scenarios</td>
<td>Low</td>
</tr>
<tr>
<td>Energy Consumption</td>
<td>Fair/Moderate</td>
<td>High</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

$N =$ Number of nodes in the network  
$d =$ Network diameter  
$n =$ Number of neighbours of a node
From the table it is obvious that the parameters that influence the performance of the unicast protocol in a massively dense MANETs viz. Time and Communication Complexities, method of maintaining the established routes has an improvement in the proposed GRD-ARM compared to the widely used unicast protocols.

8.5 CONCLUSION

This chapter provided the time complexity and communication complexity of the proposed protocol and also compared the proposed protocol with that of traditional protocols like AODV and DSR. The following chapter provides the overall summary of this research work.