Power Aware Multiple QoS Constraints Multipath Routing Protocol With Mobility Prediction For MANET

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Abstract— Mobile ad hoc networks (MANETs) can be defined as self organized, self coordinated, infrastructure less communication networks with mobile nodes. The protocol called “Power Aware Multiple QoS constraints Multi path Routing Protocol with Mobility Prediction (PMQMRPMP)” is a source based reactive protocol. It considers quality of service (QoS) constraints namely delay, delay-jitter, bandwidth, and cost to select multiple routing paths between a source and a destination and disseminates data packets through them as to increase packet delivery ratio, reliability and efficiency of mobile communication during path discovery. It also considers power constraints for selecting paths which have nodes with good battery power for transmission. It accumulates the residual battery power of each node for each path during route reply to satisfy the power constraint. It gives the path maintenance procedure when the link between two nodes cut off. It uses the mobility prediction formula to find the stability of a link between two nodes. Source distributes routing load among multiple nodes on different paths using uniform spreading algorithm, as to shape up the traffic and to increase throughput. This protocol scales better when more number of paths are found in MANET which may become at last as a wireless mesh.

Keywords— QoS, mobility prediction, MANET, power consumption, routing.

I. INTRODUCTION

Mobile ad hoc networks (MANETs) can be defined as self organized, self coordinated, infrastructure less communication networks with mobile nodes. They can be created suddenly for the applications such as military battlefields, emergency search, rescue sites, classrooms and conventions, where participants share information dynamically using their mobile devices [1]. Quality of Service (QoS) in MANET is defined as the collective effect of service performance, which determines the degree of satisfaction of a user of the service [2]. The QoS constraints can be classified as time constraints, space constraints, frequency constraints and reliability constraints [3]. Some of the issues identified in MANET are routing, mobility management, security, reliability and power consumption [3]. The QoS models applicable for MANET are Integrated services (IntServ), DiffServ (Differentiated Services), Flexible QoS Model for MANET (FQMM), Complete and Efficient QoS Model for MANETs (CEQMM). Intserv model maintains per flow reservation state at MANET entities. Due to enormous power consumption and more resource utilization, it is not suitable for MANET [4]. The DiffServ model is lightweight stateless model and it does not reserve resources. There is no absolute bandwidth guarantee for flows. It relies on the type of the traffic. Intermediate nodes give higher priority to real-time traffic than bulk traffic [5]. In the hybrid models FQMM [6] and CEQMM [7] the highest priority traffic is governed by IntServ model, and remaining data traffic is governed by DiffServ model. Due to control overhead, nodes consume more battery power. In-band signaling system for supporting QoS in MANET (INSIGNIA) is a QoS signaling protocol. In INSIGNIA, if the resource is available to a particular flow, then it is allocated. Otherwise, best effort service is performed [8]. Service Differentiation in Stateless Wireless Ad hoc networks (SWAN) is the stateless QoS model. It does not maintain per flow reservation state in intermediate nodes [9].

The routing protocols in MANET can be categorized as proactive and reactive [10]. These protocols are used to route discovery and route maintenance between source and destination. In proactive protocols, routing tables constructed before communication takes place and then packets are routed based on these tables. Frequently tables are updated. Periodical exchanging of table information among nodes in dense area creates communication overhead. If more nodes are in mobility, it requires more updates in tables, which increases communication overhead. So, in proactive routing, route discovery is easy but route maintenance is hard.
Reactive protocols are used when the source has data to send. These are suitable for high mobility. In reactive routing, route discovery is hard but route maintenance is easy. Some of the QoS routing algorithms for MANET are Core Extraction Distributed Ad hoc Routing (CEDAR), QoS-AODV (QAODV) and Ticket-Based Probing (TBP). CEDAR uses clustered network architecture and selects the core dynamically. In CEDAR, there may be chances for the core becomes failure due to hardware and software problems. Since more data are routed through the core node, the core node suffers from heavy traffic [11]. QAODV is based on reactive routing. In QAODV, source node specifies the QoS parameters in the RREQ packet. Every intermediate node checks whether or not it can support for that mentioned QoS [12]. TBP is a multi-path QoS routing scheme. In TBP, source sends N number of tickets to find N paths. There is no clear heuristic for computing tickets. Resource Reservation for one flow denies the availability of that resource for other flows [13].

MQRPMP (multiple QoS constraints routing protocol with mobile predicting) [10] discusses the QoS routing problem with multiple QoS constraints namely delay, jitter, bandwidth and cost metrics. It tries to minimize the control overhead for reconstructing a routing path using mobility prediction mechanism. It has better packet delivery ratio (PDR) than TBP. The cost of communication overhead is also less than TBP [10] [13]. The mobile nodes suffer from battery consumption in MANET. But MQRPMP does not address the power constraint to select a path.

There can be multiple paths between a source and destination. The links on the paths have the QoS constraints. A path can be chosen as an optimal path, if it satisfies the QoS constraints [10]. The power consumption of nodes is also a known key constraint, which affects the performance of MANET [14]. It is possible to collect the residual battery power of each and every node in each and every path between source and destination. So, identification of “n” number of paths, which satisfy link constraints, those have nodes with good battery power for transmission, is also possible.

The amount of time that the two adjacent nodes will stay connected is called as the Link Expiry Time (LET). It determines the stability of the wireless link available between those two nodes. As long as the LET value is larger, the wireless link between two nodes becomes more stable for longer duration. Since a path in MANET may have multiple hops, by accumulating the LET values of all the links on a path, it is possible to find the LET value for the entire path. It leads to determine the stability and reliability of the entire path. Likewise, LET values for each path between source and destination can be computed. The well known mobility prediction formula for finding LET is given in [10] [16].

Therefore, it is possible to identify multiple paths which satisfy the set of link constraints, with highest LET values whose battery backup is highest among others. As well as, the data can be spread between source and destination on the selected paths using an uniform spreading algorithm.

The proposed protocol PMQMRPMP is a source based reactive protocol for finding multiple optimal paths for the set of QoS constraints with power awareness using mobility prediction mechanism to spread data between source and destination on those selected paths using uniform spreading algorithm. The section 2, explains the network model of the new protocol. In section 3, mobility prediction mechanism is explained. In section 4, a new protocol with path discovery and path maintenance procedures is explained with an illustration. The section 5 gives the simulation set up and the performance comparison of PMQMRPMP over MQRPMP and TBP. Finally section 6 gives the conclusion and future scope of this research work.

II. NETWORK MODEL

This section describes the network model for the proposed protocol. The network model in MANET can be denoted by $G = \{V, E\}$ where $V$ is the set of interconnected nodes and $E$ is the set of full-duplex directed wireless communication links. The network model considers the existence multiple paths between any two nodes where each link on each path considers the QoS constraints namely Delay ($D$), Jitter ($J$), Bandwidth ($B$), and Cost($C$). The model also considers the Energy Level ($EL$) of each node ($V_i$) on each path, which meets a power constraint ($P_i$) for mobile communication. The EL of each node is the residual battery backup, which is collected and summed up for each routing path. This model also includes the parameter called LET for the selection of multiple paths. Among the existence of multiple paths ($P_1$, $P_2$, $P_3$ ... and $P_N$) for a source to destination, a set of paths ($P_1$, $P_2$, $P_3$ ... and $P_k$) are selected which satisfies all the above said constraints. So the problem of multiple QoS constraints with power awareness for multiple paths can be defined as follows:

Select $P_1$, $P_2$, $P_3$ ... and $P_k$ among ($P_1$, $P_2$, $P_3$ ... and $P_N$) whose LET > 0 where

$$\sum D_i \leq D$$
$$\sum J_i \leq J$$
$$B_i \geq B$$
$$EL (V_i) \geq P$$
$$\sum C_i \leq C$$
$$\text{MAX} (\sum EL (V_i))$$

III. MOBILITY PREDICTION MECHANISM

This section describes the mobility prediction formula for finding LET. The reliability of a path depends on the stability or availability of each link on it. In MANET, due to frequent topological changes, the reliability of a path is affected. The proposed routing protocol uses the location information from GPS (Global Positioning System) [15], to estimate the expiration time of the link between two adjacent nodes. Based on this prediction, routes are reconfigured before they disconnect [16]. The proposed protocol considers free space propagation model [16], where the received signal strength solely depends on its distance to the transmitter. Here node-moving pattern is random waypoint.
We also assume that all nodes in the network have their clock synchronized (e.g., by using the NTP (Network Time Protocol) or the GPS clock itself [16]. Therefore, using the motion parameters such as speed, direction, and the communication distance of two neighbours, the duration of time can be determined in order to estimate that two nodes remain connected or not. The LET between any two nodes is calculated at each node using the well-known mobility prediction formula. Assume two nodes $i$ and $j$ are within the transmission range $r$ of each other. Let $(x_i; y_i)$ be the coordinate of mobile host $i$ and $(x_j; y_j)$ be that of mobile host $j$. Also let $v_i$ and $v_j$ be the speeds, and $\theta_i$ and $\theta_j$ be the moving directions of nodes $i$ and $j$, respectively. Then, the amount of time that they will stay connected - LET, is predicted by the formula given in the following equation (1):

$$\text{LET} = \frac{-(ab+cd)+\sqrt{((a^2+c^2)^{\frac{3}{2}}r^2-(ad-be)^2)}}{(a^2+c^2)} \quad (1)$$

where 

- $a = v_i \cos \theta_i - v_j \cos \theta_j$,
- $b = x_i - x_j$,
- $c = v_i \sin \theta_i - v_j \sin \theta_j$, and
- $d = y_i - y_j$.

Note that when $v_i = v_j$ and $\theta_i = \theta_j$, LET is set to $\infty$ without applying the above equation.

IV. POWER AWARE MULTIPLE QoS BASED MULTIPATH ROUTING PROTOCOL WITH MOBILITY PREDICTION

This section describes path discovery and path maintenance procedure for the proposed protocol. It also specifies uniform spreading algorithm for disseminating the packets through the selected paths. During path discovery, multiple optimal paths are selected based on multiple QoS constraints and power constraint using mobility prediction formula. The paths with highest battery power and highest LET is considered as stable optimal paths for dissemination of data.

A. Path Discovery

When a source has data to send then it sends route request packet with following fields: Source-address, Destination-address, sequence number, position, speed, moving direction of mobile node, D, J, B, EL and C. The route discovery procedure for the proposed protocol is given as follows:

Procedure for Source (S):
- If Source S has no Paths to Destination D
  - Broadcast Route Request packet
  - Execute Route Reply Handling Procedure
End if

Route Request Handling procedure:
- If the node is D
  - If the received Route Request packet is not duplicate
    - Execute Route Reply Handling Procedure
  - End if
End if

If it is an intermediate node I
- If the received Route Request packet is not duplicate
  - If ($B_j \geq B_c$)
    - Forward Route Request
  - Else
    - Discard Route Request
  - End if
- Else
  - Discard Route Request
  - End if
End if

Route Reply Handling procedure:
- If it is an intermediate node I or destination D
  - If the received Packet is Route Reply and it is not duplicate and EL ($V_j$) $\geq$ $P_c$
    - Update EL as EL = EL + EL (I) within received Route Reply
    - Forward new Route Reply to S
  - End if
- End if
- If the node is S
  - Receive the Route Reply packets
  - Collect the Paths to D
- If the Collection is not NULL
  - For each Path $P$
    - If $\sum D_i + \sum J_i < J_c$ and $\sum C_i < C_c$
      - Calculate total LET
    - Else
      - Delete routing path from the Collection
    - End if
  - End for
  - Select $P_1$, $P_2$, $P_3$ … and $P_k$ among multiple paths ($P_1$, $P_2$, $P_3$ … and $P_n$) with LET $> 0$ and $\sum EL (V_j)$ is maximum
  - End if

B. Path Maintenance

Due to the dynamic changes of network topology and limitation of network resources, the computed optimal route often gets invalid. When the link is cut off, the upstream node sends route reconstruction packet to the source. Then the source once again starts the route discovery procedure. If the source receives routing reply and route reconstruction packet at the same time, it deals with the route reconstruction packet.

Route maintenance procedure by the Intermediate node:
- If the link is cut off with its neighbor
  - Construct and Send Route Reconstruct packet to S
End if
- If the Route Reconstruct packet is received from its neighbor
  - Forward the Route Reconstruct packet to S
End if

Route maintenance procedure by the Source node:
- If the Route Reconstruct packet is received from any I
  - Broadcast Route Request packet
End if
C. Dissemination of packets on selected paths

After selecting multiple paths between the source and destination the packets can be spread on those paths from source using uniform spreading algorithm. Since the routing load is distributed evenly among multiple paths, the packet delivery ratio and bandwidth utilization are increased. The work overhead of the nodes on the selected paths is reduced. The traffic within the MANET is smoothened which in turn reduces congestion at intermediate nodes.

Uniform Spreading Algorithm used by Source node:
Let the total number of paths found be K among the available number of paths N
Let the total number of packets to be sent as NPkts
While (NPkts > 0)
    Send (NPkts / K) number of packets on P1, P2, P3 … and PK
End while

D. Illustration

Figure 1 depicts a graph with QoS metrics for links in PMQMRPMP. Let Dc = 15, Jc = 30, Bc = 35 and Pc = 50. Let the energy levels of the nodes 1, 2, 3, 4, 5, and 6 are 55, 50, 60, 65, 70, and 60. The routes from the node 1 to destination 6 are requested. Let the number of packets to be sent by the node 1 is 1000 packets. According to multiple QoS constraints, power constraint and LET calculation the route is calculated. For example, the paths P1 (1,2,4,6), P2 (1,3,5,4,6) and P3 (1,3,2,4,5,6) do not satisfy delay constraint and bandwidth constraint respectively. The paths P4 (1,2,4,5,6) and P5 (1,2,3,5,4,6) do not satisfy delay constraint and bandwidth constraint. The paths P6 (1,3,5,6) and P7 (1,3,2,4,6) satisfy delay, jitter, bandwidth and cost constraints. All the above-mentioned paths satisfy energy level constraint.

![Graph with QoS metrics for links](image)

Figure 1. Graph with QoS metrics for links

The table 1 gives the details of LET calculation for the nodes in the path P6 and P7. Since the accumulated LET values of the links on P6 and P7 are greater than zero, the paths P6 and P7 are considered as stable paths and selected for disseminating data from the source node 1 to destination node 6. The Source node 1 evenly distributes its routing load by spreading 500 packets on the selected paths P6 and P7.

V. SIMULATION

The protocol is simulated in ns2 [17]. The simulation parameters are shown in the following Table III.

<table>
<thead>
<tr>
<th>Path</th>
<th>Let1</th>
<th>Let2</th>
<th>Let3</th>
<th>Let4</th>
</tr>
</thead>
<tbody>
<tr>
<td>P6</td>
<td>1.12</td>
<td>1.21</td>
<td>7.19</td>
<td>7.81</td>
</tr>
<tr>
<td>P7</td>
<td>1.12</td>
<td>1.21</td>
<td>7.19</td>
<td>7.81</td>
</tr>
</tbody>
</table>

The table 2 shows the selected optimal paths P6 and P7 with their cost, energy level and LET.

The evaluation parameters for PMQMRPMP are the cost of control overhead and success rate of data transmission. It is compared with MQRMP and TBP in figure 3 and figure 4. The success rate of data transmission is compared along with the node’s mobility speed in figure 3 to show the performance of PMQMRPMP, MQRMP and TBP. When the node’s mobility speed is 3 m/s, the success rate of data transmission of MQRMP and PMQMRPMP reaches the value 0.98 which is higher than the TBP value 0.8. While increasing the node’s mobility speed beyond 3 m/s, the performance of MQRMP, and TBP is drastically going down. But among them, in PMQMRPMP the success rate of data transmission is still higher than the others and reaches 0.7 if node’s mobility speed is 10, due to LET computation and load distribution algorithm.
secure routing protocol by adding new constraints. As well as it can be enhanced as a reliable and accurate LETs. As well as it can be enhanced as a reliable and MQRPMP, node along the path during route reply as exactly in MQRPMP, than TBP. Since it collects the residual battery back up of each node along the path during route reply as exactly in MQRPMP, there is no performance difference between and MQRPMP which is shown in Figure 4.

Based on the residual battery back up of mobile node on the selected route, the behaviour of the mobile node can be changed from reactive to proactive and vice versa to enhance this protocol as a hybrid routing protocol by fixing a threshold limit on the battery power which in turn increases packet delivery ratio considerably. Since MANET applications lend themselves well to multicast operations, this protocol can also be further extended towards a multicast communication protocol. Moreover, the number of route request packets in route discovery can be reduced to increase effectiveness of the throughput of the communication.

Figure 3. Success rate of data transmission vs. Node’s mobility speed

Figure 4. Cost of control overhead vs. Number of mobile nodes

VI. CONCLUSION

This paper discusses the new protocol PMQMRPMP with multiple QoS constraints between source and destination. The main advantage of this protocol is that it considers power constraint for nodes for efficient packet transmission. As well as load is distributed among multiple paths to increase packet delivery ratio. It uses mobility prediction formula for LET calculation to select a stable path with minimal cost. The PMQMRPMP provides a quick response to changes in the network, reduces the waste of network resources and produces significant improvement in data transmission rate, and hence reduces control overhead for reconstructing a routing path.

Future work in this direction can be the enhancement PMQMRPMP using mobility adjustment factor for calculating accurate LETs. As well as it can be enhanced as a reliable and secure routing protocol by adding new constraints.

REFERENCES