APPLICATION OF ANT COLONY OPTIMIZATION TO DEVELOP ENERGY EFFICIENT PROTOCOL IN MOBILE AD-HOC NETWORKS

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Abstract: Foraging Behavior in Ant Swarms can be very helpful when applied to the protocols in Mobile Ad hoc NETworks (MANETs). When the Ant Colony Optimization Scheme (ACO) is applied to a protocol, larger number of paths are generated from the source to destination which helps in improving the packet delivery ratio because an alternate back up path is always available in case a path gets broken due to the mobile nodes. In this paper, we apply the ACO scheme on an already existing Energy efficient protocol Conditional Max-Min Battery Capacity Routing (CMMBCR) (C.-K. Toh, 2001). The CMMBCR not only takes care of the total transmission energy in the network but also the residual battery capacity of the nodes. Hence applying ACO scheme on CMMBCR makes it more efficient in terms of energy, packet delivery ratio etc. The efficiency of our proposed protocol A-CMMBCR is then established by comparing it with some of the other existing Energy aware protocols such as Energy-Aware Routing protocol (EAAR) (Dhurandher et al., 2009), Minimum Transmission Power Routing (MTPR) (Scott and Bambos, 1996) and CMMBCR. The results are captured in the form of a graphical format.

1 INTRODUCTION

In the next generation of wireless communication systems, there will be need of networks that can establish themselves without any requirement of preexisting infrastructure. Mobile Ad-Hoc Networks (MANETS) basically refers to such type of networks. As the name suggests Mobile implies that the interconnecting nodes are not succumbed to be remain at one place, rather they can move from one place to the other. Ad-Hoc implies that the network does not depend on any preexisting infrastructure such as routers. Some of the main applications of MANETS are dynamic communication for emergency/rescue operations, disaster relief efforts and military networks.

One of the most important performance parameter in ad- hoc networks is minimizing the total transmission energy in the path and extending the battery life of the nodes. Conventional Routing algorithms such as AODV (Perkins et al., 2001), DSR (Johnson et al., 2001) and TORA (Park and Corson, 2001) ignore the residual battery of the participating nodes.

These protocols generally focus on finding the shortest path available from source node to the destination node. MTPR protocol tries to minimize the total transmission power consumption of nodes participating in an acquired route but it suffers from the drawback that it does not consider the residual battery of the nodes.

MMBCR (Singh et al., 1998) is another protocol that finds the path which has longest battery life amongst all other paths. CMMBCR is a combination of MMBCR and MTPR. In this scheme, a parameter gamma with some value assigned to it is used. Then all paths from source node to destination node are generated and the Minimum residual battery energy (MBR) for each path is compared with the parameter gamma. The paths which have MBR greater than gamma are finally selected and MTPR scheme is applied on this set of selected paths. In case no path has MBR>gamma, the MMBCR scheme is followed. Hence CMMBCR takes care of both the residual

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battery of the nodes as well as minimizing the total transmission energy.

It has been seen from [8, 9, 10] that the Ant Colony Optimization (ACO) scheme when applied to ad-hoc networks greatly enhances the packet delivery ratio. Some of the popular ACO based routing schemes are AntNet (Dorigo et al., 1991), AntHocNet (Di Caro et al., 2005) and ARA (Guenes et al., 2002). The earlier ACO – based routing schemes such as AntHocNet (Di Caro et al., 2005) and ARA (Guenes et al., 2002), devised for ad-hoc networks, were not targeted towards energy conservation.

In the protocol proposed in this paper, we have applied this ACO scheme in CMMBCR. The proposed protocol is inspired from the EAAR. In EAAR, ACO scheme is applied on the already existing MMBCR and thus significantly improving the packet delivery ratio. In the proposed work we have applied ACO scheme to develop a more efficient energy aware protocol that not only takes care of minimizing total energy consumed in the path but also gives special attention to the residual battery of nodes.

EAAR only talks about residual battery of nodes, but doesn't bother about the total transmission energy. Our protocol is better than CMMBCR because we have applied ACO scheme which ensures that there is always a back up path available in case a route breaks due to the mobile nodes. This greatly enhances the packet delivery ratio. Moreover, it also takes care of the fact that if a route gets overloaded due to traffic, an alternate route is selected for routing which ultimately takes care of the residual battery of nodes.

2 PROPOSED SCHEME

Initially, when a Source node *'S'* wishes to communicate with a Destination node *'D'* and it does not have the routing information for 'D' available, it broadcasts a route request packet (*RREQ*). Each neighbour of '*S*' thus receives the RREQ packet. At each node this Request packet is used to find the destination node and the corresponding node checks whether there is an entry in its routing table for this destination node. If an entry for the destination node '*D'* is found the node sends a route reply packet back to the source node along the same path from which it received the *RREQ*. If it does not have any entry for '*D'* available in its routing table, it further broadcasts the *RREQ* packet. Furthermore, to apply the ACO scheme, we need to calculate the pheromone for each path. A-CMMBCR considers a combination of two routing schemes, hence, we need to calculate two pheromones – *pheromone(mt)* for MTPR and *pheromone(mm)* for MMBCR.As the route request packet traverses through the path it keeps on storing the path so that the route request packet will have to traverse back along the same path in the opposite direction.

Meanwhile, all the route request packets received get converted to route reply packets as soon as they arrive to the destination and they travel back to the source retracing the path. If this is not possible because of the absence of the next hop due to node movements, the route reply packet is discarded. At the source node when *RREP* packet is received corresponding values of *pheromone(mt)* and *pheromone(mm)* are also received. Moreover the MBR of that route is also received.

Each node has a routing table associated with it. The routing table contains the addresses of destination nodes along with the neighbor node to which the source node should forward the packet in order to make it reach the destination. Moreover it contains the values of various pheromones associated with a route.

If a source node 'S' wants to send data to a destination node 'D' then following steps must take place:

Step 1: The node S checks its routing table to find whether a path to D exists or not. If a path exists, it sends the data to the next Hop; else Step 2 is performed.

Step 2: The node S broadcasts route request packet *(RREQ)*. Then Step 3 is performed.

Step 3: If any neighbor node's routing table has a path to *D* exists it replies back to node *S* through Route Reply packet *(RREP)* else it broadcasts the *RREQ*. Step3 is followed for each intermediate node thus receiving the *RREQ*. If no path for D is available, the intermediate node relays the *RREQ* packet.

Step 4: As the *RREQ* packet is broadcast in the network, it can eventually reach the destination node *D*. At the destination node, Route Reply packet *(RREP)* is generated and reply is sent back to *S*. *RREP* is passed to node *S* through the intermediate nodes along the path from which *RREQ* was received. Now as each node receives the RREP packet, it updates its routing table and inserts an entry for the destination node.

Calculations: Since we have to apply ACO we need to know the Pheromone for each route generated and our scheme requires calculation of TWO pheromones: one for MTPR and the other for

MMBCR, which are calculated as follows:

Pheromone(mt])=1/(Total Transmission energy of path * Number of Hops)

Pheromone(mm)= MBR/(Number of Hops)

where, MBR=Minimum battery of a node in the path.

Total transmission power is the sum of transmission power to send data to next hop for each node in the path.

We calculate MBR and Total Transmission energy of path during the *RREQ* packet and *Pheromone(mt)and Pheromone(mm)* during the generation of *RREP* packet.

At the source node when *RREP* packet is received corresponding values of *pheromone(mt)* and *pheromone(mm)* are also received. Moreover the MBR of that route is also received.

For all the routes obtained corresponding to a particular destination we check:

if (MBR> γ)
{Select this route for MTPR}
else
{Select this route for MMBCR}.

For all those routes obtained for MTPR category the route with highest *Pheromone(mt)* is selected for data transmission. If no such route exists the Route with highest *Pheromone(mm)* from MMBCR category is selected for data transmission.

Assuming that the battery of any node has maximum value of 100 units and applying ACO in CMMBCR we get:

CMMBCR= ACO + MTPR if MBR>γ,
ACO + MMBCR otherwise

We can take value of *gamma* depending upon our own choice.

Case 1: γ = 0
All routes will be selected for MTPR. Hence our protocol performs similar to ACO+ MTPR

Case 2: γ =100
No route will be selected for MTPR and all routes will be selected for MMBCR. Hence our algorithm behaves as MMBCR+ACO.

Case 3: Taking any Random Value of γ between 0 and 100.
The proposed scheme will be followed.

3 TEST CASES

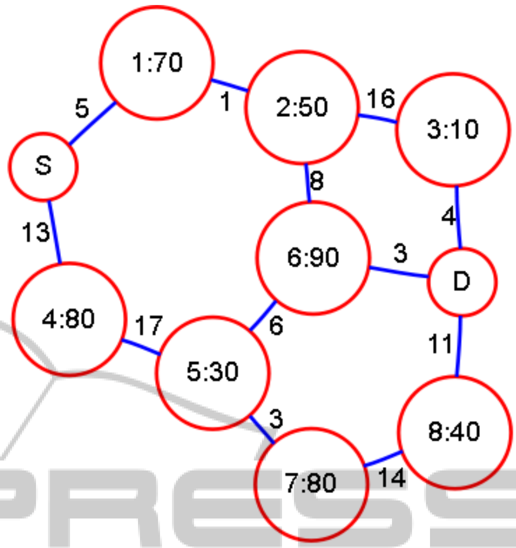

Figure 1: An Illustrative example.

Note in Figure 1 the nodes are represented by circles containing data in the form **a:b** , where a is node address and b is the node battery level left. The data on edges represents the power required to send data between nodes forming the edge.

For convenience, the node battery level is taken from 0 to 100 only.

From Figure 1 it is seen that there are 4 routes from the source node ‘S’ to the destination node ‘D’. These paths are listed below:

1. S -> 1 -> 2 -> 3 -> D
2. S -> 1 -> 2 -> 6 -> D
3. S -> 4 -> 5 -> 6 -> D
4. S -> 4 -> 5 -> 7 -> 8 -> D

For all these routes MBR, *Pheromone(mm)* and *Pheromone(mt)* are calculated.

This data is shown for each of above 4 routes below:

1. MBR=10, *Pheromone(mm)* =10/3, *Pheromone(mt)* = 1/ (26*3).
2. MBR = 50, *Pheromone(mm)* =50/3, *Pheromone(mt)* = 1/ (17*3).
3. MBR = 30, *Pheromone(mm)* =30/3, *Pheromone(mt)* = 1/ (39*3).
4. MBR = 30, *Pheromone(mm)*=30/4,

Pheromone(mt) =
1/ (47*4).

Now depending on the value of γ different routes can be selected for data transmission using MTPR or MMBCR.

In this test case:

If γ<= 49, route 2 will be selected for transmission using *Pheromone(mt).*

Else route 2 will be selected for transmission using *Pheromone(mm).*

The other routes can also be used for data transmission by comparing their MBR with the value of γ and deciding whether to use MMBCR or MTPR.

4 SIMULATION ANALYSIS AND RESULTS

In this section, we report the results generated by conducting the simulation experiments and comparing our protocol with some standard and selected benchmark protocols. Simulation was done using Glomosim tool.

The following parameters were considered for the simulations performed:

1) Simulation time: 500 seconds
2) Terrain dimensions: (2000,2000) meters square
3) Number of Nodes:30
4) Mac Protocol: 802.11
5) Initial energy of Nodes: All Nodes were initiated with equal energy.

The traffic considered n this work is the Constant Bit Rate (CBR) traffic with the following scenarios:

1) CBR 17 100 1536 1S 0S 250S
2) CBR 12 19 100 1536 1S 250S 400S
3) CBR 14 27 100 1536 1S 400S 500S

The benchmark protocols used to compare with our protocol are CMMBCR, EAAR, and MTPR.

Since our protocol is an improvement over CMMBCR hence we decided to take this protocol in our consideration. EAAR is an improvement our MMBCR in that it implements the ACO scheme. MTPR tries to optimize the energy used in the network. Hence the choice of benchmark protocols is justified.

We conducted the simulation experiments under the following six situations:

1) Data size =100 times Control Packet Size; Mobility :NONE
2) Data size =125 times Control Packet Size; Mobility :NONE
3) Data size =150 times Control Packet Size. Mobility :NONE
4) Data size =100 times Control Packet Size; Mobility speed: 10m/s, random way point model.
5) Data size =125 times Control Packet Size; Mobility speed: 10m/s, random way point model.
6) Data size =150 times Control Packet Size; Mobility speed: 10m/s, random way point model.

Parameters that we considered for comparison with other protocols are: (1) Total Energy consumed, (2) Number of dead nodes, (3) Number of packets delivered, (4) Energy per packet delivered, and (4) Number of packets dropped.

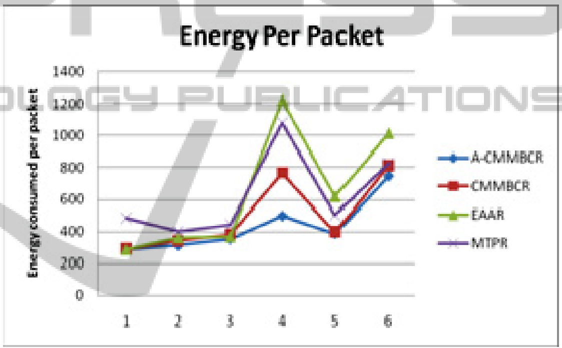

Figure 2: Energy consumed per packet.

Figure 2 shows that the energy consumed per packet in the network is the least for A-CMMBCR. A-CMMBCR performs better than CMMBCR because the ACO scheme generates multiple paths from one node to the other. When the traffic on one path increases its pheromone decreases. This is done so that the packets that would be transmitted later on would go through some different path rather than overloading this path. This helps in increasing the number of packets delivered and hence lesser energy is consumed per packet.

A-CMMBCR performs better than EAAR here because the energy consumed in the network is lesser as the path having the highest pheromone consumes lower energy than the normal path selected by ACO scheme in EAAR.

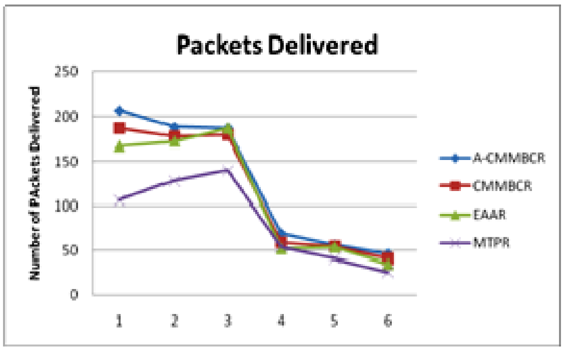

Figure 3: Number of Packets Delivered.

In the first scenario mobility is set to zero. Hence, the nodes do not move, which implies that once a path between two nodes has been established it would remain intact. Number of packets delivered using ACO scheme are higher than the normal on demand scheme as shown in figure 3.

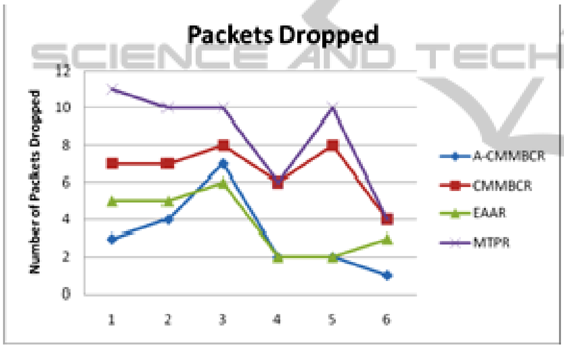

Figure 4: Number of Packets Dropped.

Figure 4 shows the number of packets dropped by each protocol for various scenarios. It can be seen that the protocol based on ACO scheme has lesser number of packets dropped; reason being that there is always an alternative path available in case the current path gets broken or is overloaded with traffic. This guarantees that most of the packets would reach the destination more often than not.

Figure 5 shows that CMMBCR and A-CMMBCR has lesser number of dead nodes than other protocols. This is due to the use of a combination of MTPR and EAAR, which ensures that the least energy would be used in the network along with taking care of weak nodes. Hence the probability of choosing a path that has weak node is very low.

From the above results, it has been seen that A-CMMBCR performs better than other three protocols because it is based on ACO scheme. Moreover, ACO scheme does guarantee the availability of multiple paths for data transfer, which ensures a higher packet delivery ratio.

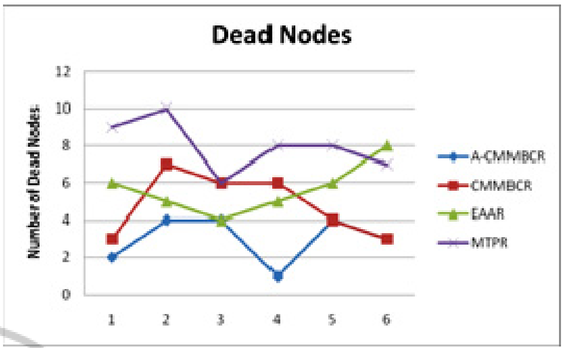

Figure 5: Number of Dead Nodes.

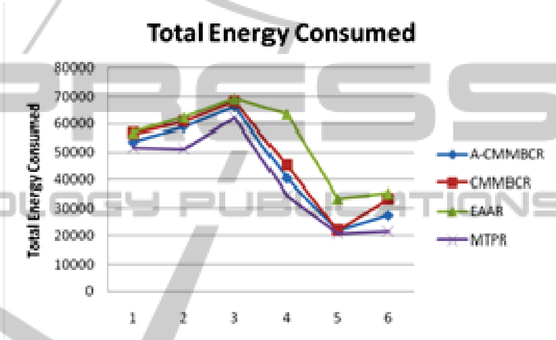

Figure 6: Total Energy Consumed in the Network.

5 CONCLUSIONS AND FUTURE WORK

This paper has presented an ACO based A-CMMBCR energy efficient routing technique to conserve energy in the process of routing of data from one node to another. Furthermore, from the graphical results it can be concluded that the proposed A-CMMBCR performs better than the CMMBCR protocol as the overall energy consumed in the network is reduced and also the number of packets dropped is decreased due to the ACO scheme applied on the CMMBCR. The results also point towards the better performance of the A-CMMBCR in terms of energy over the other energy efficient protocols, namely, EAAR and the MTPR of which EAAR is the most recently designed/proposed and is also based on the ACO technique.

One of the limitations of the proposed A-CMMBCR is that it lacks the fault tolerance aspect. So, our next work would be to ensure that the network selects only those paths in which the nodes are not prone to any fault and if there exists no such path then select those paths which are least prone to faults. The new protocol would make sure that the selected path has highest fault tolerance amongst the other paths.

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