Design and Development of Cluster based Adaptive Energy Routing Protocol to Improve the Performance in MANET

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Abstract: - The rapid evolution of mobile computing is driving a new alternative way in which infrastructure less Wireless Networks with self-configured mobile devices are called Mobile Ad hoc Networks (MANETs). Power Heterogeneity aware with load balanced congestion control is an important technical issue in MANET. Efficient Power Aware Routing (EPAR) selects path in which nodes have largest data packet transmission capacity with smallest residual battery power. Load balanced Congestion Control methodology is used to distribute the traffic load across the network for optimal resource utilization. The Load balanced Congestion Adaptive Routing (LBCAR) protocol maximizes the operational lifetime by using the congestion status of the nodes and link cost of the route in MANET. The proposed protocol, Cluster based Adaptive Efficient Power Aware Routing (CAEPAR) consists of Cluster mechanism with energy efficient load balanced congestion control. The cluster-head selection in CAEPAR is based on the energy efficiency and congestion status of the nodes in the network. The performance of MANET using CAEPAR has been analyzed and compared with DSR, MTPR, EPAR, CRP and LBCAR. In dealing with congestion control and achieving good QoS constraints, CAEPAR is highly efficient and outperforms in terms of Residual Battery Power, Battery Power Consumption, Network Lifetime and Throughput.

Key-Words: - MANET, CAEPAR, Throughput, Battery Power Consumption, Network Lifetime, Residual Battery Power.

1 Introduction

Nowadays Mobile Ad hoc Network (MANET) has become popular growing network and used in various applications. MANET consists of a collection of mobile nodes that form a network without any centralized administration. This network has dynamic topology in which the network topology may change unpredictably and continuously over time. The Mobile nodes in these networks are battery operated and extending the lifetime of battery [2] is an important issue. Each node in the network is having routing function for the establishment of communication among various mobile nodes. The power down mobile nodes due to the battery power exhaustion might cause disconnection of services from the Mobile Ad Hoc Networks.

MANET is one of the major areas of data communication networks which are flooded with various multimedia services. Due to the limitation of bandwidth, congestion [3] has become more challenging problem in Mobile Ad Hoc Network. Congestion degrades the efficiency of the network and leads to packet drops, wastage of energy and time due to the congestion recovery techniques. The load balancing mechanism shares traffic load among all nodes that can be a part of data packets transmission and maximizes the overall efficiency and throughput of the network.

The main goal of MANET routing protocol is to establish a communication with an efficient route between a pair of nodes. The communication among different mobile nodes with guaranteed QoS is employing by the division of the Mobile Ad Hoc Network into clusters [4] with load balanced congestion control and energy efficiency. So the energy efficient and load balanced congestion control clustering scheme maximizes the network operational lifetime and throughput in MANET.

2 Related Works

Divya M. et al. [1] have analyzed and compared different energy routing protocols in MANET. During the data communication, the Efficient Power Aware Routing Protocol (EPAR) minimized the variance in the residual battery power of mobile nodes in the network. So it has utilized the battery lifetime of the mobile nodes properly in order to maximize the network operational lifetime of MANET. During the analysis and comparison, the performance of EPAR is excellent when compared with Minimum total Transmission Power Routing Protocol (MTPR) and Dynamic Source Routing Protocol (DSR). MTPR utilized the optimal path for data transfer with minimum total transmission power. It didn't concentrate the lifetime of each mobile node directly. In the case of DSR, mobile nodes didn't save energy.

Vinay Rishiwal et al. [5] have proposed a QoS constraint power aware routing protocol that selects the energy stable and QoS constrained end-to-end path in the network. This protocol has two phases. The first route discovery phase deals with the bandwidth and energy constraints like DSR protocol route discovery techniques. The second route repair phase search for an energy efficient alternate path in the network at the moment of link failure. During the simulation this protocol minimizes end-to-end delay and maximizes the throughput and network lifetime.

Soudararajan S. et al. [6] have proposed a Multipath Rate Congestion Control algorithm. Congestion degrades the performance of MANET. It can be minimized by using multipath rate congestion control technique. The traffic rate of data packets is adjusted with the estimate rate of the network. This can be estimated for traffic rate estimation and rate control techniques for routing packets. The estimated traffic rate is calculated through the intermediate nodes from the destination node to the source node. Prof. P. K. Suri et al. [7] have proposed a Cluster based QoS routing protocol (CBRQ) which provides support for efficient bandwidth. It reduces queue space requirement for the cluster members by using cluster-head. It also reduces delay in hop to hop during the data packet transmission. CBRQ takes less processing of data packets and saves power.

3 Performance Analysis

3.1 Existing Works

3.1.1 Dynamic Source Routing (DSR)

The Dynamic Source Routing (DSR) is a reactive energy routing protocol. DSR is using on-demand driven routing process. The routes are established between the nodes only if the source node needs. The procedures of DSR are route discovery and route maintenance. In the route discovery, the source node sending route request packets to its neighbor nodes and so on. When the route request packet arrives at the destination node, it will send back a route reply packet to the source node in a unicast manner through the neighbor node from which it first accepted the route-request packet. After the establishment of the route, route maintenance process keeps in each nodes route cache which is an internal data structure of a node.

The demerit of DSR is; it doesn't save energy. The data packet header of DSR contain all the intermediate node address, source and destination address and thereby decreasing the throughput. In DSR, there exists multipath from source to destination because the destination node responds route reply packet via all routes. At the same time the routing packet increases the network routing overhead. So this overhead will cause packet storm in the network. In DSR the speed of the nodes should be moderate and the diameter of the network should not be too larger in MANET. DSR doesn't contain any route prioritization or invalidation for the selection of multiple routes. Due to the high mobility of nodes in MANET results stale route cache entries of individual nodes.

3.1.2 Minimum total Transmission Power Routing (MTPR)

Minimum total Transmission Power Routing (MTPR) is a reactive energy routing protocol which tries to discover a path that has minimum total transmission power. Based on the environmental conditions, MTPR scales [8] the network. The MTPR selects path from source to destination using MTPR routing strategy. It calculates the overall network efficiency with the presence of mobile nodes which have lesser residual battery power. First of all calculate the whole transmission power of all routes. It will select the optimized [10] path with more hops. In MTPR, consider the route L= n0, n1, n2, .., n d then the total transmission power in route L can be calculated as the equation 1,

$$Pt = \Sigma\ (ni, ni+1) \text{ for all nodes ni belongs to L} \quad (1)$$

The power of a particular node k can be calculated using the equation 2,

$$Pk = \min (Pt) \quad (2)$$

The disadvantages of MTPR are; during the data packet transmission, it mainly depends on bit error ratio and interference. It doesn't focus the network lifetime of each node directly so that it will increase end-to-end delay. If the available routes are always through a particular node then the depletion of residual battery power will occur frequently. The MTPR reduces the total consumed transmission power per data packet.

3.1.3 Efficient Power Aware Routing Protocol (EPAR)

Efficient Power Aware Routing Protocol (EPAR) is a reactive routing protocol that utilizes battery lifetime properly and thereby increases the MANET operational lifespan. Compared to conventional power aware routing algorithms, EPAR identifies the node capacity depends on i ts residual battery power and the battery power consumption over a particular link in the network. EPAR selects the optimal path using mini-max formulation. EPAR also considers the concept of the traffic load density for the improvement of the packet delivery ratio. This protocol thus minimizes the overall variance in the residual battery power of each node in the network with dynamic topology. This is an important aim of the EPAR protocol. The total power can be calculated using the equation 3,

$$\max_{k}(k)T_k(t) = \min_{i\epsilon k}(k)T_i(t) \quad (3)$$

The consumed power can be calculated using the equation 4,

$$E_c = \sum_{i=1}^{k} T(n_i, n_{i+1}) \quad (4)$$

Due to the high mobility of nodes and dynamic network topology will increase the overhead message within network for the large size mobile ad hoc networks. This will cause topology maintenance thereby increasing the network routing overhead. Such type of network topology is suffering longer end-to-end delay and takes more number of hops within the network. This is the demerit of the EPAR protocol.

3.1.4 Congestion Control in MANET

Congestion is one of the major issues in MANET. In MANET, applications are sending more packets than the network devices such as routers and switches can hold. In this situation buffers on networking devices will overflow. So congestion is a state of the network in which too many packets are accumulated. ie; congestion occurs when the traffic offered to the network exceeds the resource availability. Hence it degrades the network performance. Congestion control mechanism consists of three phases. In the congestion detection phase, congestion can be detected by monitoring the queue length of the network devices. The congestion feedback phase deals with the number of data packets that has timed out and retransmitted. Based on the congestion levels, the sending-rate control phase informs transmitting devices for reroute or delay the transmission of data packets through the network.

3.1.4.1 Congestion adaptive Routing Protocol (CRP)

Congestion adaptive [9] Routing Protocol (CRP) is an on-demand unicast routing protocol. During routings, the chances of the occurrence of congestion are reduced called as congestion adaptive. At the time of congestion, the nodes which are appearing on the suitable route warn its previous node makes use of the bypass route for the transmission of data packets to the first non-congested node in the shortest path. Traffic is splitting over bypass route, thus efficiently reduced the chances of congestion. CRP maintains the network routing overhead small by lessening the use of multipath for data packet transfer. The bypass route is detached after the solution of congestion recovery from the network. This will improve the efficiency of the network.

3.1.4.2 Load Balanced Congestion Adaptive Routing Protocol (LBCAR)

Load Balanced Congestion Adaptive Routing Protocol (LBCAR) is also an on-demand energy efficient congestion adaptive routing protocol. LBCAR helps to reduce the congestion in the mobile ad hoc network by a dapting to the frequent changes in the congestion status of each of its local neighbor nodes. After receiving data packets, neighbor nodes updating the details of traffic load information of their neighbors in their own neighborhood table. So this protocol selects the optimal route with low traffic load information of their neighbors in their own neighborhood table. This protocol selects the optimal path with low traffic load density and high network lifetime for the transmission of data packets. Congestion status of the route is measured by the link cost of the route. To balance the network load, transfer the load from congested nodes to nodes with lesser traffic load for the establishment of the route. Then it will reduce congestion, maximize the data packets transmission rate and improve the efficiency of network lifetime.

3.2 Proposed Work

3.2.1 Cluster based Adaptive Efficient Power Aware Routing Protocol (CAEPAR)

Cluster based Adaptive Efficient Power Aware Routing Protocol is a cluster based on-demand energy routing protocol. CAEPAR contains clustering technique for supporting congestion control and for achieving efficient QoS constraints in mobile ad hoc network. The clustering technique divides the nodes in the network into different groups. Each group in the network consists of cluster-head and one or more cluster members. The cluster members elect their own cluster-head which acts as the local coordinator. The cluster formation and cluster-head selection is prepared in a distributed method. If a node comes into one cluster then that node will be a part of that cluster. Cluster-head records the routing details and details of the cluster members. I n clustering, a node with minimum congestion level and efficient energy level elected as cluster-head by the cluster members. Congestion level of each node in the cluster is measured by the corresponding clusters in the network. In the network, congestion level of the node mainly depends on the traffic rate. The traffic rate is mainly affected by the new incoming and existing data packet flows, total number of nodes and data communication efficiency of the nodes in the network.

If a node in a cluster wants to send a data packet, it sends a route request packet to its cluster-head. The cluster-head searches for the updated route in its routing table. If the route is found then the data packets transmission begin. If the route is not found, a route- request (RREQ) packet broadcasts by the source node through the cluster-head in the network in a hop-by-hop manner until the destination node reaches. During broadcasting of RREQ, if any intermediate cluster-head found a route in its routing table, then its send a route reply data packet back to the source cluster-head node.

The source cluster-head and the intermediate cluster-head record this updated route in their own routing table and begin data communication. So this clustering method provides optimized route with minimum congestion. The process of cluster-head selection is mainly based on the residual battery power which is the basis of threshold value. So the death of cluster-head will never happen. Hence this protocol maximizes the lifetime of the route and minimizes the network routing overhead.

Algorithm (CAEPAR)

Step 1: Divide Mobile Ad hoc Network into clusters C[0], C[1], .., C[n-1] for cluster formation.
Step 2: For the cluster-head CH[0], CH[1], .., CH[n-1] selection process in each cluster,
Step 2.1: Calculate the congestion level and residual battery power of each node in the cluster.
Step 2.2: Node having the lowest congestion level and highest residual battery power will become the cluster-head, CH[i], of each cluster C[i], in MANET.
Step 2.3: When two or more nodes having the same congestion level and residual battery power then the cluster members elects the cluster-head, CH[i], with lowest cluster-Id.
Step 3: For Load Balancing, cluster-head, CH[i], re-election taking place when
Step 3.1: a cluster-head, CH[i], go out of the region of cluster because in MANET, nodes are mobile.
Step 3.2: A new node arrives into the region of cluster.
Step 3.3: the congestion level of a cluster-head, CH[i], goes up from the threshold value or the residual battery power goes down from the threshold value.
Step 4: Begins data packet communications.

4 Network Performance Metrics for the Efficiency of the Energy Routing Protocols

In MANET, the efficiency of the CAEPAR is calculated and compared with different energy routing protocols using these various network performance metrics.

4.1 Residual Battery Power

The performance of CAEPAR is analyzed and compared with existing energy routing protocols with respect to power. The total number of routed data packets by each node in MANET versus the residual battery power is taken as t he network performance metric. The residual battery power of a particular node k can be calculated using the equation 5,

Residual Battery Power of a node k = ∑k(power of a node k at time t) (5)

4.2 Battery Power Consumption

In MANET, sending or forwarding and receiving of data packets by the nodes consume battery power. If a node remains active in the network then it utilizing power. The battery power starts depletion process if the node is in sleepy mode or idle mode in the network. The consumed battery power indicates that the power spent for the calculations of routing table maintenance and other routing decisions by nodes. The Battery Power Consumption can be calculated using the equation 6,

Battery power consumption of a node k = total power of a node k - power of a node k at time t (6)

The total power of a node can be calculated using the equation 7,

Total power = ∑k(energy of node k at time t) (7)

The number of packets versus Residual Battery Power is considered as the network performance metric.

4.3 Network Lifetime

In MANET, if the residual battery power in all mobile nodes are high then the network operational lifespan will increase. It improves the total network efficiency. The Residual Battery Power versus simulation time is taken for the Network Lifetime as the network performance metric.

4.4 Throughput

Network Throughput is the successful data packets delivery over a data communication channel across the network at a particular time. The throughput can be measured by either in bits per second or in data packets per second. The number of data packets delivery by a particular node in the network versus simulation time is taken for the Throughput as the network performance metric.

5 Results and Discussion

The Cluster based Adaptive Efficient Power Aware Routing (CAEPAR) protocol was developed using NS 2.29 Network Simulator. For the simulation, 50 nodes are arranged in different clusters in the simulation area. The channel capacity was set to 1 Mbps for this proposed protocol. Table 1. Shows the Simulation parameters which are used for the simulation.

The screenshot of the CAEPAR simulation is shown in Fig 1. The screenshot consists of base stations, cluster-heads and cluster members which are red, yellow and green color nodes respectively. All nodes are mobile since it is MANET.

Table 1. Simulation Parameters

Number of nodes	50
Area Size	1500x1000
Mobility Model	Random Way Point
Traffic Type	FTP
Bandwidth	1Mbps
Transmit Power	0.5J
Receive Power	0.5J
Initial Battery Power	100J
Packet Size	1500
Communication System	MAC/ IEEE 802.11
Routing Protocols	CAEPAR, LBCAR, CRP, EPAR, MTPR, DSR

When the congestion level of the cluster-head goes up from the threshold value and the residual battery power goes down from the threshold value then the process of cluster-head re-election is taking place then the data communication begin. So the proposed protocol maximizes the network lifetime and minimizes the network routing overhead.

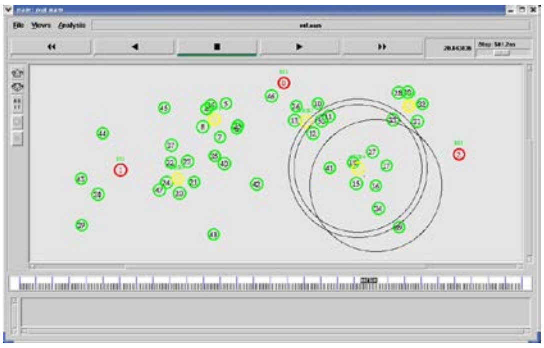

Fig 1. CAEPAR Simulation

The xgraph result of Residual data packets. This result shows that the performance Battery Power of MTPR, EPAR, CRP, LBCAR and CAEPAR in MANET is shown in Fig 2. During the simulation, the Residual Battery Power of MTPR, EPAR, CRP, LBCAR and CAEPAR are having 75J, 85J, 86J, 93J and 96J respectively for sending 860 of CAEPAR is dominating when compared with these existing energy routing protocols.

The xgraph result of the performance of the network in terms of Residual Battery Power of

MTPR, EPAR, CRP, LBCAR and CAEPAR in MANET is shown in Fig 2.

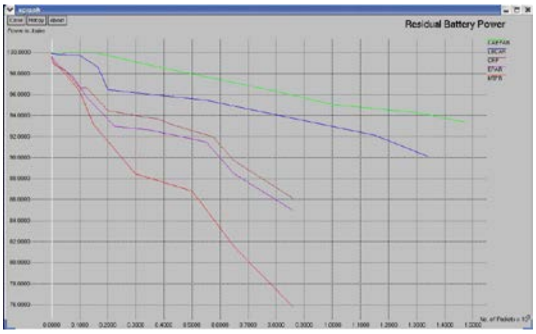

Fig 2. Residual Battery Power

During the simulation, the Residual Battery Power of MTPR, EPAR, CRP, LBCAR and CAEPAR are having 75J, 85J, 86J, 93J and 96J respectively for sending 860 of CAEPAR is dominating when compared with these existing energy routing protocols.

The xgraph result of Network Lifetime of MTPR, EPAR, CRP, LBCAR and CAEPAR in MANET is shown in Fig 3. At the end of the simulation, the

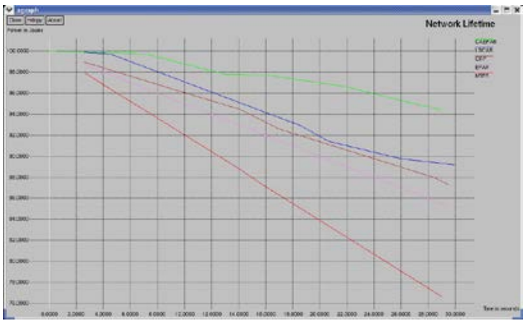

Fig 3. Network Lifetime

Network Lifetime of MTPR, EPAR, CRP, LBCAR and CAEPAR are 76.8J, 85.5J, 89.3J and 94.5J respectively. This proves that the performance of the proposed protocol is excellent when compared with these existing energy routing protocols.

The Battery Power Consumption of the nodes of

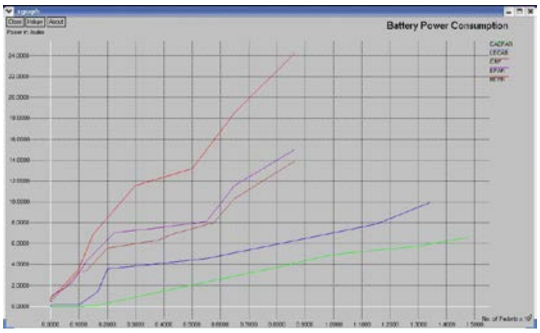

Fig 4. Battery Power Consumption

MTPR, EPAR, CRP, LBCAR and CAEPAR is shown in Fig 4. For sending 860 data packets, the Battery Power consumed by MTPR, EPAR, CRP, LBCAR and CAEPAR is 24J, 15J, 14J, 6J and 4J respectively. This result shows that the proposed protocol consumes less power than that of these existing energy routing protocols.

This shows the efficiency of CAEPAR is excellent. The throughput of MTPR, EPAR, CRP, LBCAR and CAEPAR in MANET is shown in Fig 5. During the simulation, the throughput of the energy routing protocols is almost same because

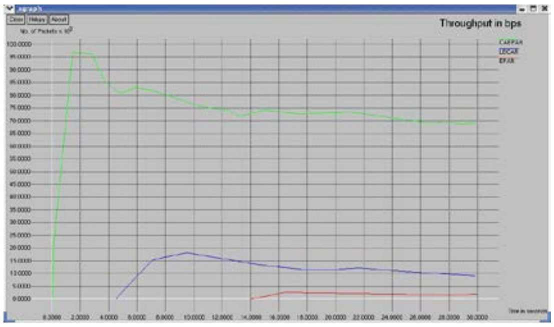

Fig 5. Throughput

these protocols mainly concentrating the energy efficiency of MANET. But in the case of Congestion adaptive energy routing protocols, the throughput of LBCAR is more than that of CRP.

So the proposed protocol is compared with LBCAR and EPAR during the analysis. At 30s, the throughput of EPAR, LBCAR and CAEPAR is 4000bps, 9000bps and 69000bps respectively. This xgraph result shows that the efficiency of CAEPAR is dominating and outperforms when compared with EPAR and LBCAR.

After analyzing these results, the performance and efficiency of CAEPAR is excellent when compared with LBCAR, CRP, EPAR, MTPR and DSR in terms of Residual Battery Power, Battery Power Consumption, Network Lifetime and Throughput.

6 Conclusion

In this paper, a Cluster based Adaptive Efficient Power Aware Routing Protocol (CAEPAR) has designed and developed. CAEPAR was compared with existing energy routing protocols (EPAR, MTPR and DSR) and Congestion adaptive Routing Protocols (LBCAR and CRP). The proposed protocol selects the cluster-head on the basis of lowest congestion level and highest residual battery power of each node in the cluster. During the simulation, CAEPAR selects the route with maximum lifetime and minimum routing overhead in the network. This comparison shows that the efficiency of CAEPAR is dominating and outperforms when compared with LBCAR, CRP, CRP, EPAR, MTPR and DSR in terms of Residual Battery Power, Battery Power Consumption, Network Lifetime and Throughput.

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