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Designing Energy Routing Protocol With Power Consumption Optimization in MANET

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ABSTRACT As technology rapidly increases, diverse sensing and mobility capabilities have become readily available to devices and, consequently, mobile ad hoc networks (MANETs) are being deployed to perform a number of important tasks. In MANET, power aware is important challenge issue to improve the communication energy efficiency at individual nodes. We propose efficient power aware routing (EPAR), a new power aware routing protocol that increases the network lifetime of MANET. In contrast to conventional power aware algorithms, EPAR identifies the capacity of a node not just by its residual battery power, but also by the expected energy spent in reliably forwarding data packets over a specific link. Using a mini-max formulation, EPAR selects the path that has the largest packet capacity at the smallest residual packet transmission capacity. This protocol must be able to handle high mobility of the nodes that often cause changes in the network topology. This paper evaluates three ad hoc network routing protocols (EPAR, MTPR, and DSR) in different network scales, taking into consideration the power consumption. Indeed, our proposed scheme reduces for more than 20% the total energy consumption and decreases the mean delay, especially for high load networks, while achieving a good packet delivery ratio.

INDEX TERMS MANETs, EPAR, DSR, MTPR, residual battery power.

I. INTRODUCTION

Wireless network has become increasingly popular during the past decades. There are two variations of wireless networks-infrastructured and infrastructureless networks. In the former, communications among terminals are established and maintained through centric controllers. Examples include the cellular networks and wireless Local Networks (IEEE802.11). The latter variation is commonly referred to as wireless adhoc network. Such a network is organized in an adhoc manner, where terminals are capable of establishing connections by themselves and communicate with each other in a multi-hop manner without the help of fixed infrastructures. This infrastructureless property makes an ad hoc networks be quickly deployed in a given area and provides robust operation. Example applications include emergency services, disaster recovery, wireless sensor networks and home networking.

Communication has become very important for exchanging information between people from, to anywhere at any time. MANET is group of mobile nodes that form a network independently of any centralized administration. Since those mobile devices are battery operated and extending the battery lifetime has become an important aim. Most of the researchers have recently started to consider power-aware development of efficient protocols for MANETs. As each mobile node in a MANETs performs the routing function for establishing communication among different mobile nodes the "death" of even a few of the nodes due to power exhaustion might cause disconnect of services in the entire MANETs.

So, Mobile nodes in MANETs are battery driven. Thus, they suffer from limited energy level problems. Also the nodes in the network are moving if a node moves out of the radio range of the other node, the link between them is broken. Thus, in such an environment there are two major reasons of a link breakage.

- Node dying of energy exhaustion
- Node moving out of the radio range of its neighboring node.

Applications of MANETs.

- **Military Scenarios:** MANET supports tactical network for military communications and automated battle fields.
- **Rescue Operations:** It provides Disaster recovery, means replacement of fixed infrastructure network in case of environmental disaster.
- **Data Networks:** MANET provides support to the network for the exchange of data between mobile devices.
- **Device Networks:** Device Networks supports the wireless connections between various mobile devices so that they can communicate.
- **Free Internet Connection Sharing:** It also allows us to share the internet with other mobile devices.
- **Sensor Network:** It consists of devices that have capability of sensing, computation and wireless networking. Wireless sensor network combines the power of all three of them, like smoke detectors, electricity, gas and water meters.

II. RELATED RESEARCH WORK

Most of the previous work on routing in wireless ad-hoc networks deals with the problem of finding and maintaining correct routes to the destination during mobility and changing topology [17]–[18]. In [7], the authors presented a simple implementable algorithm which guarantees strong connectivity and assumes limited node range. Shortest path algorithm is used in this strongly connected backbone network. However, the route may not be the minimum energy solution due to the possible omission of the optimal links at the time of the backbone connection network calculation. In [4], the authors developed a dynamic routing algorithm for establishing and maintaining connection-oriented sessions which uses the idea of proactive to cope with the unpredictable topology changes.

A. PROACTIVE ENERGY-AWARE ROUTING

With table-driven routing protocols, each node attempts to maintain consistent [1]–[3] up to date routing information to every other node in the network. This is done in response to changes in the network by having each node update its routing table and propagate the updates to its neighboring nodes. Thus, it is proactive in the sense that when a packet needs to be forwarded the route is already known and can be immediately used. As is the case for wired networks, the routing table is constructed using either link-state or distance vector algorithms containing a list of all the destinations, the next hop, and the number of hops to each destination.

B. REACTIVE ENERGY-AWARE ROUTING

With on-demand driven routing, routes are discovered only when a source node desires them. Route discovery and route maintenance are two main procedures: The route discovery process [4]–[6] involves sending route-request packets from a source to its neighbor nodes, which then forward the request to their neighbors, and so on. Once the route-request reaches the destination node, it responds by uni-casting a route-reply packet back to the source node via the neighbor from which it first received the route-request. When the route-request reaches an intermediate node that has a sufficiently up-to-date route, it stops forwarding and sends a route-reply message back to the source. Once the route is established, some form of route maintenance process maintains it in each node's internal data structure called a route-cache until the destination becomes inaccessible along the route. Note that each node learns the routing paths as time passes not only as a source or an intermediate node but also as an overhearing neighbor node. In contrast to table-driven routing protocols, not all up-to-date routes are maintained at every node. Dynamic Source Routing (DSR) and *Ad-Hoc On-Demand Distance Vector* (AODV) [7], [18] are examples of on-demand driven protocols.

C. DSR PROTOCOL

Through the dynamic source protocol has many advantages [8], [14]; it does have some drawback, which limits its performance in certain scenarios. The various drawbacks of DSR are as follows:- DSR does not support multicasting. The data packet header in DSR consists of all the intermediate route address along with source and destination, thereby decreasing the throughput. DSR sends route reply packets through all routes from where the route request packets came. This increases the available multiple paths for source but at the same time increases the routing packet load of the network. Current specification of DSR does not contain any mechanism for route entry invalidation or route prioritization when faced with a choice of multiple routes. This leads to stale cache entries particularly in high mobility.

D. ENERGY AWARE METRICS

The majority of energy efficient routing protocols [11], [12] for MANET try to reduce energy consumption by means of an energy efficient routing metric, used in routing table computation instead of the minimum-hop metric. This way, a routing protocol can easily introduce energy efficiency in its packet forwarding. These protocols try either to route data through the path with maximum energy bottleneck, or to minimize the end-to-end transmission energy for packets, or a weighted combination of both. A first approach for energy-efficient routing is known as Minimum Transmission Power Routing (MTPR). That mechanism uses a simple energy metric, represented by the total energy consumed to forward the information along the route. This way, MTPR reduces the overall transmission power consumed per packet, but it does not directly affect the lifetime of each node. However, minimizing the transmission energy only differs from shortest hop routing if nodes can adjust transmission power levels, so that multiple short hops are more advantageous, from an energy point of view, than a single long hop.

In the route discovery phase [15], the bandwidth and energy constraints are built in into the DSR route discovery mechanism. In the event of an impending link failure, a repair mechanism is invoked to search for an energy stable alternate path locally.

III. DESIGN AND IMPLEMENTATION

This is one of the more obvious metrics (16)–(17). To conserve energy, there should minimize the amount of energy consumed by all packets traversing from source node to destination node. i.e. we want to know the total amount of energy the packets consumed when it travels from each and every node on the route to the next hop. The energy consumed for one packet is calculated by the equation (1)

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

where, n_i to n_k are nodes in the route while T denotes the energy consumed in transmitting and receiving a packet over one hop. Then we find the minimum E_c for all packets. The main objective of EPAR is to minimize the variance in the remaining energies of all the nodes and thereby prolong the network lifetime.

A. ROUTE DISCOVERY AND MAINTENANCE IN PROPOSED ALGORITHM

EPAR schemes make routing decisions to optimize performance of power or energy related evaluation metrics. The route selections are made solely with regards to performance requirement policies, independent of the underlying ad-hoc routing protocols deployed. Therefore the power aware routing schemes are transferable from one underlying ad hoc routing protocol to another, the observed relative merits and drawbacks remain valid.

There are two routing objectives for minimum total transmission energy and total operational lifetime of the network can be mutually contradictory. For example, when several minimum energy routes share a common node, the battery power of this node will quickly run into depletion, shortening the network lifetime. When choosing a path, the DSR implementation chooses the path with the minimum number of hops [13]. For EPAR, however, the path is chosen based on energy. First, we calculate the battery power for each path, that is, the lowest hop energy of the path. The path is then selected by choosing the path with the maximum lowest hop energy. For example, consider the following scenario. There are two paths to choose from. The first path contains three hops with energy values 22, 18, and 100, and the second path contains four hops with energy values 40, 25, 45, and 90. The battery power for the first path is 18, while the battery power for the second path is 25. Because 25 is greater than 8, the second path would be chosen.

EPAR algorithm is an on demand source routing protocol that uses battery lifetime prediction. In Fig. 1, DSR selects the shortest path AEFD or AECD and MTPR selects minimum power route path AEFD. But proposed EPAR selects ABCD only, because that selected path has the maximum lifetime of the network (1000s). It increases the network lifetime of the MANET shown in equation (2). The objective of this routing protocol is to extend the service lifetime of MANET with dynamic topology. This protocol favors the path whose lifetime is maximum. We represent our objective function as follow:

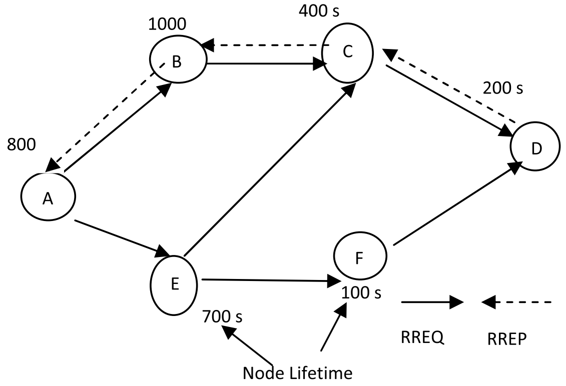

FIGURE 1. **Route discovery and maintenance process in EPAR.**

$$\underset{k}{Max}\,\underset{k}{T}(t) = \underset{i\in k}{Min}\,T_i(t) \tag{2}$$

where, $T_k(t)$ = lifetime of path , $T_i(t)$ = predicted lifetime of node i in path k.

Proof:

1. $T_k(0) = Min\ T\underset{i\in k}{_i}\ (0) = Min(T_A(0), T_B(0), T_C(0), T_D(0))$
   $T_k(0) = Min\ \underset{i\in k}{T_i}(0) = Min(800, 1000, 400, 200) = 200$
2. $T_k(0) = Min\ T\underset{i\in k}{_i}\ (0) = Min(T_A(0), T_E(0), T_C(0), T_D(0))$
   $T_\pi(0) = Min\underset{i\in k}{T_i}(0) = Min(800, 700, 400, 200) = 200$
3. $T_k(0) = Min\ T\underset{i\in k}{_i}\ (0) = Min(T_A(0), T_E(0), T_F(0), T_D(0))$
   $T_\pi(0) = Min\ \underset{i\in k}{T_i}(0) = Min(800, 700, 100, 200) = 100$

Hence $Max_k Tk(0) = (200, 200, 100) = 200$.

Our approach is a dynamic distributed load balancing approach that avoids power-congested nodes and chooses paths that are lightly loaded. This helps EPAR achieve minimum variance in energy levels of different nodes in the network and maximizes the network lifetime.

B. DATA PACKET FORMAT IN EPAR

The P_t value must be the power that the packet is actually transmitted on the link. If for any reason a node chooses to change the transmit power for hop i, then it must set the P_t value in minimum transmission power (***MTP[i])*** to the actual transmit power. If the new power differs by more than $\boldsymbol{M}_{\mathbf{thresh}}$ then the ***Link Flag*** is set.

Table 1 shows the data packet format for EPAR. The packet includes the DSR fields besides the special fields of EPAR.

TABLE 1. **Data packet format in modified EPAR.**

IP Header	DSR fixed Header	DSR Source Header	DSR source Route Address [1..N]	EPAR Source Route MTP [1…N]	Link Flag	DATA

IV. NETWORK METRICS FOR PROPOSED PROTOCOL PERFORMANCE

A. REMAINING BATTERY POWER

However, remaining battery life $\tau_i = P_i/r_i$ depends on an unknown mobile nodes i, r and consequently, is considered as a random variable. Let T_i be an estimate of the remaining battery life $\tau_i = P_i/r_i$, and $u_i = u(T_i)$ be the *utility* of the battery power at node i. The number of nodes in the network versus the average remaining battery power is considered as the metric to analyze the performance of the protocols in terms of power.

B. POWER CONSUMPTION

The mobile node battery power consumption is mainly due to transmission and reception of data packets. Whenever a node remains active, it consumes power. Even when the node sleepy participating in network, but is in the idle mode waiting for the packets, the battery keeps discharging. The battery power consumption refers to the power spent in calculations that take place in the nodes for routing and other decisions. The number of nodes in the network versus average consumed battery power is considered as a metric.

C. DROPPED PACKETS

The fraction of dropped packets increases as the traffic intensity increases. Therefore, performance at a node is often measured not only in terms of delay, but also in terms of the probability of dropped packets. Dropped packet may be retransmitted on an end-to-end basis in order to ensure that all data are eventually transferred from source to destination. Losses between 5% and 10% of the total packet stream will affect the network performance significantly.

D. NETWORK LIFETIME

It is the time span from the deployment to the instant when the network is considered nonfunctional. When a network should be considered nonfunctional is, however, application-specific. It can be, for example, the instant when the first mobile node dies, a percentage of mobile nodes die, the network partitions, or the loss of coverage occurs. It effects on the whole network performance. If the battery power is high in all the mobile nodes in the MANET, network lifetime is increased.

V. SIMULATION SETUP AND RESULT DISCUSSION

Extensive simulations were conducted using NS-2.33. The simulated network consisted of 120 nodes randomly scattered in a 2000x2000m area at the beginning of the simulation. The tool *setdest* was used to produce mobility scenarios, where nodes are moving at six different uniform speeds ranging between 0 to 10 m/s and a uniform pause time of 10s. Table 2 shows the simulation parameter setting for the protocol evaluation. These were generated using the tool *EPAR..tcl*, with the following parameters.

TABLE 2. Simulation parameters.

Number of nodes	120
Area size	2000×2000
Mobility model	Random Way point
Traffic type	CBR
Channel capacity	2 M bps
Transmit power	0.5 J
Receiver power	0.1j
Idle power	0.01J
Initial energy	7.1 J
Communication system	MAC/IEEE 802.11G
Routing Protocols	DSR,EPAR,MTPR

Fig. 2 shows that the consumed power of networks using EPAR and MTPR decreases significantly when the number of nodes exceeds 60. On the contrary, the consumed power of a network using the DSR protocol increases rapidly whilst that of EPAR based network shows stability with increasing number of nodes.

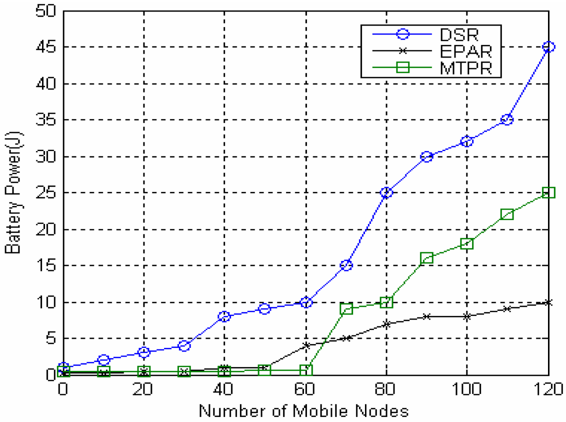

FIGURE 2. Average consumed power versus no.of nodes.

Fig. 3 shows that the end to end delay with respect to pause time of network using MTPR and DSR increases significantly when the pause time exceeds 70secs. On the contrary, the end to end delay operating EPAR protocol increases slowly compared with MTPR based network shows a gentle increase with increasing number of pause time. Observe that EPAR protocol maintenance the stable battery power while calculating the end to end delay.

Fig. 4 shows the throughput of DSR protocol becoming stable when the number of nodes exceeds 60 while the MTPR increases significally. On the other hand the throughput of EPAR increases rapidly when the nodes exceeds 60 with 80% efficiency than MTPR and DSR.

Fig. 5 shows that the DSR protocol becomes inefficient when the network consists of more than 700 traffic size for low density network while for high density network becomes inefficient when the network consist more than 1000 sources.

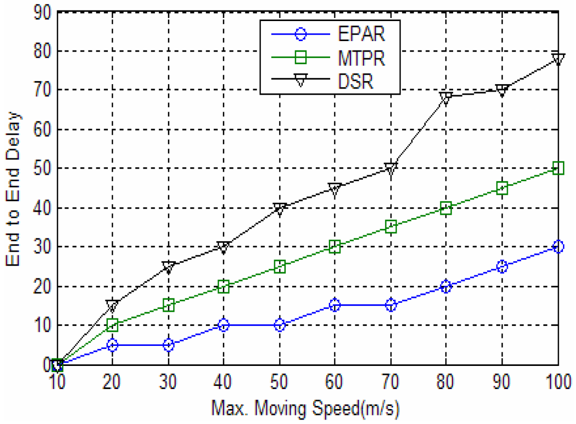

FIGURE 3. End to end delay v/s pause time (moving speed).

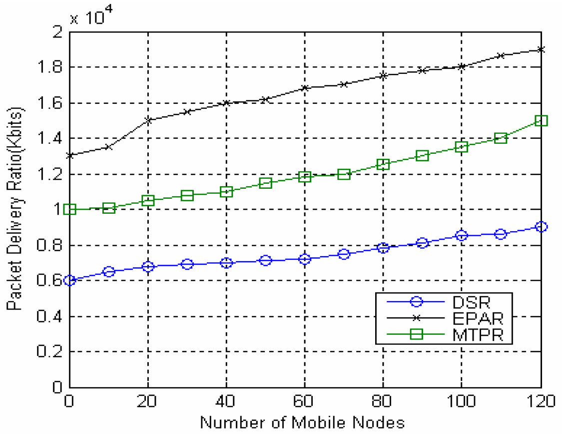

FIGURE 4. Number of nodes versus throughput for 120 nodes.

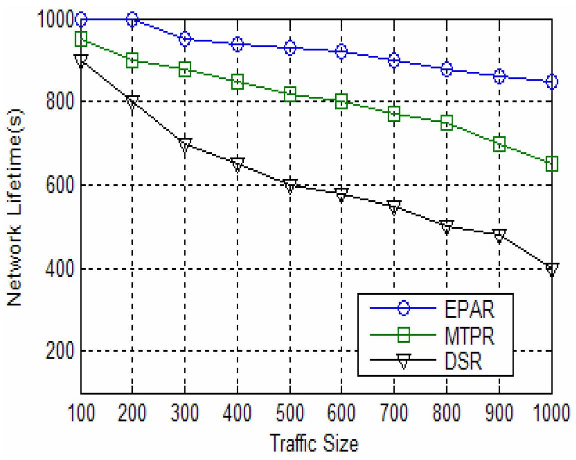

FIGURE 5. N/W lifetime varying with respect network size (traffic load).

EPAR shows the best performance with maximum network lifetime than MTPR and DSR.

Fig. 6 shows the network lifetime as a function of the number of nodes. The life-time decreases as the number of nodes grow; however for a number of nodes greater than 100, the life-time remains almost constant as the number of nodes increases. Lifetime decreases because MANET have to cover more nodes as the number of nodes in the network size increases. we observe that the improvement achieved through EPAR is equal to 85 %. Energy is uniformly drained from all the nodes and hence the network life-time is significantly increased.

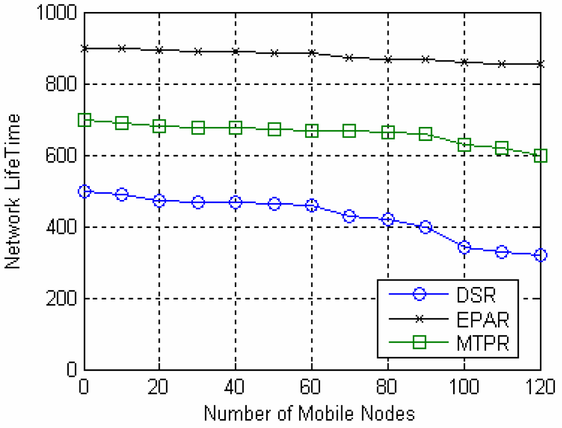

FIGURE 6. Lifetime as the function of the number of nodes.

VI. CONCLUSION

This research paper mainly deals with the problem of maximizing the network lifetime of a MANET, i.e. the time period during which the network is fully working. We presented an original solution called EPAR which is basically an improvement on DSR. This study has evaluated three power-aware adhoc routing protocols in different network environment taking into consideration network lifetime and packet delivery ratio. Overall, the findings show that the energy consumption and throughput in small size networks did not reveal any significant differences. However, for medium and large ad-hoc networks the DSR performance proved to be inefficient in this study. In particular, the performance of EPAR, MTPR and DSR in small size networks was comparable. But in medium and large size networks, the EPAR and MTPR produced good results and the performance of EPAR in terms of throughput is good in all the scenarios that have been investigated. From the various graphs, we can successfully prove that our proposed algorithm quite outperforms the traditional energy efficient algorithms in an obvious way. The EPAR algorithm outperforms the original DSR algorithm by 65%.

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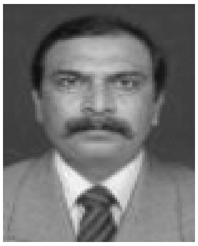

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