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A Survey on Energy Efficient and Reliable Routing For Ad Hoc Wireless Networks to Maximize the Lifetime of Network

Anitha A[1], Karthik R[2]
PG Scholar[1], Assistant Professor[2]
M.E, Department of Computer Science and Engineering
SVS College of Engineering, Coimbatore
Tamil Nadu - India

ABSTRACT

This paper focuses on an in-depth study of energy efficient-routing in ad hoc wireless network. Since the nodes are powered by batteries with limited capacity, energy management of a node and whole network is a critical issue in ad hoc wireless networks. Energy management is an optimization technique, used to maximize the operational lifetime of networks through energy-efficient routing. Various energy efficient routing algorithms are proposed for ad hoc network to improve the life time of network by considering the various parameters such as remaining battery energy, link quality, etc. This paper surveys various proposed energy-efficient routing algorithms and also presents a comparison among them.

Keywords:- Ad Hoc Networks, Energy Aware Routing, Battery Aware Routing, Energy Efficiency, Reliability, End-To-End Retransmission, Hop-By Hop Retransmission.

I. INTRODUCTION

Ad hoc wireless networks have received significant attention in recent years due to their quick and economically less deployment and potential applications such as emergency disaster relief, military and etc. Ad hoc network is type of wireless network that uses multi-hop radio relaying and are capable of operating without any backbone infrastructure. If the communication nodes are close enough, then the communication session is achieved either through a single-hop transmission or relaying by inter-mediate nodes otherwise. In many scenarios, wireless communication protocols design requires two requirements that are Energy efficiency and resilience to packet losses. Management of energy resources has considerable impact on the ad hoc network since the nodes are powered by batteries with limited power. During transmission various factors such as fading, interference, multi-path effects and collisions, lead to heavy loss rates on wireless links, so handling losses in wireless environments entails central importance. Many applications needs end to- end reliability requirement, it is necessary to know how such reliability can be guaranteed in wireless environments in an energy efficient way. In this paper we focus the problem of energy efficient routing in wireless network that appropriately handles packet losses in the wireless environment. Since wireless links are prone to transmission errors, End-to-end reliability on multi hop path is achieved by using retransmission schemes.

A. Retransmission Schemes

- Hop-by-hop retransmissions- lost packet in each hop is retransmitted by the sender when necessary, to ensure link level reliability. Acknowledgements are generated when receiver receives packet correctly
- End-to-end retransmissions- here the retransmissions happen only between end nodes(source and destination), and acknowledgements are generated at destination node

Now a day various routing algorithms have been proposed aiming at increasing reliability, energy-efficiency and the lifetime of wireless ad hoc networks (e.g., [1], [2], [3], [4], [5], [6],[7], [8]). We can broadly group these algorithms into three categories.

The first category includes algorithms that consider the reliability of links to find more reliable routes [e.g., proposed algorithm in [1]. These algorithms found the reliable routes that consist of links requiring less number of packet retransmissions during lost packet recovery. Since they require less number of retransmissions such routes may consume less energy, but they do not necessarily minimize the energy consumption for E2E packet traversal. Furthermore, giving a higher priority for reliability of routes may result in overusing some nodes. The higher reliable links will frequently be used to forward packets than other links. Nodes along with these reliable links will fail quickly, because they have to forward many packets on behalf of other nodes.

The second category includes algorithms that focus on finding energy-efficient routes (e.g., the proposed algorithms in [2], [3], [6], [7]). Even though some of these algorithms (e.g., the proposed algorithms in [6], [7]) address energy-efficiency and reliability together, they do not avoid overuse of nodes since they do consider the remaining battery energy of nodes. And the major drawback of these algorithms is they consider only the transmission power of nodes and do not consider the actual energy consumption of nodes (that is the energy consumed by processing elements of transmitters and receivers) during energy-efficient route discovery. This will negatively affects reliability, energy-efficiency, and the operational lifetime of the network altogether.

The third category includes algorithms that aim to prolong the lifetime of network by finding routes along with the nodes having higher level of battery energy (e.g., the proposed algorithms in [4], [5]). However, these algorithms do not address reliability and energy-efficiency. Since the routes discovered by these algorithms may neither be reliable nor be energy-efficient, this can increase the overall energy consumption in wireless network.

The rest of the paper is structured as follows: Section 2 describes the preliminaries. Section 3 reviews the proposed algorithms. Section 4 presents the comparison among the proposed algorithms. Finally Section 5 presents the conclusion.

II. PRELIMINARIE

B. Communication Model

We consider the topology of multi-hop wireless networks as a graph G = (V, E) where V is the set of nodes and E is the edge set. E (u, v) is a between u and v which means that *u* can send messages to *v* and d (*u*, *v*) is the distance between nodes *u* and *v*. Let us assume R be the maximum range of communication. In given graph $G = (V, E)$, let n be the number of nodes in ad-hoc network and it is defined as $n = |V|$. In network each node is assigned a unique integer identifier between 1 and n. let N (*u*) be the neighbor set of vertex *u*, which is defined as

$$N(u) = \{v \mid (u, v) \in E\} \quad (1)$$

The transmission range of a node $u \in V$ represents the maximum distance between *u* and a node which can be able to receive its broadcast, and it is denoted by $r(u)$ with $0 \le r(u) \le R$

C. Energy Model

When transmitting a message between sender and receiver, the energy consumption of network interface is calculated by using the range of the sender *u* and it is defined as:

$$E(u) = r(u)^{\wedge}\alpha \quad (2)$$

where r(u) is transmission range and $\alpha \geq 2$.

In particularly, thereby some more energy is needed for MAC control messages and overheads due to signal processing. Herewith a constant *c* is added to the previous equation. The common energy consumption formula is defined as:

$$E(u) = (r(u)^{\wedge}\alpha) + c \quad (3)$$

where c is a constant.

The remaining battery energy of node u ∈ V is symbolized by C_u. let as assume C_{th} be the threshold energy and it is considered to be zero. The node is considered to be dead when the battery energy of a node falls below a threshold C_{th}.

As a fundamental requirement for energy-efficient routing, we assume that each node can adjust its own power level, *i.e.* each node support adjustable transmission range. A transmission range allocation on the vertices in *V* is a function: $r \rightarrow V$ in an real interval [0, *R*] where *R* is the maximum transmission range of nodes. The transmission range at each node u ∈ V has finite number of possible values meaning that *r* is a function into a finite subset of R. while maintaining the connectivity of the graph, each node in wireless network has to reduce its transmission range. The amount of total power consumption is given by the following formula:

$$E = \sum_{(u \in V)} (E(u)) \quad (4)$$

where E is total power consumption and E(u) is the power consumption of node u.

D. Energy-Efficient Reliable Routing

Energy efficient reliable routing finds the routes which minimize the energy cost for packet traversal. The energy cost of a route is related to its reliability since larger amount of energy will be consumed per packet due to retransmissions of the packet if routes are less reliable

III. LITERATURE REVIEW

In [4], C. Toh et al. proposed a Conditional Max-Min Battery Capacity Routing (CMMBCR) scheme to maximize the life time of MANET based on the previous work, Max-Min Battery Capacity Routing (MMBCR).

E. Max-Min Battery Capacity Routing (MMBCR)

MMBCR is a power-aware routing algorithm that addressed the problem of increasing the operational life time. MMBCR used Min-Max route selection scheme (it is an algorithm which selects the path that has the highest value for its most critical node). Like Min-Max route selection scheme, MMBCR selects the route whose critical node has the highest residual battery energy. In MMBCR, a cost metric Cp associates with a specific path P is given by

$$C_p = \min\{B_i\} \quad (5)$$

where B_i is the residual battery capacity of node i lies on route P. The path selected by P_{MMBCR} is given by

$$P_{MMBCR} = \max\{C_p\} \quad (6)$$

This scheme can prevent nodes from being overused. This extends the time until the first node powers down and increases the operation time before the network is partitioned. However, these power-aware routing protocols tend to select longer paths, which increase the average relaying load for each node and therefore reduction of average node lifetime

F. *Conditional Max-Min Battery Capacity Routing (CMMBCR)*

To counteract MMBCR, Conditional MMBCR scheme uses minimum energy path if all nodes in the selected routes have sufficient battery capacity else it switches from minimum energy path to MMBCR When the battery capacity for some nodes goes below a predefined threshold. However, both MMBCR and CMMBCR do not take into account the possibility of error probabilities and varying transmission energy costs of links

In [5], A. Misra et al. proposed a power-based route selection algorithm called the Maximum Residual Packet Capacity (MRPC) for energy-efficient routing that increases the operational lifetime of multi-hop wireless networks by considering node specific parameters (e.g. residual battery energy) and link specific parameters (e.g. Channel characteristics of links)

G. *Maximum Residual Packet Capacity (MRPC)*

MRPC identifies the capacity of a node by take into account both residual battery energy and expected energy spent in reliably forwarding a packet over a specific wireless link. Like *MMBCR*, *MRPC* also used Min-Max route selection scheme. MRPC selects the route whose critical node (the one with the smallest residual packet transmission capacity) has the largest packet capacity. Let $C_{i,j}$ be a node-link metric for the link (i, j) and is defined as

$$C_{i,j} = B_i/E_{i,j} \tag{7}$$

where B_i is the residual battery capacity of node and $E_{i.j}$ is the transmission energy required by node i to transmit a packet over the link (i, j). Mathematically speaking, *MRPC* associates with a specific path P, the maximal lifetime (the maximum number of packets that may be potentially forwarded between source and destination over the path P) $Life_p$ given by

$$Life_p = \min \{C_{i,j}\} \tag{8}$$

The path selected by P_{MRPC} is given by

$$P_{MRPC} = \max \{Lifp_p\} \tag{9}$$

H. *Conditional variant of MRPC (CMRPC)*

Conditional MRPC scheme uses minimum energy routing when the $life_p$ associated with the chosen route lies above the specified threshold else it switches from minimum energy routing to MRPC

Though these schemes *(MRPC and CMRPC)* extend the lifetime of the network and transmit a considerably larger number of packets at higher energy efficiency, these will avoid lossy links to improve energy efficiency in the presence of increased network size

In [6], S. Banerjee et al. addressed the issue of energy-efficient reliable wireless transmission in the presence of unreliable or lossy wireless link in multi-hop wireless networks and proposed two centralized algorithms, BAMER and GAMER, one distributed algorithm, DAMER. These algorithms optimally solve the minimum energy reliable communication problem in presence of unreliable links. Let $W_{i,j}$ be the non-negative *weight that* denotes the minimum transmission power required to maintain a realistically good quality link from node i to node j. $N(i,j)$ is the expected number of transmissions of a successful delivery over a link (i,j). $N(i, j)$ is defined as

$$N_{i,j} = 1/(1-Er(i, j) \tag{10}$$

where $Er(i, j)$ is the probability that a transmission over link (i, j), $Er(i, j)=0$ for reliable links.

I. *Basic Algorithm for Minimum Energy Routing (BAMER)*

BAMER is a generalized extension of Dijkstra's shortest path algorithm, which finds minimum energy paths from source to all other nodes in the end-to-end retransmission model. While Dijkstra's shortest path algorithm consider only link weight, BAMER consider both link weight and link error rate

$$C(P(s, v)) = N(u, v) * [C(P(s, u)) + W(u, v)] \tag{11}$$

where C(P (s, v)) is the energy consumption of successfully delivering a packet along that path from s to v and P(s, u) denote the part of P (s, v)

J. *General Algorithm for Minimum Energy Routing (GAMER)*

GAMER is further generalization of BAMER, here each individual link may or may not provide per hop reliability

$$C(P(s, v)) = C(P(s, u)) + N(u, v) * W(u, v) \tag{12}$$

where C(P (s, v)) is the energy consumption of successfully delivering a packet along that path from s to v and P(s, u) denote the part of P (s, v)

K. *Distributed Algorithm for Minimum Energy Routing (DAMER)*

DAMER computes minimum energy paths from each node to every other node in the general mixed retransmission model from each node to every other node. Let M_v be the route exchange message broadcast by node v and R(w) records the expected number of end-to-end transmissions required to deliver a packet from u to w while C(w) records the expected energy consumption to deliver a packet from u to w. Mv.C(w) and Mv.R(w) denote the broadcasting of C(w) and R(w) by node v, respectively. Then the key idea behind *DAMER* is defined as follows

$$C(w) = M_v.C(w) + M_v.R(w) *N(u, v) *W(u, v) \quad (13)$$

Although these algorithms addressed energy-efficiency and reliability together, and finds minimum energy paths in any network configuration, but they do not consider the remaining battery energy of nodes to avoid overuse of nodes and they considered only the transmission power of nodes neglecting the energy consumed by processing elements

In [8], J. Vazifehdan et al. proposed two novel energy aware routing algorithms, called reliable minimum energy cost routing (RMECR) and reliable minimum energy routing (RMER) for ad hoc wireless network to maximize the network operational life time. RMECR is suitable for both the networks with E2E retransmissions providing E2E reliability and hop-by-hop (HBH) retransmissions providing link layer reliability

L. Reliable Minimum Energy Cost Routing (RMECR)

RMECR addressed three important requirements of ad hoc networks that are reliability, energy-efficiency, and prolonging network lifetime. This scheme considered the following ideas while pioneering studies [1], [2], [3], [4], [5], [6], [8] neglected those ideas

- Considered the impact of limited number of retransmission allowed per packet and packet size
- Considered the impact of acknowledgment packets
- Considered energy utilization of processing elements of transmitter and receiver.

RMECR scheme considered the energy utilization, the remaining battery energy of nodes and quality of links to find energy-efficient and reliable paths that increase the operational span of the ad hoc network.

M. Reliable Minimum Energy Routing (RMER)

On the other hand, RMER algorithm finds path which minimizes the total energy required for end-to-end packet traversal. RMER does not take into account the remaining battery energy of nodes, and which is used as a point of reference to study the energy-efficiency of the RMECR algorithm. RMER saves more energy compared to existing energy efficient routing algorithms (e.g., [2], [3], [4], [5], [6], [7]) and also increases the reliability of wireless ad hoc networks.

IV. COMPARISON OF ENERGY EFFICIENT ROUTING PROTOCOLS

In wireless ad hoc network, there are huge numbers of routing protocols using for to the better energy consumption, reliability and operational life time. The table I represents several routing protocols which enable to produce energy efficiency, reliability together. The goal is to maximize the lifetime throughout the network.

Comparison among the energy efficient routing protocols is provided in TABLE I.

TABLE I
ENERGY EFFICIENT ROUTING PROTOCOLS

S.No	***Energy Efficient Routing Protocols***			
	Protocol	***Goals***	***Characteristics***	***Limitations***
1	MMBCR CMMBCR	Maximizing network life time	Spread the transmission cost evenly among available nodes	Does not consider link error probabilities and varying transmission energy costs of link
2	MRPC CMRPC	Maximizing network life time	consider both node specific parameter and link specific parameter	Avoid lossy links to improve energy efficiency in the presence of increased network size
3	BAMER GAMER DAMER	Maximizing energy-efficiency and reliability	Address energy-efficiency and reliability together	Does not consider the remaining battery energy of nodes to avoid overuse of nodes
4	RMER RMECR	Maximizing energy-efficiency, reliability and operational time of network	Address energy efficiency, reliability of links and residual energy of nodes together	Does not reduce over head

In our simulations the network lifetime is defined as the time that the first node failure happens in the network due to battery exhaustion. Achieving a superior network lifetime by a routing algorithm shows its potential to avoid nodes being overused.

Now, we consider RMECR and RMER with HBH retransmissions and maximum residual packet capacity (MRPC) [5] which is similar to RMECR considers both link reliability and battery energy of nodes in route selection but does not consider the lossy links if network size is large. Fig. 1 and Fig. 2 show the comparison of MRPC [5], RMER and RMCER [8] routing algorithms as a function of the mean PDR of links for data packets. Fig. 1 shows that the network lifetime when

RMECR algorithm used is much higher than the network lifetime when RMER because RMER does not consider the lifetime when RMER because RMER does not consider remaining battery energy of nodes. Since RMER considers the link reliability it has higher network life time comparing to MRPC, although MRPC considers battery energy of nodes in routing

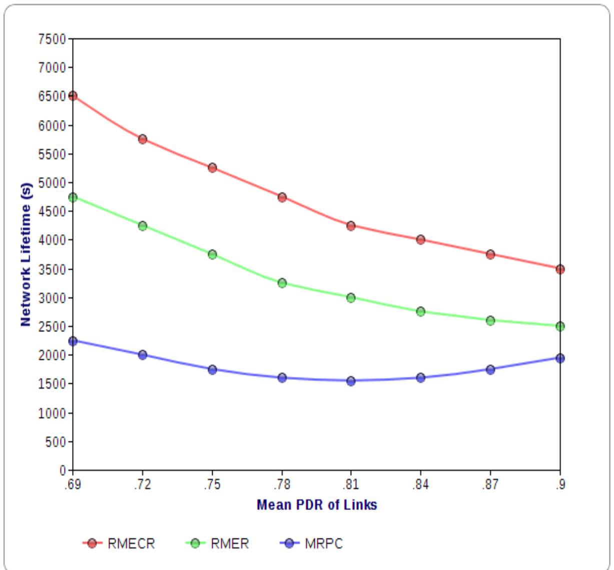

Fig. 1 Average number of packets delivered to destination nodes before the first node failure occurs in the network

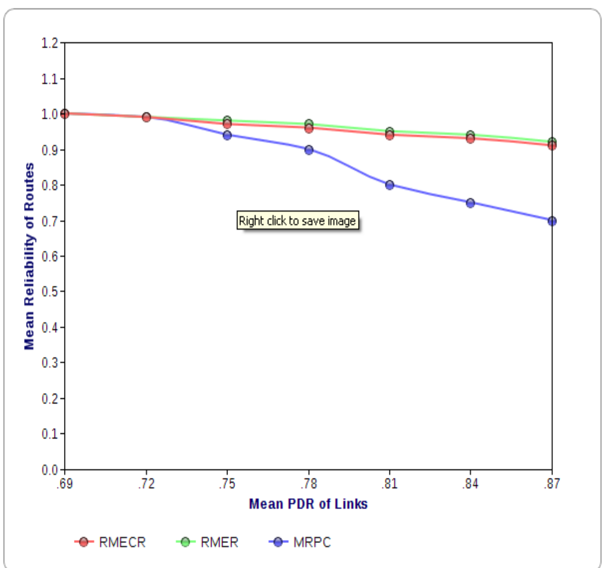

Fig. 2 Average E2E reliability of selected routes

Fig. 2 shows reliability feature of the algorithms. Similar to the RMER algorithm, RMECR is another algorithm used for able to find more reliable routes and also have better results comparing to MRPC

V. CONCLUSION

In this survey we have focused energy efficient and reliable routing protocols for extending operational life time of ad hoc networks. Some proposed schemes related to energy aware routing are summarized and some common drawbacks are detected. The idea of energy-aware routing should be further enriched with the energy overheads associated with signaling and mobility management in ad hoc wireless environments.

REFERENCES

[1] D.S.J. De Couto, D. Aguayo, J. Bicket, and R. Morris, "A High- Throughput Path Metric for Multi-Hop Wireless Routing," Proc. ACM MobiCom, pp. 134-146, 2003.

[2] S. Singh and C. Raghavendra, "PAMAS—Power Aware Multi-Access Protocol with Signalling for Ad Hoc Networks," ACM Computer Comm. Rev., vol. 28, pp. 5-26, 1999.

[3] J. Gomez, A.T. Campbell, M. Naghshineh, and C. Bisdikian,"PARO: Supporting Dynamic Power Controlled Routing in Wireless Ad Hoc Networks," Wireless Networks, vol. 9, no. 5,pp. 443-460, 2003.

[4] C. Toh, "Maximum Battery Life Routing to Support Ubiquitous Mobile Computing in Wireless Ad Hoc Networks," IEEE Comm. Magazine, vol. 39, no. 6, pp. 138-147, June 2001.

[5] A. Misra and S. Banerjee, "MRPC: Maximizing Network Lifetime for Reliable Routing in Wireless Environments," Proc. IEEE Wireless Comm. and Networking Conf. (WCNC '02), pp. 800-806, 2002.

[6] Q. Dong, S. Banerjee, M. Adler, and A. Misra, "Minimum Energy Reliable Paths Using Unreliable Wireless Links," Proc. ACM MobiHoc, pp. 449-459, May 2005.

[7] S. Banerjee and A. Misra, "Minimum Energy Paths for Reliable Communication in Multi-Hop Wireless Networks," Proc. ACM MobiHoc, pp. 146-156, June 2002.

[8] V. Javad, R. Venkatesh, N. Ignas, "Energy-Efficient Reliable Routing Considering Residual Energy in Wireless Ad Hoc Networks",IEEE comm. Trans, on Mobile Computing, vol. 13, no. 2, February 2014.