Reliable Minimum Energy Cost Routing (RMECR) to improve the Lifetime in Wireless Ad Hoc Networks

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Abstract: Due to the today wireless communication devices (PDA's) are low-configured, energy aware routing become an effective cost efficient communication process for on-demand ad hoc networks. In real time these low configured wireless device networks are often fails due to the inefficient energy management. Although many former researchers were concentrated on implementing energy efficient solutions for low configured devices, they are protocol dependent. In this paper we are extending the functionalities of Reliable Minimum Energy Cost Routing (RMECR) and Reliable Minimum Energy Routing (RMER) to make them as generic methodologies. Here we first discuss about RMER and RMECR methodologies in detail and later we explains the way of customizing the RMER and RMECR with other proactive routing protocols in an efficient manner without any architecture incompatibilities. Our research experiments will prove the energy-efficiency improvements with RMER and RMECR along with results comparison.

Keywords: Energy-Efficient routing, Battery-aware routing, end-to-end and hop-by-hop retransmission, reliability and acknowledgement

I. Introduction

Low configured wireless devices become a part in human's life as mobiles, sensors and other PDA's. These devices are widely used for communication and data exchange through respective protocol based applications. As they are low configured resources (battery life, processer time and memory availability etc.) management is an important task for efficient utilization of resources while communication. Energy is a prominent resource for these low-configured devices, whose consumption is highly subjective to routing techniques. Energy efficient routing is the prominent and wide research scoped area in WSN, which saves the energy cost in communication of wireless network nodes. The main aim of energy efficient routing is identifying the shortest paths for communication with longer life nodes to establish the stable connectivity. Although the primary consideration is reliability while routing the nodes, energy efficient routing considers the second priority for energy cost. Efficient implementation of routing methodologies with reliability and energy cost ensures the robust paths with longer connectivity. Figure 1 shows the basic wireless network architecture with a block diagram.

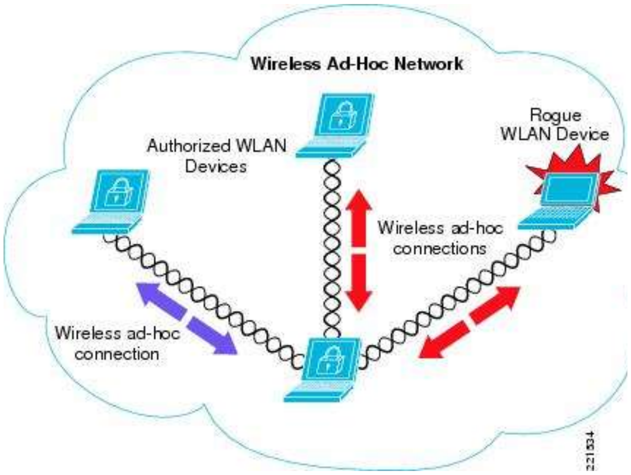

Figure1 Block diagram of Wireless Ad hoc Networks

There are several routing algorithms were introduced by previous research scholars of this area to implement energy efficiency, life time and reliability [1 and 2]. Energy efficient algorithms will ensure the life time of network connectivity by balancing the energy levels of nodes in a streamlined manner. The other two types of algorithms like life time based and reliability considered were not assured the energy efficiency in routing [3]. Due to this the over use of low battery devices may be used frequently by these algorithms in routing cause to link failures [2 and 4] while data transfer. Henceforth we should implement the network routing, which is aware of node battery life to create the stable network connectivity. For this reason we need to concentrate more on energy efficient routing to ensure the robust connectivity and reliability also. Although many researches proposed energy efficient routing, they are having a major drawback is they won't predicate the actual energy consumption [5] of nodes to discover energy efficient routing.

In this paper we are extending the functionalities of Reliable Minimum Energy Cost Routing (RMECR) and Reliable Minimum Energy Routing (RMER) to make them as more efficient and energy aware. These algorithms calculate the actual energy consumption based on current usage and past usage statistics while designing the routing between the given nodes. Our proposed algorithm considers the reliability, life time and energy efficiency in an integrated manner. We implemented the same for WSN routing and represented as Reliable Minimum Energy Cost Routing (MECR) [6] and Reliable Minimum Energy Routing (RMER). Here we first discuss about RMER and RMECR methodologies in detail and later we explains the way of customizing the RMER and RMECR with other proactive routing protocols in an efficient manner without any architecture incompatibilities. We compared our proposed approaches with the existing routing approaches to evaluate the efficiency in terms of energy consumption while transmitting the data over network. Our research experiments will prove the energy-efficiency improvements with RMER and RMECR along with results comparison. In experiments part of our research paper we discuss that in detail.

II. Related work

In this section we discuss about the ad hoc routing in wireless networks and energy efficient network design with energy aware routing. Due to the mobility nature designing the routing in WSN's becomes very difficult due to the position changing frequently. In general while design of routing algorithms all former approaches were concentrated only on shortest path and stability. This kind of routing may fail often due to energy levels consumption or even low in some conditions. Later the world realized that energy is also an important factor, which should be considerable while designing the routing algorithms for protocol development. Apart from the energy is also a considerable metric which makes causes to establish robust connectivity in data transfer.

Current Protocol Metrics

Many previous networking protocols were concerned on shortest path routing are DSDV, TORA, AODV, WRP, ZRP, DARPA etc. Majority of these protocols were concentrated only on shortest path routing only, which alone cannot guarantee the scalability and robustness. SSA and WRP concentrated on link quality along with shortest path, which is important for communication and routing. TORA and DARPA [7] were concentrated on time overheads (delays) in computing the efficient routing for transferring the data packets. AODV initiated clustered packet transfer with acknowledgement and without acknowledgement and reliable link construction with link weights.

Energy efficient metrics

In this energy efficient metrics we will concentrates on battery levels, bandwidth availability, stable links, reliability, mobility etc. The main aim of this energy efficient mechanism is used to develop the routing protocol which considers the shortest path priority in parallel to energy efficient metrics which ensure the reliable data transfer along with shortest paths. Finally, we note that in most cases, link quality and location stability are orthogonal to the goal of power-awareness and therefore can be used in conjunction with the new metrics.

In contrast, energy-aware routing protocols for variable-power scenarios aim to directly minimize the total power consumed over the entire transmission path. PAMAS [9] is one such minimum total transmission energy protocol, where the link cost is set to the transmission power and Dijkstra's shortest path algorithm is used to compute the path that uses the smallest cumulative energy. In the case where nodes can dynamically adjust their power based on the link distance, such a formulation often leads to the formation of a path with a large number of hops. A link cost that includes the receiver power as well is presented in [8]. By using a modified form of the Bellman-Ford algorithm, this approach resulted in the selection of paths with smaller number of hops than PAMAS.

III. Energy-Aware Reliable Routing with RMECR and RMER

In this section we discuss about the RMER and RMECR algorithms to implement the data transfer in E2E network groups. Initially we estimate the cost of energy for the selected path while transmitting the data from source node to destination node.

The energy cost of a path is analyzed in four steps:

1. Analyzing the expected transmission count of data and ACK packets,

2. Analyzing the expected energy cost of a link taking into account the energy cost of retransmissions,

3. Analyzing the E2E reliability of a path,

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4. Formulating the energy cost of a path taking into account the energy cost of links and E2E reliability of the path.

This in-depth analysis of the energy cost lays the foundation for designing RMER and RMECR algorithms for the E2E System. First we designed a generic algorithm to find the Minimum Energy Cost Path (MECP) between the given end points. We adopted the energy cost parameter as considerable metric while designing the algorithm for shortest path finding. Here we customized the Dijkstra's algorithm to co-ordinate the both metrics like shortest path and energy cost. As the energy cost is additive metric, shortest path algorithm can be used to find the MECP for the given end points.

RMECR and RMER Algorithm

In E2E data transfer we calculate and add the weights to the links to formulate the path design in routing of two end nodes. To formulate the link weight in RMCER, let Cu be the remaining battery energy of u and Cv be the remaining battery energy of v. the energy consumed by u to deliver a packet to v is defined by $a_{u;}v(L_{d\text{Þ}})$, and the energy consumed by v for receiving the packet is defined by $b_{u;}v(L_{d\text{Þ}})$.

Steps in RMECR:

Input : source node S and destination node D

- define source and destination
- initiate routing design
- identify the neighbor nodes in intermediate location
- Capture the impact of the quality of links
- Assess the energy levels at each node
- Find the life time and reliability of each node
- Calculate the energy cost and distance
- start routing with cost and distance params
- initiate data transfer

Similar to the HBH system, in the E2E system, the energy cost of a link $a_{u;}v(L_{d\text{Þ}})$ in RMECR is defined as the fraction of the remaining battery energy of the two end nodes consumed to forward a packet across a link. In the E2E system, the energy consumed by the transmitting node to forward a packet of length Ld is $b_{u;}v(L_{d\text{Þ}})$. We can design another generalized version of the Dijkstra's shortest-path routing algorithm for finding MECP for the E2E system.

In the E2E system of RMER, the expected energy cost of path for transferring a data packet from the source node to the destination is the expected energy cost during a single transmission from the source to the destination multiplied by the expected number of times that the source transmits the packet. Here, the problem is not only the dependency of the path cost to the E2E reliability of the forward and reverse paths, but also the dependency of the path cost to the energy cost of the reverse path for transferring ACKs (referred to as downstream-links dependency). In this paper, we propose two heuristic solutions for the E2E system to find MECP using a modified version of Dijkstra's algorithm.

The expected number of times that a data packet of length Ld is transmitted from the source to the destination (including the first transmission) is denoted by NP(Ld). Furthermore, we denote MP(Le) as the expected number of times that an E2E ACK of length Le [bit] is transmitted for the data packet by the destination node. Since E2E retransmissions are to ensure E2E reliability, we assume that the number of E2E retransmissions is large enough.

We name the resulting algorithm RMER, which is an energy-efficient routing algorithm minimizing the total amount of energy consumed to route a packet from a source node to a destination node. Compared to the RMECR, RMER does not consider the remaining battery energy of nodes. We will use RMER as a benchmark algorithm to study the energy-efficiency of RMECR. The RMECR and the RMER algorithms for the HBH system have been summarized.

IV. Simulations and Results Comparison

In this section we discuss about the conducted simulation experiment to prove the efficiency of our proposed routing approach. To implement the simulation of this research we used JAVA as a base platform for simulator implementation. After the design of simulator we transformed the design of our RMECR and RMER as a java program file with extension java. To identify the energy efficient shortest paths for data transmission in our routing approach RMECR, we used Standard Shortest Path Routing algorithm. We started the simulation with 19 active nodes starts from A-S with predefined link weight as shown in figure 4.

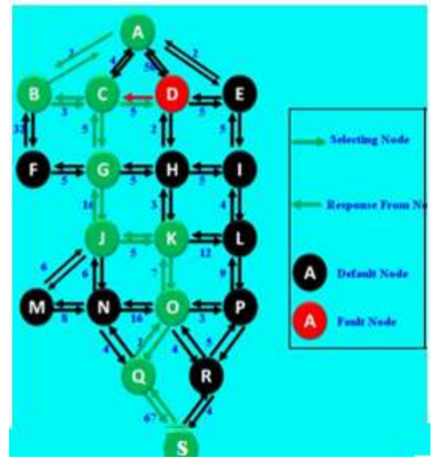
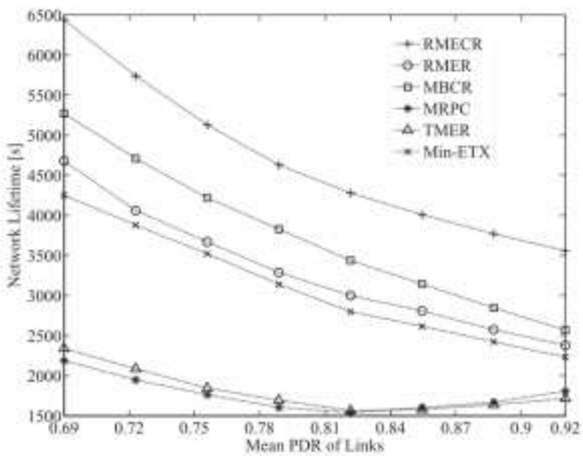


Figure 2 Energy efficient routing of RMECR and RMER algorithms

We applied the RMECR and RMER approaches for efficient routing in wireless ad hoc networks. Initially all the nodes will be in black color and once the routing started each node will be verified in terms of distance, quality of link and cost of path construction to determine which path is better to select among available options. In our experiments, we identified various nodes under various iterations by changing source and sink nodes. In this present case the source is A, and the sink is S, while routing the path between these 2 nodes we encountered the fault node as D. Our RMECR approach declared the D as fault because from C -> D -> H -> K the energy cost to too high than C -> G -> J -> K and energy levels of D is very less compared J and G. Due to this our energy aware routing algorithms decided that use of G is better the D to create a stable connectivity to resist from link failures.



Graph1. RMECR and RMER comparison with other algorithms

At the end we compared our simulation results with the other algorithms like MBCR [5], MRPC [6], TMER [4] and Min-TEX [9] to prove the stability and lifetime of our approach. We compare the reliability and the energy-efficiency of discovered routes by the RMECR algorithm with that of other routing algorithms. We also compare the network lifetime when each of them is deployed in the network. We compare different algorithms in a completely similar setting. We deploy a network randomly in each simulation run. We then create several replicas of the deployed. Simulations results shows from Graph1 that our RMECR and RMER algorithms have the high lifetime of network links than any other approach.

V. Conclusion and Future work

In this paper we considered the concept is energy aware routing in wireless ad hoc networks and proposed two algorithms like RMECR and RMER with energy efficient routing capability. Apart from the traditional properties like distance, time, quality our RMECR and RMER will also considers the energy cost which guarantee's the life time of network. RMECR can increase the operational lifetime of the network using energy-efficient and reliable routes. In the design of RMECR, we used a detailed energy consumption model for packet transfer in wireless ad hoc networks. Experimental simulations also proven that, our RMECR and RMER algorithms have the high lifetime of network links than any other approach.

In future we would like upgrade this algorithms to co-ordinate other minor metrics also to consideration to create a robust network based on routing table past statistics instead of assumptions.

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