A Novel Energy-Link Failure Recovery Routing (E-LFRR) Algorithm for QOS Optimization in Wireless Sensor Network

M. Jayekumar
Department of Electronics and Communication
Manakula Vinayagar Institute of Technology,
Puducherry, India
placement@mvit.edu.in

Dr. V. Nagarajan
Department of Electronics and Communication,
Adhiparasakthi Engineering College,
Melmaruvathur, Tamil Nadu, India
nagarajanece31@gmail.com

Abstract- Wireless Sensor Network (WSN) is a collection of sensor devices capable of sensing and transmitting environmental changes to a common base station (BS) or sink. Energy efficiency and lifetime enhancement is complex in these networks due to lack of centralized control system, data intensive nature and battery limited communications. Several energy preserving techniques including clustering and tree based routing were proposed to overcome energy drain and data handling issues, as a part of optimizing network. The fore said authentication process compromise with Quality of Service (QoS) and increases complexity that ceases the performance of the routing algorithm. We propose an integrated approach for energy optimization and node recovery post failure method, Energy-Link Failure Recovery Routing (E-LFRR) algorithm that utilizes both traditional routing process and specific node selection scheme in an adaptive fashion. E-LFRR monitors node energy level through Monitored Transmission (MT) and pursues communication through Replaced Transmission (RT. E-LFRR intend to minimize early energy drain and uncontrolled broadcasts in the network. Simulation results prove the combined approach minimizes overhead, energy utilization and delay, retains appreciable count of alive nodes and thus improving network performance.

Keywords: WSN, Energy Efficient Routing, Duty Cycle, Link Failure Recovery, Energy Hole, Link Utilization

I. INTRODUCTION

Wireless sensor networks are collection of nodes which monitor physical activities and communicate it to the destination. Sensor nodes have many research issues like Energy, Routing, Security, Localization, etc... Sensor nodes are equipped with battery which has a very limited energy and drains quickly. Due to limited energy, nodes die which leads to network failure so efficient energy conservation is necessary to increase the lifetime of the sensors. To improve network lifetime energy efficient routing has to be considered, that plays a vital role in handling the energy of the nodes. Many algorithms have been designed but fail to provide better solutions in handling the energy of the network. So we have planned to provide better solutions than the existing protocols and algorithms such as GROUP [3] which is based on genetic approach increases network lifetime. EERP [5] which utilizes A star algorithm for identifying shortest path and prolonging network lifetime on the basis of residual energy. EESOR [6] identifies its neighbours on the basis of distance for improving network lifetime and reducing end to end delay. FACOR [7] uses ant colony optimization in collaboration with Fuzzy logic to reduce energy consumption. E2R2 [8] a clustering protocol which resists link failures and improves network lifetime and EEEMRP [10] is based on AOMDV protocol to improve throughput.

II. LITERATURE SURVEY

Alemdar and Ibnkahla [1] have studied various applications of wireless sensor networks and discussed about the research issues. A few challenges that are to be considered before organizing sensors in applications include a) Energy b) Integrated circuits c) Routing d) Distributed signal processing and e) Security. We consider energy, routing and security for our work from the above mentioned research issues.

Qaisar et al., [2] surveyed various communication and networking challenges and recommended integration of Cyber Physical Systems (CPS) and cloud computing technologies with wireless sensor networks applications extend support for environmental monitoring, vehicular and location detection etc.

Chakraborty et al., [3] proposed a genetic approach on routing protocols to identify energy efficient route namely genetic algorithm inspired routing protocol (GROUP). Each chromosome produced in GROUP is evaluated by a fitness function for route selection.

Chen et al., [4] have proposed a population based approach namely Free Search with Double Populations (FSDP) to identify shortest energy consumption path. FSDP functions in three phases namely initialization, exploration and termination to optimize energy consumption of the network.

Ghaffari [5] proposed an energy efficient routing protocol (EERP) using A-Star algorithm to find energy aware shortest path between the source and base station. In this method, a node is discarded from the network if its residual energy falls behind the threshold. Depending on the threshold energy the load is adjusted which extends the network lifetime.

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Devi et al., [6] proposed an energy efficient selective opportunistic routing (EESOR) algorithm based on distance. Each node updates its position and its distance to the source at the time of broadcast. The data forwarding node list is shortlisted and sorted in descending order according to the distance to minimize energy consumption.

Amiri et al., [7] proposed fuzzy ant colony optimization routing (FACOR) that uses forward ants and backward ants for routing. The forward ants moves from source destination; backward ants traverse in the same path as the forward ant, to update routing table and pheromone concentration of the paths. Using fuzzy the optimal route between source and destination is identified.

Sarma et al., [8] proposed a hierarchical clustering protocol named "energy efficient reliable routing" which prolongs network lifetime and fault tolerance. To reduce transmission energy multi hop forwarding is used. In the absence of cluster head the deputy cluster head performs the functions of the cluster head. The base station maintains the routing decision to prevent sensor node to drain energy on routing decision.

Mishra and Kaur [9] have studied various energy efficient neighbour selection algorithms such as flat protocols, data centric protocols, location based protocols and QoS protocols.

Raj and Sumathi [10] proposed an enhanced energy efficient multipath routing based on cuckoo search (EEEMRP). It is an extension of AOMDV based on cuckoo search. It maintains a routing table and if the source fails to receive route reply packets then the entry from the routing table will be removed. Through cuckoo search, the best path is identified with the maximum energy.

Abbasi et al., [11] proposed a localized and distributed algorithm least disruptive topology repair (LeDiR) which detects failure through actor nodes. An actor node periodically transmits messages to its one hop neighbours and if messages are lost then the actor nodes are considered as failure. The identification of faulty actor nodes are done using depth first search algorithm. Reachable nodes are connected after eliminating the failed node that is replaced by its one hop neighbour.

Bakr and Lilien [12] proposed a clustering protocol LEACH-SM which is based on LEACH protocol. LEACH-SM is developed to fulfil the goals of optimal spare node selection, spare node management and lifetime estimation. LEACH-SM improves scalability, reduced transmissions and redundant data.

Rao and Singh [13] proposed a AODV routing with nth backup route (AODV nthBR). AODV nthBR supports source with additional backup route to overcome link failures due to energy drain. After a route node's energy drain, the next neighbour with higher energy is selected for transmission. This improved network lifetime, throughput and minimizes delay.

Naik and Reddy [14] proposed check point route recovery algorithm (CPRRA) with AODV routing protocol to overcome network link failure. Route discovery is ensured by AODV, CPRRA is responsible for failure detection and partial fault node replacement and Network Topology Management is responsible for node replacement. The cooperative process improves network throughput, packet delivery ratio and minimizes delay.

Roy and Sarma [15] have studied energy efficient MAC protocols and tabulated their performances and their drawbacks. DCF, SMAC and TMAC are some of the protocols considered which are compared for energy efficient parameters such as throughput, delay and packet delivery ratio.

III. PROBLEM DEFINITION

Energy Efficient Routing based on clustering and tree approaches increases overhead, energy consumption for Cluster Head (CH) selection process or increases delay due to the gaining entire network knowledge. With respect to overhead and delay, the process energy conservation and network lifetime optimization remains in a trade-off state. To overcome the trade-off issue and to improve the overall network performance, E-LFRR Algorithm is proposed.

IV. PROPOSED METHOD

4.1 Network Model

The wireless sensor network is deployed with 'n' nodes in an X*Y region with multi source multi sink communication. The communications between source and sink node (SN) is multi hop based. Sensor node initiates communication using broadcast, establishes path using control messages. Each sensor node switches between active and sleep states to remain active for longer time.

Transmitting and receiving nodes are said to be in Active State (AS), the contrary are said to be in Sleep State (SS). The network is deployed with few Actuator Nodes (ANs) for monitoring and transmission. AN does not transmit packets when all possible nodes remain above half drain state. AN does not require additional energy as in Relay Nodes (RN). AN is assumed to have lesser mobility. Each node initiates data transfer (d_t) for N transmission cycles. The transmitting nodes are represented as t_n

4.2 Energy-Link Failure Recovery Routing (E-Lfrr) Algorithm

The proposed routing method selects node based on optimal energy availability state; receiving update from the Actuator Node (AN). E-LFRR Algorithm works in two transmission planes: Monitored Transmission Plane (MTP) and Replaced Transmission Plane (RTP).

4.2.1 Monitored Transmission Plane (Mtp)

Initially the source node transmits data through shortest path through its available neighbours to the sink node. One-hop neighbour to the source updates its energy level post transmission to the source node. Indirect neighbour energy levels are monitored and updated to the source by the Actuator Nodes. Active neighbours and the nodes in the current transmission path are moved to transmission enabled

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state called active state. The rest-of-nodes are moved to idle state; the initial method to preserve unnecessary energy drain of unused nodes as per duty-cycle process [16], [17].

In a duty cycle process, an inactive node is moved to sleep state (s) to prevent energy drain. The nodes in active state (a) will be utilized for transmission. The Energy consumption (E) of a node [18]-[20] is given by Eq. (1)

$$E = E_{tx} + E_{rx} + E_s + E_l \quad (1)$$

Where, E_{tx}, E_{rx}, E_s, E_l is the energy utilized for transmission, reception, sleep state and listen state respectively.

Energy utilized by a node for transmission and reception is given by Eq.(2) and Eq.(3)

$$E_{tx} = d_t \times E_{ut} \times t_t \quad (2)$$

$$E_{rx} = d_r \times E_{ur} \times r_t \quad (3)$$

Where, d_t and d_r is the data transfer rate and received rate respectively, t_t and r_t is the transmission time and reception time; E_{ut} and E_{ur} is the energy used for transmission and reception respectively.

AN tracks the link utilization (LU) and Energy Level of the nodes in range. A node on reaching its half drain energy level will be moved to sleep state and a current sleep state in-range neighbour will be replaced, in the path.

Half Energy (H_E) and Residual Energy (R_e) of a node is given by Eq.(4) and Eq.(5)

$$H_E = \frac{E_0}{2} \quad (4)$$

$$R_e = E_0 - E \quad (5)$$

Where, E_0 is the initial energy of the node.

A node, whose half drain is achieved, will be replaced with a current idle state node and the half drain node will be moved to sleep state.

4.2.2 Replaced Transmission Plane (Rtp)

AN prioritizes updates about half energy drain node to the source, recommending change in dispatching nodes. The AN forecasts the alternate active node information to the sender, the sender re-routes further transmissions through next possible path. When the nodes in the alternate path achieve their drain condition, sender initiates multipath concurrent transmissions. On initiating concurrent transmission, the AN monitors the link utilization of the multipath nodes.

Link Utilization (L_U) of a current transmission node [21] is given by Eq. (6)

$$L_U = \frac{d_t}{l_r} \quad (6)$$

l_r is the link transmission rate which is given by Eq. (7)

$$l_r = \left(\frac{lr\max}{E_{tx}}\right) \quad (7)$$

Where, $lr\max$ is the maximum link acceptance rate.

If the number of transmissions are incomplete and the available neighbours in-range to the AN are not capable of transmitting data, the source requests AN to transmit data as a replacement to the low energy level nodes.

V. PERFORMANCE EVALUATION

5.1 *Simulation Parameters*

The performance of E-LFRR algorithm is implemented using Network Simulator-2. Table 1 shows the simulation parameters used for evaluation.

Table I: Simulation Parameters

Parameter	Value
Network Area	1000x1000
Protocol	DSR
No. of Sensor Nodes	100
Network Topology	Flat Grid
IEEE Standard	802.11
Broadcasting Range	250mts
Application Type	CBR
No. of Packets	1500
Initial Energy	10 Joules

5.2 *Comparative Analysis*

The performance of the proposed E-LFRR algorithm is compared with A-Star and Fuzzy integrated Protocol (AF Protocol) and traditional Energy Efficient Routing Protocol (EERP). The network is analyzed in terms of Residual Energy, count of alive nodes, delay and overhead.

5.2.1 *Residual Energy Comparison*

Fig. 2 illustrates the performance analysis of E-LFRR, AF Protocol and EERP with respect to residual energy. In an E-LFRR, duty cycle state Switching helps to prolong the node lifetime. A dead node is replaced by an AN, conserving unwanted energy drain. Therefore, the nodes retain considerable residual energy despite the transmissions. E-LFRR retains 20.5% and 47.83% of residual energy when compared to AF protocol and EERP respectively.

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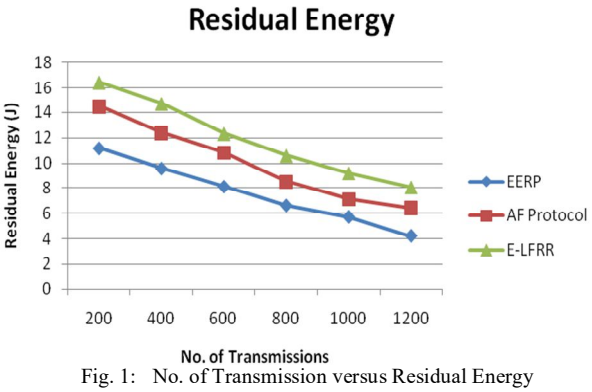


Fig. 1: No. of Transmission versus Residual Energy

5.2.2 *Alive Nodes Comparison*

Fig. 3 shows the count of available active nodes in E-LFRR, AF Protocol and EERP. In E-LFRR, the lifetime of a node is prolonged by a dedicated AN and duty cycle algorithm. Due to dispersed Actuator Nodes, certain lossy node links are replaced, helping the network to increase the count of alive nodes after frequent transmissions. E-LFRR increases the alive nodes in the network by 4.72% and 14.29% compared to AF protocol and EERP.

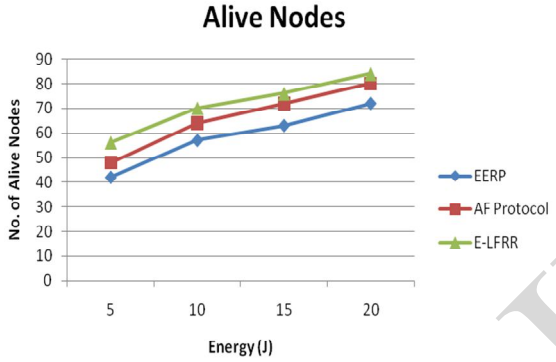


Fig. 2: Energy versus No. of Alive Nodes

5.2.3 *Overhead Comparison*

Fig. 4 shows the overhead observed in the network based on EERP, AF Protocol and E-LFRR Algorithm. The number of control messages generated in E-LFRR is less due to fore hand routing decisions. E-LFRR minimizes overhead by 36.79% and 41.53% when compared to AF protocol and EERP.

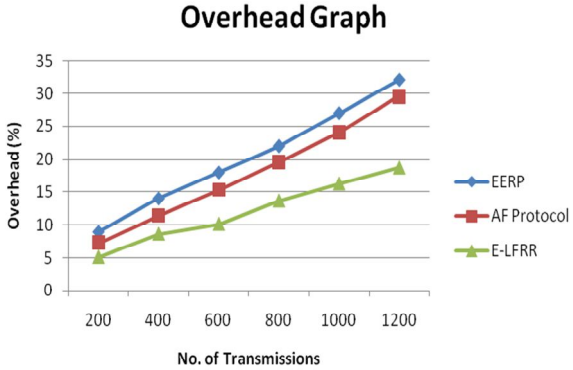


Fig. 3: No. of Transmission versus Overhead

5.2.4 *Delay Comparison*

Fig. 5 illustrates delay observed using EERP, AF Protocol and E-LFRR algorithm. As the number of re-transmisisons and frequency of neighbor selection is high in EERP and AF Protocol, delay is high when compared to E-LFRR. E-LFRR uses multipath to retain throughput and consurrent transmissions to retain delay. When compared to AF protocol and EERP, E-LFRR minimizes delay by 17.422 % and 25.78% respectively.

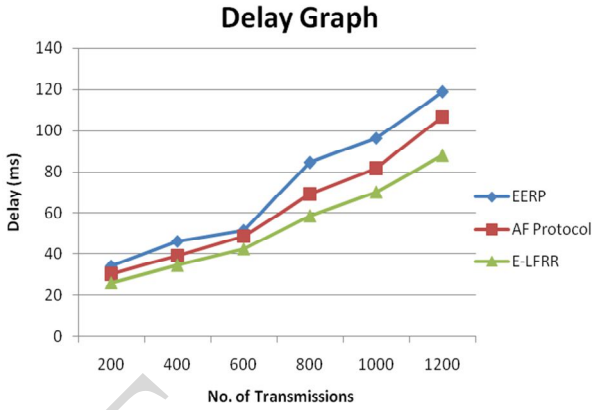


Fig. 4: No. of Transmission versus Delay

VI. CONCLUSION

We propose an energy conservation and link recovery algorithm called Energy-Link Failure Recovery Routing Algorithm. The independent process are integrated with the neighbour selection process based on energy, link utilization for achieving maximum alive nodes in the network and to minimize overhead and energy consumption. The proposed algorithm works under two adaptive modes of transmission with different neighbours/ actuator node. The monitored transmission mode helps in identifying drain nodes at an early stage and the replaced transmission mode utilizes the long time idle actuator node as a replacement for lossy link. The proposed method outwits the traditional and trade-off based optimized techniques in terms of delay, overhead, alive node count and residual energy. The further process of E-LFRR Algorithm is the opportunistic neighbour selection process for energy efficient data gathering that probably optimizes energy and improves data transfer rate.

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