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An Adaptive Energy Efficient Reliable Routing Protocol for Wireless Sensor Networks

M.Riyaz pasha* B.V.Ramana Raju K.Vali Babu
Department of ECE, GPCET Department of ECE, GPCET Department of ECE, GPCET

Abstract— **A reliable routing protocol for wireless sensor networks (WSN) should be capable of adjusting to constantly varying network conditions while conserving maximum power. Existing Routing protocols provide reliability at the cost of high energy consumption. In this paper, we propose to develop an Adaptive Energy Efficient Reliable Routing Protocol (AEERRP) with the aim of keeping the energy consumption low while achieving high reliability. In our proposed protocol, the data forwarding probability is adaptively adjusted based on the measured loss conditions at the sink. So only for high loss rates, a node makes use of high transmission power to arrive at the sink. Whenever the loss rate is low, it adaptively lessens the transmission power. Since the source rebroadcasts the data, until the packet loss is minimized, high data reliability is achieved. By simulation results we show that the proposed protocol achieves high reliability while ensuring low energy consumption and overhead.**

Keywords— Sensor Networks, Reliability, overhead.

I. INTRODUCTION

A. Wireless Sensor Networks

In recent years, the advancement of technologies has resulted in the deployment of minute, low-power, cheap, distributed devices that can be subjected to local processing and wireless communication in a real time [1]. These nodes are referred as sensor nodes. Each sensor node processes to a limited level. But these nodes possess the capability of evaluating a physical environment completely when managed by the particulars obtained from a number of other nodes. Hence, a sensor network can be identified as a set of sensor nodes which organizes to execute certain functions. In comparison the conventional networks the sensor networks rely on dense co-ordination and deployment to perform their functions. Typically, the sensor networks comprise of few sensor nodes that are connected to a central processing station. However, these days the spotlight is on wireless, distributed sensing nodes. The distributed sensor enables a closer allocation as per the phenomenon whereas a single sensor would allow unless the correct location of the specified phenomenon is unknown. The multiple sensor nodes are needed in most of the situations to surmount over environmental hindrances namely obstructions, line of sight constraints etc. Also, the environment under supervision does not possess an infrastructure for energy or communication. It is very essential that the sensor nodes have to persist on minute, finite energy sources and communicate by means of a wireless communication channel.

Sensor networks are applied in a number of ways in several areas. For instance, it consist of environmental monitoring – that includes examining air, soil and water, condition based maintenance, habitat monitoring (estimating the population and behavior of plant and animal species), military surveillance, seismic detection, inventory tracking, smart spaces and so on. In fact sensor networks have the capability of converting a better way to comprehend and assemble complex physical system [1] because of the pervasive nature of micro-sensors.

B. Routing Protocols for Sensor Networks

Routing in sensor networks is difficult for the reason that numerous features distinguish them from the modern communication and wireless ad-hoc networks.

- It is not feasible for constructing a global addressing scheme for the deployment of pure number of sensor nodes. Consequently, classical IP-based protocols cannot be employed to sensor networks
- By contrasting to characteristic communication networks nearly the entire applications of sensor networks necessitates the sensed data flow from multiple regions (sources) to a specific sink.
- Multiple sensors may generate similar data within the adjacent area of a phenomenon and this leads to a main redundancy in the generated data traffic. Such redundancies have to be utilized by the routing protocols to enhance
- Sensor nodes are forcefully bounded in terms of transmission power, processing capacity, onboard

energy, and storage and therefore they necessitate cautious resource management.

- Node failures and packet losses are anticipated to be general in several sensor networks. These failures or losses could be for the short-term in nature, for instance because of the temporary wireless interference.

Accordingly, a routing protocol for such challenged networks would be competent of adjusting to constantly varying network conditions while conserving maximum power.

Normally, power save protocols offers two choices to the user based on the broadcast. First, the broadcast can attain a comparatively low latency, if no power save is employed, although at the sacrifice of large energy costs to listen for broadcasts. The second choice is to employ the power save protocol. This option conserves extra energy than the first option; however it possesses high latency which is not suitable to a few applications.

Every single data or request packet is blindly rebroadcasted or forwarded by the other nodes, in the blind flooding which augments the energy utilization and communication overhead. Each mobile node rebroadcasts a packet on the basis of a predetermined forwarding probability p, in the traditional probabilistic broadcast schemes. So as to create rebroadcast decisions, global topological information on the network is not necessary in the probabilistic broadcast schemes. However, general probabilistic methods had concentrated on pure probabilistic state of affairs with comparatively modest inspection on the effects of broadcast algorithms on particular applications namely route discovery.

Routing Protocols can be categorized on the basis of subsequent techniques [2]:

- Flooding protocols such as SPIN [4] ,
- Gradient protocols like Directed Diffusion [5] and GRAB [8] ,
- Clustering protocols namely LEACH [3] and HEED [10]
- Geographic protocols namely GPSR [7], GAF [6] and GEAR [9].

II. Related Work

An easy way to comply with the conference paper Deepak Ganesan et al. [11] has addressed two issues. First, they have defined localized algorithms for the construction of alternate paths. For reasons of robustness and energy-efficiency, sensor network data dissemination mechanisms used localized decisions for path setup and for recovery from failure. They have proposed localized algorithms to compute approximations to the idealized disjoint and braided paths. Second, they have evaluated the relative performance of disjoint and braided multipaths.

Vidhyapriya and Vanathi [12] have proposed an energy efficient adaptive multipath routing technique which utilized multiple paths between source and the sink, adaptive because they have low routing overhead. That protocol was intended to provide a reliable transmission environment with low energy consumption, by efficiently utilizing the energy availability and the received signal strength of the nodes to identify multiple routes to the destination.

Matthew J. Miller and Indranil Gupta [13] have discussed that the devices became more reliant on battery power, it was essential to design energy efficient protocols. In their previous work, they have proposed Probability-Based Broadcast Forwarding (PBBF) to address broadcast power save by allowing users to select a desired tradeoff between energy consumption, latency, and reliability. In their paper they have extended their previous work. They have introduced a parameter that allowed a tradeoff between reliability and packet overhead to give users more options.

Michele Zorzi and Ramesh R. Rao [14] have proposed a novel forwarding technique based on geographical location of the nodes involved and random selection of the relaying node via contention among receivers. They have focused on the multihop performance of such a solution, in terms of average number of hops to reach a destination as a function of the distance and of the average number of available neighbors.

Dandan Liu et al. [15] have considered a distributed and efficient information dissemination and retrieval system for wireless sensor networks. In such a system each sensor node operates autonomously with no central node of control in the network, and it can be a data source (it produces data) as well as a data sink (it consumes data). They have aimed at developing energy efficient protocols that disseminate information sensed at a source node to any other nodes that are interested in the information. They have proposed two protocols, one was based on the quorum scheme and the other was based on the home agent scheme. Their protocols have three advantages: (1) fully distributed. (2) High success rate for data retrieval; (3) capable of dealing with mobile sensors as well as static sensors.

A priority-based multi-path routing protocol (PRIMP) was proposed by Yuzhe Liu and Winston K.G. Seah [16] for sensor networks to offer extended network lifetime and robust network fault tolerance. Extensive simulations have validated that PRIMP exhibits significantly better performance in energy conservation, load-balancing and data delivery than its comparable schemes. Moreover, PRIMP addresses the slow startup issue occurred in datacentric routing schemes.

A reliable energy-efficient routing (REER) protocol was proposed by Min Chen et al. [17] to achieve the goals for dense wireless sensor networks (WSNs). Based on the geographical information, REER’s design harnesses the advantage of high node density and relies on the collective efforts of multiple cooperative nodes to deliver data, without depending on any individual ones. They have initially selected reference nodes (RNs) between source and sink. Then, multiple cooperative nodes (CNs) are selected for each RN. The reliability was attained by cooperative routing: each hop keeps multiple CNs among which any one may receive the broadcast data packet from the upstream hop to forward the data successfully. The distance between two adjacent RNs provides a control knob to trade off robustness, total energy cost and end-to-end data latency.

Zijian Wang et al. [18] have proposed an energy efficient and collision aware (EECA) node-disjoint multipath routing algorithm for wireless sensor networks. With the aid of node position information, the EECA algorithm attempts to find two collision-free routes using constrained and power adjusted flooding and then transmits the data with minimum power needed through power control component of the protocol.

Kavitha, C. and Viswanatha, K.V. [19] have proposed an energy efficient fault-tolerant multipath routing technique which utilized multiple paths between source and the sink. Their protocol was intended to provide a reliable transmission environment with low energy consumption, by efficiently utilizing the energy availability and the available bandwidth of the nodes to identify multiple routes to the destination. To achieve reliability and fault tolerance, their protocol selects reliable paths based on the average reliability rank (ARR) of the paths. Average reliability rank of a path was based on each node's reliability rank (RR), which represents the probability that a node correctly delivers data to the destination. In case the existing route encounters some unexpected link or route failure, their algorithm selects the path with the next highest ARR, from the list of selected paths.

III. Proposed Protocol

A. System Design and Protocol Overview

In this paper, we assume the following sensor network model. Many minute, stationary sensor nodes are deployed over a field. The user acquires the sensing data by means of the stationary sink which communicates within the network. Each event is identified by multiple sensor nodes which are closer and one among them produces the reports as a source. Reports are forwarded over several hops before arriving at the sink owing to the limited radio range. Nodes are competent to tune their transmitting powers to manage how long the transmissions may travel. These power adjustments are able to conserve energy and lessen collisions when it is needed. Sensor nodes endure unpredictable and recurrent failures because of the disturbing environment [8].

In our proposed protocol, we estimate the density of a region by employing the neighborhood information of nodes located in that region. The neighborhood information is obtained using a topology discovery scheme. Based on this, the current number of forwarding nodes is kept in a forward node count (CFN), at each node. If the packet loss ratio at the neighbor of the sink is more than a maximum-threshold value, CFN is incremented adaptively until the loss ratio is less than the maximum threshold value. This guarantees the reliability of data. When the loss ratio value becomes less than the maximum-threshold value, it specifies the successful packet delivery. In this scenario, the FNC is decremented until the CFN is equal to its minimum forwarding node count.

In contrast to existing routing protocols, our protocol is neither single-path nor multi-path; rather each node adapts the paths based on the estimated loss conditions. In this protocol, only for high loss rates, a node makes use of high transmission power to arrive at the sink. Whenever the loss rate is low, it adaptively lessens the transmission power. Since energy consumption is lowered, the network lifetime is maximized. Since the source rebroadcasts the data, until the packet loss is minimized, high data reliability is achieved.

B. Topology Discovery Phase

In this phase, the sink broadcasts a topology discovery (*TOPDIS*) packet in the network. This packet is employed to determine the cost of each forwarding node. A node's cost is defined as the minimum power needed to reach the sink by this node. Thus, the nodes which are nearer to the sink have smaller cost while nodes which are far away from the sink have larger cost. We presume each node can estimate the cost of sending data to its nearby neighbors on the basis of the signal-to-noise-ratio (SINR) of the neighbors. The packets trace the direction of lessening cost to reach the sink. When multiple paths of lessening cost exist, they develop a forwarding mesh. As soon as a topology request packet is sent to all the sensor nodes by the AP, the next phase begins. After acquiring this packet, a node first settles whether it comes from a neighbor or interferer. It makes use of the received signal strength information from its interference model, to fix on the origin of the packet. If the transmitting node occurs to be the next hop of the receiving node, with minimum cost, the receiving node appends its own cost information to the packet and rebroadcasts it. The receiving node maintains an array to store the cost and signal strength of this transmitting node. Once this phase has been completed, the energy efficient forwarding phase begins, which is discussed in the next section

C. Energy Efficient Forwarding

After the topology discovery phase, each node N maintains a Neighbor Information Table (NIT), which contain the fields Node Id, Distance and Cost. Node Id is the id of the neighbor node, Distance is the distance between that node with N and Cost is the power required to send a packet from that node to the sink.

Let N_i, i = 1,2,...n be the neighbors of N . Then N sorts the NLT based on the distances of N_i. (i.e.) the nodes with shortest distance with N are listed first. Each node maintains a forward node count (C_{FN}), which denotes the broadcast or rebroadcast probability.

Initially C_{FN} $[N_k]$ = $C_{FN\ \min}$, for all nodes Nk, k = 1,2,…C_{FN} min is the minimum number of forwarding nodes. Without loss of generality, we can assume that $C_{FN\ \min} = 1$.

The steps involved in the adaptive energy efficient forwarding phase are given below:

1) Suppose N wants to send the collected data to the sink, it attaches its cost to the data packet and broadcast the packet to the nearest neighbors.
2) When a neighbor N1 receives the packet from N , it first checks its cost is less than that of N . If it is less, it further forwards the packet. Otherwise it drops the packet, since N1 is not towards the direction of the sink.
3) When the packet reaches the destination D , it measures the loss ratio (LR), which is the ratio of number of packets dropped and total packets broadcast from the source.
4) Then D sends this LR value as a feed back to the source

5) When N receives this value, it checks the value of LR. It then modifies the value of CFN as

$$C_{FN} = C_{FN} + \gamma \text{ , if } LR > LR \max$$

.Where γ is the minimum increment of decrement count and *LR*max is the maximum threshold value of loss rate

6) It then rebroadcast the data packets with the incremented C_{FN}, so that increasing the reachability of the sink. The total power required to reach the sink is thus calculated based on the cost field of all the nodes in C_{FN}. For example, if $C_{FN} = 4$, then the minimum required power will be 4 * cost of each neighbor node in the NIT.

7) When the rebroadcast packets reach the destination *D* , it again calculates the losses ratio LR and sends back to *N* .

8) It then reassigns the value of C_{FN}, depending on the value of LR. Once $LR < LR \max$, then

$$C_{FN} = C_{FN} + \gamma \text{, until } CFN \geq CFN \min$$

IV. PERFORMANCE EVALUATION

A. Simulation Setup

We evaluate our AEERRP scheme through NS2 simulation. We considered a random network deployed in an area of 500 X 500 m. The number of nodes is varied as 25, 50, 75 and 100. Initially the nodes are placed randomly in the specified area. The sink is assumed to be situated 100 meters away from the above specified area. The initial energy of all the nodes assumed as 5 joules. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. The simulated traffic is CBR with UDP source and sink. All experimental results presented in this section are averages of five runs on different randomly chosen scenarios. The following table summarizes the simulation parameters used.

TABLE I
SIMULATION PARAMETERS

No. of Nodes	25,50,75 and 100
Area Size	500 X 500
Mac	802.11
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512
Transmit Power	0.335w
Receiving Power	0.395w
Idle Power	0.335w
Initial Energy	5 J
Transmission Range	75m

B. Performance Metrics

We compare AEERRP with the extended PBBF [13] scheme**.** We evaluate mainly the performance according to the following metrics.

Control overhead**:** The control overhead is defined as the total number of routing control packets normalized by the total number of received data packets.

Average end-to-end delay**:** The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Average Packet Delivery Ratio**:** It is the ratio of the number .of packets received successfully and the total number of packets transmitted.

Loss Ratio**:** It is the average energy consumption of all nodes in sending, receiving and forward operations.

C. Simulation Results

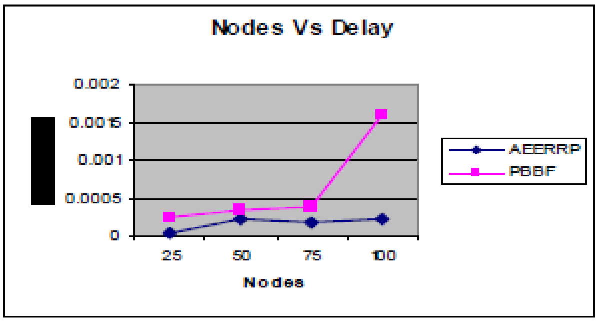

Figure 1. Nodes Vs End-to-End Delay

Figure 1 shows the results of average end-to-end delay for the 25, 50, 75 and 100. From the results, we can see that AEERRP scheme outperforms the PBBF scheme by attaining low delay.

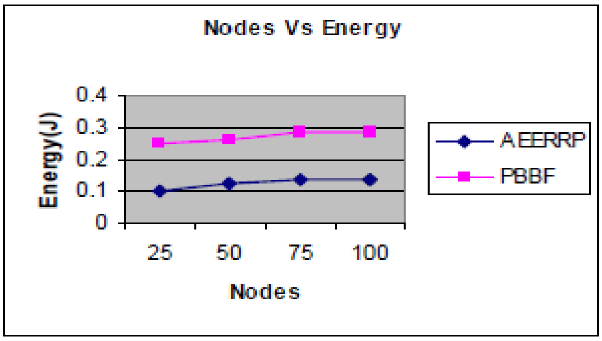

Figure 2. Nodes Vs Energy

Next, we measure the average energy consumption of the network. From Figure 2, we can see that, our AEERRP consumes less energy when compared with the PBBF.

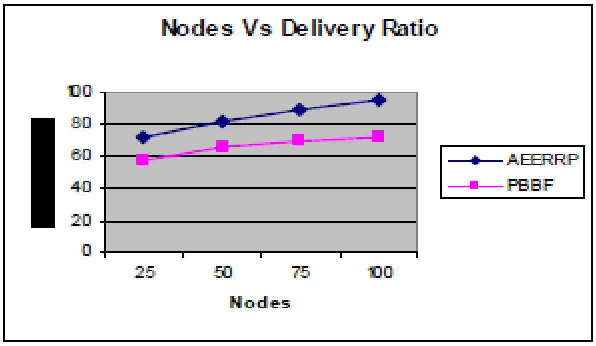

Figure 3. Nodes Vs Delivery Ratio

Figure 3 shows the results of average packet delivery ratio for the nodes 25, 50, .100. Clearly our AEERRP scheme achieves more delivery ratio than the PBBF scheme since it has both reliability features.

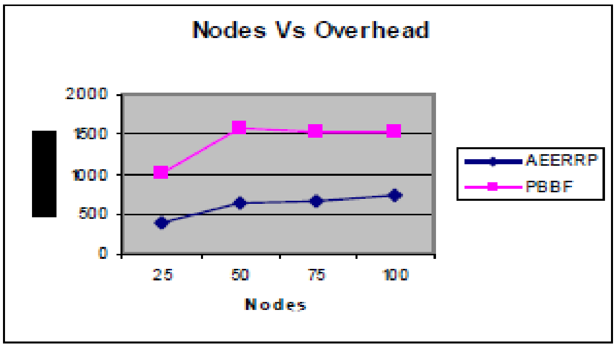

Figure 4.Nodes Vs Overhead

Figure 4 shows the results of routing overhead for the nodes 25, 50, .100. From the results, we can see that AEERRP scheme outperforms the PBBF scheme by attaining low overhead

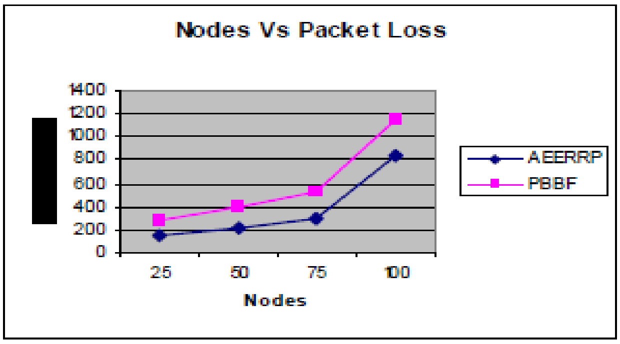

Figure 5. Nodes Vs Packet Loss

Finally, we measure the average packet loss. From Figure5, we can see that, our AEERRP has low packet loss when compared with the PBBF.

V. Conclusion

In order to achieve high data reliability in wireless sensor networks, most of the data forwarding protocols uses blind flooding or probability based broadcast forwarding, at the cost of high energy consumption. In this paper, we have developed an Adaptive Energy Efficient Reliable Routing Protocol (AEERRP) with the aim of keeping the energy consumption low while achieving high reliability. In our proposed protocol, we estimate the density of a region using the neighborhood information of nodes located in that region. The neighborhood information is collected using a topology discovery scheme. The data forwarding probability is adaptively determined based on the measured loss conditions. So only for high loss rates, a node uses high transmission power to reach the sink and whenever the loss rate is low, it adaptively reduces the transmission power. Since the source rebroadcast the data, until the packet loss is minimized, high data reliability is achieved. By simulation results we have shown that the proposed protocol achieves high reliability while ensuring low energy consumption and overhead.

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