Grid Based Multipath Energy Aware Routing Protocol for WSNs

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ABSTRACT: **In wireless sensor networks, the energy of nodes is limited. So designing efficient routing for reducing energy consumption is important. This paper proposed Grid Based Multipath Energy Aware Routing Protocol (GMEAR) for Wireless Sensor Networks. In this paper, the proposed work can conserve energy and provide the best path to route the data according to the probability of more energy available to the sensor node within some defined range and the network area partitioned into grid-by-grid manner with the same size and sensor node are densely deployed in the region. Simulation results by MATLAB show the energy efficient network and prolong the network lifetime as compared to SMEAR.**

Keywords: Data gathering, Energy-balanced routing, Energy efficient, Grid network, Wireless sensor network.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) is an emerging technology with a wide range of potential applications such as patient monitoring systems, earthquake detection, environment monitoring etc. Sensor networks are also being deployed also for military applications, such as navigation, surveillance, security and target tracking management [1]. A wireless sensor networks is a collection of nodes organized into a cooperative network as shown in Fig. 1 consists of components of sensor nodes. WSNs typically consist of small, inexpensive, resource-constrained devices that communicate among each other using a multi-hop wireless network. Each sensor node, has one sensor, embedded processors, limited memory, low power radio and is normally battery operated. Each sensor node of the network is responsible for sensing an event locally which is desired and at end user event is reported which is for relaying a remote event sensed by other sensor nodes. Sensor has limited energy resources and their functionality continues until their energy is drained. Therefore, applications and protocols for WSNs should be carefully designed in terms of energy-efficient manner so that the lifetime of sensor can be longer. The sensing element of a sensor probes the surrounding environment [2]. The components of sensor node are sensing unit, processing unit, transmission unit, power unit which are shown in the Fig.1.

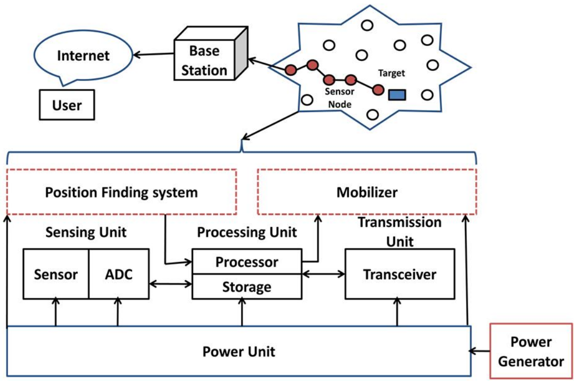

Fig.1 Components of Sensor node

The power saving modes of operation are sensor nodes communicate using shortest paths, the shorter the packets, the more dominance of startup energy, operation in a power saving mode is energy efficient in that case when the time spent in that mode is more than a certain threshold.

The remaining paper is organized as follows: Related work in Section II. Grid based energy aware routing protocol for WSN is discussed in Section III. Deployment of WSN along with the corresponding algorithm describes in Section IV. Simulation results of GMEAR are discussed in Section V. Then at last paper is concluded in Section VI.

II. RELATED WORK

Zhengyu et al in [3] proposed a new energy-aware grid multipath routing protocol in MANET to overcome the shortcoming of on demand unipath routing protocols. Simulation results indicate that this new energy-aware protocol can save energy of mobile hosts and improve data packet delivery ratio.

Shanti et al in [4] worked on an integrated MAC and routing protocol called delay guaranteed routing and MAC (DGRAM) for delay-sensitive WSNs applications. The average delay experienced by packets and the average total energy spent in the network are much lesser in a network using DGRAM than that using FlexiTP or the basic TDMA MAC.

Zhengyu et al in [5] proposed a new routing algorithm called grid-based energy aware node-disjoint multipath routing algorithm (GEANDMRA). Simulation results indicate that GEANDMRA outperforms AODV and DSR.

Banimelhem et al in [6] worked on as a new routing protocol that is grid-based multi-path with congestion avoidance routing (GMCAR) protocol for WSNs that handles real-time and non-real time applications in WSNs is proposed. Simulation results have shown that the proposed protocol has the capability to extend the lifetime of the sensor network and to utilize the available storage.

Zhibin et al in [7] proposed a joint priority-based algorithm (JPA) that eliminates congestion and achieves weighted fairness in multi-path and multi-hop wireless sensor networks and enhance the energy of the network.

Asjad Amin et al in [8] proposed an efficient load sharing routing algorithm to increase lifetime of all sensor node in a way to get maximum efficiency from the network. Simulation is performed to evaluate the performance of proposed algorithm and simulation result clearly indicates an increase in lifetime of a network but a small increase in transmission time is the only drawback of efficient load sharing routing algorithm.

Zayneb et al in [9] proposed an analytical model based on energy consumption analysis to predict the lifetime of IEEE 802.15.4 WSNs. Compared to NS-2 simulation, performance evaluation shows that the predict network lifetime better than other approaches ignoring the energy waste caused by overhearing and collisions due to interference. This analysis proved also the importance of these two parameters essentially in the case of small inter-node distance and heavy traffic cases.

Vijayalakshmi et al in [10] proposed a TDMA-based energy efficient integrated MAC and routing called Slot Management based Energy Aware Routing (SMEAR) which provides deterministic delay guarantee. Traditional TDMA MAC protocols suffer from high latency. This paper compared the performance of the network using SMEAR and without using SMEAR, showed that SMEAR outperforms in terms of energy consumption, number of packets received at the sink and packet reception ratio.

To overcome these shortcomings, a new routing algorithm called Grid Based Multipath Energy Aware Routing Protocol (GMEAR) for Wireless Sensor Networks is proposed.

III. GRID BASED MULTIPATH ENERGY AWARE ROUTING PROTOCOL(GMEAR)

The sensor network field has been divided into grid as shown in Fig 2. The proposed work can conserve energy and provide the best path to route the data according to the probability of more energy available to the sensor node within some defined range and the network area which is partitioned into non-overlapping square zones or grid-by-grid manner with the same size and sensor node are densely deployed in the region.

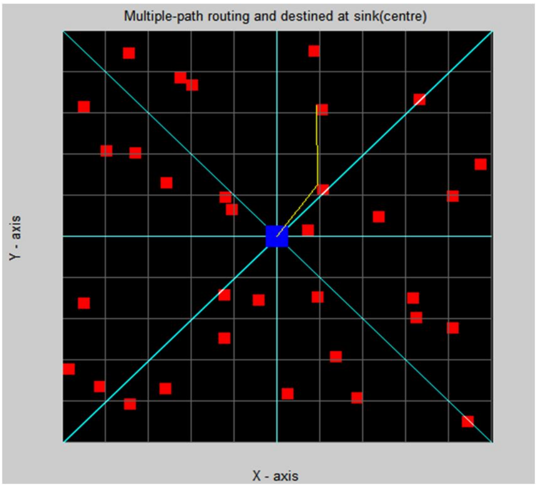

Fig.2 Grid Topology

Routing is performed in a grid-by-grid manner within some defined range and tries to follow the original path (diagonal path) as shown in Fig.2. For each grid, node which is selected has the high probability of energy responsible for forwarding route discovering requests to neighboring grids and propagating data packets to neighboring grid defined by range and then finally data send to sink. Grid Topology is well suited to meet the requirements of resource- constrained wireless sensor networks. The goal is to maintain a connected network using minimum power. The MATLAB is used to achieve the performance improvement in terms of energy efficient and prolong network lifetime.

This paper proposes a TDMA-based energy efficient integrated MAC and routing, called Grid based Energy Aware Routing Protocol (GMEAR) for WSN and compared the performance of the network using GMEAR with SMEAR [10], shows that GMEAR outperforms in terms of energy consumption and network life time.

IV. DEPLOYMENT OF WSN

In WSN, deployment includes Topology, Location of Sensors, Multipath Forwarding Decisions, Proposed (GMEAR) Algorithm.

1. Topology

This paper assumes a grid sensing area and that the sensing area has a sink. The sensor nodes sense the event of interest and transmit these data to the sink using a MAC described in the paper. The nodes are randomly deployed with uniform density all around sink, with the sink at the center of the area as shown in Fig 2. Sensor nodes which are on the diagonal, follow its original path for communication, random nodes, which are deployed in the region, have its own lookup table for routing packets. Each of these nodes has multiple paths for routing. Depending on the energy level of the path, it selects the path and forwards the packets to sink. And also depending on the distance of a node from the sink and the transmission range of the nodes, data have to traverse single or multiple hops before being received by the sink. GMEAR is designed with the following assumptions:

- **i.** The nodes and the sink are stationary.
- **ii.** Each node knows its location relative to the sink.
- **iii.** Each node knows its route relative to the sink
- **iv.** Each node is programmed with the total number of nodes in the network.
- **v.** The sink is at the center of the grid sensing area.

2. Location of the Sensors

GMEAR is most optimal when there is uniform density of sensors in the grid sensing area. One of the main assumptions made above is that each node knows its path with respect to the sink. So that path finding rate has to be reduced. As mentioned before, this can either be achieved by manually programming the sensors with their coordinates or by using some known distributed algorithm [11] [12]. The position of a sensor node is represented in grid coordinates with the sink at the origin as shown in Fig 2.

3. Multipath Forwarding Decisions

Assuming for each node the multiple path exits as one path to send data from source to sink fails it can follow the next path within defined range which sensor node has maximum energy. GMEAR due to multiple path following reduce collision. In order to guarantee the existence of more than one path, one can adjust the transmission power to prolong the network connectivity.

4. Proposed (GMEAR) Algorithm

- Step 1: Create topology.
- Step 2: Select source node (Ns) to transmit.
- Step 3: if Ns is on the diagonal then follow its original path.
- Step 4: else if Ns is in the region then
- Step 5: For each time period check energy of the defined path,
- Step 6: Compute the best path among the possible paths.
- Step 7: end.

5. Performance Metrics

Here considering energy consumption in Joules (J) and the simulation results obtained with the above mentioned simulation parameters are appended in graph. The graphs show comparison between GMEAR and using SMEAR.

5.1 Packet Reception Ratio (PPR)

Packet Reception Ratio is the ratio of the data packets delivered to the destinations to those generated by the sources.

Packet Reception Ratio (PRR) = Total Packets Delivered to destination / Total Packets Generated.
It can be expressed as mathematically [13],

$$P = \frac{1}{C} \sum_{f=1}^{e} \frac{R_f}{N_f} \qquad \text{------ (1)}$$

Where,

C is the total number of flow or connections,
f is the unique flow id serving as index,
P is the fraction of successfully delivered packets,
N_f is the count of packets transmitted to flow f and
R_f is the count of packets received from flow f.

TABLE 1. Simulation Parameters and Settings [10]

PARAMETERS	SETTINGS
No. of Nodes	33
No. of Sources	1
No. of Sink	1
Sink Position	Center of the area
Initial Energy of Nodes	1J
Transmission Energy	0.3J/packet
Reception Energy	0.3J/packet
Propagation Model	Two Ray Ground
MAC Protocol	IEEE 802.15.4
Queue Size	50
Traffic Model	Poisson Traffic
Data Transfer Model	Direct Data Transmission
Packet Size	80
Simulation Area(m*m)	80*80
Data Rate	300 kbps
Single time slot duration	33.33µs

5.2 Remaining Energy in GMEAR

In the network, the calculation of the maximum power consumption of node running on GMEAR and in WSN, power consumption can be because of event transmitting, event sensing reports to the sink and exchanging control information. The power consumed due to event reporting only, since the first component is common to all protocols and the last component is negligible, as control messages are only exchanged one time in GMEAR at the time of deployment of nodes. TDMA has each slot duration is ϕ. The idle time between slots is T_{idle} and the notation used is defined in Table 2. If total time is T [4]

$$T_{idle} = T - \Phi \qquad \text{------ (2)}$$

Node spent maximum energy (E_{Max}) during a single TDMA slot is the energy spent by it when it has no packets to receive or send. If the node is supposed to receive from d nodes, it has to check the channel in the beginning of d slots for a possible transmission.
For this,

$$E_{Min} = d * E_{grx} + E_{idle} \quad \text{------ (3)}$$

Node spent maximum energy (E_{Max}) in a TDMA frame is when it receives in all its d slots and transmits in its slot.

$$E_{Max} = E_{Min} + d * E_{Rx} + E_{Tx} \quad \text{------ (4)}$$

Node consumed maximum power (P_{Max}) over a TDMA frame can be computed as follows:

$$P_{Max} = E_{Max} / T_{frame} \quad \text{------ (5)}$$

Node's remaining energy (P_{re}) can be calculated as follows:

$$P_{re} = P_{in} - P_{Max} \quad \text{------ (6)}$$

TABLE 2. Notations used in Calculation [10]

NOTATION	DEFINITION
ϕ	Single time slot duration
T_{grx}	Duration of channel check at the beginning of a reception slot
T_{idle}	Time duration for which the node is idle
T_{Min}	Maximum lifetime of a node
P_{idle}	Power consumption when the radio is idle
P_{Rx}	Power consumption when the radio is receiving
P_{Tx}	Power consumption when the radio is transmitting
$E_{Rx} = P_{Tx} * \phi$	Energy spent by a node to receive in a single slot
$E_{Tx} = P_{Tx} * \phi$	Energy spent by a node to transmit in a single slot
E_{Max}	Maximum energy spent by a node
E_{Min}	Minimum energy spent by a node
$E_{grx} = P_{Rx} * T_{grx}$	Energy spent in checking the channel at the beginning of a reception slot
$E_{idle} = P_{idle} * T_{idle}$	Energy spent by a radio whereas idle
P_{in}	Initial Energy
P_{Max}	Maximum Energy consumed

5.3 Calculation of packet drop in the sensing area

The worst- case packet drop when no other neighboring node in the defined range and route fails to send the packet to sink.

Packet dropped in the sensing area= Total Packets Generated from source - Total Packets Delivered to destination.

V. SIMULATION RESULTS ANALYSIS (GMEAR)

Simulation results indicate that this new energy aware routing protocol (GMEAR) can save energy and make the network energy efficient, prolong network lifetime as compared to SMEAR [10].

Energy Consumption

The energy consumption of GMEAR is shown in Fig 3. The mechanism of GMEAR guarantees low energy average energy consumption than SMEAR. The energy needed to power up or down the radio of a node in a time interval is fixed because in a TDMA cycle, a node switches on and off for a fixed number of times. This is a good characteristic of GMEAR. SMEAR also has time slot management but as compared to GMEAR, the average energy consumption for routing which is using SMEAR is higher as compared to GMEAR. This can be seen from Fig 3. GMEAR consumes lesser energy, because of the time slot management. Number of collisions and number of packets dropped decreases in time slot management. This increases the network longevity.

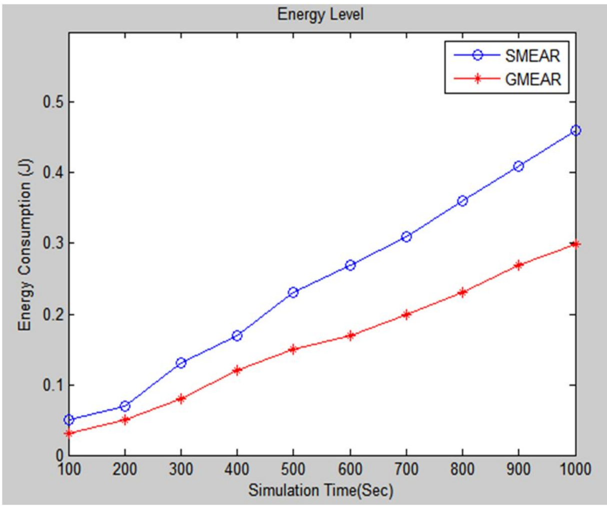

Fig. 3 Comparison of Energy Consumption using GMEAR with SMEAR

VI. CONCLUSION

The comparison of the performance of GMEAR and SMEAR for Ad-hoc networks using MATLAB evaluated. GMEAR is fully self-configuring and slot assignment is done without exchange of any control messages and reduces collision and congestion controlled in an effective and proper manner. The simulation results comparison in between the network with GMEAR and network which is using SMEAR showed that GMEAR routing is a much better choice in terms of performance metrics energy consumption and network lifetime. The performance of GMEAR using grid topology and SMEAR for circular web topology with varying simulation times are given in graph shown above. At particular time slot only some of the nodes are participating for communication, whereas other nodes are in sleep mode. So, it conserves energy. This result shows that, the Timeslot Management Routing algorithm (GMEAR) is energy efficient as compared to SMEAR. At the same time, due to the various time slots, number of collisions at the sink also has been reduced. This result shows that the network is energy efficient.

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