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Energy Efficient Grid Based Routing Protocol

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***Abstract* — In this paper, we propose an Energy efficient Grid-based routing protocol with better delivery ratio routing protocol that is suited for grided sensor networks. We employ the idea of dividing the sensor network field into grids. Inside each grid, one of the sensor nodes is selected as a master node which is responsible for delivering the data generated by any node in that grid and for routing the data received from other master nodes in the neighbour grids. For each master node, paths that connect the master node to the sink are stored as routing entries in the routing table of that node. A congestion avoidance mechanism is proposed in order to relieve the congested areas in case of congestion occurrence. Simulation results show that our proposed protocol has the potential to achieve energy saving, better delivery ratio enhancement when compared to another QoS routing protocol. However, when compared to the basic grid-based coordinated routing protocol, it achieve energy saving. In addition, the proposed protocol shows its superiority in achieving better delivery ratio.**

***Index Terms*— Grid-based, master node, routing table, styling, insert.**

1. INTRODUCTION

Recent advances in wireless sensor networks have led to many new routing protocols specifically designed for sensor networks where energy awareness is an essential design issue. In general, packet routing algorithms are used to exchange messages with sensor nodes that are outside of a particular radio range. This is different to sensors that are within radio range where packets can be transmitted using a single hop.

Furthermore, one hop sensor networks are not recommended in applications due to the energy cost of long range transmissions. Thus came into existence the multi-hop where the data packets are transmitted from source to destination through many intermediate nodes or routers. Nowadays many routing protocols use multi-hopping pattern where it needs less energy cost of short range transmissions. The routing techniques in wireless sensor networks have common objectives of trying to extend the lifetime of sensor network while not compromising data delivery.

Over the past few years, the number of applications that could be implemented using sensor networks is increasing rapidly. This necessitates developing new routing protocols that take into consideration the severe sensor resource constraints. These constraints represent major issues that make the implementation of traditional routing protocols infeasible.

Although an extensive and huge number of energy aware routing protocols have been proposed in the literature, the emergence of real-time applications in WSNs raises new design issues. To explain the requirements of these applications, consider an Air Defence Missile System (like patriot) that uses sensors to detect enemy rockets intrusion. Once a sensor detects an enemy rocket, it reports the event to the sink to launch an interception rocket. Needless to say that time for this application is very critical in order to trigger certain events.

The previous example shows how the routing delay for real-time systems greatly affects the network performance. This encourages the development of new delay aware routing protocols that are designed to deliver the delay sensitive data to the destination before missing the deadlines.

In this paper, we propose an Energy efficient Grid-based routing protocol with better delivery ratio routing protocol that is suited for grided sensor networks. We employ the idea of dividing the sensor network field into grids. Inside each grid, one of the sensor nodes is selected as a master node which is responsible for delivering the data generated by any node in that grid and for routing the data received from other master nodes in the neighbour grids.

2. RELATED WORK

Numerous numbers of QoS protocols have been proposed to address the problem of routing real-time in sensor networks. The proposals common goal is to provide certain end-to-end performance guarantee. This requires the protocols to utilize the available paths in order to select the route that matches packet requirements. Since it is the main reason behind increasing packet delay and reducing network throughput, it is very important also to detect, avoid and handle network congestion.

In this protocol, every node build a neighbour table that will be used later for routing the packets. When a node has packets to forward, the node checks the packet destination and searches the table for the optimum forwarding that has the lowest routing delay and the highest remaining energy. In our case every node is sending data to the sink which collects data from all nodes in the network.

Adaptive Real-time Routing Protocol (ARP) investigates the tradeoff between the real-time transmission and the energy dissipation. The protocol has a specific module that handles the real-time packets only by adjusting their transmission rates. The goal behind incorporating this module into the protocol is to support multi-classes of traffic and saves nodes energy.

MQOSR is another QoS-enabled multipath routing protocol which is based on the assumption that the base stations are typically many orders of magnitude more power than common sensor nodes. MQOSR is an improved version of the Secure and Energy-Efficient Multipath protocol(SEEM)
. While SEEM did not avoid the collision problem that may occur when there are multiple source nodes are sending at the same time, the problem is resolved by MQOSR protocol.

SPEED is a stateless protocol for Real Time Communication in sensor networks . Nodes on SPEED maintain neighbour's information and periodically exchange beacon packets to update these information. Upon detecting a heavily loaded links, SPEED modules cooperate to distribute the traffic and this helps in reducing and even avoiding the congestion. In the case of congestion occurrence, the sender is back pressured to reduce the transmitting rate.

COMUT is a cluster-based congestion control scheme that supports multi-classes of traffic in WSNs. The mechanism is based on self-organizing the network into clusters, where the cluster sentinel periodically monitors congestion within its localized scope. The protocol uses traffic intensity estimation within and across the clusters in order to determine the level of congestion. Upon detecting the congestion, the cluster nodes exchange control information to regulate sensors sending rates. To support multi-classes of traffic, the sensors adjust their sending rates based on the importance of the information being reported. This method requires the cluster head to monitor the traffic intensity information across the cluster and periodically forward it. EQSR is an energy efficient QoS multipath routing protocol. In the proposed protocol, multiple paths are created between the source and the destination during the paths discovery phase. Each path is associated a cost that is function of residual energy, buffer occupancy and SNR for the nodes along the path. The node with the highest remaining energy, lowest buffer occupancy and best interference is chosen as the next hop. EQSR utilizes the available paths in order to support node failure recovery without invoking network-wide flooding for path discovery. For that purpose, the proposed protocol splits up the transmitted message into a number of equal sized segments. Then, a Forward Error Correction (FEC) technique is used in order to generate error correction codes of the same size as the data segment. Then, the data segments and the correction codes are transmitted over multiple paths simultaneously. Moreover, EQSR employs service differentiation by transferring the real-time traffic along the paths that have the minimal end-to-end delay while the higher delay paths are used for forwarding non real-time traffic. EQSR estimates the end-to-end delay of each path using the elapsed time of the control message (called RREQ message) that is used to construct the path. That time is calculated since the transmission of RREQ message from the node's neighbour till it is received by the node itself. When compared with another protocol, simulation results have shown that EQSR achieves lower average delay, more energy savings, and higher delivery ratio.

In fact EQSR and GMCAR protocols have common functionalities. Both are state-based protocols which mean that they have to maintain some kind of routing information as tables in their memory.

Directed diffusion is a data centric protocol that is designed to make use of caching and aggregation to reduce energy consumption in routing sensor nodes information. In its original format, directed diffusion is not designed to route the data generated from delay-sensitive applications. Li et al. proposed a multi-path routing protocol that is based on directed diffusion to route multimedia data in sensor networks. The protocol aims to deliver the multimedia traffic to the destination before missing their deadline; therefore directed diffusion is modified so that multiple disjoint paths are created between the source and the destination. Each path is assigned a cost that is a function of link quality and latency. The path that satisfies the packet delay constraints is

selected as a forwarding candidate.

Basically there are major differences between our proposed protocol and the two aforementioned. Our protocol assumes the existence of several and concurrent traffic-generating sources where creates paths between single source and the sink. When WSN is deployed, hundreds of sensors are deployed in the field, so depending on a single (unreliable) sensor to report the events will not be the best assumption in terms of fault tolerance. Furthermore, when a heterogeneous WSN is deployed to monitor a variety of phenomena, it is likely to find two non-similar events that are being reported concurrently by two non-similar sensors. For these reasons, we believe that we accommodate more *realistic assumptions in developing GMCAR.

It is worth to mention, that the authors of this paper have previously published the idea of GMCAR . However, this paper presents a vast extension and improvement to the old version of the paper in terms of many aspects. The related work section has been enlarged with discussions/comparisons with more recent works appeared in the literature. Also, this version of the paper presents a more sophisticated and detailed study of GMCAR phases and operation. The major elaboration achieved in this paper is the huge extension to the performance analysis section where additional simulation experiments have been conducted to extensively study the performance of GMCAR in terms of energy consumption, delivery ratio.

3. THE PROPOSED PROTOCOL

The main idea of developing an efficient wireless sensor network by dividing them into grids, for each particular grid area, a representative node acts as the leader to transmit the data to other nodes. The leader node however, does not do any aggregation or fusion. Inside each grid, one of the sensor nodes is selected as master node which has the responsibility to deliver data generated by any nodes in that grid and to route data from other master nodes in the neighbor grids. The routing table of master node has diagonal, vertical and horizontal paths that may connect themselves to the sink node and stored as routing entries of that node.

3.1. Protocol Phases

The functionality of the proposed protocol could be divided into three phases: Grids formation phase, building routing tables phase and data transmission phase.

3.1.1. Grid Formation Phase

The sensor nodes are deployed either uniformly or randomly. The terrain where the nodes are deployed is

divided into logical squared-shaped grids of a predefined size. Global Positioning System (GPS) is used to determine to which grid every node belongs. For each non-empty grid, a node is selected to act as the grid master node. This node is responsible for routing the data generated in the grid or received from the neighbour grids. If the grid contains a single Node, that node becomes the master node otherwise the node with the highest ID is selected as the master node. Then, every master node broadcasts its status to the other nodes in the grid. They reply by sending their IDs back to the master node. In order to ensure the connectivity, the maximum grid size must satisfy the relation R where R is the sensor radio range. This ensures that each node is capable of communicating with any node in the same grid or any node in any one of the neighbour grids. An example of a grid sensor network is shown in Fig.1, the sensor field is divided into 16 grids. In the figure, master nodes are shown in filled squares.

3.1.2. Building Routing Table Phase

After forming the grids, the sink initiates a flooding message to enable the master nodes to discover the available paths from each grid to the sink.. The Sink Location can be four possible cases: Sink locates at top left corner,Sink locates at top right corner, Sink locates at bottom left corner, Sink locates at bottom right corner. In our case sink is located at the top left corner of the topology (as in Fig. 1). Grid density is nothing but the total number of nodes in each grid. Grid density is also calculated. The node ID filed records the node ID from which the flooding message is broadcasted. The Master node field determines the master node id for the grid specified by grid ID field. The grid has two types , boundary grids and non-boundary grids. The Hop count (H) field determines the number of hops the grid is far away from the sink. The Grid density records the total number of nodes in the grid.

Assuming that the base station is always located in one of the topology corners; we can differentiate between two types of grids: boundary and non-boundary grids. Boundary grids are those grids that lay on the vertical or horizontal line with the sink, wherein non-boundary grids lay elsewhere. Fig. 2 demonstrates this naming convention. It is evident that determining whether the grid is boundary or not depends on the Sink Location value, thus it is appended to the flooding message to enable master nodes to decide if they belong to a boundary grid or not. Thus the vertical boundary grids IDs are {1, 5, 9, 13} and the horizontal boundary grids IDs are {1, 2, 3, 4}.

So by the end of this phase every master node has the information on vertical grids, horizontal grids, sink location, Routing table to reach sink.

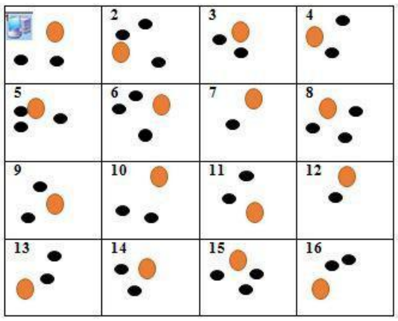

Fig.1. An Example of Grid Sensor Network

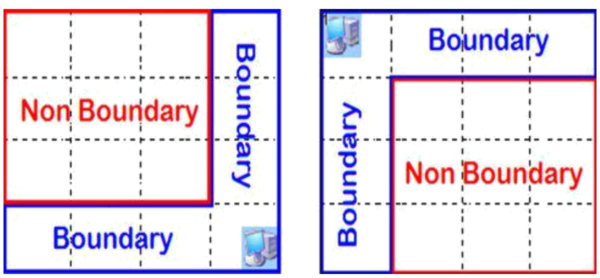

Fig.2. Boundary vs non-boundary grids in 4x4 grid network

Destination Node	Next Hop	Hop count	Density
"52"	"10"	4	3

Table 1. Routing table format at master node of grid 14

3.1.3. Data Transmission phase

After establishing the routing tables, nodes can start transmitting their data to the sink. In any grid, every non master node transmits its data packets to the master node. The master node in turns selects the suitable next master node to forward the data to.

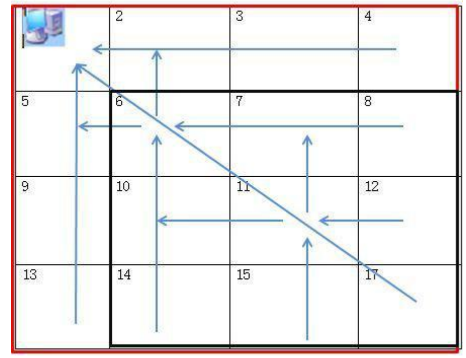

Fig 3. Multi-path routing in grid based network

3.2. Congestion Avoidance

We avoid congestion occurrence by creating parallel vertical and horizontal paths to the sink where the master nodes can distribute the traffic along these paths. Load balancing is used when two of the parallel paths have been used.

4. EXPERIMENTAL RESULTS

Several simulations have been performed to evaluate the performance of our routing protocol. We assume that there is only one stationary sink in the sensor field. A one hundred sensor nodes are deployed over a 800X800 m2 area, with initial energy equal to 50 joules. The area is divided into 16 grids each of 200 m width; thus the minimum acceptable radio range equals to 20 m but we use radio range of 200 m. GPRS system is used initially so that each node knows to which grid it belongs. The MAC layer protocol used in our experiments is distributed coordination function. The complete set of parameters used in our simulation is given in Table 2. We compared our proposed protocol with other two protocols.

4.1. Energy Analysis

Simulation results show that our protocol is superior in saving nodes energy and extending network lifetime. Figure 4 shows average residual energy during different points of simulation time. The energy saving in the proposed protocol comes from the multiple energy aware schemes that are used. First, not all nodes participate in paths establishment phase; just one node per grid broadcasts/receives grid based routing information. Second, non-master node sends any available data to the grid master node, which handle routing. Although this drains master nodes energy it saves grid nodes energy. Third, upon detecting topology changes (such as when a grid becomes empty or when an area became congested) few control messages are exchanged between the involved master nodes without flooding the network with update messages. It's worth to mention that these topology update messages are exchanged on demand not periodically. Forth, the way in which the paths are established (diagonal for non-boundary and vertical/horizontal for boundary) aims to utilize the grids energy evenly. Finally, based on (1) paths going through densely deployed areas are preferential, this help maintaining network connectivity and extending network lifetime.

4.2. Delivery Ratio

Simulation results show that our protocol is superior in delivery ratio and so that number of packets getting received at sink is more compared to other protocol. So the reliability of proposed protocol is more compared to other protocols. Figure 5 shows delivery ratio of the proposed protocol at different point of simulation. It has better delivery ration compared to other protocols.

4.3. Reliability

Delivery ratio of the proposed protocol can be considered as the reliability factor the protocol. Simulation results show it has better delivery ratio compared to other protocol so the chance of packet getting received at destination is quite fair. It shows the reliability of proposed protocol.

Simulation Parameter	Value
Topology size	800x800 m^2
Number of Sensors	52
Deployment Type	Random
Number of grids	16
Grid size	200x200m^2
Radio range	200
Traffic type	Variable bit rate
Data packet size	128 bytes
Initial sensors energy	50 Joules
Energy to run transceiver circuitry	50nJ/bit
Transmit amplifier	100pJ/bit/m^2

Table 2: Parameters used in simulation

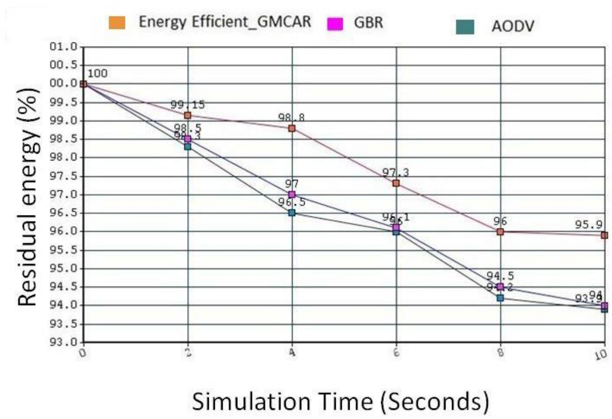

Fig.4. Residual Energy

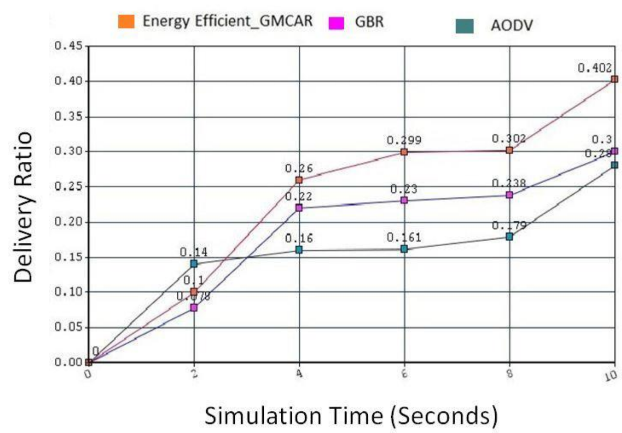

Fig.5. Delivery Ratio

5. CONCLUSION

In this paper, energy efficient Grid Based multipath routing protocol with better delivery ratio is designed to address two main important issues in wireless sensor networks: extending network lifetime and routing real-time traffic. Moreover, to achieve reliability through providing better delivery ratio. Simulation results have shown that our proposed protocol extends the life time of the sensor network and residual energy is more compared to other protocol. At the same time it is reliable through giving better delivery ratio. As a future work, we are planning to study the protocol performance for networks with mobile base and compare GMCAR performance to other cluster based routing protocols.

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