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Energy Efficient Routing Protocol for Wireless Sensor Networks

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Abstract— **Wireless Sensor Networks (WSNs) are composed of large number of nodes referred to as sensors. Sensors are low cost, low-power, multi-functional devices that communicate untethered in short distances. Hence, sensors are resource-low devices equipped with lower processing and transmission capabilities, and less battery life. In WSNs, the collaborative operation of the sensors enables the distributed sensing of a physical phenomenon. After sensors detect an event in the deployment field, the event data is distributive processed and transmitted to other sensor which act as the cluster head, which gather, process, and eventually reconstruct the event data. WSNs can be considered a distributed control system designed to react to sensor information with an effective and timely action. For this reason, in WSNs it is important to provide real-time coordination and communication to guarantee timely execution of the right actions and energy efficiency of the networking protocols is also a major concern, since sensors are resource-constrained devices. We propose an energy efficient routing protocol for wireless sensor networks to cope with these challenges keeping in mind the resource constraints of the network and the early response by the actor nodes for delay sensitive applications with number of transmissions as less as possible. Our protocol is based on clustering (virtual grid) and Voronoi region concept.**

Keywords— **Wireless Sensor Networks, Voronoi Diagram, sensor, clustering**

I. INTRODUCTION

A Wireless Sensor Network (WSN)[1-7] can be considered as a specialized wireless networks with the addition of resource-rich actor nodes that have better processing capabilities, Wireless Sensor Networks (WSNs) have the capability for sensing, processing and wireless communication all built into a tiny embedded device. The primary function of wireless sensor networks is to collect and disseminate critical data that characterize the physical phenomena within the target area. Depending on the application scenario WSNs can be categorized into two main streams: Wireless Scalar Sensor Networks (WSSNs) and Wireless Multimedia Sensor Networks (WMSNs). Sensor nodes cooperatively sense information in the covered region, then the perceived data will be sent to the base station. Wireless sensor networks are self-organized and data-centric. It can be widely used in military, environmental science, health, space exploration, disaster relief and other fields. The sensor nodes are always deployed in the outdoor and even hostile region. Because of the special working environment of wireless sensor networks, the adversary can attack sensor nodes in a variety of ways, for example, they can disturb data collection as well as the network's stability, and cause the user to make the wrong decision. So the security issues need to be resolved immediately for the wireless sensor networks.

A WSN can be generally described as a network of nodes that cooperatively sense and may control the environment enabling interaction between persons or computers and the surrounding environment [8]. On one hand, WSNs enable new applications and thus new possible markets; on the other hand, the design is affected by several constraints that call for new paradigms. In fact, the activity of sensing, processing, and communication under limited amount of energy, ignites a cross-layer design approach typically requiring the joint consideration of distributed signal/data processing, medium access control, and communication protocols [9].

Functionality: The key functionality of a modern sensor node, in addition to sensory data gathering, is the partial processing and transmission of the collected data to the neighboring nodes or to some central facility. A modern node could be considered as a microscopic computer embedding all the units

required for sensing, processing, communicating and storing sensory information, as well as power supply units able to support such operations. The most important units that are present in a sensor node are the following Processing unit: It is responsible not only for processing the collected data, but also for orchestrating the cooperation and synchronization of all other motes units towards realizing the promised functionality.

- Communication unit: It also known as transceiver, that enables motes to communicate with each other for diseminating the gathered sensory data and aggregating them in the sink nodes.
- Power supply unit: It provides power for the operation of such tiny devices. A typical power source does not exceed the 0.5Ah under a voltage of 1.2V and is most commonly a battery or a capacitor.
- Sensor unit: It is responsible for sensing the environment and measuring physical data. Sensors are sensitive electronic circuits turning the analog sensed signals into digital ones by using Analog-to-Digital converters. There is a large variety of sensors available today with the most popular of them being able to sense sounds, light, speed, acceleration, distance, position, angle, pressure, temperature, proximity, electric or magnetic fields, chemicals, and even weather related signals.

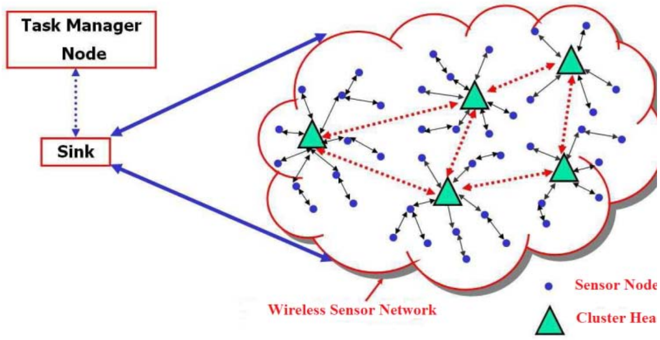

Figure 1: Wireless Sensor Network Architecture.

II. RELAETED WORK

Wireless sensor networks are emerged and useful networks in most of the applications. It has more attention today in the technology innovations.

A. VORONOI DIAGRAM

Voronoi diagram is a most fundamental data structure in computational geometry [11]. Voronoi diagram can be used in finding a partition of the given set of points into subsets whose members are similar. Let S be the set of N nodes on a plane. For two nodes P and Q of S the dominance of P over Q is defined as the subset of the nodes being at least as close to P as to Q. Dominance of P and Q is a closed half plane bounded by the perpendicular bisector of P and Q. The bisector separates all nodes of the plane closer to P from those closer to Q and will be termed as the separator of P and Q. The region of a node P is the portion of the plane lying on all the dominance of P over the remaining nodes in S. They form a polygonal partition of the plane. These partitions are called Voronoi regions and combination of such regions for a plane is referred as Voronoi diagram. As we know that the set A= {a_1, a_2, a_3, ...a_n} of actor nodes are sparsely deployed. It is advisable for each sensor node to report sensed events to the closest actor node in order to reduce latency and communication cost. All the sensors which are closer to an actor a_i than any other actor in the region called Voronoi region at ai, denoted by V(a_i). The Voronoi region V(a_i) is a set of points closer to a_i than any other actor a_j , where $i \neq j$. Union of all Voronoi regions of A is called Voronoi diagram. In other words Voronoi diagram of a set of actors is a partitioning the plane into regions such that each actor node is associated to a region in which all points of that region is closest to it than any other actor node. Formal definition of Voronoi diagram of a set A = { a_1, a_2, a_3, ...a_n } of actors is defined as follows: We denote the set of points closer to a site a_i than the site a_j is denoted by B(a_i, a_j). Voronoi region V (a_i) of a site a_i is

$$\bigcap_{i=1, j\neq 1}^{n} = B(a_i, a_j)$$

Voronoi diagram of the set of points

$$\bigcap_{i=1}^{n} V(a_i)$$

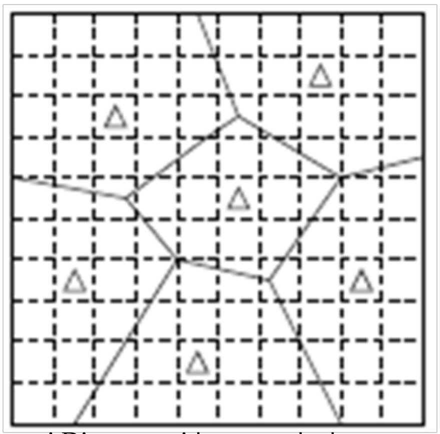

Figure2: Voronoi Diagram with sensor deployment

B. SYSTEM MODELING AND ASSUMPTIONS

In this, we consider the few assumptions for simplicity in the building new protocol for sensor networks.

1. In the network, it composes with N_s Sensors and they are deployed uniformly area with high density of sensor nodes.
2. Every sensor node associates itself to one or more sensors nodes, which are nearer to the sensor nodes.
3. Based on the cluster selection we select the highest energy node as the cluster head.
4. This election process will be generated when the cluster head reach the threshold value T_r.
5. Any new sensor wants register in any of cluster, first it will be in the range of cluster head (that should be up to 3 hops away only)
6. Sensors are homogeneous and wireless channels are bi-directional, symmetric and error-free and equipped with a low data rate radio interface. This interface is used to communicate with other sensor(s), if they are in the communication range of sensors.
7. Sensors nodes are to be static so the data transmission and reception are to be major energy consuming activities.

Many authors have been proposed single-channel [23] [24] [25] MAC (medium access control) protocols for Adhoc networks where all nodes share a common channel in the network. Due to high contentions and collisions, the performance of single-channel MAC protocols degrades quickly with the increase in number of nodes in the network. Recently many Multi-channel MAC protocols for general Adhoc networks have been proposed.

C. SINGLE RADIO SOLUTIONS:

Gang Zhou [1] proposed first multi-channel MAC protocol for Wireless Sensor Networks (WSN). In this protocol author provided four different frequency multi-channels to fulfill the requirements for various applications. To reduce the contention in the time synchronized channel access, a non-uniform back-off algorithm is derived and its lightweight approximation is provided in MMSN. This protocol provides to utilize parallel transmission among neighboring nodes and also achieves high energy efficiency when multiple frequency channels are available. Paramvir Bahl [13] proposed Slotted Seeded Channel Hopping (SSCH) for Capacity Improvement in IEEE 802.11 Ad-Hoc

Wireless Networks. To increase the network capacity, SSCH switches each radio across multiple channels within the transmission range of each other can concurrently occur on orthogonal channels. It is a distributed protocol and does not require synchronization among nodes, suitable in a multi-hop wireless network. ZHANG [14] designed a Cluster-Based Multi-Channel Communications Protocol for VANET. This protocol contains three core mechanisms as Cluster Configuration protocol, Intercluster Communication and Intracluster communication protocol. In Cluster Configuration Protocol, vehicles which are moving in the same direction have form into clusters and a single vehicle will be elected as a cluster-head, while the Intercluster Communication Protocol used to send safety and non safety messages among clusters over two separate IEEE 802.11 MAC-based channels and in Intracluster Coordination and Communication Protocol uses multichannel MAC algorithms for each cluster-head to collect/deliver safety messages from/to cluster-member vehicles using the upstream TDMA/downstream-broadcast method and allocating available data channels to cluster member vehicles for no safety messages.

CMMP: Taeoh Kim [15] proposed a Clustering-Based protocol for Vehicular Adhoc networks. It separates the channels into control and data channels. A vehicle wants to send data to other vehicle then it transmits Request Channel Assignment (RCA) packet using CSMA/CA method to the cluster header to negotiate the usage of data channel and checks the Channel Usage List which is periodically broadcasted by the cluster header to gather information about the available channels. If any data channel is available then vehicle sends its data to the destination otherwise it retransmits its RCA packet. The channel usage list contains the number of channels, data channel each vehicle is using, information about the time when the nodes using this channel will change to use other channel. This protocol has reduced transmission delay and packet loss ratio.

D. MULTI RADIO SOLUTIONS:

Marcel C. Castro [16] proposed a non-static multi-radio/multi-channel MAC Protocol for wireless mesh networks, nodes need to switch channels in order to communicate with different neighbors. Existing schedulers algorithms does not consider priority of the packet, so time sensitive packets are delayed unnecessarily which reduce the quality of service. To overcome this problem in this protocol author designed scheduling algorithm selects the next channel based on the priority of the current channel and the priority of all other channels, which have packets to send, assigned priority to a channel according to the priority of packets which are waiting in queue to be sent for this channel. If packets with different priorities are queued, the highest priority among all packets is used. The currently used channel might not have packets queued. In this case the priorities of packets since the last channel switch are taken into account. A packet's priority is calculated by using DiffServ Code Point. The main aim of scheduling algorithm is to minimize the delay for time sensitive traffic and at the same time providing reasonable throughput for delay-insensitive traffic.

Yong Ding [17] proposed a hybrid multi-channel multi-radio wireless mesh network protocol, where each node has both static and dynamic interfaces. In this paper author presented two protocols an Adaptive Dynamic Channel Allocation protocol which maximize the throughput and reduces delay in the channel assignment and an Interference and Congestion Aware Routing protocol (ICAR) balances the channel usage in the network.

Junaid Ansari [18] presented a dual-radio based medium access control protocol for WSN. It uses high and low frequency bands for data and control, to utilize power efficiently. Later Zhiwu Liu [18] designed a Dynamic Multi-radio Multi-channel (DMMA) MAC Protocol for Wireless Sensor Networks. DMMA uses two radios, control and data radio. Control radio is used to send control message on control channel while data radio is used to transfer data on multiple data channels. This protocol chose the channel dynamically according to the change in spectrum environment, and makes the network more robust to the interferences from external environment. It uses a sleeping-based scheme to reduce power consumption.

E. TRAFFIC-AWARE CHANNEL ASSIGNMENT:

Yafeng Wu [21] designed a Traffic-Aware Channel Assignment in WSN. Each node is assigned a traffic weight based on its future reception data rate and nodes exchange their IDs and traffic weights among two communication hops. After collecting traffic information from two hop neighbors then nodes make channel decisions in the decreasing order of their traffic weight, with smallest node ID used as a tie breaker and beacons the chosen channel within two hops. Later Nessrine Chakchouk [22] proposed an interference and traffic aware multi channel multi radio for WSN, which increases the overall throughput of the network by discarding the interference between the wireless mesh routers. This protocol contains two main phases, in the first phase it performs a joint channel and time scheduling whose aim is to maximize the capacity of active links based on their traffic loads, interference and radio constraints and produces a set of active links, each assigned one time slot and a number of channels. In the second phase it checks the possibility of increasing the radio usage further by assigning more time slots and channels to active links.

III. Energy Efficient Routing Protocol for WSN

In this, mainly this protocol uses two kinds of operation Route discovery and route maintenance. Basically these operations are depends on the available energy information. So it uses control messages, with the help of control messages sensors nodes are find the best possible shortest path for sink node.

A. PROTOCOL DESCRIPTION

The protocol has three different phases. Before we discuss details of the procedure. We will take a look at overview of procedure

A.1 INITIALIZATION PHASE

Sensor nodes are deployed uniformly throughout the network area under consideration. Each node uses location and grid size to determine the grid ID. The estimation of Grid size is also important for reliable connectivity and we have to ensure that the active members in adjacent grids are within transmission range. Active member in adjacent grids must communicate with each other provided they are within their transmission range. If the grid size is too large some active member in adjacent grids may be out of transmission range. This must be avoided so as not to experience early network partition. The upper bound for a square grid with width r is calculated as follows:

$$r \leq \frac{R_c}{2\sqrt{2}}$$

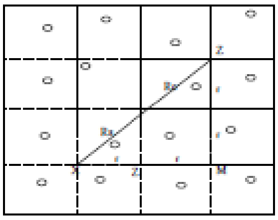

Figure 3; Grid Formation

R_c is the maximum transmit distance, the active member in adjacent grids are within their transmission ranges.

A2. NODE SCHEDULING

Sensor nodes within a grid coordinate and the node having highest energy level becomes active. Each sensor node calculates an expected life time considering maximum utilization of its energy level. After some predefined time interval, every other sensor node of that grid wakes up to receive a message broadcasted by current active sensor node. The broadcasted message contains the nodes remaining life and the next wakeup time for other sensor nodes of that grid. At this moment, if the current active sensor node expected life value is less than a threshold value, the awake sensor nodes remain awake until the next sensor node having highest energy level becomes active and broadcasts its expected life along with the next wake-up time for other sensor nodes.

A3. NEIGHBOR DISCOVERY

Once node scheduling is formed among grid members, the active member in the grid sends HELLO message to one-hop grid neighbors. This hello message including location id, grid-id, rate of energy consumption, fraction of energy consumption. The last two parameters are useful in selecting next hop neighbors while forwarding data to sink.

IV SIMULATION RESULTS

We use the following performance metrics to analyze the performance of our protocol in terms of throughput, packet delivery ratio, average delay and normalized routing overhead.

1. Throughput: Throughput is considered as one of the significant performance metric for any routing protocol. It is computed as the amount of data transferred (in bits) divided by the simulated data transfer time (the time interval from sending the first CBR packet to receiving the last CBR packet).
2. Packet Delivery Ratio: It is measured as the ratio of the number of packets delivered to destination and the number of packets sent by source.
3. Average Delay: Average delay is the ratio of sum total of delay for each packet and the total number of received packets.
4. Average Energy Consumption: The metric is measured as the percent of energy consumed by a node with respect to its initial energy.

1	Simulator	NS-2
2	Simulation time	200sec
3	Simulation Area	200×200
4	Number of Nodes	200
5	Transmission Range	50 meters/sec
6	Grid size	15 meters
7	Traffic Type	CBR
8	Data Payload	128 bytes
9	MAC Layer	802.11
10	Propagation Model Two	RayGround
11	Antenna	Omni-directional

Table 1: Simulation Parameters

During the simulation process we have closely observed the different performance metrics for various CBR intervals ranging from 0.25 seconds up to 2.0 seconds with a step of 0.25 seconds. This is basically the variation of traffic load in the network. Graphs for CBR intervals (traffic load) against all the performance metrics (as mentioned in the above section) were constructed which clearly depicts that our protocol outperforms in all respects. First four graphs are comparing the greedy forwarding vs energy aware greedy forwarding against all performance metrics. Rest graphs are comparing all performance metrics by considering two actors, three actors, four actors. For the all simulation results are taken with initial energy of each sensor node is considered as 25 units and transmission power is 0.6w, receiving power is 0.3w.

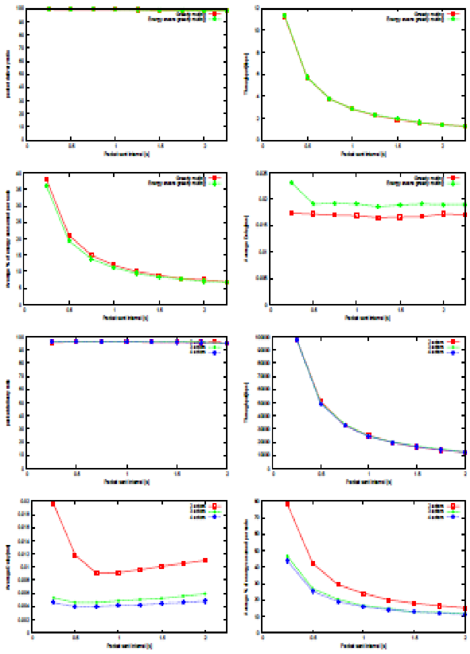

Figure 4: Simulation Results

CONCLUSIONS

The protocol divides the network area into grids and in each grid only one sensor node remains active. Sensor nodes gather event information and send it to nearest actor node based on Voronoi region. The important characteristics like real-time requirements and efficient utilization of available node energy are also taken into consideration. The advantage is that as for each sensor node there is only one closest sensor node based on the Voronoi region, there will be no problem of deciding the actor node to which data needs to be transmitted upon detecting an event which is a major challenge in WSN.

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