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Centralized Hierarchical Routing to minimize Propagation Delay in Wireless Sensor Networks

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ABSTRACT: *WSNs is a collection of wireless nodes with limited energy capabilities that may be mobile or stationary and are located randomly on a dynamically changing environment. The routing strategies selection is an important issue for the efficient delivery of the packets to their destination. Moreover, in such networks, the applied routing strategy should ensure the minimum of the energy consumption and hence maximization of the lifetime of the network. Hierarchical routing architecture divides the whole network in to a group of cluster and only cluster head is responsible to forwarding the data to base station directly or via other cluster heads. During the creation of network topology, the process of setting up routes in WSNs is usually influenced by energy considerations, because the power consumption of a wireless link is proportional to square or even higher order of the distance between the sender and the receiver. Hierarchical routing can be centralized or non- centralized. In non-centralized hierarchical routing, the sensor nodes self-configures for the cluster head on the basis of selecting a random number. They don't consider the case of residual energy. But in centralized routing the base station is responsible to create cluster. In hierarchical routing architecture, sensor nodes self-configure themselves for the formation of cluster heads. The proposed work is to design a routing protocol which is energy efficient and reduce propagation delay. The results are compared with HEED routing protocol which is also a hierarchical routing protocol.*

1. INTRODUCTION

A sensor node is a node in a wireless sensor network that is capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network. The typical architecture of the sensor node is shown in Figure 1.1. The main components of a sensor node as seen from the figure are microcontroller, transceiver, external memory, power source and one or more sensors [1].

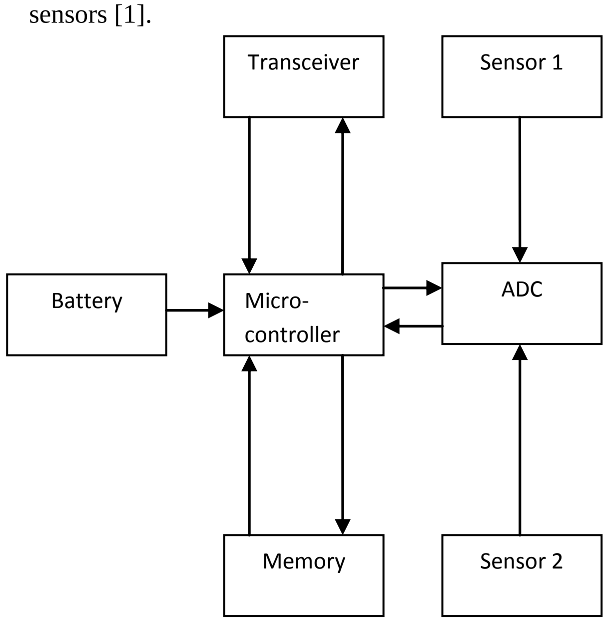

Figure 1: A typical architecture of the sensor node [1]

Sensor nodes can be deployed in a WSN in two ways:

1. Manual: Location of each sensor node is planned with required level of precision e.g. fire alarm sensors in a building, habitat monitoring, sensors planted underground for precision agriculture.
2. Random: Locations of sensor nodes are random e.g. airdropped in a disaster hit area or war fields.

1.1 Routing Challenges in WSNs

WSNs have several restrictions, such as limited energy supply, limited computing power, and limited bandwidth of the wireless links connecting sensor nodes. One of the main design goals of WSNs is to carry out data communication while trying to prolong the lifetime of the network and prevent connectivity degradation by employing aggressive energy management techniques. The design of routing protocols in WSNs is influenced by many challenging factors. These factors must be overcome before efficient communication can be achieved in WSNs. In the following, we summarize some of the routing challenges and design issues that affect the routing process in WSNs.

(a) ***Node deployment*:** Node deployment in WSNs is application-dependent and can be either manual (deterministic) or randomized. In manual deployment, the sensors are manually placed and data is routed through predetermined paths. However, in random node deployment, the sensor nodes are scattered randomly, creating an ad hoc routing infrastructure. Therefore, it is most likely that a route will consist of multiple wireless hops [13].

(b) ***Energy Consumption*:** In a multi hop WSN, each node plays a dual role as data sender and data router. The malfunctioning of some sensor nodes due to power failure can cause significant topological changes, and might require rerouting of packets and reorganization of the network [13].

(c) ***Data reporting method*:** Data reporting in WSNs is application-dependent and also depends on the time criticality of the data. Data reporting can be categorized as either time-driven, event driven, query-driven, or a hybrid of all these methods. The routing protocol is highly influenced by the data reporting method in terms of energy consumption and route calculations [13].

(d) ***Fault tolerance*:** Some sensor nodes may fail or be blocked due to lack of power, physical damage, or environmental interference. The failure of sensor nodes should not affect the overall task of the sensor network. Therefore, multiple levels of redundancy may be needed in a fault-tolerant sensor network.

(e) ***Scalability*:** The number of sensor nodes deployed in the sensing area may be on the order of hundreds or thousands, or more. Any routing scheme must be able to work with this huge number of sensor nodes.

(f) ***Network dynamics*:** In many studies, sensor nodes are assumed fixed. However, in many applications both the BS or sensor nodes can be mobile. As such, routing messages from or to moving nodes is more challenging since route and topology stability become important issues, in addition to energy, bandwidth, and so forth.

(g) ***Transmission media*:** In a multi-hop sensor network, communicating nodes are linked by a wireless medium. The traditional problems associated with a wireless channel (e.g., fading, high error rate) may also affect the operation of the sensor network.

(h) ***Connectivity*:** High node density in sensor networks precludes them from being completely isolated from each other. Therefore, sensor nodes are expected to be highly connected.

(i) ***Coverage*:** In WSNs, each sensor node obtains a certain view of the environment. A given sensor's view of the environment is limited in both range and accuracy; it can only cover a limited physical area of the environment. Hence, area coverage is also an important design parameter in WSNs.

(j) ***Data aggregation*:.** Data aggregation is the combination of data from different sources according to a certain aggregation function (e.g., duplicate suppression, minima, maxima, and average). This technique has been used to achieve energy efficiency and data transfer optimization in a number of routing protocols [13].

(k) ***Quality of service*:** In some applications, data should be delivered within a certain period of time from the moment it is sensed, or it will be useless. Therefore, bounded latency for data delivery is another condition for time-constrained applications.

1.2 Traffic Patterns in WSNs

In difference to traditional networks, the WSNs exhibit unique asymmetric traffic patterns. This is mainly faced due to the function of the WSN which is to collect data, sensor nodes persistently send their data to the base station, while the base station only occasionally sends control messages to the sensor nodes. Moreover, the different applications can cause a wide range of traffic patterns. The traffic of WSNs can be either single hop or multi-hop. The multi-hop traffic patterns can be further divided, depending on the number of send and receive nodes, or whether the network supports in-network processing,

a. *Local Communication.* It is used to broadcast the status of a node to its neighbors. Also it is used to transmit the data between the two nodes directly [7].

b. *Point-to-Point.* Routing. It is used to send a data packet from an arbitrary node to another arbitrary node. It is commonly used in a wireless LAN environment.

c. *Convergence.* The data packets of multiple nodes are routed to a single base node. It is commonly used for data collection in WSNs.

d. *Aggregation.* The data packets can be processed in the relaying nodes and the aggregate value is routed to the base node rather than the raw data.

e. *Divergence.* It is used to send a command from the base node to other sensor nodes. It is interesting to investigate the traffic patterns in WSNs along with the mobility of the nodes, as node mobility has been utilized in a few WSN applications such as health care monitoring. One of the first attempts on doing this is provided in [4]. However, there is still an ongoing research area that will gather great attention on the following years.

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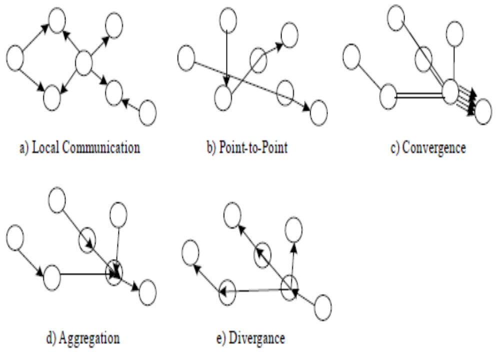

Figure 2: The traffic patterns in WSNs [7]

1.3 Applications of WSNs

Current and potential applications of sensor networks include: military sensing, physical security, air traffic control, traffic surveillance, video surveillance, industrial and manufacturing automation, distributed robotics, environment monitoring, and building and structures monitoring. The sensors in these applications may be small or large, and the networks may be wired or wireless. However, ubiquitous wireless networks of micro sensors probably offer the most potential in changing the world of sensing.

a. ***Environment and Habitat Monitoring***: Environment and habitat monitoring is a natural candidate for applying sensor networks, since the variables to be monitored, e.g., temperature, are usually distributed over a large region [4]. Environmental sensors are used to study vegetation response to climatic trends and diseases, and acoustic and imaging sensors can identify, track, and measure the population of birds and other species.

b. ***Security Monitoring***: Our second class of sensor network application is security monitoring. Security monitoring networks are composed of nodes that are placed at fixed locations throughout an environment that continually monitor one or more sensors to detect an anomaly. A key difference between security monitoring and environmental monitoring is that security networks are not actually collecting any data. This has a significant impact on the optimal network architecture [4].

c. ***Infrastructure Security***: Sensor networks can be used for infrastructure security and counterterrorism applications. Critical buildings and facilities such as power plants and communication centers have to be protected from potential terrorists. Networks of video, acoustic, and other sensors can be deployed around these facilities [4].

d. ***Military Applications:*** In the battlefield context, rapid deployment, self-organization, fault tolerance security of the network should be required. The sensor devices or nodes should provide following services:

- Monitoring friendly forces, equipment and ammunition
- Battlefield surveillance
- Reconnaissance of opposing forces
- Targeting
- Battle damage assessment
- Nuclear, biological and chemical attack detection reconnaissance

e. ***Industrial Sensing***: Commercial industry has long been interested in sensing as a means of lowering cost and improving machine (and perhaps user) performance and maintainability. Monitoring machine "health" through determination of vibration or wear and lubrication levels, and the insertion of sensors into regions inaccessible by humans, are just two examples of industrial applications of sensors [4].

f. ***Traffic Control***:Sensor networks have been used for vehicle traffic monitoring and control for quite a while. Most traffic intersections have either overhead or buried sensors to detect vehicles and control traffic lights.

2. RELATED WORKS

In [3], the authors present a survey that is focused on the energy consumption based on the hardware components of a typical sensor node. They divide the sensor node into four main components: a sensing subsystem including one or more sensors for data acquisition, a processing subsystem including a micro-controller and memory for local data processing, a radio subsystem for wireless data communication and a power supply unit. Also the architecture and power breakdown as the solution to reduce power consumption in wireless sensor networks is discussed.

In [4], the design issues of WSNs and classification of routing protocols are presented (2009). Moreover, a few routing protocols are presented based on their characteristics and the mechanisms they use in order to extend the network lifetime without providing details on each of the described protocols.

The Authors in [5] presents the challenges in the design of the energy-efficient Medium Access Control (MAC) protocols for the WSNs. Moreover, it describes few MAC protocols (12 in total) for the WSNs emphasizing their strengths and weaknesses, wherever possible. However, the paper neither discusses the energy-efficient routing protocols developed on WSNs nor provides a detailed comparison of the protocols. Our survey is concentrated on the energy-efficient routing protocols

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discussing the strengths and weaknesses of each protocol in such a way as to provide directions to the readers on how to choose the most appropriate energy-efficient routing protocol for their network.

In [6], few energy-efficient routing techniques for Wireless Multimedia Sensor Networks (WMSNs) are presented. Also the authors highlight the performance issues of each strategy. They outline that the design challenges of routing protocols for WMSNs followed by the limitations of current techniques designed for non-multimedia data transmission. Further, a classification of recent routing protocols for WMSNs is presented.

In [7], the authors propose and evaluate a clustering technique called a Developed Distributed Energy-Efficient Clustering scheme for heterogeneous wireless sensor networks. This technique is based on changing dynamically and with more efficiency the cluster head election probability. Simulation results show that our protocol performs better than the Stable Election Protocol (SEP) by about 30% and then the Distributed Energy-Efficient Clustering (DEEC) by about 15%in terms of network lifetime and first node dies.

In [8], authors provide a systematical investigation of current state-of-the-art algorithms (2007). They are classified in two classes that take into consideration the energy-aware broadcast/multicast problem in recent research. The authors classify the algorithms in the MEB/MEM (minimum energy broadcast/multicast) problem and the MLB/MLM (maximum lifetime broadcast/multicast) problem in wireless ad hoc networks.

3. METHODOLOGY

3.1 HEED (Hybrid Energy Efficient Distributed Protocol)

There are N sensor nodes, which are randomly dispersed within a 150m*100m region. Following assumptions are made regarding the network model is:

1. Nodes in the network are quasi-stationary.
2. Nodes locations are unaware i.e. it is not equipped by the GPS capable antenna.
3. Nodes have similar processing and communication capabilities and equal significance.
4. Nodes are left unattended after deployment.

Cluster head selection is primarily based on the residual energy of each node. Since the energy consumed per bit for sensing, processing, and communication is typically known, and hence residual energy can be estimated. Intra cluster communication cost is considered as the secondary parameter to break the ties. A tie means that a node might fall within the range of more than one cluster head [2].

Each node performs neighbor discovery, and broadcasts its cost to the detected neighbors. Each node sets its probability of becoming a cluster head, *CHprob*, as follows:

$$CHprob = max\ (c{=}Cprob * (Eresidual/Emax),\ pmin) \quad (1)$$

Where, *Cprob*is the initial percentage of cluster heads among n nodes (it was set to 0.05), while *Eresidual*and *Emax* are the residual and the maximum energy of a node (corresponding to the fully charged battery), respectively. The value of *CHprob* is not allowed to fall below the threshold *pmin*(i.e. 10-4).

3.2 CHRP (Centralized Hierarchical Routing Protocol)

The foundation of CHRP lies in the realization that the base station is a high-energy node with a large amount of energy supply. Thus, CHRP utilizes the base station to control the coordinated sensing task performed by the sensor nodes. In CHRP the following assumption are to be considered.

• A fixed base station is located far away from the sensor nodes.
• The sensor nodes are energy constrained with a uniform initial energy allocation.
• The nodes are equipped with power control capabilities to vary their transmitted power.
• Each node senses the environment at a fixed rate and always has data to send to the base station.
• All sensor nodes are immobile.

The radio channel is supposed to be symmetrical. Thus, the energy required to transmit a message from a source node to a destination node is the same as the energy required to transmit the same message from the destination node back to the source node for a given SNR (Signal to Noise Ratio). Moreover, it is assumed that the communication environment is contention and error free. Hence, there is no need for retransmission.

3.2.1 Algorithm

1. Initially, base station is centralized and 100 nodes are setup in a particular region (100 x 100) and each node has equal energy (0.5 joules).
2. In round 1, Cluster Head will be created according to probability condition.
3. The decision of each node to become cluster head is taken based on the suggested percentage of cluster head nodes *p*. A sensor node chooses a random number, *r*, between 0 and 1. If this random number is less than a threshold value, *T (n)*, the node becomes a cluster-head for the current round. The threshold value is calculated based on an

equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last (1/*P*) rounds, denoted by G. *T (n)* is given by:

$$T(n) = \begin{cases} \dfrac{p}{1 - p*(r \bmod \frac{1}{p})} & if \;\; n \in G, \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

Optimal number of cluster heads is estimated to be 10% of the total number of nodes.

4. Then, Nodes sends the data to their respective cluster heads and energy consumption will be calculated.
5. Cluster Head will aggregate the data and send it to the base station and energy consumption will be calculated for each node and cluster heads.
6. In round 2, the nodes will become cluster heads according to probability condition i.e. according to minimum distance from base station and threshold energy.

Where, threshold energy is the energy required by cluster head to transmit data packets to base station. It can be calculated as:

1.5*((ETX+EDA)*(4000) + Emp*4000*(Distance^4)) (3)

ETX: Transmission energy
EDA: Data Aggregation Energy
Emp: Multipath fading energy
Distance: distance between cluster head and base station

7. After selection of cluster heads, Nodes sends the data to their respective cluster heads, that will be selected according to the minimum distance of a particular node from cluster heads and energy consumption will be calculated.
8. Cluster Head will aggregate the data and send it to the base station and energy consumption will be calculated.
9. This process will be repeated until the whole network gets down or number of rounds finished.
10. Performance will be evaluated according to parameters like network lifetime, energy dissipation, no. of data packets sent etc.

4. IMPLEMENTATION AND RESULTS

Parameter Value

Network field: 150x100m
N (Number of nodes): 200
Initial energy: 1 Joule
Eelec (E.Dissipation for ETx&ERx): 50 nJ/bit
εfs (free space): 10 pJ/bit/m^2
εmp (Multipath fading): 0.0013 pJ/bit/m^4
EDA (Energy Aggregation Data):5 nJ/bit/signal
Data packet size: 4000 bits
Tool used for implementation: MATLAB 7.6.0

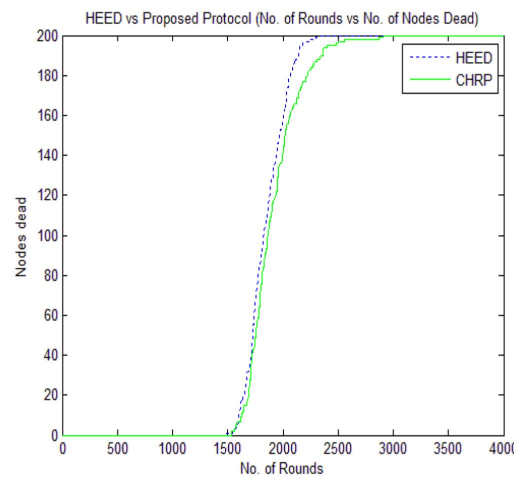

Figure 3: Number of Rounds vs Number of Nodes Dead

Figure 3 shows the comparison of routing protocols HEED and Centralized Hierarchical Routing protocol (CHRP) in terms of Number of nodes dead. Figure 3 shows the overall lifetime of the network. Here, we can observe that CHRP performs better as compared to HEED.

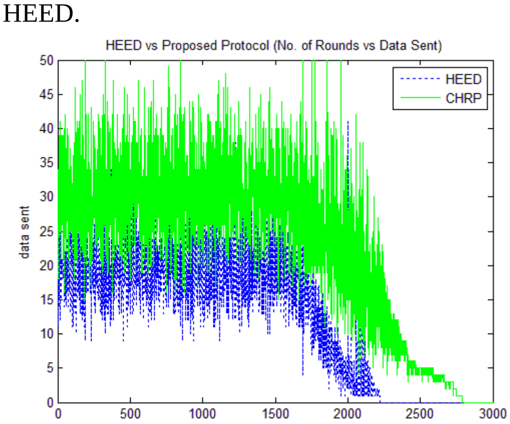

Figure 4: Data sent to base station in each round vs Number of Rounds

Figure 4 shows the comparison of routing protocols HEED and Centralized Hierarchical Routing protocol (CHRP) in terms of Data sent to base station in each round. Here, we can observe that CHRP performs better as compared to HEED.

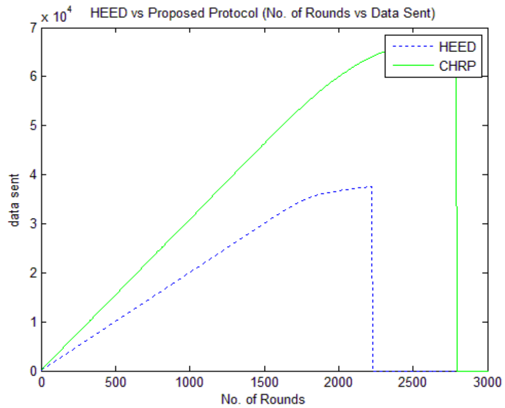

Figure 5: Number of Rounds vs Data Packets sent

Figure 5 shows how much data will be sent from nodes to base station. From figure 5, we can observed that, in HEED protocol data sent to base station is relatively less as compared to CHRP.

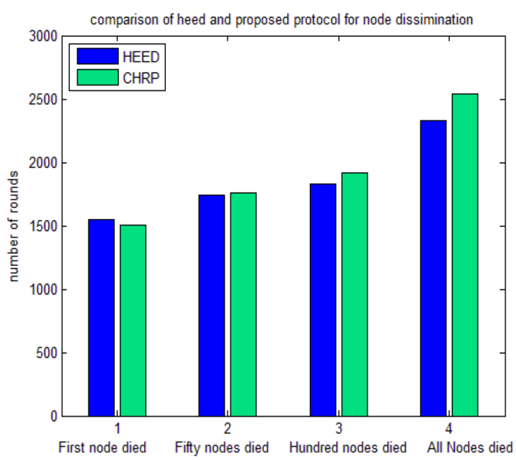

Figure 6: Comparison of Network Lifetime HEED and CHRP

Figure 6 also shows network lifetime with the help of BAR graph. Figure 6 shows exactly in which round the first node, fifty nodes, hundred node and whole network dies. It can be observed from the Figure 6 that CHRP performs better as compared to HEED.

5. CONCLUSION & FUTURE SCOPE

This new routing protocol named Centralized Hierarchical Routing Protocol (CHRP) which is hierarchical routing based with the whole control to the base station or we can say that base assisted. Basically, the question is how the cluster formation between the senor nodes will be. In non-centralized hierarchical routing, sensor nodes self-configure them for the formation of cluster head. While self-configuring, the nodes are unaware about the whole logical structure of the network. But in CHRP, the base station first collects information about the logical structure of the network and residual energy of each node. So, with the global information about the network base station does cluster formation better in the sense that it has information about the residual energy of each node. Finally, CHRP is compared with already developed routing protocol HEED by the help of MATLAB. A comparison between two is done on the basis of energy dissipation with time, data packet sent and the system lifetime of network. System lifetime is basically for how long the system works.

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