Long Life of Wireless Sensor Network Using Leach Design

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Abstract: *Wireless sensor networks consist of small nodes with sensing, computation, and wireless communications capabilities. Minimizing energy dissipation and maximizing network lifetime are important issues in the design of applications and protocols for sensor networks. Energy-efficient sensor state planning consists in finding an optimal assignment of states to sensors in order to maximize network lifetime. In this paper, we address the optimal planning of sensors' states in cluster-based sensor networks. Typically, any sensor can be turned on, turned off, or promoted cluster head, and a different power consumption level is associated with each of these states. We seek an energy-optimal enhancement to the network in such way that maximizes network lifetime while ensuring simultaneously full area coverage and sensor connectivity to cluster heads.*

Keywords: *Wireless Sensors Network (WSN), Routing protocol, Clustering base station, Cluster head*

1. INTRODUCTION

A wireless sensor and actuator network is a collection of small randomly dispersed devices that provide three essential functions; the ability to monitor physical and environmental conditions, often in real time, such as temperature, pressure, light and humidity; the ability to operate devices such as switches, motors or actuators that control those conditions; and the ability to provide efficient, reliable communications via a wireless network. Since they are designed for low traffic monitor and control applications, it is not necessary for them to support the high data throughput requirements that data networks like Wi-Fi require. Typical WSN over-the-air data rates range from 20 kbps to 1 Mbps. Consequently they can operate with much lower power consumption, which in turn allows the nodes to be battery powered and physically small.

WSANs are typically self-organizing and self-healing. Self-organizing networks allow a new node to automatically join the network without the need for manual intervention. Self-healing networks allow nodes to reconfigure their link associations and find alternative pathways around failed or powered-down nodes. How these capabilities are implemented is specific to the network management protocol and the network topology, and ultimately will determine the network's flexibility, scalability, cost and performance[1].

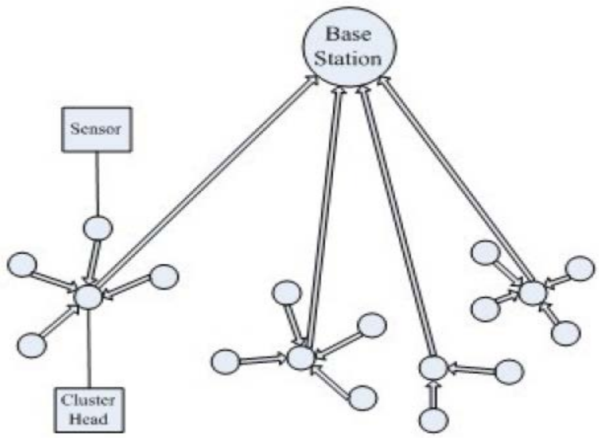

Figure 1.4 : Wireless Sensor Network Architecture [16]

Typically, a wireless sensor node (or simply sensor node) consists of sensing, computing, communication, actuation, and power components. These components are integrated on a single or multiple boards, and packaged in a few cubic inches.

A WSN usually consists of tens to thousands of such nodes that communicate through wireless Channels for information sharing and cooperative processing. The primary responsibilities of WSNs are to collect and report data and events, typically to a base station [2-6].

2. APPLICATIONS OF WSN

WSN suits the application requirements in comparison with wired sensing systems, since it is easily deployable and reconfigurable even in an inaccessible areas and reduces the system installation and condition monitoring cost in general. Wireless sensor network enables low-cost sensing of environment. Wireless sensor networks are well suited for the structural health monitoring for buildings, wind turbines, coal mines, tunnels and bridges. To monitor a structure, we measure behavior (e.g. vibration, displacement) of structure, and analyze health of the structure based on measured data [7-11].

- Area monitoring
- Environmental Monitoring
- Greenhouse Monitoring
- Landslide detection
- Industrial Monitoring
- Water/Wastewater Monitoring
- Agriculture
- Fleet Monitoring
- Forest fire Monitoring
- Volcano Monitoring

3. UNIQUE CHARACTERISTICS OF A WSN INCLUDE

There are lots of characteristics of WSN which includes [12-15]

- Limited power they can harvest or store
- Ability to withstand harsh environmental conditions
- Ability to cope with node failures
- Mobility of nodes
- Dynamic network topology
- Communication failure
- Heterogeneity of nodes
- Large scale of deployment
- Unattended operation
- Node capacity is scalable, only limited by bandwidth of gateway node.

4. NEED OF LEACH PROTOCOL FOR WSN

Low-Energy Adaptive Clustering Hierarchy (LEACH), is a clustering-based routing protocol for WSNs proposed by Heinzelman, et al. (Heinzelman, 2000)[6] This communication protocol is developed to reduce the overall energy waste for networks. It deploys a randomized rotation of cluster-heads techniques. Minimizing energy dissipation and maximizing network lifetime are important issues in the design of applications and protocols for sensor networks. Energy-efficient sensor state planning consists in finding an optimal assignment of states to sensors in order to maximize network lifetime. For example, in area surveillance applications, only an optimal subset of sensors that fully covers the monitored area can be switched on while the other sensors are turned off. Typically, any sensor can be turned on, turned off, or promoted cluster head, and a different power consumption level is associated with each of these states. We seek an energy-optimal enhancement to the network in such way that maximizes network lifetime while ensuring simultaneously full area coverage and sensor connectivity to cluster heads

A. Communication Patterns

Kulkarni et al. defines three types of communication patterns in wireless sensor networks: broadcast, converge cast, and local gossip. Broadcast type of communication pattern is generally used by a base station (sink) to transmit some information to all sensor nodes of the network. Broadcasted information may include queries of sensor query-processing architectures, program updates for sensor nodes, control packets for the whole system. The broadcast type communication pattern should not be confused with broadcast type packet. For the former, all nodes of the network are intended receivers whereas for the latter the intended receivers are the nodes within the communication range of the transmitting node. In some scenarios, the sensors that detect an intruder communicate with each other locally. This kind of

Communication pattern is called local gossip, where a sensor sends a message to its neighboring nodes within a range. The sensors that detect the intruder, then, need to send what they perceive to the information center. That communication pattern is called converge cast, where a group of sensors communicate to a specific sensor. The destination node could be a cluster head, data fusion center, base station. In protocols that include clustering, cluster heads communicate with their members and thus the intended receivers may not be all neighbors of the cluster head, but just a subset of the neighbors. To serve for such scenarios, we define a fourth type of communication pattern, multicast, where a sensor sends a message to a specific subset of sensors. . A sensor network is composed of a large number of tiny autonomous devices, called sensor nodes. Each sensor node has four basic components: a sensing unit, a processing unit, a radio unit, and a power unit. All these units fit into a matchbox-sized (or even smaller) module. Since a sensor node has limited sensing and computational capabilities and can communicate only within short distances, a sensor network is the corporative effort of hundreds or thousands sensor nodes. These nodes are deployed densely and coordinate amongst themselves to achieve a common task.

5. OBJECTIVE OF LEACH DESIGN

This communication protocol is developed to reduce the overall energy waste for networks. In addition to this function it must also takes into consideration other factors used in its design so as to improve network performance and providing good network services for various applications. WSN mainly comprises of scalability and adaptability, energy efficiency, channel utilization, through put, latency, and fairness [16-23].

5.1 Energy Efficiency: Energy efficiency is one of the most important parameters which should be considered while designing LEACH protocol for sensor networks. It is defined as energy consumed per unit of successful communication. As sensor nodes are usually battery operated and thus, it is very difficult or nearly impossible to modify or charge batteries repeatedly, a LEACH protocol should be energy efficient so that it can maximize not only lifetime of sensor nodes but also lifetime of whole network.

5.2 Scalability: Scalability is defined as ability for accommodating the change in network size. In case of sensor networks, number of sensor nodes used may be of order of tens hundreds or thousands.

5.3 Adaptability: Adaptability is defined as ability for accommodating the changes in node density and network topology. In case of sensor networks node density is generally very high. A node may join or move or fail which results in change of node density and network topology.

5.4 Latency: Latency is defined as delay from time period under which a sender has packet to send till packet is successfully received by a receiver. In case of sensor networks latency relies on different applications. Although it is true that latency is not crucial factor for some applications such as data collection for scientific exploration, many applications may have needed latency requirements such as real time monitoring of fire alarms.

5.6 Throughput: Through put is defined as amount of data which has been successfully passed from a sender to receiver in a given interval of time. It is generally measured in bits or bytes per second. It suffers from efficiency of collision avoidance, control overhead, channel utilization and latency. Just as latency, importance of through put relies on different applications.

5.7 Fairness: Fairness is defined as ability of different sensor nodes to share the common transmission channel equally. In case of traditional networks, it is necessary for achieving fairness so that quality of service can be maintained. Nevertheless all nodes must cooperate with each other to reach the single common task. The important task is not to achieve per node fairness, but to make such quality of service for old task which can be achieved. In general, energy utilization is most important factor which effects the operation lifetime of individual nodes and entire network. However, performance of such network relies on energy efficiency. Hence, energy efficiency is of primary concern in such networks. For this it is needed to modify network performance.

6. FACTORS AFFECTING ENERGY EFFICIENCY

Energy is very important parameter during the creation of a WSN infrastructure, and to support long lifetimes, energy-efficient operation is a key technique. Options to look into include energy-efficient data transport between two nodes (measured in J/bit) or, more importantly, the energy-efficient determination of requested information.

6.1 Life time: Wireless sensor networks (WSNs) are known to be highly energy-constrained and each network’s lifetime has a strong dependence on the node’s battery capacity. As such, the network lifetime has been a critical concern in WSN research.

6.2 Topology and design: WSN have been deployed in various fields. Because of some hardware problems, especially with respect to energy supply and miniaturization, WSN have certain short comings such as routing challenges and design issues, topology issues and Quality of Service support issues. Design issues emphasize on designing the Wireless Sensor Networks in such a way that it should provide a fault tolerant communication with low latency.

6.3 MIMO based and multi hop sensor networks
The total energy consumption includes both the transmission energy and the circuit energy consumption. Considering multi-input-multi-output (MIMO) systems having good spectral efficiency but more circuitry that consumes energy. As compared to individual single-antenna nodes that cooperate to form multiple-antenna transmitters or receivers.

6.4 Node Density: Decentralized detection in a network of wireless sensor nodes involves the collection of redundant information about a phenomenon of interest (PoI) from geographically dispersed nodes. The energy overheads involved in transmission & processing of redundant information can be avoided by data aggregation techniques viz. min, max, mean etc.

6.5 Congestion and contention: Wireless Sensor Networks (WSNs) are characterized by the collaborative information transmission from multiple sensor nodes observing a physical phenomenon. Due to the limited capacity of shared wireless medium and memory restrictions of the sensor nodes, channel contention and network congestion can be experienced during the operation of the network. In fact, the level of local contention and the network congestion are closely coupled due to the multi-hop nature of sensor networks.

6.6 Optimization as per environment: Adaptive behavior of autonomously working WSNs tries to maximize the cost efficiency of deployments. This includes maximizing the lifetime through power consumption optimization and recharging energy reservoirs with the use of energy harvesting. The adaptive behavior that leads to efficient resource usage needs information about the WSNs energy balance for decision making.

6.7 Clustering: Clustering is one of the most popular approaches used in wireless sensor networks to conserve energy and increase node as well as network lifetime. LEACH is among the most popular clustering protocols proposed for wireless sensor networks. Network lifetime and energy consumption analysis for cluster-based wireless sensor networks based upon LEACH protocol for periodic monitoring applications induce unbalanced energy consumption among sensor nodes and hence affect the network lifetime when compared with the results obtained from the analytical model of this protocol. This highlights the need for an adaptive clustering protocol that can increase the network lifetime by further balancing the energy consumption among sensor nodes.

7. ROUTING CHALLENGES AND DESIGN ISSUE

Despite the innumerable applications of WSNs, these networks have several restrictions, e.g., limited energy supply, limited computing power, and limited bandwidth of the wireless links connecting sensor nodes.

7.1 Node deployment: Node deployment in WSNs is application dependent and affects the performance of the routing protocol. The deployment can be either deterministic or randomized. In deterministic deployment, the sensors are manually placed and data is routed through pre-determined paths. However, in random node deployment, the sensor nodes are scattered randomly creating an infrastructure in an ad hoc manner. If the resultant distribution of nodes is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy efficient network operation

7.2 Energy consumption without losing accuracy: sensor nodes can use up their limited supply of energy performing computations and transmitting information in a wireless environment. As such, energy- conserving forms of communication and computation are essential. Sensor node lifetime shows a strong dependence on the battery lifetime [24].

7.3 Data Reporting Model: Data sensing and reporting in WSNs is dependent on the application and the time criticality of the data reporting. Data reporting can be categorized as either time-driven (continuous), event-driven, query-driven, and hybrid [25]. The time-driven delivery model is suitable for applications that require periodic data monitoring. As such, sensor nodes will periodically switch on their sensors and transmitters, sense the environment and transmit the data of interest at constant periodic time intervals. In event-driven and query-driven models, sensor nodes react immediately to sudden and drastic changes in the value of a sensed attribute due to the occurrence of a certain event or a query is generated by the BS

7.4 Node/Link Heterogeneity: In many studies, all sensor nodes were assumed to be homogeneous, i.e., having equal capacity in terms of computation, communication, and power. However, depending on the application a sensor node can have different role or capability. The existence of heterogeneous set of sensors raises many technical issues related to data routing.

7.5 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. If many nodes fail, MAC and routing protocols must accommodate formation of new links and routes to the data collection base stations.

7.6 Scalability: The number of sensor nodes deployed in the sensing area may be in the order of hundreds or thousands, or more. Any routing scheme must be able to work with this huge number of sensor nodes. In addition, sensor network routing protocols should be scalable enough to respond to events in the environment. Until an event occurs, most of the sensors can remain in the sleep state, with data from the few remaining sensors providing a coarse quality.

7.7 Network Dynamics: Most of the network architectures assume that sensor nodes are stationary. However, mobility of both BS's or sensor nodes is sometimes necessary in many applications [26]. Routing messages from or to moving nodes is more challenging since route stability becomes an important issue, in addition to energy, bandwidth etc. Moreover, the sensed phenomenon can be either dynamic or static depending on the application, e.g., it is dynamic in a target detection/tracking application, while it is static in forest monitoring for early fire prevention.

7.8 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

7.9 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. This, however, may not prevent the network topology from being variable and the network size from being shrinking due to sensor node failures. In addition, connectivity depends on the, possibly random, distribution of nodes.

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

7.11 Quality of Service: In some applications, data should be delivered within a certain period of time from the moment it is sensed; otherwise the data will be useless. Therefore bounded latency for data delivery is another condition for time-constrained applications. However, in many applications, conservation of energy, which is directly related to network lifetime, is considered relatively more important than the quality of data sent. As the energy gets depleted, the network may be required to reduce the quality of the results in order to reduce the energy dissipation in the nodes and hence lengthen the total network lifetime. Hence, energy-aware routing protocols are required to capture this requirement.

8. ENERGY EFFICIENT LEACH PROTOCOL FOR WSN

Heinzelman, et. al. [31] introduced a hierarchical clustering algorithm for sensor networks, called Low Energy Adaptive Clustering Hierarchy (LEACH). LEACH is a cluster-based protocol, which includes distributed cluster formation. LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotate this role to evenly distribute the energy load among the sensors in the network. In LEACH, the cluster head (CH) nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station. LEACH uses a TDMA/CDMA MAC to reduce inter-cluster and intra-cluster collisions. However, data collection is centralized and is performed periodically. Therefore, this protocol is most appropriate when there is a need for constant monitoring by the sensor network. A user may not need all the data immediately. Hence, periodic data transmissions are unnecessary which may drain the limited energy of the sensor nodes. After a given interval of time, a randomized rotation of the role of the CH is conducted so that uniform energy dissipation in the sensor network is obtained. The authors found, based on their simulation model that only 5% of the nodes need to act as cluster heads.

The operation of LEACH is separated into two phases, the setup phase and the steady state phase. In the setup phase, the clusters are organized and CHs are selected. In the steady state phase, the actual data transfer to the base station takes place. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead.

9. CONCLUSION

Energy efficiency is the most burning and desirable issue in Wireless Sensor Networking technology. There are a lot of reasons and parameters to use energy efficient LEACH DESIGN. Wireless technologies are constantly improving and many different applications are already successfully implemented in different application scenarios. Recent advances in electronic components, MEMS sensors and wireless communications have created many opportunities that were not previously possible.

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