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ENERGY EFFICIENT ALGORITHMS FOR WIRELESS SENSOR NETWORK: A SURVEY

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ABSTRACT

The resources especially energy in wireless sensor networks (WSN) are quite limited. Since sensor nodes are usually much dense, data sampled by sensor nodes have much redundancy, data aggregation becomes an effective method to eliminate redundancy, minimize the number of transmission, and then to save energy. Energy consumption is the most important factor to determine the life of a sensor network because usually sensor nodes are driven by battery. Sometimes energy optimization is more complicated in sensor networks because it involved not only reduction of energy consumption but also prolonging the life of the network as much as possible. The optimization can be done by having energy awareness in every aspect of design and operation. The design of routing protocols for WSNs must consider the power and resource limitations of the network nodes, the time-varying quality of the wireless channel, and the possibility for packet loss and delay. To address these design requirements, several routing strategies for WSNs have been

KEYWORDS: Wireless Sensor Network, Routing Algorithms, Protocols

Wireless sensor networks (WSN) are one of the most actively developing areas in network research Communities. As the technologies for wireless nodes improve, the requirements for networking are increasing. That enables possibilities for new applications. To reduce costs and time of the Deployment process, simulation of the network is a preferred task before testing with real hardware many sensors connect to controllers and processing stations directly (e.g., using local area networks), an increasing number of sensors communicate the collected data wirelessly to a centralized processing station. This is important since many network applications require hundreds or thousands of sensor nodes, often deployed in remote and inaccessible areas. Therefore, a wireless sensor has not only a sensing component, but also on-board processing, communication, and storage capabilities. With these enhancements, a sensor node is often not only responsible for data collection, but also for in-network analysis, correlation, and fusion of its own sensor data and data from other sensor nodes. When many sensors cooperatively monitor large physical environments, they form a wireless sensor network (WSN). Sensor nodes communicate not only with each other but also with a base station (BS) using their wireless radios, allowing them to disseminate their sensor data to remote processing, visualization, analysis, and storage systems. For example, Figure 1 shows two sensor fields monitoring two different geographic regions and connecting to the Internet using their base stations. The capabilities of sensor nodes in a WSN can vary widely, that is, simple sensor nodes may monitor a single physical phenomenon, while more complex devices may combine many different sensing techniques[A. Boukerche 2009] (e.g., acoustic, optical, magnetic). They can also differ in their communication capabilities, for example, using ultrasound, infrared, or radio frequency technologies with varying data rates and latencies. While simple sensors may only collect and communicate information about the observed environment, more powerful devices (i.e., devices with large processing, energy, and storage capacities) may also perform extensive processing and aggregation functions. Such devices often assume additional responsibilities in a WSN, for example, they may form communication backbones that can be used by other resource-constrained sensor devices to reach the base station. Finally, some devices may have access to additional supporting technologies, for example, Global Positioning System (GPS) receivers, allowing them to accurately determine their position. However, such systems often consume too much energy to be feasible for low-cost and low-power sensor nodes

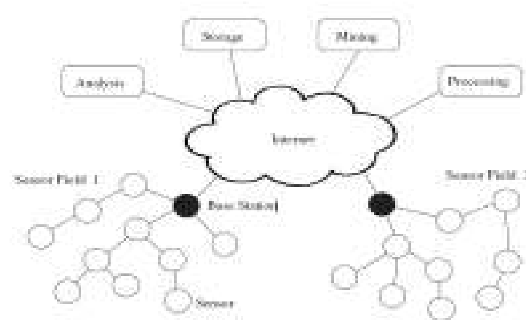

Figure 1

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ENERGY CONSUMPTION ISSUES IN WIRELESS SENSOR NETWORK

Energy consumption is the most important factor to determine the life of a sensor network because usually sensor nodes are driven by battery. Sometimes energy optimization is more complicated in sensor networks because it involved not only reduction of energy consumption but also prolonging the life of the network as much as possible. The optimization can be done by having energy awareness in every aspect of design and operation. This ensures that energy awareness is also incorporated into groups of communicating sensor nodes and the entire network and not only in the individual nodes. A sensor node usually consists of four sub-systems [Bharathidasan, A., Anand, V., Ponduru, S. 2001]

Computing Subsystem

It consist of a microprocessor (microcontroller unit, MCU) which is responsible for the control of the sensors and implementation of communication protocols. MCUs usually operate under various modes for power management purposes. As these operating modes involves consumption of power, the energy consumption levels of the various modes should be considered while looking at the battery lifetime of each node.

Communication subsystem

It consists of a short range radio which communicates with neighboring nodes and the outside world. Radios can operate under the different modes. It is important to completely shut down the radio rather than putting it in the Idle mode when it is not transmitting or receiving for saving power.

Sensing subsystem

It consists of a group of sensors and actuators and link the node to the outside world. Energy consumption can be reduced by using low power components and saving power at the cost of performance which is not required.

Power supply subsystem

It consists of a battery which supplies power to the node. It should be seen that the amount of power drawn from a battery is checked because if high current is drawn from a battery for a long time, the battery will die faster even though it could have gone on for a longer time. Usually the rated current capacity of a battery being used for a sensor node is less than the minimum energy consumption. The lifetime of a battery can be increased by reducing the current drastically or even turning it off often.

To minimize the overall energy consumption of the sensor network, different types of protocols and algorithms have been studied so far all over the world. The lifetime of a sensor network can be increased significantly if the operating system, the application layer and the network protocols are designed to be energy aware. These protocols and algorithms have to be aware of the hardware and able to use special features of the micro-processors and transceivers to minimize the sensor node's energy consumption. This may push toward a custom solution for different types of sensor node design. Different types of sensor nodes deployed also lead to different types of sensor networks. This may also lead to the different types of collaborative algorithms in wireless sensor networks arena.

PROTOCOLS & ALGORITHMS OF WIRELESS SENSOR NETWORK

In WSN, the main task of a sensor node is to sense data and sends it to the base station in multi hop environment for which routing path is essential. For computing the routing path from the source node to the base station there is huge numbers of proposed routing protocols exist [S Sharma and S K Jena 2011]. The design of routing protocols for WSNs must consider the power and resource limitations of the network nodes, the time-varying quality of the wireless channel, and the possibility for packet loss and delay. To address these design requirements, several routing strategies for WSNs have been proposed in [M. A. Labrador, 2005].

The first class of routing protocols adopts a flat network architecture in which all nodes are considered peers. Flat network architecture has several advantages, including minimal overhead to maintain the infrastructure and the potential for the discovery of multiple routes between communicating nodes for fault tolerance.

A second class of routing protocols imposes a structure on the network to achieve energy efficiency, stability, and scalability. In this class of protocols, network nodes are organized in clusters in which a node with higher residual energy, for example, assumes the role of a cluster head. The cluster head is responsible for coordinating activities within the cluster and forwarding information between clusters. Clustering has potential to reduce energy consumption and extend the lifetime of the network [I.F. Akyildiz , 2002].

A third class of routing protocols uses a data-centric approach to disseminate interest within the network. The approach uses attribute-based naming, whereby a source node queries an attribute for the phenomenon rather than an individual sensor node. The interest dissemination is achieved by assigning tasks to sensor nodes and expressing queries to relative to specific attributes. Different strategies can be used to communicate interests to the sensor nodes, including broadcasting, attribute-based multicasting, geo-casting, and any casting [S. Waharte, 2006].

A fourth class of routing protocols uses location to address a sensor node. Location-based routing is useful in applications where the position of the node within the geographical coverage of the network is relevant to the query issued by the source node. Such a query may specify a specific area where a phenomenon of interest may occur or the vicinity to a specific point in the network environment.

we discuss some of the major routing protocols and algorithms to deal with the energy conservation

FLOODING

Flooding is a common technique frequently used for path discovery and information dissemination in wired and wireless ad hoc networks which has been discussed in[6]. The routing strategy of flooding is simple and does not rely on costly network topology maintenance and complex route discovery algorithms. Flooding uses a reactive approach whereby each node receiving a data or control packet sends the packet to all its neighbours. After transmission, a packet follows all possible paths. Unless the network is disconnected, the packet will eventually reach its destination. Furthermore, as the network topology changes, the packet transmitted follows the new routes. Fig. 2 illustrates the concept of flooding in data communications network. As shown in the figure, flooding in its simplest form may cause packets to be replicated indefinitely by network nodes.

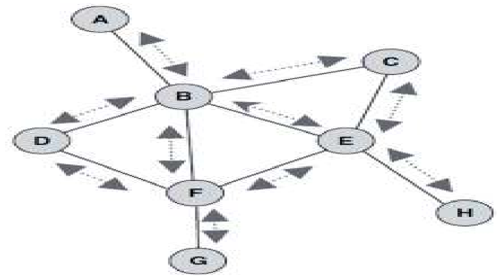

Figure 2

Flooding in data communication networks

Gossiping

To address the shortcomings of flooding, a derivative approach, referred to as gossiping, has been proposed in[J. Kulik,2002]. Similar to flooding, gossiping uses a simple forwarding rule and does not require costly topology maintenance or complex route discovery algorithms. Contrary to flooding, where a data packet is broadcast to all neighbours, gossiping requires that each node sends the incoming packet to a randomly selected neighbour. Upon receiving the packet, the neighbour selected randomly chooses one of its own neighbours and forwards the packet to the neighbour chosen. This process continues iteratively until the packet reaches its intended destination or the maximum hop count is exceeded.

Protocols for Information via Negotiation (SPIN)

Sensor protocols for information via negotiation (SPIN), is a data-centric negotiation-based family of information dissemination protocols for WSNs [Heinzelman, W,2000]. The main objective of these protocols is to efficiently disseminate observations gathered by individual sensor nodes to all the sensor nodes in the network. Simple protocols such as flooding and gossiping are commonly proposed to achieve information dissemination in WSNs. Flooding requires that each node sends a copy of the data packet to all its neighbours until the information reaches all nodes in the network this is shown in fig 3. Gossiping, on the other hand, uses randomization to reduce the number of duplicate packets and requires only that a node receiving a data packet forward it to a randomly selected neighbour.

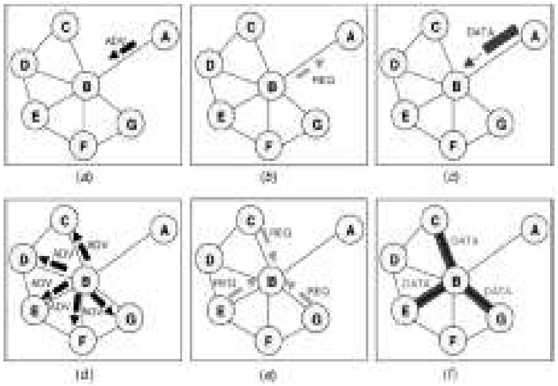

Figure 3

Low-Energy Adaptive Clustering Hierarchy (LEACH)

Low-energy adaptive clustering hierarchy (LEACH) is a routing algorithm designed to collect and deliver data to the data sink, typically a base station [A. Manjeshwar,2002]. The main objectives of LEACH are:

- Extension of the network lifetime
- Reduced energy consumption by each network sensor node
- Use of data aggregation to reduce the number of communication messages

To achieve these objectives, LEACH adopts a hierarchical approach to organize the network into a set of clusters. Each cluster is managed by a selected cluster head. The cluster head assumes the responsibility to carry out multiple tasks. The first task consists of periodic collection of data from the members of the cluster. Upon gathering the data, the cluster head aggregates it in an effort to remove redundancy among correlated values. The second main task of a cluster head is to transmit the aggregated data directly to the base station over single hop. The third main task of the cluster head is to create a TDMA-based schedule whereby each node of the cluster is assigned a time slot that it can use for transmission. The cluster head announces the schedule to its cluster members through broadcasting. To reduce the likelihood of collisions among sensors within and outside the cluster, LEACH nodes use a code-division multiple access–based scheme for communication.

The basic operations of LEACH are organized in two distinct phases. The first phase, the setup phase, consists of two steps, cluster-head selection and cluster formation. The second phase, the steady-state phase, focuses on data collection, aggregation, and delivery to the base station. The duration of the setup is assumed to be relatively shorter than the steady state phase to minimize the protocol overhead.

At the beginning of the setup phase, a round of cluster-head selection starts. To decide whether a node to become cluster head or not a threshold T(s) is addressed in [A. Manjeshwar,2002] which is as follows:

$$T(S) = \begin{cases} \dfrac{p_{opt}}{1 - p_{opt}\cdot\left(r.mod.\dfrac{1}{p_{opt}}\right)}, if \in G' \\ 0, otherwise \end{cases}$$

Where r is the current round number and G is the set of nodes that have not become cluster head within the last $1/p_{opt}$ rounds. At the beginning of each round, each node which belongs to the set G selects a random number 0 or 1. If the random number is less than the threshold T(s) then the node becomes a cluster head in the current round

Threshold-sensitive Energy Efficient Protocols (TEEN and APTEEN)

Two hierarchical routing protocols called TEEN (Threshold-sensitive Energy Efficient sensor Network protocol), and APTEEN (Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network protocol) are proposed in [D. P. Agarwal,2001]. These protocols were proposed for time-critical applications. In TEEN, sensor nodes sense the medium continuously, but the data transmission is done less frequently. A cluster head sensor sends its members a hard threshold, which is the threshold value of the sensed attribute and a soft threshold, which is a small change in the value of the sensed attribute that triggers the node to switch on its transmitter and transmit. Thus the hard threshold tries to reduce the number of transmissions by allowing the nodes to transmit only when the sensed attribute is in the range of interest. The soft threshold further reduces the number of transmissions that might have otherwise occurred when there is little or no change in the sensed attribute. A smaller value of the soft threshold gives a more accurate picture of the network, at the expense of increased energy consumption. Thus, the user can control the trade-off between energy efficiency and data accuracy. When cluster-heads are to change, new values for the above parameters are broadcast. The main drawback of this scheme is that, if the thresholds are not received, the nodes will never communicate, and the user will not get any data from the network at all.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS)

Power-efficient gathering in sensor information systems (PEGASIS) and its extension, hierarchical PEGASIS, are a family of routing and information-gathering protocols for WSNs. The main objectives of PEGASIS are twofold. First, the protocol aims at extending the lifetime of a network by achieving a high level of energy efficiency and uniform energy consumption across all network nodes. Second, the protocol strives to reduce the delay that data incur on their way to the sink. The network model considered by PEGASIS assumes a homogeneous set of nodes deployed across a geographical area. Nodes are assumed to have global knowledge about other sensors' positions. Furthermore, they have the ability to control their power to cover arbitrary ranges. The nodes may also be equipped with CDMA-capable radio transceivers. The nodes' responsibility is to gather and deliver data to a sink, typically a wireless base station. The goal is to develop a routing structure and an aggregation scheme to reduce energy consumption and deliver the aggregated data to the base station with minimal delay while balancing energy consumption among the sensor nodes. Contrary to other protocols, which rely on a tree structure or a cluster-based hierarchical organization of the network for data gathering and dissemination, PEGASIS uses a chain structure

Directed Diffusion

Directed diffusion is a data-centric routing protocol for information gathering and dissemination in WSNs. The main objective of the protocol is to achieve substantial energy savings in order to extend the lifetime of the network. To achieve this objective, directed diffusion keeps interactions between nodes, in terms of message exchanges, localized within limited network vicinity. Using localized interaction, direct diffusion can still realize robust multi-path delivery and adapt to a minimal subset of network paths. This unique feature of the protocol, combined with the ability of the nodes to aggregate response to queries, results into significant energy savings

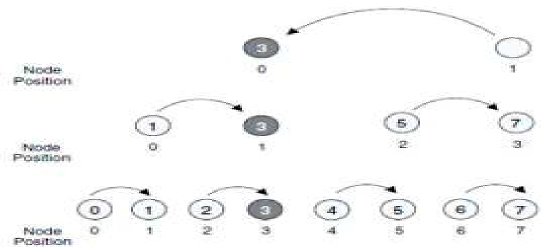

Figure 4

The main elements of direct diffusion include interests, data messages, gradients, and reinforcements. Directed diffusion uses a publish-and-subscribe information model in which an inquirer expresses an interest using attribute–value pairs. An interest can be viewed as a query or an interrogation that specifies what the inquirer wants it is shown in fig 4.

CONCLUSION

The goal of this paper is to discuss few important issues of WSNs, energy efficient routing algorithms from the application, design and technology points of view. For designing a WSN, we need to consider different factors such as the flexibility, energy efficiency, fault tolerance, high sensing fidelity, low cost and rapid deployment, above all the application requirements. We hope the wide range of application areas will make sensor networks an integral part of our lives in the future. However, realization of sensor networks needs to satisfy several constraints such as scalability, cost, hardware, topology change, environment and power consumption. Since these constraints are highly tight and specific for sensor networks,

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