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Energy Efficient Communication Protocols for Wireless Sensor Networks

Rakesh Poonia[1], Amit Kumar Sanghi[2] and Dharm Singh [3]
[1,2]SGV University, Jaipur
[3]Maharana Pratap University of Agriculture and Technology, Udaipur.

***Abstract*-Energy saving is a paramount issue in wireless sensor networks (WSNs) as the sensor nodes are expected to have typical life of few years. WSN distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. One of the limitations of wireless sensor nodes is their inherent limited energy resource. Since these devices rely on battery power and may be placed in hostile environments replacing them becomes a tedious task. Besides maximizing the lifetime of the sensor node, it is preferable to distribute the energy dissipated throughout the wireless sensor network in order to minimize maintenance and maximize overall system performance. In this paper various energy-efficient routing protocols were simulated using ns2 and compare among themselves and analyze the energy-efficiency of the system on the basis of the network lifetime. Results show that study the LEACH minimizes energy dissipation by exploiting the data-gathering aspect of micro sensor networks**.

INTRODUCTION

Wireless sensor networks (WSNs) have a wide spectrum of civil and military applications that call for security, e.g., target surveillance in hostile environments. Typical sensors possess limited computation, energy, and memory resources. Over the last half a century, computers have exponentially increased in processing power and at the same time decreased in both size and price. These rapid advancements led to a very fast market in which computers would participate in more and more of our society's daily activities. In recent years, one such revolution has been taking place, where computers are becoming so small and so cheap, that single purpose computers with embedded sensors are almost practical from both economical and theoretical points of view. Wireless sensor networks are beginning to become a reality, and therefore some of the long overlooked limitations have become an important area of research [1].

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. In addition to one or more sensors, each node in a sensor network is typically equipped with a radio transceiver or other wireless communications device, a small microcontroller, and an energy source, usually a battery. The envisaged size of a single sensor node can vary from shoebox-sized nodes down to devices the size of grain of dust. Eventually, the data being sensed by the nodes in the network must be transmitted to a control center or base station, where the end-user can access the data.

Distinguished from traditional wireless networks, sensor networks are characterized by severe power, computation, and memory constraints. Due to the strict energy constraint, energy efficiency for extending network lifetime is one of the most important issues. Sensor nodes are likely to be battery powered, and it is often very difficult to change or recharge batteries for these nodes. Prolonging network lifetime for these nodes is a critical issue. Therefore, all aspects of the node, from hardware to the protocols, must be designed to be extremely energy efficient. The Routing protocol is a set of rules defining the way for router machines to find the way that packets containing information have to follow to reach the intended destination [2, 4].

ENERGY CONSIDERATIONS IN WSNS:

The sensor nodes due to their small form factor have limited power. In order to prolong the life of the wireless sensor networks, the routing protocols apart from being robust and scalable, needs to be highly energy efficient. A lot of research has taken place in this direction and various routing protocols are proposed to achieve these objectives.

In a fully connected network, all nodes can directly access the base station. However, wireless being a broadcast medium, the congestion in such a network is very high. Typically, each node in a multihop WSN would discover a path to the base station and route its data through this path. This causes the nodes near the base station to be used more frequently than the nodes away from the base station. The reason is the former set of nodes not only send their own sensed data, but are also responsible for forwarding the packets from the far off nodes in the network. This results in a bottleneck around the base station. If the nodes around the base station go dead, then the nodes away from base station will be unable to send the data unless they increase their transmission ranges.

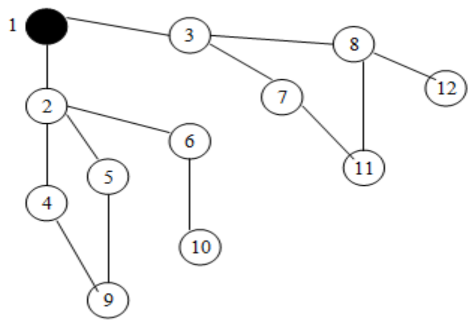

Figure 1: Typical sensor network

Figure1 shows an example of a typical sensor network. The filled black node is the base station. The lines depict the connectivity and the filled gray nodes are the normal sensing nodes. In this example node-2 and node-3 are one hop nodes. Node-2 is responsible not only for sending its own data but also for forwarding the data from nodes-4, 5, 6, 9 and 10. Similarly, node-3 is responsible for sending its own data and as well as forwarding data of nodes-7, 8, 11 and 12. Thus the nodes situated at a distance of one hop from base station are used more often than the other nodes. It causes such nodes to dissipate energy at a substantially higher rate than the rest of the nodes in the network. Consequently, the network becomes dead very soon. The residual energy in the nodes near the base station may be sufficient to sense, but may not be sufficient communicate the sensed data to the base station.

LEACH, LEACH-C, AND STATIC CLUSTERING

In this study investigators compare the results using different protocols LEACH, LEACH-C, and static clustering using ns2 simulator. In LEACH, nodes organize themselves into clusters using the distributed algorithm. Once the clusters are formed, the cluster-head nodes create TDMA schedules. Nodes transmit their data during their assigned slot, and the cluster-head aggregates all the data into representative signal to send to the base station. This protocol has the advantage of being distributed, self-configuring, and not requiring location information for cluster. In addition, the steady-state protocol is low-energy. However, the draw-back is that there is no guarantee as to the number or placement of cluster-head nodes within the network. LEACH-C uses a centralized cluster formation algorithm to guarantee many nodes in the cluster and minimize the total energy spent by the non-cluster-head nodes by evenly distributing the cluster-head nodes throughout the network. The steady-state protocol in LEACH-C is the same as LEACH, where nodes transmit data to the cluster-head, and the cluster-head performs data aggregation to reduce the data sent to the base station. This protocol produces a better cluster distribution than LEACH, as it has global knowledge of the location of all nodes in the network. However, this requires that nodes be equipped with GPS or other location-finding algorithms. In addition, if the base station is very far away from the network, the cost to configure the network will be high. Static clustering sets up fixed clusters with fixed cluster-head nodes. The nodes use a TDMA schedule to send data to the cluster-head, and the cluster-head aggregates the data before transmission to the base station. This approach has little overhead, but when the cluster-head node runs out of energy, the nodes within the cluster lose communication ability with the base station [4].

SIMULATION SETUP

In this paper for experimental purposes, Investigators considered ns2 simulator. NS, a network simulator which was developed by Berkeley University, is used for simulation purposes [7]. A variety of network protocols such as TCP and UDP, traffic source behavior such as FTP, Telnet, CBR and VBR, etc. routing algorithms such as Dijkstra and more are implemented in it. NS also implements multicasting and some of the MAC layer protocols for LAN simulations. It helps in developing tools for simulation results display, analysis and converters that convert network topologies to NS formats. NS2 is written in C++ and OTcl (Object-oriented tool command language).

For the first set of experiments, each node begins with only 2 J of energy and an unlimited amount of data to send to the base station. Since all nodes begin with equal energy in these simulations, each node uses the probabilities to determine its cluster-head status at the beginning of each round, and each round lasts for 20 seconds. We tracked the rate at which the data are transferred to the base station and the amount of energy required to get the data to the base station. Since the nodes have limited energy, they use up this energy during the course of the simulation. Once a node runs out of energy, it is considered dead and can no longer transmit or receive data. For these simulations, energy is removed whenever a node transmits or receives data and when-, this corresponds to a 15 mg battery ever it performs data aggregation. Using spread-spectrum increases the number of bits transmitted, thereby increasing the amount of energy dissipated in the electronics of the radio. Therefore, the energy to transmit or receive a signal depends on whether or not spread-spectrum is being used. In this study we do not assume any static energy dissipation, nor do we remove energy during carrier-sense operations.

Although quality is an application-specific and data-dependent quantity, one application- independent method of determining quality is to measure the amount of data (number of actual data signals or number of data signals represented by an aggregate signal) received at the base station. The more data the base station receives, the more accurate its view of the remote environment will be. If all the nodes within a cluster are sensing the same event, the actual and effective data will contain the same information, and there is no loss in quality by sending effective or aggregate data rather than actual data. If, on the other hand, the nodes are seeing different events, the cluster-head will pick out the strongest event (strongest signal within the signals of the cluster members) and send that as the data from the cluster. In this case, there will be a loss in quality by aggregating signals into a single representative signal. If the distance between nodes within a cluster is small compared with the distance from which events can be sensed or if the distance between events occurring in the environment is large, there is a high probability that the nodes will be sensing the same event. LEACH is almost as effcient as LEACH-C (LEACH-C delivers more data per unit time than LEACH). This is because the base station has global knowledge of the location and energy of all the nodes in the network, so it can produce better clusters that require less energy for data transmission. In addition, the base station formation algorithm ensures that there are k = 5 clusters during each round of operation. As there are only 100 nodes in the simulation, even though the expected number of clusters per round is k = 5 in LEACH, each round does not always have 5 clusters. While the average is 5, some rounds have as little as 1 cluster and some rounds have as many as 10 clusters. Therefore, the base station algorithm, which always ensures 5 clusters, should perform better than distributed clustering. In this study static clustering performs poorly, because the cluster-head nodes die quickly, ending the lifetime of all nodes belonging to those clusters

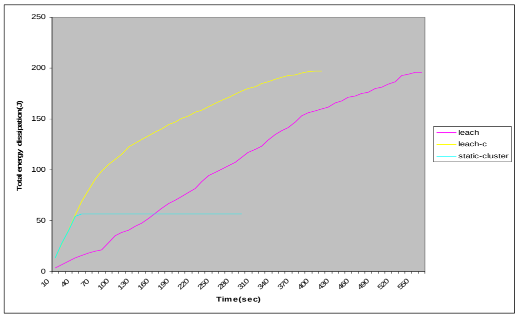

Figure 2:- The total amount of energy dissipated in the system over time.

CONCLUSIONS

Use of the wireless channel is growing at an amazing speed. Advances in energy efficient design have created new portable devices that enable exciting applications for the wireless channel. While the wireless channel enables mobility, it adds constraints that are not found in a wired environment. Specifically, the wireless channel is bandwidth-limited, and the portable devices that use the wireless channel are typically battery-operated and hence energy-constrained.

The wireless channel is error-prone and time-varying. Therefore, it is important to design protocols and algorithms for wireless networks to be bandwidth and energy efficient as well as robust to channel errors. This can be accomplished using cross-layer protocol architectures that exploit application-specific information to achieve orders of magnitude improvement in bandwidth and energy efficiency and improvements in application-perceived quality. In this study the LEACH minimizes energy dissipation by exploiting the data-gathering aspect of micro sensor networks. Since LEACH is a cluster-based protocol, nodes within a cluster are located close to each other and thus are likely to have correlated data. Performing local data aggregation on the correlated data can greatly reduce energy dissipation when the energy required for computation is less than the energy required for communication.

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