Energy Efficient Networking Protocols for Wireless Sensor Networks

P. Jayarajan
Department of ECE, SKCT
Coimbatore, India.

F. Nathirulla Sheriff
Department of ECE, SKCT
Coimbatore, India.

R. Maheswar
Department of ECE, SKCT
Coimbatore, India.

***Abstract*—A Wireless Sensor Network (WSN) consists of a large number of sensor nodes deployed over a geographical area for monitoring physical phenomena like temperature, humidity, vibrations, seismic events, and so on. WSNs have broad applications like environment monitoring, target tracking and surveillance. The unique characteristics of WSNs such as limited bandwidth, computing capacity, data delivery delay and severe energy constraints make their design more challenging. A critical issue in wireless sensor networks is the limited availability of energy and many researches are carried out to for optimizing energy. The best way to improve the network lifetime is by developing energy efficient protocols and this paper provides a survey on different energy efficient protocols for improving the lifetime of the wireless sensor node.**

Keywords-*Wireless sensor network; energy; protocol; network lifetime*

I. INTRODUCTION

A sensor network model consists of one (or more) sink(s) and a high number of sensor nodes deployed over a large geographic area (sensing field). Data are transferred from sensor nodes to the sink through a multi-hop communication paradigm. The architecture of a typical wireless sensor node is shown in Figure 1. It consists of four main components: (i) a sensing subsystem including one or more sensors (with associated analog-to-digital converters) for data acquisition; (ii) a processing subsystem including a micro-controller and memory for local data processing; (iii) a radio subsystem for wireless data communication; and (iv) a power supply unit. Depending on the specific application, sensor nodes may also include additional components such as a location finding system to determine their position, a mobilizer to change their location or configuration (e.g., antenna's orientation), and so on. The battery source is very important to improve the network lifetime and hence many techniques have been introduced to prolong the network lifetime.

Applications

Wireless Sensor Networks have broad applications like environment monitoring, target tracking and surveillance. Unlike Mobile Ad-hoc NETworks (MANETs), WSNs are usually application-specific. The areas where WSNs finds its major applications are:

Area monitoring

Area monitoring is a common application of WSNs. In area monitoring, the WSN is deployed over a region where some phenomenon is to be monitored. An example in the military application is the use of sensors to detect enemy intrusion; a civilian example is the geo-fencing of gas or oil pipelines. When the sensors detect the event being monitored (heat, pressure), the event is reported to one of the base stations, which then takes appropriate action (e.g., send a message on the internet or to a satellite). Similarly, wireless sensor networks can use a range of sensors to detect the presence of vehicles ranging from motorcycles to train cars.

Air pollution monitoring

Wireless sensor networks have been deployed in several cities to monitor the concentration of dangerous gases causing air pollution. These can take advantage of the ad-hoc wireless links rather than wired installations, which also support mobility for testing readings in different areas.

Forest fire detection

A network of sensor nodes can be installed in a forest to detect the occurrence of forest fire. The nodes can be equipped with sensors to measure temperature, humidity and gases which are produced by fires in the trees or vegetation. The early detection is crucial for a successful action of the fire, the fire brigade will be able to know how the fire spreads.

Greenhouse monitoring

Wireless sensor networks are also used to control the temperature and humidity levels inside commercial greenhouses. When the temperature and humidity drop below specific levels, the greenhouse manager must be notified via e-mail or cell phone text message, or host systems can trigger misting systems, open vents, turn on fans, or control a wide variety of system parameters.

Landslide detection

A landslide detection system makes use of a wireless sensor network to detect the slight movements of soil and changes in various parameters that may occur before or during a landslide. With the data gathered it may be possible to know the occurrence of landslides long before it actually happens.

Machine health monitoring

Wireless sensor networks have been developed for machinery condition-based maintenance as they offer significant cost savings and enable new functionalities. In wired systems, the installation of enough sensors is often limited by the cost of wiring. Previously inaccessible locations, rotating machinery, hazardous or restricted areas, and mobile assets can now be reached with wireless sensors.

Agriculture

Using wireless sensor networks within the agricultural industry is increasingly common; using a wireless network frees the farmer from the maintenance of wiring in a difficult environment. Gravity feed water systems can be monitored using pressure transmitters to monitor water tank levels, pumps can be controlled using wireless I/O devices and water use can be measured and wirelessly transmitted back to a central control center for billing. Irrigation automation enables more efficient water use and reduces waste.

Structural monitoring

Wireless sensors can be used to monitor the movement within buildings and infrastructure such as bridges, flyovers, embankments and tunnels and thus enable monitoring of assets remotely with out the need for costly site visits, as well as having the advantage of daily data, whereas traditionally this data was collected weekly or monthly, using physical site visits, involving either road or rail closure in some cases. It is also far more accurate than any visual inspection that would be carried out.

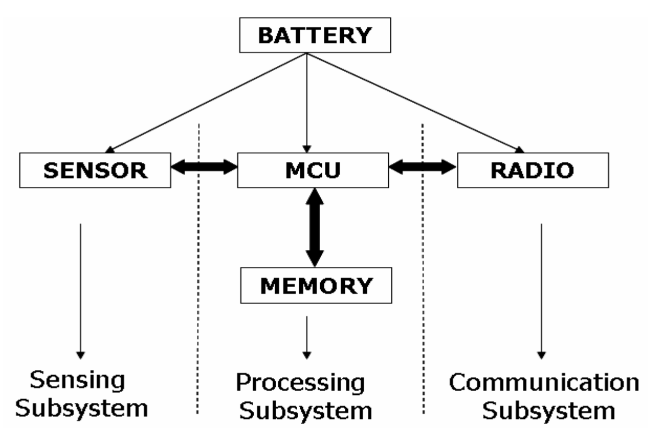

Figure 1. Architecture of a typical wireless sensor node

Providing energy efficient protocols at each layer reduce the energy cost at each layer and hence the network lifetime increases.

II. ENERGY EFFICIENT NETWORKING PROTOCOLS

Networking protocols for sensor networks have been extensively studied and constitute a large part of the research activity on sensor networks. Specifically, in this section, the survey is about how energy efficiency can be achieved at different layers of the OSI reference model. In fact, energy conservation is a cross- layer issue and should be implemented at each layer of the protocol stack.

Physical and Data Link Layers

For Physical and Data Link layers the power efficiency questions are similar to those addressed in wireless networks: how to transmit in a power efficient way bits and frames, respectively, to devices one-hop away. Apart from medium access control, these problems include identifying suitable modulation schemes, efficient FEC strategies, etc. ([1]). Of course, the solutions of these problems are strongly affected by the sensor-device resources' constraints. The proposed solutions are generally independent from the applications; however, recently some authors proposed to apply data-centric policies also at the MAC layer. The basic idea is to exploit spatial correlation among neighboring nodes to reduce the number of transmissions at the MAC layer.

Network layer

Many solutions have been proposed in the literature for energy efficient routing in wireless sensor networks. A comprehensive presentation of this topic can be found in [2]. Almost all routing protocols for sensor networks can be classified by means of the network structure they exploit. These network-structure-based protocols can be further divided in three categories:

- Location-based routing protocols
- Hierarchical routing protocols
- Flat routing protocols

(a) Location-based routing protocols

Location-based routing protocols exploit nodes' position or proximity to route data in the network. Many of these protocols – e.g. SPAN [3] and ASCENT [4] – also use location information to power off the nodes which are not involved in the routing process. For example, GEAR [5] splits the forwarding process in two steps: forwarding toward the target region and forwarding within the target region. The first step uses an estimated cost based on nodes' distance and residual energy. The second step involves a combination of geographic forwarding and restricted flooding.

(b) Hierarchical routing protocols

Hierarchical routing protocols, also referred to as clustering protocols, superimpose a structure in the network, i.e., they give some nodes a special role in the communication process. Clustering was introduced in 80's to provide distributed control in mobile radio networks. Inside the cluster one device is in charge of coordinating the cluster activities (cluster head). Beyond the cluster head, inside the cluster, ordinary nodes that have direct access only to this one cluster head, and gateways, i.e., nodes that can hear two or more cluster heads [6]. As all nodes in the cluster can hear the cluster head, all inter-cluster communications occur in (at most) two hops, while intra- cluster communication occurs through the gateway nodes. Ordinary nodes send the packets to their cluster head that either distributes the packets inside the cluster, or (if the destination is outside the cluster) forwards them to a gateway node to be delivered to the other clusters. Only gateways and cluster heads participate in the propagation of routing control/update messages. In dense networks this significantly reduces the routing overhead, thus solving scalability problems for routing algorithms in large ad hoc networks. In traditional wireless scenarios the main goals of clustering are scalability and efficiency. In wireless sensor networks clustering is also used for data aggregation and energy-aware communication.

(c) Flat routing protocols

Flat routing protocols assume all nodes in the network behave the same for data processing and delivery, in contrast with the hierarchical approach. Flat routing follows the data- centric communication paradigm, i.e. in sensor networks data are more important than the individual nodes' identities. Thus, routing and forwarding inside a sensor network require a form of data-centric data dissemination to/from the sensor nodes. In this case, information is referred by using attributes of the phenomenon.

Upper Layers

Sensor nodes in the sensing region X are typically set up to achieve in a cooperative way a pre-defined objective (e.g., monitoring the temperature in region X). This is achieved by distributing tasks to be performed on the sensor nodes. Therefore a sensor network is similar to a distributed system on which, at the same time, multiple applications are running. Each application is composed by several tasks that run on different (sensor) nodes. Starting from this view of a sensor network, in [7] the authors propose middleware- layer algorithms to manage, in a power-efficient way, a set of applications that may differ for the energy requirements and users' rewards. Specifically, the authors propose an admission control policy that, when an application starts, decides (given its energy costs and users' rewards) to accept/reject it to maximize the users' rewards. A policing mechanism is adopted, at runtime, to control that applications conform to the resource usage they declared at the admission stage.

III. CONCLUSION

Sensor nodes are powered by battery and since they are deployed at large numbers where human finds difficult to go, it is tedious to replace battery. Hence, some mechanisms are required to improve the lifetime of the sensor network. This paper describes the energy efficient protocols to prolong the sensor network lifetime. Networking protocols for sensor networks have been extensively studied and constitute a large part of the research activity on sensor networks. Specifically, in this paper, the survey is about how energy efficiency can be achieved at different layers of the OSI reference model. In fact, energy conservation is a cross- layer issue and should be implemented at each layer of the protocol stack.

REFERENCES

[1] Karl, H., Willig, A. "A short survey of wireless sensor networks", TKN Technical Report TKN-03-018.

[2] Al-Karaki, J., and Kamal, A. "Routing Techniques in Wireless Sensor Networks: a Survey", IEEE Wireless Communications, Vol. 11, N. 6, pp. 6- 28, December, 2004.

[3] Chen, B., Jamieson, K., Balakrishnan, H., and Morris, R. "Span: An Energy-Efficient Coordination Algorithm for Topology Maintenance in Ad Hoc Wireless Networks", ACM Wireless Networks, Vol. 8, N. 5, September., 2002.

[4] Cerpa, A., and Estrin, D. "Ascent: Adaptive Self-Configuring Sensor Network Topologies, Proc. IEEE INFOCOM, 2002.

[5] Yu, Y., Estrin, D., and Govindan, R. "Geographical and Energy-Aware Routing: A Recursive Data Dissemination Protocol for Wireless Sensor Networks", UCLA Computer Science Department Technical Report, UCLA-CSD TR-01-0023, May, 2001.

[6] Baker, D.J., Ephremides, A., and Flynn, J.A. "The Design and Simulation of a Mobile Radio Network with Distributed Control", IEEE Journal on Selected Areas in Communications, Vol. 2, N. 1, January, 1984.

[7] Boulis, A., and Srivastava, M. "Node-Level Energy Management for Sensor Networks in the Presence of Multiple Applications", Proc. IEEE International Conference on Pervasive Computing and Communications (PerCom 2003), Dallas (USA), March, 2003.

AUTHORS PROFILE

P.Jayarajan completed his B.E and M.E degree in the years 2004 and 2008 respectively and currently working as Assistant Professor at SKCT, Coimbatore. His research area is WSN.

F. Nathirulla Sheriff completed his B.E and M.S degree in the years 2005 and 2011 respectively and currently working as Assistant Professor at SKCT, Coimbatore. His research area is WSN.

R. Maheswar completed his B.E, M.E and Ph.D degree in the years 1999, 2002 and 2012 respectively and currently working as Associate Professor at SKCT, Coimbatore. His research area is WSN.