A SURVEY OF ENERGY CONSERVATION TECHNIQUES IN WIRELESS SENSOR NETWORKS

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ABSTRACT

The number of wireless sensor networks (WSNs) deployments for real life applications has rapidly increased. In wireless sensor networks, energy efficiency plays a major role to determine the lifetime of the network. The network is usually powered by a battery which is hard to recharge. Hence, one major challenge in wireless sensor networks is the issue of how to extend the lifetime of sensors to improve the efficiency. In order to reduce the rate at which the network consumes energy, researchers have come up with energy conservation techniques, schemes and protocols to solve the problem. This paper presents a brief overview of wireless sensor networks, outlines some causes of its energy loss and some energy conservation schemes based on existing techniques used in solving the problem of power management.

Keyword : - *Wireless sensor network, Energy conservation, Duty cycling*

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1. INTRODUCTION

A Wireless Sensor Network (WSN) consists of small devices with very limited capabilities, called wireless sensor nodes that collect information from the environment by sensors, process the information, locally make decisions and wirelessly communicate with other nodes in the network. A scheme of a WSN connected to the Internet is presented in Fig. 1.

WSNs are implemented in a wide range of distributed, remote and wireless sensing applications in environmental monitoring, agriculture, production and delivery, military, structural health monitoring, ambient intelligence, medical applications, etc. Deployment of WSNs avoids installation costs due to wire depositions, introducing at the same time power efficiency as a main challenge. Wireless sensor nodes are mainly battery-powered, thus having restricted amounts of energy.

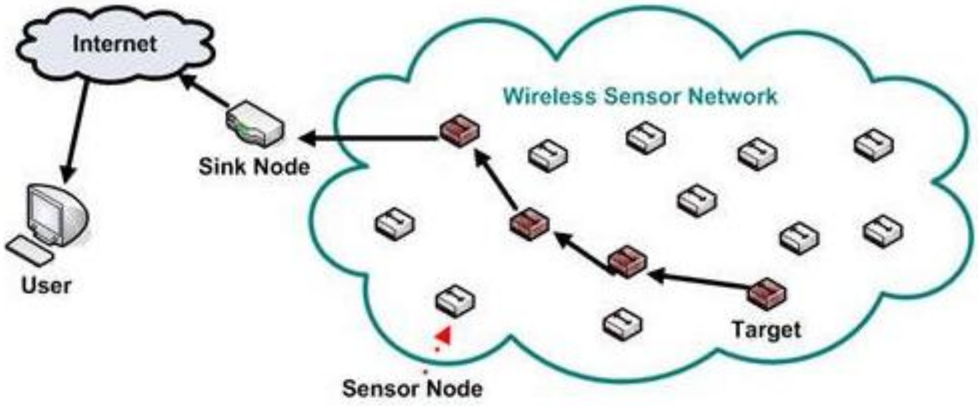

Fig-1: A Wireless Sensor Network

1.1 Nodes Lifetime

A node's lifetime is defined as the node's operating time without the need for any external intervention, like battery replacement. A WSN lifetime can be defined as the lifetime of the shortest living node in the network, but, depending on the application, density of the network and possibilities of reconfiguration, it can be defined as the lifetime of some other (main or critical) node. Anyway, in order to prolong a WSN lifetime, it is required to reduce the energy consumption of the nodes as much as possible and form an Energy and context-aware system. A wireless sensor node usually consists of a power unit, sensing unit, communication unit (transceiver) and a computing unit, as showed in Fig. 2. Each unit contributes to the node power consumption.

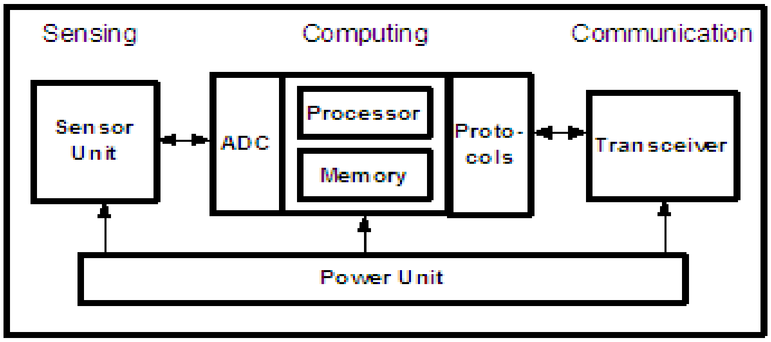

Fig- 2: Wireless Sensor Node Architecture

Each node in the network is equipped with a battery with limited capacity which is very difficult to change or recharge due to the kind of environment in which they are deployed Wireless sensor network is likely to become significant enabling technology in many areas such as scientific, logistic, environmental monitoring, agriculture, production and delivery, military, structural health monitoring or healthcare applications.

The combination of different techniques is needed to prolong the lifetime of a sensor network. During network activities, energy efficient protocols are used to reduce energy consumption to the minimal. It is important to note that a large percentage of energy is consumed by other components such as central processing unit and radio even in the idle state (Dimirkol, et al, 2006). Hence, power management schemes are used to switch off components that are not yet needed. In this paper, a review of energy conservation schemes is carried out.

2. ENERGY CONSERVATION TECHNIQUES

Energy is one of the most critical resources for wireless sensor networks but one problem common to most of these WSNs is lack of reliable power for each sensor node in the network. The data transmission consumes much more energy than data processing. However the energy consumed by the sensing subsystem varies depending on each node. In some cases, sensing consumes less energy than the one required for data processing while in other cases, it even consumes more than the energy needed for data transmission.

Most energy conservation techniques target the networking subsystem and sensing subsystem thus, both energy efficient protocols to minimize energy consumption during network activities and power management schemes for switching off idle node components are necessary for maximum energy conservation in wireless sensor networks (Pottie and Kaiser, 2002).These schemes and protocols can be grouped into three; duty-cycling, data reduction, and mobility, each of the schemes is further broken into several parts as shown in fig 3.

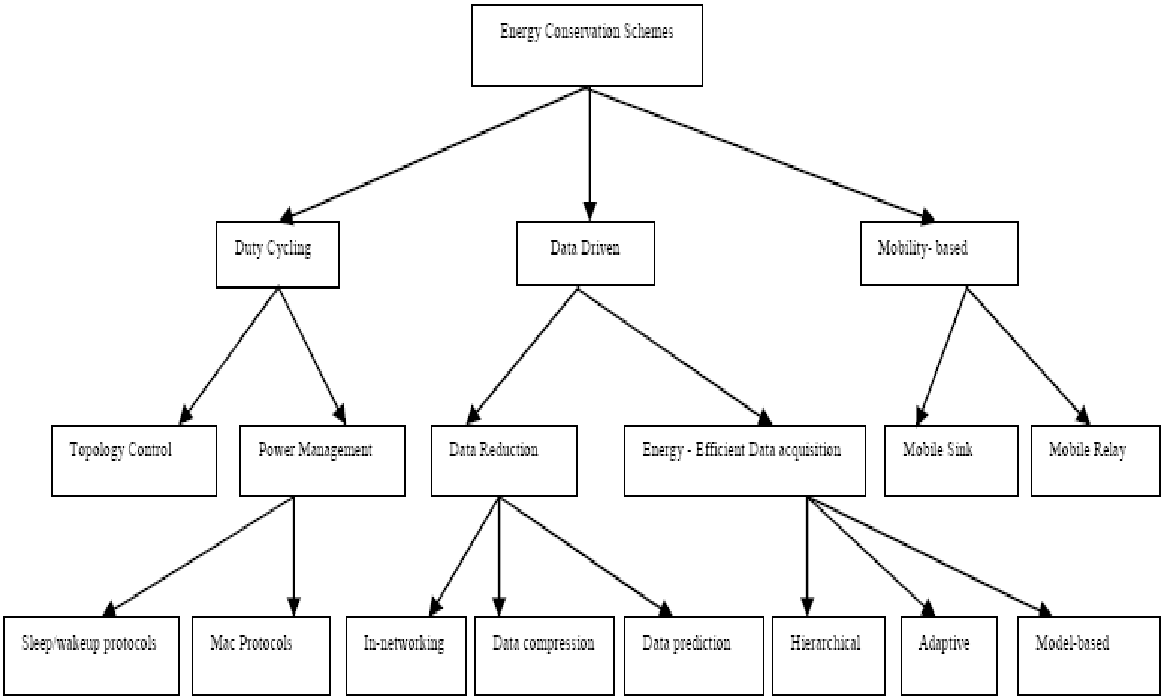

Fig -3: **Classification Of Energy Conservation Schemes**

2.1 Duty cycling

Duty cycling is mainly focused on the networking subsystem. The most effective energy-conserving operation is putting the radio transceiver in the (low-power) sleep mode whenever communication is not required. Ideally, the radio should be switched off as soon as there is no more data to send/receive, and should be resumed as soon as a new data packet becomes ready. In this way nodes alternate between active and sleep periods depending on network activity.

Duty cycling can be achieved using two different approaches. The first is topology control which reduces the number of nodes involved in forwarding and routing packets generated by the other nodes without reducing network connectivity and coverage. It ensures that nodes not currently needed for connectivity go to sleep and save energy thereby prolonging the network longevity.

2.2 power management scheme

The second method is a power management scheme which introduces MAC protocols and a wakeup scheduling scheme in which during idle state, a node sleeps in more slots and still maintains network connectivity.
Sleep/wakeup schemes can be defined for a given component (i.e. the radio subsystem) of the sensor node, without relying on topology or connectivity aspects. Independent sleep/wakeup protocols can be further subdivided into three main categories [15]: on-demand, scheduled rendezvous, and asynchronous schemes (fig 4).

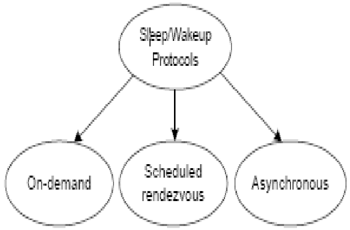

Fig-4:Classification Of Sleep/Wakeup Protocols

On-demand protocols take the most intuitive approach to power management. The basic idea is that a node should wakeup only when another node wants to communicate with it. The main problem associated with on-demand schemes is how to inform the sleeping node that some other node is willing to communicate with it. To this end, such schemes typically use multiple radios with different energy/performance tradeoffs (i.e. a low-rate and low-power radio for signaling, and a high rate but more power hungry radio for data communication).

An alternative solution consists in using a scheduled rendezvous approach. The basic idea behind scheduled rendezvous schemes is that each node should wake up at the same time as its neighbors. Typically, nodes wake up according to a wakeup schedule, and remain active for a short time interval to communicate with their neighbors. Then, they go to sleep until the next rendezvous time.

Finally, an asynchronous sleep/wakeup protocol can be used. With asynchronous protocols, a node can wake up when it wants and still be able to communicate with its neighbors. This goal is achieved by properties implied in the sleep/wakeup scheme, thus no explicit information exchange is needed among nodes.
TDMA (Time Division Multiple Access) schemes naturally enable a duty cycle on sensor nodes as channel access is done on a slot-by-slot basis. As nodes need to turn on their radio only during their own slots, the energy consumption is ideally reduced to the minimum required for transmitting/receiving data.

Contention-based protocols are the most popular class of MAC protocols for wireless sensor networks. They achieve duty cycling by tightly integrating channel access functionalities with a sleep/wakeup scheme similar to those described above. The only difference is that in this case the sleep/wakeup algorithm is not a protocol independent of the MAC protocol, but is tightly coupled with it.

Finally, hybrid protocols adapt the protocol behavior to the level of contention in the network. They behave as a contention-based protocol when the level of contention is low, and switch to a TDMA scheme when the level of contention is high.

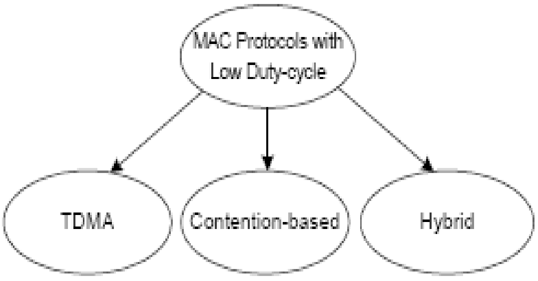

Fig-5:classification of MAC protocols with low Duty-Cycle

2.3. Data Driven Approach

There are two ways by which data driven approach affects energy consumption (Arunraja & Malatha, 2012):
First it sorts out unneeded samples which results in useless energy consumption and stops them from being transmitted to the sink. Secondly, it minimizes the power consumption of the sensing subsystem by keeping the accuracy of the sensor at a reasonable level.
Data reduction schemes: This scheme employs three different techniques to reduce the amount of data that is transmitted to the sink node. They are in- networking processing, data compression and data prediction.

In-network processing performs data aggregation at intermediate nodes to reduce the amount of data that is transmitted from the source to the sink. It should be noted that, this scheme is good where readings accuracy is not important and the sensors readings are static (Zhang, 2012).

Data compression encodes information at the source nodes and decodes it at the sink in order to reduce the amount of data transmitted.

Data reduction by prediction scheme uses adaptive filters to predict data both at the source node and the sink nodes.
Energy efficient data acquisition scheme

Energy efficient data acquisition techniques are not focused on reducing the energy consumption of the sensing subsystem but they highly reduce radio energy consumption (Alippi et al, 2009). They aimed at reducing data samples thereby minimizing the number of communication as well. This data acquisition scheme can be divided into three; hierarchical sensing, adaptive sampling and model based sampling.

The hierarchical sampling approach requires that nodes are equipped with different types of sensors. Each sensor is characterized by its own accuracy and its associated energy consumption. This technique dynamically determine which class to activate, in order to get a tradeoff between accuracy and energy conservation.

Adaptive sampling techniques exploit similarities among the sensed data with respect to the available energy to reduce the amount of data to be acquired from the transducer.

Model-based active sampling builds a model of the sensed phenomenon on a sample data so that next data can be forecasted. This technique exploits the obtained model to reduce the number of data samples thereby reducing the amount of data to be communicated to the sink.

2.4. Mobility

Mobility can finally be used as a tool for reducing energy consumption (beyond duty cycling and data-driven techniques). In a static sensor network packets coming from sensor nodes follow a multi-hop path towards the sink(s). Thus, a few paths can be more loaded than others, and nodes closer to the sink have to relay more packets so that they are more subject to premature energy depletion (funneling effect) [21].

If some of the nodes (including, possibly, the sink) are mobile, the traffic flow can be altered if mobile devices are responsible for data collection. Mobile sinks are needed to notify sensor nodes about their new location information whenever the needs arise. They can be used to balance the consumption of energy in Wireless Sensor Networks (Wang et al, 2008). Most of the approaches proposed by researchers on sensor networks with mobile sinks applied a Linear Programming (LP) formulation to maximize network lifetime and other parameters.

Mobile-Relay-based Approaches: The Mobile Relay (MR) model for data collection in multi-hop ad hoc networks has already been explored in the context of opportunistic networks [12]. One of the most well-known approaches is given by the message ferrying scheme [22],[23]. Message ferries are special mobile nodes which are introduced into a sparse mobile ad hoc network to offer the service of message relaying. Message ferries move around in the network area and collect data from source nodes. They carry stored data and forward them towards the destination node. Thus, message ferries can be seen as a moving communication infrastructure which accommodates data transfer in sparse wireless networks.

A similar scheme has also been proposed in the context of sparse wireless sensor networks through the data-MULE system . In detail, the data-MULE system consists of a three-tier architecture (fig6.).

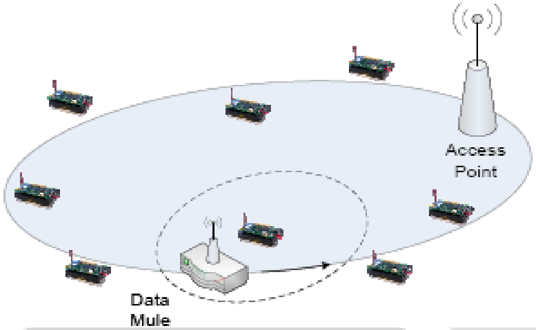

Fig-6:System Architecture Of Wireless Sensor Networks With Mobile Relay

(i) The lower level is occupied by the sensor nodes that periodically perform data sampling from and about the surrounding environment.

(ii) The middle level consists of mobile agents named Mobile Ubiquitous LAN Extensions, or MULEs for short. MULEs move around in the area covered by sensors to gather their data, which have previously been collected and temporarily stored in local buffers. Data MULEs can be for example people, animals, or vehicles too. Generally, they move independently from each other and from the sensor positions by following unpredictable routes. Whenever they get within reach of a sensor they gather information from it.

(iii) The upper level consists of a set of Access Points (APs) which receive information from the MULEs. They are connected to a sink node where the data received is synchronized and stored, multiple copies are identified, and acknowledgments are managed.

Sensor nodes – which are supposed to be static – wait for a MULE to pass by and send data to it. Sensor-to-MULE transmissions make use of short-range radio signals and hence energy consumption is low. While moving around, the MULE eventually passes by any AP and transmits the collected sensors' data to it.

3. CONCLUSIONS

In this paper we have surveyed the main approaches to energy conservation in wireless sensor networks.

We can draw final observations about the different approaches to energy management. As far as "traditional" techniques to energy saving, an important aspect which has to be investigated more deeply is the integration of the different approaches into a single off-the-shelf workable solution. This involves characterizing the interactions between different protocols and exploiting cross-layer interactions.

Another interesting point is that most of the solutions proposed in the literature assume the energy consumption of the radio is much higher than the energy consumption due to data sampling or data processing. Many real applications, however, have shown the power consumption of the sensor is comparable to, or even greater than, the power needed by the radio.

In addition, the sampling phase may need a long time – especially if we compare it to the time needed for communications – so that the energy consumption of the sensor itself can be very high as well. We think that the field of energy conservation targeted to data acquisition has not been fully explored yet, so that there is room for developing convenient techniques to reduce the energy consumption of the sensors.

Finally, we observe an increasing interest towards a sparse sensor network architecture. In many practical applications such a network can be very efficient and robust if communication protocols can appropriately exploit the mobility of collector nodes.

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