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A survey of Optimizing Energy Utilization in Wireless Sensor Network using Duty Cycle Approach

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***Abstract*:** A Wireless Sensor Network is a network that consists of large number of low cost, low power sensor nodes that are interconnected by means of wireless medium and it finds major application in the field of environment monitoring, target tracking, vehicle tracking and surveillance. The distinctive features of WSNs such as restricted bandwidth, computing capability, data delivery delay and strict energy constraints make their design more difficult. An important concern in wireless sensor networks is the restricted availability of energy and a lot of researches are carried out to for enhancing energy. The finest method to advance the network life span is by switching the node on/off as per the functionalities. This paper provides a review of different duty cycling schemes for increasing the life span of the wireless sensor node.

Keywords-Wireless sensor network; energy; duty cycling; network lifetime; TDMA

I. INTRODUCTION

A wireless sensor network (WSN) consists of sensor nodes which are skilled in sensing the environment, process, store and broadcasts the sensed data through wireless channels. Wireless sensor network can be a system with static sensors or a system with mobile nodes. The sensor nodes are deployed over an area and are calculating locally the information collected from the environment. They also have the capability to sense information such as temperature, vibration, humidity and other physical environmental conditions. Information is then handled locally and the result is sent to the sinks.

Each node in the network is fitted with a battery with restricted power which is very hard to change or recharge because of the kind of environment in which they are deployed [1]. Wireless sensor network is likely to turn into noteworthy enabling technology in many areas such as scientific, logistic, environmental monitoring, agriculture, production and delivery, military, structural health monitoring or healthcare applications.

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The architecture of a classic wireless sensor node has four main parts:

i. micro controller
ii. radio transceiver
iii. one or more sensors
iv. memory chip
v. battery

Besides the basic components, sensor nodes can also contain a location finding system to find the location and a mobilizer to change the location. The mixture of diverse techniques is desirable to increase the life span of a sensor network. During network activities, energy competent protocols are used to decrease energy utilization to the smallest level. It is essential to note that a huge percentage of energy is used by other components such as central processing unit and radio even in the idle state [2]. For this reason, power management techniques are mainly used to turn off components that are not yet needed.

In this paper, a review of energy conservation schemes is carried out. Emphasis is laid on duty cycling approach.

II. ENERGY WASTE IN WIRELESS SENSOR NETWORKS

There are a number of challenges in wireless sensor networks, the majority of which leads to energy waste [3]. The main reasons of energy waste in wireless sensor nodes communication are the following:

- **Idle listening:** It occurs when nodes wake up and pay attention for incoming data packets even when there is no transmission. This reduces the life span of wireless sensor networks.
- **Collision:** It happens when two or more close stations wish to broadcast packets at the same time. When this happens, all packets involved in the collision have to be abandoned and retransmitted which outcome in energy waste.
- **Over-hearing:** when a node in the wireless sensor network transmits a message, various nodes around the sender may possibly overhear the packet transmission even when they are not the planned recipients of these transmissions. Overhearing needless traffic can outcome in energy loss.
- **Control packet overhead:** control packets spend a lot of energy in sending, receiving and listening, As a result it is appropriate that a lesser number of control packets should be employed for data transmission with the intention to reduce the overhead.

III. ENERGY CONSERVATION TECHNIQUES

Energy is one of the most critical resources for wireless sensor networks but one problem which is common to the majority of these wireless sensor network is inadequacy of reliable power for each sensor node in the network. The usage of the energy used in the network depends on the specific sensor node. Results from a number of experiments demonstrate that the cost of transmitting a single bit of information is equivalent to the one required to process a thousand operations [4]. Fundamentally, data transmission utilizes a great deal of energy than data processing.

On the other hand the energy utilized by the sensing subsystem varies depending on each node. In some cases, sensing consumes a smaller amount of energy than the one required for data processing whereas in other cases, it even utilize more than the energy required for data transmission. Taking into consideration, numerous research works has been carried out to resolve the energy problem which consequences in different schemes and protocols. Most energy conservation techniques target the networking subsystem and sensing subsystem therefore, both energy efficient protocols to reduce energy utilization during network actions and power management schemes for switching off idle node components are essential for highest energy conservation in wireless sensor networks [5]. These schemes and protocols can be organized into three; duty-cycling, data reduction, and mobility, each of the schemes is further broken into several parts which are given below.

IV. DUTY CYCLING

Duty cycling is mainly focused on the networking subsystem. The basic idea of duty cycling process is to set the radio transceiver in the low-power sleep mode when communication is not necessary. Preferably, the radio should be turned off the moment there is no further data to send/receive and supposed to be resumed the moment a new data packet becomes ready. In this way, nodes shift between active and sleep periods depending on network activity. Duty cycle is defined as the fraction of time nodes which are active during their life span.

Duty-cycling can be done using two distinct and complementary schemes. From one side, it is feasible to utilize node redundancy which is typical in sensor networks and adaptively choose only a least subset of nodes to stay active for maintaining connectivity. In several applications the events are characteristically uncommon and therefore sensor nodes spend a greater part of their time in the idle period which decreases the life span and the effectiveness of the sensor networks. Nodes that are not presently required for ensuring connectivity can go to sleep and save energy. To estimating the best subset of nodes that assure connectivity is called topology control. Alternatively, active nodes (i.e. nodes selected by the topology control protocol) do not require maintaining their radio constantly on. They can turn off the radio (i.e. put it in the low-power sleep mode) when there is no network activity, as a result alternating between sleep and wakeup periods. All the way through we will refer to duty cycling operated on active nodes as power management. Hence, topology control and power management are complementary techniques that apply duty cycling with different granularity.

Power management protocols could be implemented either as independent sleep/wakeup protocols running on the top of a MAC protocol. Several criterions can be also used to make a decision which nodes to activate/deactivate and when.

Independent Sleep/wakeup Protocols

Sleep/wakeup schemes are regularly outlined for a known element the radio subsystem of the sensor node, although not counting topology or connectivity aspects. Throughout this section, gives that the most sleep/wakeup schemes implemented as single layer protocols on prime of the MAC protocol at the network or the application layer. Independent sleep/wakeup protocols are mainly subdivided into three main classes:

On-demand

Scheduled rendezvous

Asynchronous protocols

- ***On-demand***
  On-demand protocols [6] take the most sensitive way to power management. On-demand schemes are based on the idea that a node need to be active only when there is demand to collect a packet from a neighboring node which decrease the energy consumption and, consequently, makes on-demand schemes considerably suitable for sensor network applications with an extremely low duty cycle. In these types of cases, sensor nodes are among the monitoring state for a number of the time. The point an event is encountered, nodes transit to the transfer state. STEM (Sparse Topology and Energy Management) [7] uses two separate radios for wakeup signal and data packet transmissions, respectively.
- ***Scheduled Rendezvous***
  Scheduled rendezvous schemes are based on the idea that all neighboring nodes wake up at the same time. Generally, nodes wake up at times to verify for possible communications. Afterward, they go another time to sleep in expectation of the next rendezvous time. The key advantage of such schemes is that when a node is awake it is sure that all of its neighbors are awake. This allows sending broadcast messages to all neighbors. On the other side, scheduled rendezvous schemes want nodes are synchronized with the aim of wake up at the same time. Clock synchronization is mandatory in wireless sensor networks. A fully synchronized wakeup scheme is also used in MAC protocols such as S-MAC [8] and T-MAC [9].
- ***Asynchronous protocols***
  To avoid node synchronization an asynchronous sleep/wakeup protocol can be used [10]. In the scheme a node can wakeup when it needs and still be able to talk with their neighbors. This goal can be achieved by planning a sleep/wakeup scheme such that any two neighboring nodes forever have overlapped active periods inside a specified number of cycles. These schemes are generally easier to implement and can promise network connectivity even in extremely dynamic scenarios where synchronous schemes (i.e., scheduled rendezvous) become insufficient. This superior flexibility is

remunerated by lesser energy efficiency. In the asynchronous schemes nodes want to wakeup more regularly than in scheduled rendezvous protocols. Consequently, asynchronous protocols usually result in a superior duty cycle for network nodes than their synchronous counterparts. Asynchronous wakeup was initially given in [11] with reference to IEEE 802.11 ad hoc networks. The fundamental IEEE 802.11 Power Saving Mode (PSM) has been conceived for single-hop ad hoc networks and therefore it is not appropriate for multi-hop ad hoc networks, where nodes may also be movable.

MAC protocols with low duty cycle

MAC protocols with low duty cycle can be mainly subdivided into three main categories:

Contention-based

TDMA-based

Hybrid protocols

- ***Contention-based***
  Contention-based MAC protocols are primarily based on the Carrier Sense Multiple Access (CSMA) or Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA). The main plan is that when a node wants to transmit data it will contend for wireless channel. Contention-based protocols do not need any synchronization among the nodes using the channel. Colliding nodes will back off for a random period of time before attempting to access the channel. PAMAS [Singh et al., 1998] is CSMA based protocol tries to keep away from overhearing, but does not bypass collisions. S-MAC [8] is an enhancement over PAMAS, by making idle nodes turn off their radios, in this manner shortens more depletion of energy. The disadvantage of S-MAC is that the nodes will stay awake throughout the complete non-sleeping period even if they are neither sending nor receiving data. T-MAC [9] solves the S-MAC problem by using short non-sleeping period when the channel is idle. The typical contention-based MAC protocols are S-MAC [8], T-MAC [9], and UMAC [13].
- ***TDMA-based***
  In comparison with contention-based MAC, scheduling based TDMA techniques provides an inherent collision free scheme by allowing exclusive time slots for each node to send or receive data. The first benefit of Time Division Multiple Access is that interference between adjacent wireless links is certain to be avoided. As a result, the energy waste coming from packet collisions is decreased. Second, TDMA can resolve the hidden terminal problem with no extra message overhead for the reason that neighboring nodes transmit at different time slots. TRAMA [14] is a TDMA based protocol uses traffic-based scheduling to stay away from wasting slots. E-MAC [15] does not need a central manager or base stations. The nodes are competent of selecting their own time slots. The nodes can make the decision to become either active or passive based on the local information. Main TDMA-based MAC protocols are μ-MAC [16], DEE-MAC [17], SPARE MAC [18].
- ***Hybrid protocols***
  From the past sometime, there have been some hybrid proposals, which unite the benefits of contention-based MAC with that of TDMA-based MAC. All these protocols separate the access channel into two parts. Control packets are sent in the random access channel, and data packets are broadcasted in the scheduled channel. The control channel program the data access. The hybrid protocols can grow huge energy savings and provide better scalability and flexibility than any of contention-based MAC or TDMA-based MAC. IEEE802.15.4 [19] is the mixture of TDMA and CSMA, which allows devices to access channels in a contention access period or a collision free period. Z-MAC [20] and A-MAC [21] also the hybrid type protocols, robust to synchronization errors, efficient in slot assignment failures and time varying channel conditions.

V. CONCLUSION

As the sensor nodes are typically supported by battery with constraint power, energy efficiency is vital for applications of wireless sensor networks and the MAC protocol is the main decisive factor in WSN energy performance. So how to design an energy efficient MAC protocol is a significant issue. Therefore, some mechanisms are required to enhance the life span of the sensor network. This paper describes the duty cycling methods to increase the sensor network life span. Power management protocols can be implemented either as independent sleep/wakeup protocols running on top of a MAC protocol or strictly integrated with the MAC protocol itself. Nowadays with wireless sensor applications and hardware growing fast, how to achieve better energy efficiency in MAC for wireless sensor networks is still a critical issue and need more studies.

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