Energy Conserving schemes for MAC Layer in Wireless Sensor Networks

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***Abstract*— Wireless Sensor Networks (WSN) are made up of sensor nodes that are deployed randomly to communicate with the physical world. The sensor nodes are battery equipped which is power confined and difficult to substitute or change. So energy efficiency is a prime need in a wireless sensor network (WSN). To avoid wasting the limited energy, various energy saving schemes are proposed for MAC protocols. Energy efficient MAC can reduce the major energy wastes in the network. Developing such a scheme in MAC protocol has been a hot research area in WSN. In this paper, we discuss need of energy conservation in WSNs. A brief discussion of various energy saving schemes that can be anticipated in MAC protocols in WSN is done.**

Keywords- : Wireless Sensor Networks (WSNs), Energy Conservation, Medium Access Control(MAC)

I Introduction

A wireless sensor network is consist of large number of sensor nodes deployed in an area to sense and collect information. These nodes collect data by sensing and monitoring the area and send the collected information to one node that is generally termed as a sink node for further processing. The major application areas [1, 2] are home and office, healthcare, , security and surveillance, entertainment, control and automation, environmental monitoring, agriculture, military activities, education and training. Sensor nodes are tiny structures having limited processing, storage, communications and transmission capabilities. Due to limited power support for sensor nodes, energy efficiency is one of the major problems. From analysis on the sensor nodes, it is found that the communication module is consuming maximum part of energy, which is the main optimization goal. The replacement of node as well as battery is difficult. The Medium Access Control (MAC) protocol directly controls the communication module, so it has significant effect on the nodes' energy consumption. A large number of MAC protocols are proposed for conservation of energy[3][4]. Every scheme use different practices to gain high level of energy conservation in order to prolong network life. In this paper, in Section 2, we discuss about medium access control ,various energy conservation schemes at MAC in wireless sensor networks. In Section 3, we discuss external factors that support energy conservation and management in WSN thereafter followed by conclusion in Section 4 .

II Medium Access Control (MAC) Layer

A MAC protocol is fundamentally used for access control of channel in a network. MAC plays important role to save energy by controlling possible energy wastes. It is used to regulate when and how a nodes should access the shared medium for communication. Medium Access Control (MAC) protocol directly controls the communication phase of a network operation, so it has significant effect on the nodes' energy consumption. In order to avoid all factors of energy waste, researchers have proposed different types of MAC protocols to improve energy consumptions so that the WSN can have a long lifetime.

The MAC layer is mainly focuses for high throughput ,reliability, energy efficiency, & low access delay to optimally utilize the energy-limited resources of sensor nodes. Maximum amount of energy wasted in MAC protocol operations like collision, overhearing, control packet overhead and interference. To minimize the energy expenditure at WSNs energy efficient MAC techniques like duty cycling, packet scheduling adaptive transmission range, and adaptive transmission period.

A. Sources of Energy Exhaustion

Major sources of energy waste in wireless sensor network are basically of four types[6][7]:

- Collision Due to interference, a transmitted packet has to be discarded and the retransmissions of same packet results in increased depletion of energy resources.
- Idle listening The last major source of inefficiency is idle listening i.e., listening to receive possible traffic that is not sent. This is especially true in many sensor network applications. If nothing is sensed, the sensor node will be in idle state for most of the time. The main goal of any MAC protocol for sensor network is to minimize the energy waste due to idle listening, overhearing and collision.
- Packet Overhead control signals that are used to reduce collision probability also results in energy depletion. So control packet exchanged should be minimum to avoid energy depletion.
- Overhearing overhearing occurs, when a node picks up packets that are addressed to other nodes

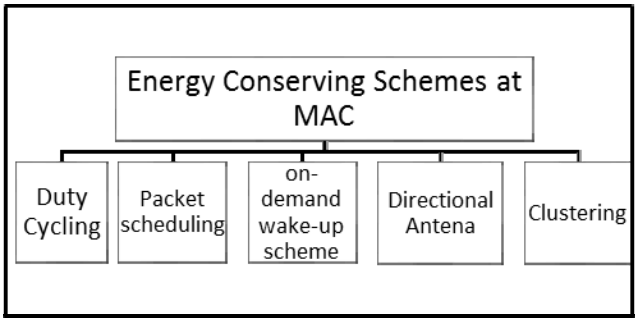

Figure 1. Represents energy conserving schemes at MAC

B. Factors for Energy Conserving

In present scenario, sensor networks are used in a wide range of applications according to requirement and purpose. The network type, topology and deployment of nodes (sensors) may affect the usage of energy by the sensor nodes in any particular scenario. Because of limited resources available in a sensor node, the MAC protocols should be dynamic enough to control and fulfil the need of application and also to limit the usage of energy as much as possible. Besides the schemes of a MAC protocol, the efficiency of Energy depend on other aspects such as design and deployment features of a node. These aspects are not only important as well as very decisive and eventually affect the overall working of a MAC protocol .The factors that affect energy efficient parameters while designing MAC protocols are as follows:

- Delay
- Type of network
- Antenna Mode
- Transmission Range
- Dimensions of area to be sensed
- Throughput
- Control schemes for network
- Quality of service (QoS) requirements
- Node arrangement/Layout in the Network
- The number of channels in communication
- Node deployment strategy

To save the valuable energy in a sensor network, researchers have used various energy saving schemess. The wide range of methodologies used in various MACs significantly influences the energy consumption in a sensor network. In next section, we discuss these schemes in detail for MAC layer in WSN.

C. Energy Conserving Schemes at MAC layer

- duty cycling,
- Packet scheduling,
- on-demand wake-up scheme,
- energy efficiency through directional antena
- clustering

1) Duty Cycling

Duty cycling is a schemes in which a node periodically switches between wake up and sleep mode. Sensor node goes to sleep mode(radio is turned OFF) when communication is not required and wake up mode(radio is turned ON) as soon as a new data packet becomes ready to send/receive to safeguard energy. Duty cycling is an effective

method of reducing energy dissipation in wireless sensor networks (WSNs). In wireless networks, nodes spend most of their time idle for monitoring the channels. Using heavy duty cycling in each node low activity rate can be achieved. In duty cycled operation [6], a node follows a sleep-wake up-sample compute-communicate cycle in which majority of the cycle spend their time in low power sleep state. In long duty cycle , the nodes will be in sleep mode for longer and more energy will be saved, whereas less number of nodes will be actively participate in data routing, which will decrease the throughput and increase transmission latency[11]. So in order to reduce the duty cycle, the active time of the node should be short enough to take into account some limitations. Duty-cycled does not require continuous sampling or communication which makes its operation possible in WSNs.

2) Scheduling

The scheduling is crucial to coordinate the transmissions of different users. By scheduling the nodes know their schedules ahead of time, they can simply turn off their radios to save energy if it is not the time for them to grep the channel. Thus the chance of overhearing and idle listening can greatly decreased, and the corresponding energy spending can be reduced too. With scheduling, each node transmits with the pre-assigned frequency or code, or at the pre-assigned set of slots. Therefore, no collision in the MAC layer can occur. In this way,energy waste due to packet retransmission can be avoided and the improvement of network throughput and effective channel utilization. scheduling-based MAC protocols can achieve better energy conservation due to collision avoidance. Different scheduling schemes provides different results according to their assumptions about sensors, network structure, deployment strategy, sensing area, transmission range, detection and failure model, time synchronization and the ability to obtain location and distance information. Effective Packet scheduling can reduce the energy consumption by considering the demand of the situation .If channel conditions are bad then longer transmission cycles can conserve more energy in contrast to uniform TDMA schedule. It is also analysed that the WSN node lifetime also depends on the packet size of data. Data packet size is inversely proportional to the life time of the node. As data packet size is increased, the lifetime of the battery is decreased [12].

However, the complicated control involved in the setup and maintenance of a schedule may compensate the saved energy obtained from collision avoidance, if it does not exacerbate the energy consumption. On the other hand, scheduling-based MAC protocols may not work well for bursty traffic, as the schedules are fxed, regardless of the user's real need. Another restriction on the application of these techniques is the topology dynamism. Scheduling-based protocols require that the network topology remains stable or changes slowly such that a schedule can effect for longer time to compensate the high setup overhead. Thus, they cannot be applied to highly mobile or other dynamic environments directly

3) On-Demand Wake-Up Scheme

In this scheme, out of band radio signals are used to wake up a node from sleep state and communicate. A wake-up tone is used to wake up all neighbors. The tone is broadcasted on different channel for a obvious duration. Generally any encoding scheme is not used while broadcasting wake-up tone. According to the requirement of scheme multiple radio architecture are used —one for waking up neighbours and other for sending data. The frequency used in wake-up radio is generally different from normal communication radio of the node. A wake-up radio uses less energy through low duty cycling and extra low powered hardware device .In this receiver has to detect only energy on channel rather than decode a packet and can be implemented using simple hardware . It helps to maximize sleep time for a node[13]. On the wrong way, in this a wake-up tone awakes entire neighborhood thereby wasting energy in the unnecessary wake ups and also need of extra hardware

4) Directional Antenna

Usually the omnidirectional antenna have an even gain in all direction. While directional antenna are used to increase throughput and reduce delay and interference, while requiring lower transmission power. Omnidirectional transmissions block the communication channel and transmit energy in unnecessary directions. A directional antenna receives/transmits signals from one direction at a time. directional antenna is capable of transmitting over larger range than an omnidirectional antenna[14]. A directional communication focuses all the radiated power towards the intended target, reducing the required power for a given range. Multiple communications can occur in close proximity using directional antenna. Along with it energy waste may still happen due to directional antenna adjustments for mobile node or multichannel environment and directional antenna may face the deafness problem[16].

5) Clustering

Clustering provides scalability and robustness for the network; it allows spatial reuse of the bandwidth and simpler routing decisions and results in decreased energy dissipation of the whole system by minimizing the number of nodes that takes part in long distance communication.

In this scheme, full network is divided into small clusters. All the clusters are maintained and coordinated by head. Cluster heads(CH) collect, process, aggregate and send data. Communications can be either intra cluster or inter cluster[10]. In most clustering approaches, first a set of cluster heads are selected among the nodes in the network. After that rest nodes are clustered around these CHs. Different clustering schemes uses a different

approach to choose CH and form clusters. Besides selection of cluster heads, cost of clustering is also a major design issue in this type of protocol.

III EXTERIOR SUPPORTING FACTORS

Along with MAC level schemes, other schemes that are not implemented on MAC layer but reflects a considerable impact on energy efficiency are discussed as follow:

- energy-efficient routing,
- energy efficiency through topology control,
- data aggregation.

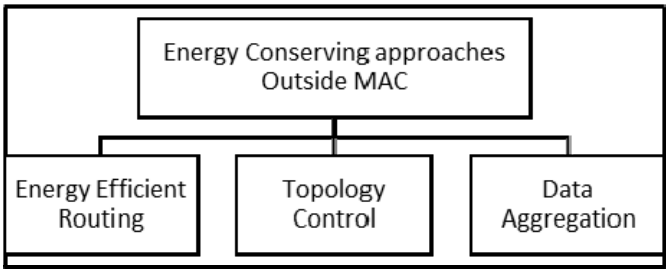

Figure 2. Represents exterior schemes at MAC influencing energy conservation

1) Energy-Efficient Routing

The efficient use of energy source in a sensor node is most desirable criteria for prolong the life time of wireless sensor network. Routing is abundantly important in WSNs compared to any other networks The energy spent in communication (transmission and reception) is much higher than Idle and sleep state of the sensor node. It shows that energy saving in data communication is needed in the WSNs. The sensed data communicating to the sink node involves transmission from the source and intermediate nodes needs to receive and transmit the data to the next neighboring nodes. Energy efficient routing protocol may reduces energy consumption quite significantly and prolongs the life time of sensor network.

2) Energy Efficiency through Topology Control

The physical deployment plays important role to control energy consumption in network. The optimal deployment enhances lifetime of the network, along with determination of deployment cost, coverage, connectivity, etc. A good deployment is important to achieve load balance and prolong the network lifetime

3) Data Aggregation and In-Network Processing

Incorporating sensor nodes with data aggregation capability to transmit fewer data flows, into wireless sensor networks, could reduce the total energy consumption. This field is an active research area, and works are ongoing in this direction. Since sensor nodes might generate a significant amount of redundant data, similar packets from multiple nodes can be aggregated so that the number of transmissions would be reduced It is reported whether the sources are clustered near each other or located randomly, significant energy gains are possible with data aggregation. As it is a well-known fact that computation costs less energy than communication, substantial energy savings can be obtained through data aggregation. Data aggregation in sensor networks can be done either using cluster-based or tree-based approach.

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IV Conclusion

The fundamental challenges in wireless sensor networks are smaller storage capacity, less amount of node energy, slow processing speed, smaller transmission range etc. Along with infrastructure based issues, WSNs bear many issues to researchers to address. In this study, we get to know about various energy saving schemes for MAC protocols. Although all approaches anticipated to improve energy usage in the network, there are still inbuilt issues need to be resolved. To improve the performance of WSNs, primary focus is to reduce the usage of energy and to increase the lifetime of network. Although there are various schemes for energy conservation at MAC layer for sensor networks, still there is need for further improvement. Application scenario is main aspect for MAC protocol performance and energy efficiency protocols. The main reason behind this is the MAC protocol choice is application dependent, it indicates that there will not be *one* standard MAC for sensor

networks. Another supportive reason for this fact is the lack of standardization at lower layer and sensor hardware.

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