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A Review on Energy Optimization in Wireless Sensor Networks

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Abstract

IEEE 802.11 standard defines the principles of Wireless LAN (Local Area Network). It mainly categorized into 2 different topologies: Infrastructure Network and Ad-hoc network. Ad-hoc networks can uses only created networks for "this purpose only" goal. On other way, Infrastructure network uses fixed "permanent" infrastructure. The main objective behind this both type of topology is to save energy in Wireless Sensor Nodes (WSNs). Connection of different WSNs are called as Wireless Sensor Networks. In this paper, we will review some of the techniques for energy optimization in Wireless Sensor Networks.

Keywords— *Energy Optimization, Wireless Sensor Network, Review, Power saving, MAC protocols, Routing protocol, survey*

I. INTRODUCTION

Sensor Network (WSN) is a typical sensor network made up of a huge number of less power, less cost distributed devices. These devices are called as nodes. They are deployed in the environment that is being sensed and controlled [1].This network is composed of a large number of small nodes which able to pass messages with each other and it can be used to monitor inaccessible areas. Due to this reason, each node has memory, processor, battery and wireless antenna. Nodes can not only sense scalars like acoustic, light and temperature from the environment but may also process and transmit them by radio. It uses free band 2.4 GHz to transmit the data. Some special nodes must be present with special configuration and special hardware to process, collect and store data from the WSN's nodes. The special node is known as Base Station (BS). Now a day, the WSNs are mostly based on low cost processors and low energy consumers and small memory. The WSNs must have long life because in many applications, the networks are used for remote areas where recharging and/or replacement of power supply is very difficult or prohibitive due to some restriction or safety issues. But the availability of cheap hardware for the radio communication frequency, there can be a lot numerous topologies for WSNs [2][3][4].So, in such type of areas, we need to use protocols that can self organize and optimize energy consumption[2].

WSNs must have following characteristics [3]

1. It must be self-organizing
2. It must use small range wireless communication and multi-hop routing protocols
3. Very huge number of nodes and cooperation between nodes.
4. Different WSN topologies.
5. Resources like battery, memory must be limited.

The challenges in deployment of WSNs are as follows [1-3][5][6]:

1. The WSNs are used for not only collecting environmental information but it also used for changing the environment information.
2. The resources are limited and memory is less. It should manage all the complex functionality using different topologies.
3. There are many uncertainties in WSNs. They can affect the functionality of WSN.
4. One of the big challenges of WSN is to make the node as self-organizing and self-optimizing.
5. There can be a large number of WSN nodes but network must have limited number of nodes that guarantee the desired WSN service.
6. WSN operates in the real world. So, it must have real-time features as per need.
7. WSNs are not safe because it uses free band. So, there must be some security for managing original data.

WSNs are made up of integrate general-purpose computing with heterogeneous sensing nodes and wireless communication and low power sensor. The power unit is one of the most important components of a sensor node [8].A WSN can limit the radio frequency channel, due to, that is to say, unstable links, limit of physical protection of each sensor node, actual of each nodes connection, variation topology in addition dangerousness about routing security is high by activity spite nodes. The restrictions in the hardware of the sensor nodes, makes it difficult to guarantee the maintenance of security because of its vulnerability.[9][10].A WSN is consists of spatially distributed autonomous sensors together monitor physical or environmental conditions. A sensor network normally makes a wireless ad-hoc network, that is, each sensor is deployed with a multi-hop routing algorithm. The network does not have any already existing infrastructure, such as routers in wired networks or access points in managed (infrastructure) wireless networks. In place of this, each node participates in routing by just forwarding the data for other nodes, and so the determination of which nodes forward data is made based upon the network connectivity and many other parameters. Base Stations act as a gateway between the sensor nodes and the end user. Figure 1 shows the basic components of a sensor node [11].

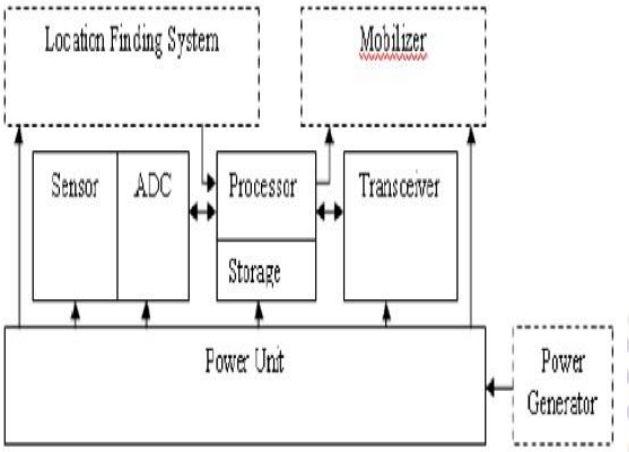

Figure 1 Components of Sensor node [11]

II. MOTIVATING EXAMPLE

The RFId (Radio Frequency Identifier) is also one type of identifier in small wireless networks. It can be used in many applications. In a library, each and every book can identify by its ID called RFId. In a case where anyone want to take a book out of library without knowing to the administrative staff, the sensor of RFId near to the exit of the library can catch such persons. So, these RFId is just playing role of transmitter and receiver. In another example, forest fire monitoring system, the RFId's are used for monitoring the fire in the forest where human can not be available all the time. All RFIds are placed in the areas where we want to know about fire. The RFIds are very cheap in cost, so there can be many RFIds in such places. So, whenever the rapid change in temperature is found, the RFIds can pass the message to other nearer nodes and make a chain to pass the message to observer. Here, RFIds are not having capability of processing the inputs. So, the concept of Wireless Sensor Node was introduced. WSNs can provide same functionality as provided by RFId. Both uses Radio Frequency free band (i.e 2.4 GHz). We can have some processing capability in WSNs. There are same resource constraints (battery life, memory) in both. WSNs are used in such type of applications. Another important application of WSNs is to monitor the inside sea movements. Sensors can be thrown freely (sensors are very cheap) in the ocean and they are monitored by the base station. The Base Station can make decision in problematic situations. WSNs are always having a Base Station (BS) to receive the signal from the sensors. Due to energy constraints, sensors can not pass the message directly to the BS but it send to neighbour node and then similar way the message can reach to BS. The main constraint is energy as WSNs are operated with small battery life. So, to improve the battery life of WSNs we need to go for energy optimization techniques for WSNs. It is discussed in the subsequent sections.

III. VARIOUS WSN PROTOCOLS AND TECHNIQUES

A. *MAC layer techniques*

The main portion of the node's energy is spent on radio transmission and on listening the medium for message [7]. For sending and receiving the data, node requires more energy compared to processing data. The performance depends upon how fairly and efficiently the node shares the medium because they have a single medium for communication shared by nodes. MAC protocols manage communication and regulate the shared medium such that performance is improved.

i) ZigBee technology The main aim of ZigBee technology is to have WSNs, made up of large nodes, work with less energy consumption. It is based on Open System Interconnection (OSI). ZigBee works with IEEE 802.15.4 standard. It defines the lower physical and MAC layer. Its physical layer operates in 2 frequencies 868/915 MHz or 2.4GHz. It can have maximum 255Kbps of maximum transfer rate. It is mainly based upon Carrier Sense Multiple Access - Collision Avoidance (CSMA-CA). IEEE 802.15.4 can operation in one of the 2 modes namely Beaconless Mode (without beacon packet) and Beacon Mode (beacons are periodically sent to co-ordinate nodes).

ii) Other techniques Other techniques used as MAC layer techniques are Time Division Multiple Access (TDMA) and Duty Cycles (DC). In TDMA, the time spent by devices on the channel is divided into time periods called as time slots.Each time slot is used by one device exclusively. The TDMA MAC protocol is based upon cross layer optimization based upon Physical layers and MAC[12].Its main goal is to reduce the energy consumption. FlexiTP and PEDAMACS are TDMA MAC protocol examples. The Duty Cycles (DC) techniques divides the operating time of devices into 2 periods namely Active and Inactive(sleeping). Shorter the Active time, lesser the energy consumption and higher energy saving. Longer the active time, more energy is utilized.

B. *Network layer (Routing) approaches*

The main objective of WSNs application is to gather the data from nodes and transfer the data to sink in energy efficient way using proper routing protocol. A clustering protocol REACA's functions are divided into 2 cycles: in first cycle, network configuration is done, while in second cycle, message transmission is considered. In this protocol, cluster head is choosen based upon battery energy level[13]. EARQ is another routing protocol based upon energy

level. Its main objective is to use greatest energy level path inside WSN. It can be implemetable in industry applications. MMSPEED is another routing protocol approach which is able to guarantee probabilistic QoS (Quality of Service) in WSNs. It considers different options of speed delivery in time domain[14]. The q-switch routing algorithm is a routing technique for the support of non uniform node distribution strategy. In this approach, authors also suggested that in this protocol, the unbalanced energy consumption is unavoidable[15]. Energy Efficient Broadcast Problem (EEBP) in ad hoc wireless networks is : find a broadcast tree such that the energy cost of the broadcast tree is minimized. Green Wave Sleep Scheduling(GWSS) was inspired by synchronized traffic lights. The main objective is to support Duty Cycling in WSN's routing. Moving sequence of consecutive green light (active states) is called as Green Wave. In this approach, the sleeping nodes are considered as red light and the data is not passed from such nodes [16].

C. Transmission control approaches

There are many Transmission Power Control (TPC) approaches available. Its main goal is to reduce the energy consumption and improve the channel capacity. TPC solutions work with single transmission power for whole network. Some of the TCP studies focus on the improvement of the channel capacity.Some of experimental studies shows that energy consumption is reduced in low-power WSNs.One of the algorithm is Power Control Algorithm with Backlisting (PCBL), in this algorithm, each node transmit the packet with different transmission power levels to find optimal trasmission power based on Packet Reception Ratio (PRR) [17]. To get the optimal transmission power for a particular link, Adaptive Transmission Power Control (ATPC) algorithm is used. To empoy a feedback based ATPC algorithm and to estimate optimal transmission power level, the Received Signal Strength(RSS) and the Link Quality Indicator (LQI) parameters are being used.

IEEE 802.11 WLANs and IEEE 802.15.1 Bluetooth wireless networks operates on 2.4 GHz ISM band. So, there is a chance that these devices interefere the normal working of WSN devices because transmission power of WSN devices is less compared to bluetooth and WLAN devices[18]. Practically, TPC algorithm is considered as Interference aware Transmission Power Control (I-TPC) [18]. In this algorithm, each node adjust the RSS target to provide acceptable SINR (Signal- to - Interference - plus - Noise - Ratio) when interference are detected.

Local algorithms individually adjust the node's transmission power [19]. These type of approaches do not require any MAC protocol or dedicated route protocols.They implements Local Mean Algorithm (LMA). In it, each node periodically sends a life message and each receiving nodes respond with life acknowledge messages. Everytime before sending any information, each node counts the number of received acknowledge messages and compare it with the threshold value. LMA approach allow each node to have count of each neighbors. Some of the global approaches like Equal Transmission Power (ETP) are comparable with local algorithms. When going for network's confidence level, scalability and implimatability, local algorithms are better compared to global.

D. Autonomic Approaches

Autonomic computing was introduced by IBM in 2001 to describe the systems that are self-manageable [20].The main properties with are [21]:
Self- configuration: It concern with system's ability to configure by itself for achieving high level goals.
Self-optimization: It concern with the change in system pro-actively to optimize the performance or quality of service.

Self-healing: It deals with the identification and solving the problem in the system.
Self-protection: It concern with system security against malicious attacks or unauthorized changes.

Generic Machine Learning Algorithm (GMLA) was developed to make use of trade-off between different metrices. When network topology is unknown to base station, GMLA's main goal is to improve the communication efficiency[22]. Another algorithm called Variable Offset Algorithm (VOA) was proposed to reduce the communication efficiency in dense WSN with star topology [22].

IV. Conclusions

Wireless Sensor Network is the best solution to access the data from inaccessible areas. The devices used for this analysis is having restriction of limited battery life. In this paper, we have discussed different possible areas where we can reduce the energy consumption caused by the node and result into saving the battery life. Moreover, we can say that the main reason behind energy consumption is the data processing process and data transmission process. We can look for the algorithms which can reduce this both criteria. From above discussion, we can conclude that MAC protocols can manage energy consumption during WSN communication. It is the most energy consuming process in WSNs. On other hand, transmission power consumption is also a major problem in WSNs. Transmission control protocols can be used to lower the transmission power overhead. But if the transmission power becomes still lower then it can increase the vulnerability to fluctuations generated by SINR. Based upon the route selected, the energy consumed by the node can be increase or decrease. So, in order to reduce the energy consumption, routing protocols

are used. Some of the protocols obey the property of "self". These protocols can handle, manage and decide based upon the different situation and take their decision.

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