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Energy Conservation Protocols for Wireless Sensor Networks - A Survey

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ABSTRACT

Wireless sensor network is a network where low power devices named as sensor nodes sense the information of network and then transfer this sensed data to the sink node. There are various application in which sensor networks are used such as in military applications, forest, weather forecasting, health monitoring etc. Energy is the main issue in wireless sensor network. Sensor nodes in the network are of very small size and have low batter power and sensor nodes are deployed at remote locations due to which replacement of battery is not possible sometimes. Therefore, main issue in wireless sensor network is less energy consumption and increase the lifetime of the sensor network. Energy conservation can be achieved by using various scheduling protocols in WSN. Several schedule-based protocols will be discussed in this paper and how they will help to increase the lifetime of the network.

Keywords: Wireless sensor network, MAC protocols, TDMA, Energy consumption

I. INTRODUCTION

Wireless sensor network is collection of many small power devices named as sensor nodes that are randomly deployed in the sensor network at various locations or sometimes at remote locations. These small devices have very low power and sometimes it is not possible to replace the battery of these devices and this will take more energy in processing or sensing the data. It will take more energy in sensing data in the network and then transferring this data to the base station leads to decrease the lifetime of the network. Wireless sensor network (WSN) can sense various environmental conditions like pollution, level of temperature, wind effects etc. WSN has both single hop and multi- hop communication. If two nodes are adjacent to each other in the network or in it radio range than they can communicate through single hop communication but if two nodes are not in, the equal radio range of each other than they transfer or communicate through two hop or multi hop communication method.

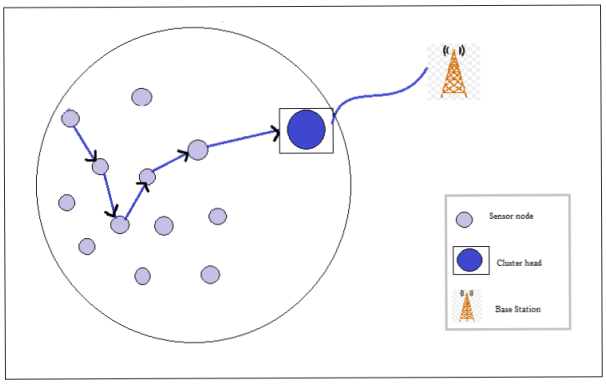

Figure 1. Wireless sensor network architecture

Each sensor node in the WSN has three main components: sensing part, processing component, power supply unit, communication. These play an important role in the transmission of sensed data from nodes to the base station. The growth in the wireless environment is how the sensors are assimilated by the changes largely. The base station is where the data is aggregated from sensor nodes on

transmission link and then examined for decision making procedures. A wireless sensor network (WSN) composed of distributed sensor nodes to detect various conditions of environment like motion, vibration, humidity, sound, pressure, temperature or pollutants. The objective of the sensor nodes is to transmit their data to base station. [1]The energy-conserving component is available at each layer in WSN. Therefore, there are chances of energy consumption at different design stages by using the software optimizations techniques to minimize the consumption of energy and to increase the lifetime of the wireless sensor network.

The sensor network that consists of these sensor nodes is fault tolerant as most of the nodes are involved in sensing of same data. Nodes collect and aggregate their data and evaluate them which denotes accurate sensing of information. Finally the sensor nodes transmits this collected information to the base station. [2] In this procedure, efficient utilization of energy is the main concern. Routing protocols and sleep/wake scheduling protocols are designed for this issue that provide a higher energy efficient sensor network. Various tdma/scheduling protocols have been discussed in this paper with their advantages and disadvantages.

A. Issues in WSN

Various important issues, which can degrade the performance and design of sensor network, are discussed here: [3]

- Energy: Sensor nodes have very less power and nodes require more power for some operations that use higher energy for their functionality such as data collection, data processing, and communication. So the main challenge or issue in the WSN is energy. Less energy should be consumed so that lifetime of WSN will be increases.[4][5]
- Hardware and Software: The hardware should be exactly dictated for the energy conservation. In this, Energy conservation is discussed by considering design in WSN applications. There are finite parts, of which the WSN generally consists of. These devices and their characteristics are to be elected effectively within the guideline satisfaction. The over-characterized devices remains idle and less utilized as well as increase the consumption of power in the sensor node.[1]
- Quality of Service: It is the service that sensor network provides to the users. As there is dynamic network topology of sensor nodes in the network due to this available data can be lost. Sensors networks must have larger bandwidth so that network can achieve required QoS.[6][7]
- Security: Security is the most crucial issue in the WSN as sensor node are not only deployed in the nearby areas but also to the remote locations. So to make the sensed data confidential security is the main issue that has to be considered otherwise data can be theft in between by an intruder and it will affect the performance of WSN and thereby decrease the lifetime.[8]
- Limited Storage Space: Sensor network has a very limited memory to store the sensed information so algorithm space complexity should also be small to tackle this kind of problem.
- Fault tolerance capability: Sensor network must work in the situation when any node failure occurs. So network should be able to handle these node failures. Efficient algorithm should be applied to tackle this challenge.[9]
- Time Synchronization: This clock synchronization provides a common time to all the nodes so that their local clocks will get synchronized. Sometimes these synchronization techniques will also consume more energy thereby degrade the performance of the network. Synchronization techniques must be chosen according to the applications.[10]

B. Characteristics of WSN

- Energy harvesting: Sometimes WSN consumes extra energy in most of the applications. Various energy harvesting by power consumption constraints are available in WSN that can improve the performance of the network
- Node failure handling: Sensor nodes has the ability to handle node failure in the network. Node failure causes packet loss in the network which consume extra energy but wireless sensor network can handle such problems
- Scalability: Sensor network provides scalability and efficient performance of the network.
- Ease of use: As wireless sensor network are not centralized in nature, there is no central component to handle all the nodes. Sensor nodes are randomly deployed so it is easy to use this type of network in a distributed network.
- Mobility of nodes: Nodes' mobility is another major characteristic in wireless sensor network. Nodes are mobile in nature that can work efficiently and thereby increase the network's performance.

C. Application of WSN

There are various application of the sensor network, overview of which is provided in this part.[11]

- Military Applications: WSN is used for military applications such as command, communication, intelligence systems. Decentralized and self configuration technique of sensor network make it a very crucial thing in military applications. Sensor nodes are randomly deployed in the network and nodes have low cost due to which it is used in military field. It can be used to investigate the forces and tracking their movements etc.
- Health Monitoring Applications: Wireless sensor network is used in finding the health problem related issues in hospital. By deploying sensors in the hospital, patient all information about his health can be recorded in those sensors which help doctors to know about the health of the patient, if he/she needs medical attention or not at that time.
- Home Applications: WSN provides a simple, efficient and convenient environment for working in home. Like, it can be used to monitor the reading of the electricity and then inform to a remote center about those readings. Sensor network allows people to control or manage home appliances locally as well as remotely.
- Agriculture: By using the WSN in agriculture area, the need to manage the wiring will be decreased. Sensors can monitor the water level of tank, pumps by using pressure transmitters. In addition, it can be used to sense the readings of water and electricity and then send those readings to the remote centers.
- Industrial Monitoring: WSN can be used to control and manage various industrial applications such as automation etc. In industries, it can keep track of machines whether machines are working properly or not. It can be used for data logging, waste monitoring, production rate etc.
- Environmental Sensing: There are several application for monitoring environmental conditions in which there is requirement of WSN such as air pollution, forest fire detection, landslide detection, water quality, natural disaster prevention etc.

II. RELATED WORK

Various scheduling protocols has been proposed till now to minimize the energy consumption in the sensor networks by using different techniques to assign time slots to the sensor nodes.

Meirui Ren, et.al, (2017), have recommended the use of sensor data on various buildings, in forests and in other applications. For [12] the use in different applications a large amount of sensor data is generated frequently and streamed from sensors. For

the support of data analysis low latency time is need to be provided by also managing the velocity and volume of the big sensor data is become a very big difficulty in these areas of applications. The volume of big sensor data can be reduced by the use of data aggregation, but it is very time consuming operation in wireless sensor networks, particularly when WSNs are in high density. Therefore, the main focus of researchers in this paper is to propose a scheme which will minimize the latency of data aggregation and taken it as NP-hard problem. For getting the required results the authors have proposed a cluster-based distribution data aggregation algorithm and name it (DMPMC), that prove to be good in minimizing the data aggregation latency in case of both multi- channel and multi-power WSNs. For saving the energy the authors have used a low transmission power for transmitting the packets inside of cluster and high power is used for transmitting the packets among the clusters. The simulation results show that the proposed DMPMC algorithm achieves the lowest average latency.

Sarath Pattathil, et.al, (2017), have considered the problem of optimal distributed scheduling for delay minimization in single-hop wireless networks. They did focus on static scheduling policies, where the CSMA channel access rates are determined by the long-run traffic statistics, but not the instantaneous queue states. In case of heterogeneous traffic flow, such kind of static scheduling is preferable over the max-weight like dynamic scheduling. In this [13] paper, the authors have formulated the problem of optimizing the channel access rates of different links subject to an upper bound on the access rate of each link. As this is a hard non-convex optimization problem that's why the authors have proposed approximate solution that is asymptotically optimal in the limit as the maximum permissible channel access rate grows to infinity. To achieve the objective the authors have also studied the role of the intra-queue scheduling policy. Two policies have been considered in this paper name as first come first served (FCFS) and pre-emptive last come first served (PLCFS).

Junhee Lee, et.al, (2015), have proposed the conflict-free TDMA link scheduling algorithm. The main objective of proposing this algorithm is to minimize the slot length in multi channel operation of wireless multi-hop sensor networks. For all the links in the network the authors have exploit the conflict graph model to schedule a conflict free transmission. Including the entire link for transmission the minimum slot length is calculated by the use of max-min optimization. By ordering the link transmissions with the use of proposed algorithm the end to end delay have been minimized. The performance of MTS algorithm have been evaluated and than its results compared with the MPD and distribution FIFO algorithms. The [14] results have been evaluated in terms of total slot length and energy consumption in multi-hop many to one network configuration. By varying the different parameters such as the amount of channel bandwidth, the number of paths and the length of frame the performance results have been evaluated. The simulation results of this paper states that the MTS algorithm achieves the minimum total slot length with reasonable end to end delay. The total slot length of proposed algorithm shows the 20% improvement compare with MPD algorithm in the large network.

Yang G. Kim, et.al, (2014), have concluded that Timely communication in wireless multihop sensor networks requires high throughput and low delay. The requirement stated above can be achieved by exploiting multiple channels and time slots. If multiple channels and time slot are utilized then it will lead to inefficient scheduling. The problem of optimum scheduling of multiple channel and time slots in multi-hop networks have become a NP-complete problem. This problem can't be solved by normal scheme that's why the authors [15] have proposed a new scheme by using the meta-heuristic

approaches. The one more reason of using this approach is that not only the global solution but near-optimal solutions can satisfy a given end-to-end bound of delay. For the purpose of scheduling the resources the authors have used the simulated annealing (SA) and particle swarm optimization (PSO). To validate the feasibility of scheduling via these two approaches, number of measure and stopping conditions are explored and than its performance have been compared to satisfy the desired end to end delay. From the simulation results it has been seen that when we talk about the performance of individual algorithm the PSO based scheduling outperforms SA-base scheduling in terms of end to end delay.

Tifenn Rault, et.al, (2014), have recommended that the design of sustainable wireless sensor networks (WSN) is a very challenging issue. It is expected that energy constraint sensors should run for a long period of time. In this hostile environment, it is very cost prohibitive to replace the exhausted batteries. On the other hand, WSNs are designed for one particular application which only ranges from small size healthcare surveillance systems to large scale environment monitoring systems can be result to large cost. Every application have different things to be consider so, while designing the WSNs the deployment should be done in a way which will satisfy a requirements of different applications. The [16] authors have work on proposing the energy saving problem in WSNs. In this paper, the authors have presented a top-down approach to study the trade-offs between application requirements and lifetime extension that arise when designing wireless sensor networks. Then finally they analysed the techniques applied in WSNs to achieve trade-off between multiple requirements, such as multi-objective optimization

R. Rathna, et.al, (2012), have focused on the wireless sensor network for environmental sensing. A Wireless Sensor Network composed of thousands of sensor nodes and a sink node. The number and type of sensor nodes are application specific, also the design protocols for the wireless sensor network are application specific. The sensor data in this application may be variations in humidity, pressure, light intensity and temperature. In this paper, the authors have given more attention to routing and clustering. The [17] proposed algorithm is completely based on TDMA. It helps to reduce the energy consumption by reducing the number of times; a node has to wake up, during a time slot, to be in active mode. The main focus of authors is using the energy efficiently which can be achieved by the use of new proposed scheme by the authors. By using the proposed scheme the delay in time is also reduced too much extent. It has been proved also. In future, the work can be done by taking both the TDMA and FDMA (hybrid combination) based slot allocation.

Vinicius Galvao et.al, (2013) have proposed a dynamic timed energy efficient and data collision free MAC protocol for wireless sensor networks based on TDMA with the concept of duty cycling that can reduce the energy consumption in the network. This protocol works on individual channel and by using a carrier sensing method provides energy efficient wireless sensor network. In this for a network structure, nodes have the synchronization beacons to join the network. When any sensor node listens to the channel and find beacons then it will exchange data with the head and get an identification for that cluster or group and listens to all groups for maintaining connectivity in the network. A node that has the highest energy in the group become the leader of the group. In this, RTR(request to register) and RSlot(request slot) these terms are used to register for a slot and sending the information to the base station. This protocol combines the two approaches of TDMA and CSMA to achieve collision free data transmission with less energy consumption compared to the other such as SMAC.[18]

Siddarth Watwe et.al (2015) have proposed a new approach for minimizing the energy consumption in the WSN. He used a different approach and improve the energy efficiency by clock synchronization in WSN. By clock synchronization all the nodes in the network are set to a common clock either to an external clock or with the time of an internal node. Energy consumption by such protocols is based on the time of synchronization part and how it will execute. So to reduce the energy, clock synchronization must take less time as possible. This protocol synchronize the clock of all the neighbouring nodes by using a TDMA based MAC protocol. A technique named as IWICS (improved weighted average based clock synchronization) is applied in this paper to reduce the energy consumption and thus the TDMA based this protocol becomes TIWICS protocol. This result will be attained without maximizing the synchronization accuracy.[19]

Table 1. Comparison of energy conserving protocols

Protocol	Advantages	Disadvantages	Year
DMPMC [12]	Provide low data aggregation latency, Highly efficient and effective	Message overhead due to continuously transmission of messages by neighbouring clusters	2017
Optimal - distributed scheduling.-for single-hop networks[13]	It reduces the mean response time for single hop wireless networks	Not suitable for multi-hop wireless sensor networks	2017
Multi channel TDMA link scheduling for multihop wireless sensor networks[14]	Minimize the slot length and end to end delay and reduces energy consumption	Sometimes high initial overhead in ordering the link transmissions	2015
Scheduling multi channel and multislot in time constrained sensor networks via PSO and SA[15]	Minimize the end to end delay hence network lifetime increases	Trade-off between solution quality and computation time during execution of algorithm	2014
Energy efficiency in WSN- a Top down survey[16]	Help in achieving the tradeoffs between lifetime and application requirements	Not limited to large scale applications	2014
Improving energy efficiency in WSN	Reduces the energy consumption by reducing the wakeup time of nodes	Not efficient to hybrid combinations of both TDMA and	2012

Protocol	Advantages	Disadvantages	Year
through scheduling and routing[17]		FDMA	
DyTEE[18]	Less energy consumption by providing collision free network with high throughput	Not much efficient for real automation systems	2013
TIWICS[19]	Reduce the energy consumption without reducing synchronization accuracy	Can increase the delay in the network	2015

III. CONCLUSION

Energy is a very critical issue in wireless sensor network as the sensor nodes have very less power and it is not always possible to replace the battery of nodes that are located at remote locations. Various scheduling techniques have been discussed in this paper that improved the efficiency of wireless sensor network by increasing the lifetime. In scheduling techniques, different time slots are assigned to each node to send or receive the data to neighbouring nodes, cluster head and to the base station. Time synchronization is also applied in a protocol to prevent from any clock drift in the network. This will increase the lifetime of network and make it much more efficient than the other CSMA based protocols based on various parameters like throughput, packet loss, energy consumption, end to end delay. In future, this work can be enhanced for higher mobile nodes. Also a hybrid combination approach (combining static nodes with the mobile nodes)can be considered in future to extend the lifetime of sensor network.

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