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A SURVEY ON ENERGY EFFICIENCY TECHNIQUES IN WIRELESS SENSOR NETWORKS

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Abstract: Wireless Sensor Network consists of an enormous number of sensor nodes with data processing and communication facilities. The sensor nodes exceed the gathered data using radio transmitter, to a sink either easily or through other nodes in a multi-hop approach. Wireless sensor network is a power consuming system, since nodes perform on restricted power batteries which decrease its lifetime. The lifetime of the sensor node is based on battery powered devices. Optimally selected modulation and coding is extremely vital technique in wireless sensor networks. This paper provides a detailed study about all the existing energy conservation techniques and also explains about limitations available in the techniques. After having identified the reasons of energy waste in WSNs, we classify energy efficient techniques based on Nodes, MAC Protocols, Networks and Software Levels. We then detail each of Levels.

Keywords: *Sensor Network, Modulation, Energy Efficiency, Lifetime, Power Consuming*

I. INTRODUCTION

Recently there are fabulous improvements in the development of Wireless Sensor Networks. Which used in many application areas consist of environmental, medical, armed forces transportation, entertainment, and smart spaces. WSN consist of a possibly huge amount of wireless networked sensors required to operate in a possibly aggressive environment for a maximum duration without human intervention. Especially in a sensor network, its lifetime depends on the energy consumption of transceivers. The sensor node is a small device that includes many components: a sensing unit for data acquisition, a microcontroller for local data processing and some memory operations, a communication unit to allow the transmission/reception of data to/from other connected devices, a power source which is usually a small battery and so on. In this survey, we handle with this lack by providing a new classification integrating more techniques [1].

II. RELATED WORK

Olaf Landsiedel performed a work on low power, low delay opportunistic routing meets duty cycling. In this paper author introduced ORW, a practical opportunistic routing scheme for wireless sensor networks. In a duty cycled setting, packets are addressed to sets of potential receivers and forwarded by the neighbour that wakes up first and successfully receives the packet. This reduces delay and energy consumption by utilizing all neighbours as potential forwarders [2].

M.Sheik Dawood analyzed the modulation schemes such as BPSK, MSK and QAM and transmission approach to improve bandwidth and energy efficiency in fault tolerant wireless sensor networks for landslide area monitoring. The total energy consumption includes both the transmitted energy and the circuit energy consumption. The modulation schemes are compared based on their energy consumptions at their transceiver node. The authors also analyzed the appropriate homogenous and heterogeneous modulation schemes to improve the energy efficiency and bandwidth efficiency in a wireless sensor network [3].

Himanshu Sharma analyzed the energy consumption of a practical Wireless Sensor Network scenario which was modeled at the bottom three layers of the traditional networking stack—the physical layer, data link layer and the MAC layer, where the optimization of energy consumption of WSN nodes was achieved using different modulation schemes to maximize the network lifetime. And also the optimized energy consumption (radio energy + circuit energy) of each node is using suitable modulation techniques, where the Energy Consumption was reduced up to 80% in a home automation scenario [4].

Yongsheng Wu described the GBF (Grouped Bit-flipping) decoding algorithm based on PPM signal has a better coding performance compared with the standard BF (Bit-flipping) decoding algorithm with the same decoding complexity. [5]

SaurabhMahajan investigated the performance of Reed Solomon code that was examined in different point of view like Code Size, Redundancy, and Code Rate. Also observed that a properly chosen error correction coding scheme can significantly improve the BER performance. The BER performance curve improves as the size of codeword (Code Size) (n) is increased at constant code rate. The BER performance also improves as the size of codeword (n) is increased at the similar error correcting capability. The error performance is improved (error correcting codes become more efficient) as the redundancy is increased (lower code rate) [6].

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RaghavendraPrabhu defined and motivated a metric called energy-per-goodbit (EPG), which represents the total energy cost to convey one bit of information without error at the receiver. Although the methods developed are quite general and can be extended to several communication scenarios of interest, it is convenient to classify the work into two main categories: a) scalar channel b) parallel channel. First, they consider a single-carrier QAM system (scalar channel), and find the optimum constellation size (spectral efficiency) and transmit power that minimizes the EPG. As a result, the energy efficiency viewpoint provides a convenient and unified perspective of the various water-filling solutions. Finally, they extend the parallel channel formulation to a MIMO-SVD system and MIMO-OFDM-SVD systems (parallel channel) [7].

Padmavathy and Chitra analyzed the hop distance estimation which is used to find the minimum number of hops required to relay a packet from one node to another node in a random network by statistical method. The energy consumption and latency are calculated from the minimum number of hops [8].

Rehna Raj analyzed a fault tolerant and energy efficient clustering Approach which organizes the whole network into smaller cluster and sub cluster groups enabling a considerable reduction of communication and processing overhead. Sub cluster formation also gives the possibility to skillfully deal with sensor nodes, node leader, and cluster head failures. Also proposed a fault tolerant approach that uses a matrix based error approximation method for providing the approximate sensor data of the failed node [9].

Yunxia Chen derived a general formula for the lifetime of wireless sensor networks which holds the network model including network architecture and protocol, data collection initiation, lifetime definition, channel fading characteristics, and energy consumption model. And referred to as the max-min approach, this protocol maximizes the minimum residual energy across thenetwork in each data collection [10]

BenignoZurita Ares analyzed the bit error rate and average energy consumption for two coding schemes proposed in the literature: Minimum Energy coding (ME), and Modified Minimum Energy coding (MME). Furthermore, a detailed model of the energy consumption is described as a function of the coding schemes, the radio transmits powers, the characteristics of the transceivers, and the dynamics of the wireless channel. A distributed radio power minimization algorithm is also addressed. Numerical results show that ME and MME coding schemes exhibit similar bit error probabilities, whereas MME outperforms ME only in the case of low data rate and large coding code words [11].

Jaeweon Kim analyzed a direct sequence code division multiple access (DS-CDMA) system combined with modified minimum energy (MME) coding. The results show that the proposed system clearly outperforms DS-CDMA systems with or without ME coding in terms of energy consumption and bit error rate. This indicates that combining MME coding and DS-CDMA is an attractive choice for wireless sensor networks [12].

Sorooshyaristract Siamak studied Autonomous Dynamic Power Control for Wireless Networks User-Centric and Network-Centric Consideration. Author presented an estimator based algorithm for distribute power control. The given algorithm is a optimal for power efficiency. The algorithm is predictive, with a user performing autonomous interference estimation and prediction prior to adapting transmitting power. A multiple access wireless network frequently modeled as a collection of radio links separating transmitters and receivers consider the random probability nature of the link gains. Sorooshyaristract Siamak conjectures that depending on a user's application and the network dynamics, a power control policy follows one of two strategies: Greedy approach, Energy efficient approach. A critical feature of this algorithm is the capability of a user to allocate power so as to address various user-centric and network-centric objectives by being either greedy or energy efficient. Simulation results demonstrate superb performance with respect to robustness to stochastic detriments caused by a time varying channel and noisy measurement [13].

Mathapati Basavaraj S. studied that the sensor nodes are operate by batteries. Thus energy conservation is a critical issue. To tackle this problem **Mathapati Basavaraj S** proposed a Energy Efficient Cluster based Mobility Prediction Routing protocol (EECMPR). Kalman filter has used in this proposal. In this Mechanism the cluster head selection is based upon the weight i.e. the node with high weight is selected as a cluster head based upon residual energy and transmission range parameters. The position of each mobile node is carry at the respective nodes using kalman filter which gives information about status update that consists of acceleration and position. This information send to the cluster head which processes this information and further send it to base station. The base station then predicts using this information of status update and compares all the received information taken from cluster head. At last base station send data packets to sensor nodes after Predicting optimal node's position. The simulation results show that this technique minimizes the overall overhead of wireless sensor network [14].

Kannadhasan.S studied that energy efficiency and data aggregation are key issues in wireless sensor network. Wireless sensor network consists of a large number of autonomous sensor nodes. The group of sensor nodes forms a cluster. Each cluster controlled by cluster head. The data aggregated by cluster head from all ordinary nodes within the cluster transmit data to base station. In this paper, Graph theory is used to detect the shortest path. Kannadhasan.S divided proposed work in four phases as 1.Distance calculation, 2.Energy calculation, 3.Shortest path detection 4.Acknowledgement. The network nodes are represented by vertices and also direct connection between the nodes by edges. Finding shortest path to send data from cluster head to base station is based upon the distance calculation and energy calculation. The results were simulated by NS2 simulator. The results show that the sensor nodes utilize less power and have long life [15].

III. ENERGY SAVING AT NODE LEVEL

In a Sensor node there are four essential parts built on the Integrated Chip (I C): processing unit, sensing unit, transceiver

unit and, power unit. *Processing unit* is a part of microcontroller unit which can read sensor data, perform some minimal computations and make a packet ready for transfer in the wireless communication channel. This unit helps in collecting information and to exchange or control data acquisition. The maximum amount of energy is used in communication module when compared to the two other modules. Sharing information between sensor nodes will consume more amount of energy than implementing the calculation within individual node. In Sensing unit, sensors are literally used for sensing temp, images, gas etc. Sensors to sense different things require different amount of energy, but to sense gas, sensors require more amount of energy than any other applications. In *Power unit,* base stations are more often connected to main power supply, whereas nodes in the network depend on batteries to supply power. Hence there is a requirement to choose power efficient hardware and various efficient-operation modes to make the network more power efficient [16].

Based on the above parts and power breakdown, several approaches have to be exploited, even simultaneously, to reduce power consumption in wireless sensor networks. At a very general level, we identify three main enabling techniques, namely, Duty cycling, Data-driven approaches, and Mobility.

Duty Cycling: The most effective energy-conserving operation is putting the radio transceiver in the 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. The duty cycle is defined as the fraction of time nodes are active during their lifetime. As sensor nodes perform a cooperative task, they need to coordinate their sleep/wakeup times. A sleep/wakeup scheduling algorithm thus accompanies any duty cycling scheme. It is typically a distributed algorithm based on which sensor nodes decide when to transition from active to sleep, and back. It allows neighboring nodes to be active at the same time, thus making packet exchange feasible even when nodes operate with a low duty cycle (i.e., they sleep for most of the time)[17].

Data-driven approaches: Data-driven approaches can be divided based on the problems like Data-reduction (In-network Processing, Data Compression and Data Prediction) and Energy-efficient Data Acquisition. All these techniques aim at reducing the amount of data to be delivered to the sink node. ***In-network processing*** consists in performing data aggregation (e.g., computing average of some values) at intermediate nodes between the sources and the sink. The amount of data is reduced while traversing the network towards the sink. ***Data compression*** can be applied to reduce the amount of information sent by source nodes. It involves encoding information at nodes which generate data, and decoding it at the sink. ***Data prediction*** consists in building an abstraction of a sensed phenomenon, i.e. a model describing data evolution. The model can predict the values sensed by sensor nodes within certain error bounds, and reside both at the sensors and at the sink. If the needed accuracy is satisfied, queries issued by users can be evaluated at the sink through the model without the need to get the exact data from nodes. Data prediction reduces the number of information sent by source nodes and the energy needed for communication as well. ***Data acquisition*** techniques are not exclusively aimed at reducing the energy consumption of the sensing subsystem. By reducing the data sampled by source nodes, they decrease the number of communications as well. Acquisition techniques have been conceived for minimizing the radio energy consumption, under the assumption that the sensor consumption is negligible [18] [19].

Mobility-based schemes: Mobility is also useful for reducing energy consumption. Packets coming from sensor nodes traverse the network towards the sink by following a multi-hop path. When the sink is static, a few paths can be more loaded than others, depending on the network topology and packet generation rates at sources. Generally, nodes closer to the sink also have to relay more packets so that they are subject to premature energy depletion, even when techniques for energy conservation are applied. Mobility-based schemes can be classified as mobile-sink and mobile-relay schemes, depending on the type of the mobile entity [20].

IV. ENERGY EFFICIENT MAC PROTOCOLS

Medium Access Control (MAC) synchronizes the channel access in an environment where numerous nodes access a shared communication medium. The MAC Layer provides an interface between the data-link layer and the Physical layer. Furthermore it can handle data service and MAC management service like generating networks. The MAC layer has a major role in making the network more power- efficient. Basically MAC is responsible for the coordination between neighbours. MAC protocol must not only be energy constrain protocol but should also be able to address scalability.

Contention free protocols

Many nodes are present in sensor network, and they are most likely distributed in non - uniform direction. When two sensor nodes attempt to access the communication channel at the same time, contention occurs. Due to contention messages could collide when traffic is frequent. As a result collision has an effect on the network life time of a sensor network A MAC protocol is believed to be contention-free if it does not allow collision. All accessible contention free MAC protocol assumes that the sensor nodes are time-synchronized in some way. In contention-free protocols, the channel is most often divided into time slots. To send the data, each node uses the time slot and thus it provides collision free communication.

Slot-based protocols : The main idea of this protocol is that the time is divided into periods which has a certain number of fixed slots, where some active slot are assigned to keep the nodes active, send the beacons to neighbours' and to listen for message acknowledgement or listen to requests from neighbour nodes. In slot-based protocol, beacon helps to communicate with any two nodes of a network.

Time Division Multiple Access (TDMA) protocols: TDMA is a channel access method that is used to share a radio link. In this technology, different users can share the same frequency channel by dividing the signal into different time slots. Idle

listening can be avoided by using TDMA protocol and MAC layer contention issue can be fixed by scheduling transmissions earlier, so that the nodes can have information in advance when the radio should be turned on and doing so they can stay away from collision. In classical TDMA protocols all the nodes can see each other while master node initiates the super frame in specific time interval for network operation. This technology is most suitable for single hop but for multihop it is very difficult for multiple simultaneous transmissions. One of the energy efficiency TDMA protocol is Traffic-Adaptive Medium Access (TRAMA). To make this protocol energy efficient, TRAMA change nodes to sleep state whenever possible and attempt to reuse transmission slot which are not use in transmission. It is quite possible when one selected node allow his transmission slot to be used by another node if it does not have any packet to send. To make use of low power, idle mode and reuse the transmission slot nodes can share existing traffic with their neighbours [21].

Contention based : In contention-based protocols, a given transmit chance towards a receiver node can in principle be taken by any of its neighbours. If two or more neighbours try their luck at the same time, they have to compete with each other. In this case a collision might occur, wasting energy for both transmitter and receiver. In Contention-based protocol, stress is made on minimizing collisions rather than avoiding it completely. In this technology all node shared single radio channel according to their demand. To reduce the probability of collision or to avoid collision distributed algorithm is used which allocates the channel between nodes. Distributed MAC protocols which are mostly contention-based uses a carrier sensing or collision-avoidance mechanism known as CSMA (carrier sensing multiple accesses) [22].

Sensor MAC (S-MAC): S-MAC supports multi-hop operation. Its key features are: Periodic listen & sleep , Collision avoidance, Overhearing avoidance and Fixed duty cycle. Sensor MAC (S-MAC) uses three new procedures to decrease energy consumption and support self-configuration. It is a contention-based protocol with low duty cycle. For SMAC, energy consumption in idle listening is to be reduced by allowing neighbouring nodes of transceiver and receiver to sleep periodically during transmission, by doing so this scheme put nodes into low duty cycle. S-MAC is based on contention. Periodically sleeping is good in low traffic cases. If a node can sleep for longer time it consumes less energy. For example, if the duty cycle is trimmed down to 50%, it means that for each second a node can sleep half a second and be active for the other half, which results in 50% of energy reduction. The S-MAC approach is to split a long message into small parts and send them out in bursts. Nodes in the S-MAC exchange their sleeping schedule and before going to sleep nodes broadcast their schedule to their neighbours as a SYNC packet. Nodes listen to this sync message and follow it. If they do not get the sync message they make their own schedule. If the new scheduler is not used to the neighbour's nodes, it can be discarded. If two nodes want to talk, the sender first will use single RTS (request to send). When it is received by another node it replies with CTS (clear to send). All the nodes will again go back to sleep mode cycle once the transmission is completed [23].

Time Out MAC (T-MAC) : The problem with S-MAC protocol is the idle listening time and also the fact that it has a fixed duty cycle. This makes S-MAC unsuitable for varying traffic load. When there is low traffic, a duty cycle wastes large amount of energy which are made or tuned for handling high traffic load. Similarly under high traffic conditions a duty cycle which is made for low traffic load will decrease the throughputs. Hence, an elaboration based on S-MAC, T-MAC has been developed to fix the problem by using adaptive duty cycle. If there is no movement or no event in the neighbours, the node goes to sleep. Apparently T-MAC has the same role as S-MAC under steady traffic, but it is more power-consuming in variable traffic.

Dynamic Sensor MAC (DS-MAC): Dynamic sensor MAC protocol is based on SMAC. In heavy traffic load nodes can use dynamic duty cycle. When interval is too large in heavy traffic then SYNC and data message helps node to increase duty cycle and vice versa in case the traffic is low. In DSMAC, duty cycles are included in the SYNC message that they transmit. To measure the traffic condition each source calculates the queuing delay from message reception to transmission completion and inserts this to an additional field for upcoming data message. In DSMAC SYNC message updates the schedule and then nodes updates their schedule itself and shared equally with period, which helps to decrease latency over heavy traffic.

Dynamic Mac (D-MAC) : Dynamic Mac protocol (D-MAC) works like S-MAC but it adequately manages active/sleep duty cycles and provides real time guarantees. When sending data in multi-hop, sinks are not alerted by the nodes that the data delivery is in progress. Hence some nodes are unaware about this transmission and as a result interruption occurs, which makes sleep delay. D-Mac is based on a data gathering tree and a systematic wake-up scheme. Targeted to achieve both energy efficiency and low latency, D-MAC is estimated to give out data along the data gathering tree. In D-MAC nodes wake up sequentially like a chain reaction and synchronize assignments of time slots on different nodes. In D-MAC, time interval is divided into sections. Receiving, sending and sleep period. In the receive mode, a node receives a data packet and sends an acknowledgement to the receiver. In the sending period, a node forwards data to the next hop, receives an ACK and the radio will be turn off when the child node does not have any work to do which actually helps to reduce power consumption [24].

V. ENERGY SAVING AT NETWORK LEVEL

Directed diffusion: It creates for the reason behind using such a scheme is to get rid of unnecessary operations of network layer routing in order to save energy. Direct Diffusion suggests the use of attribute-value pairs for the data and queries the sensors in an on demand basis by using those pairs. In order to create a query, an interest is defined using a list of attribute-value pairs such as name of objects, interval, duration, geographical area, etc. Several paths can be established so that one of them is selected by reinforcement. The sink resends the original interest message through the selected path with a smaller interval hence reinforces the

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source node on that path to send data more frequently. Figure 1 summarizes the Directed Diffusion protocol.

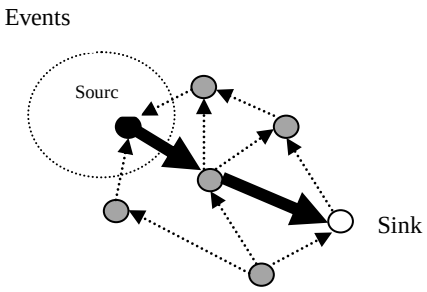

Figure 1: Data delivery

All communication is neighbor-to-neighbor with no need for a node addressing mechanism. Each node can do aggregation and caching, in addition to sensing. Caching is a big advantage in terms of energy efficiency and delay. In addition, Direct Diffusion is highly energy efficient since it is on demand and there is no need for maintaining global network topology. However, directed diffusion cannot be applied to all sensor network applications since it is based on a query-driven data delivery model. [25]

LEACH (Low Energy Adaptive Clustering Hierarchy): role of the cluster head is periodically transferred among the nodes in the network in order to distribute the energy consumption. It provides a conception of round. LEACH protocol runs with many rounds. Each round contains two states: cluster setup state and steady state. In cluster setup state, it forms cluster in self-adaptive mode; in steady state, it transfers data. The time of second state is usually longer than the time of first state for saving the protocol payload. The performance of LEACH is based on rounds. Then, a cluster head is elected in each round. For this election, the number of nodes that have not been cluster heads and the percentage of cluster heads are used. Once the cluster head is defined in the setup phase, it establishes a TDMA schedule for the transmissions in its cluster. This scheduling allows nodes to switch off their interfaces when they are not going to be employed. The cluster head is the router to the sink and it is also responsible for the data aggregation. As the cluster head controls the sensors located in a close area, the data aggregation performed by this leader permits to remove redundancy.

SPIN (Sensor Protocol for Information via Negotiation): SPIN uses meta-data which is highlevel descriptors. There is data advertisement throughout through which the Meta data is exchanged in the network by sensors, which after receiving the data advertise to the surrounding nodes. After this, request is sent by nodes for receiving data for those who have not yet received data. The data is exchanged between nodes in SPIN by the messages which are defined in SPIN. The first message is the ADV message in which a sensor has permission to advertise Meta data. The second message is the REQ message in which request is made for specific data. The third message is the DATA message which carries actual data.

PEGASIS (Power Efficient Gathering in Sensor Information System) is an improvement over LEACH. It is chain–based protocol where cluster heads are chosen randomly which means that nodes will die throughout the network in a random fashion. Hence density is maintained stable throughout the network. Node communication is only possible between close neighbours. A chain is formed which starts from the cluster head, the information of network topology is assumed to be known by PEGASIS and the chain is constructed by the use of a greedy algorithm [26].

VI.ENERGY SAVING AT SOFTWARE LEVEL

MANTIS allows prioritization of thread. Packet processing thread is configured to have a higher priority than the sensing thread. In MANTIS average processing time depends on execution time and in TinyOS processing task depends on length of the sensing task and uses average processing time to forward packet. For predictable behaviour of the system MANTIS has an edge over other operating systems. TinyOS scheduler code size is less than other thus it doesn't provide thread switching capability and core consist of an absolute minimum functionality based on FIFO queuing algorithm. The scheduler task run automatically and task will execute with respects to one another. When task finishes it will goes to sleep mode, furthermore its idle time is also more stable which helps to make the network energy efficient. But in Mantis the available time drops faster due to its context switching that mean switching context reduce idle time [27][28].

VII. CONCLUSION

This paper, we have tried to analytically study the theoretical energy efficient techniques for WSNs and some review papers have been discussed. Energy conservation approaches are based on some attributes such as power management and data driven. In the future, this wide range of application areas will make sensor networks an integral part of our lives. The sink node and sensor node were mostly fixed thus research can be done by assuming sink and source node as portable. This survey paper covers up many open research issues as well as their explanations and point out and represents the energy efficient inflection.

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