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Research Article

WIRELESS SENSOR NETWORK ENERGY MANAGEMENT BASED ON COMPRESSION AND COVERAGE – A SURVEY

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A R T I C L E I N F O

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A B S T R A C T

Wireless sensor networks are used to monitor changes in the environment of a given field. Coverage, communication and connectivity of the network are the most fundamental challenges in WSNs. Sensors nodes are mostly battery operated and are expected to work for a longer time without replacing the batteries. The measure of the efficiency of a network usually defined with respect to how efficient in sensing the given physical ambience. The constraint most often linked with sensor node is that it operates with restricted energy budgets. Energy conservation becomes the important parameter to prolong the lifetime of sensor nodes. The energy lose may occurs due to collision of data packets, idle listening of sensor node, overhearing of nodes, frequent switching of nodes to various modes. Various energy management practices are in going on to increase the life time of the sensor nodes. This paper describes the survey of energy management in WSN nodes using compression of data packets and node deployment methods.

INTRODUCTION

A common definition of a sensor is “a device that produces measurable response to a change in a physical or chemical condition” More distinctively, a sensor is "a device that responds to a stimulus, such as heat, light, or pressure, and generates a signal that can be measured or interpreted" [1-3]. Typically sensors are thought of as measuring light, sound and temperature and any other physical parameters. Sensor Network is a wireless, ad hoc network, made of hundreds or thousands of nodes, placed in random locations. [4-7]. Usually The OSI model and the layers of communication networks may not apply to sensor networks.[3]

Wireless sensor network have been identified as an important technology for the back born of many industries and services for the 21st century. A network of sensors is an collection of interconnected nodes with a capability of sensing, computing and communication elements [7-10][11][12] [13-15]. Researchers see WSNs as an emerging area of densely networked systems of power aware wireless nodes with a small amount of processing and memory capacity and large federated networks for high end sensing applications [16][17-19]. WSN provides an infrastructure based services that couple between traditional computing and real time environment. A WSN can contain few to thousands of nodes at a time.

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A wireless sensor network (WSN) consists of a large density of tiny sensors spread over an area and integrated to form a communicative network infrastructure . The distributed sensor network stepping forward with the closely associated technologies such as VLSI, leading to a novel terminology called micro- electromechanical systems (MEMS).

Wireless sensor nodes are characterized by being tiny intelligent, low in cost, battery-driven, and deployed randomly or in deterministic pattern. Network nodes are operational with wireless communication transceivers using antennas that may be unidirectional, highly directional (point-to-point), may be capable to steering the dish, or some combination thereof. [11][20]. WSN usually incorporated with actuators which allow them to interact the real world. For example, an actuator can be a valve controlling the flow of hot water, sensor controlled door that opens or shut with the help of a motor, a pump that maintains the amount of fuel injected into an engine. Thus a wireless sensor and actuator network (WSAN) takes instructions from the controller and convert these commands into control commands for the actuator, which then activates physical movement or action.

Characteristic of Sensor network

Each node is equipped with limited built in processor, storage and communication capabilities. These autonomous nodes are low power devices consist with one or more sensors, a processor, storage memory, a battery, a transceiver and an actuator. These tiny devices communicate wirelessly in short distances but having only limited bandwidth [21-22]. Sensor nodes are may be stationary or mobile, densely deployed and with these limited capabilities. Nodes sense and send their collected data towards a data processing center which is called the "sink node". [23] A variety of thermal, mechanical, optical, chemical, biological, and magnetic sensors may be attached to the sensor node to measure properties of the atmosphere.[12] The main goals of sensor networks are accuracy, flexibility, reliability, economical and easy deployment. WSN's have some limitations also, and can be characterized as the following properties: limited processing power, less memory, limited power, low data rate, limited transmission range and the devices within a WSN are mostly battery driven.[24]

Challenges

WSN is autonomous self sustained devices and being in the path of ubiquity. But to attain the ubiquitous computing properties it has to overcome some challenges The main challenges are hardware constraints, Power factors, cost of nodes, Working environments, Transmission channel factors, node distribution, etc.

Table 2 Table shows the sensor constraints details

Constraints	Description
Hardware	Size is too small 2x5x1 or even small 1x1x1
Power factors	Limited power source(battery) < 500mAh, 1.2 V AA alkaline batteries or li-AA cells
Cost	Individual node cost si critical as the density of nodes is increasingly demanding - 5$ to $10
Environment	Deployed usually in unattended remote geographical locations
Transmission Channels	Radio, Infrared, Optical ranges RF (916 MHz), Blue tooth compactable (2.4 GHz) Others (2.4 GHz to 5 GHz 802.11b and 802.11a)
Density and Topology	Density >27 nodes/m3 Usually Dynamic topology

Applications

Applications of WSN are of interest to the most assorted scenarios such as environmental monitoring, micro-surgery, agriculture , surveillance, warfare, and child education, Flood and Water Level Monitoring System, Traffic Monitoring and Controlling are only a few examples[21] [28-30] In most of the WSN applications, the network nodes are left unattended for their whole operational lifetime after the node installation. Current WSNs are deployed on land, underground, and underwater. As per the sensor deployment environment, a sensor network deals with different challenges and constraints [31][32][66][67]. The table shows the basic comparison between various applications and its characteristics. The Table 1 describes comparison of various WSN applications.

Table 1 Comparison of Application of WSN

Application	Deployment approach(Mostly)	Density of nodes	Signal Strength	Bandwidth needed
Terrestrial WSNs	Adhoc/Preplanned	Large	Good	medium
Underground WSNs	Preplanned	Less	Attenuated	Varying
Underwater WSNs	Preplanned	Less	Attenuated	Varying
Multi-Media WSN	Adhoc/Preplanned	-	Good	High
Mobile WSNs	-	Less	Good	-

Energy Management

A Wireless Sensor Network can be composed of large number of tiny of sensor nodes spread in a wide area and communicating with each other either directly or through routing mechanisms to the other nodes. One or more of the nodes are the base station with uninterrupted battery source than the other nodes. Since the devices in WSN are often tiny devices with small form factor the computational power of these devices is usually small because there will not support large amount of hardware. Furthermore as the devices are wireless they need to obtain their energy from an inbuilt battery which in the end needs to be recharged or replaced. If the battery of a device is depleted it needs an immediate substitution to function further.

Since these motes are working based on replaceable batteries power conception is the most important design consideration in WSN. Thus an intelligent hardware, software as well as set of protocols for communication is needed to attain the power management goal. Most of their power supply is consumed for their communication between nodes compared to other needs such as internal processing or sensing operation. According to [30], for transmitting a single bit over the network consumes almost as much power as executing 800-1000 instructions. Thus, power consumption of routing and communication is large enough to surpass the power consumed by the other operations. Secondary power supply that harvests power from the ambient such as solar panels may use on appropriateness of the environment.

Energy Consumption Factors

As far as sensor network is concerned energy is a very scarce resource and has to be handled cautiously or wisely in order to improve the network lifetime. Many network characteristics, which are also responsible for depletion of energy, some are also suggested be author of[31-32] are as follows:-

1. Many sensor nodes sense the same data deployed in small area.
2. Sending the repeated sensed data often to the cluster heads also lowers channel utilization.
3. To send a data, keep on listening to the channel.
4. In periodic sensing, keeping the node "on state" while not in use.
5. Sending control packets in large volume need extra energy if packet is too large.
6. Greater processing facility in sensor node consumes more power.
7. Same event may sense more than one node due to overlapping regions of area of coverage.
8. Collision and retransmission [36][37]

There is a number of power reduction practices must be used both in the design of the circuits and in the design of network protocols approaches . The major step towards reduced power consumption is a sound electronic design [32],[34] selecting the efficient circuits and applying suitable design procedure to each case. Sometimes the most important causes of energy depletion in the WSN node is the idle mode consumption, when the node is not initiate any communication but listening and waiting for information from other nodes. Energy loss due to packet collision is also a major issue, causes all data packets involved in the transmission are discarded and must be retransmitted . Another cause of energy loss is the wrong routing leads to the reception of packets to non addressed node. Next major source of energy loss is the transmission and possible retransmission of control packets, as these can be seen as protocol overhead[26]

General Energy saving methods

Time Synchronization

In WSN Time Synchronization is important for communication between nodes, but it also helps to gives the ability to detect movement and proximity. The synchronization consists of four components: send time, access time, propagation time, and receive time Fig 1. The time synchronization does not mean that necessarily all clocks are perfectly matched across the network which is difficult to implement. Precise clock synchronization is not always indispensable, so protocols from all variant from soft to strong are available to meet one's needs.

The send time is that of the sender creating time message to transmit over the network. The access time is that of the MAC layer delay in accessing the network. The time for the bits to by transmission on the medium is considered the propagation time. And, the receive time is the processing time of the receiving node to transferring it to the host. The major problem of time synchronization is packet delay along with prediction of the time spent on each mode. Eliminating any of these will greatly increase the performance of the synchronization technique.

Dynamic Power Management

The performance of the WSN is greatly depends on the power efficiency and management capability of the network.. Dynamic Power management is the major research area for the purpose of deployment and designing of the network. In recent times, there have been a good interest to use intelligent tools such as Neural Networks in energy management approaches of Wireless Sensor Networks [35], due to their simple parallel distributed computation and storage, data robustness, auto-classification of sensor nodes and sensor reading.

Real-Time Support

Due to local computation and long range communication the battery gets depleted at faster rate Communication protocols can be designed to make efficient management of energy resources of a sensor node and to obtain real time functionality [36]. All existing routing protocols Medium Access Control layer protocols supports real-time energy management functionality. There exists lots of unsolved challenges that need to be solved in MAC protocols to find out the apt solution for real time support and energy efficiency. Contention free protocols give real time support but not having energy efficiency.

Transmission Power Control

Power consumption for data communication is relatively high in WSN infrastructure. Power adaptation approaches of a transmission mode for a particular transceiver based on several factors is an approach for power optimization. Two main factors affecting the transmission power includes distance and wireless link quality. Physical barriers and climatic conditions are the two depending factors of the link quality. Controlling transmission power according to link quality is an efficient approach. Multi Hop communication is the most prominent research area by activating intermediate nodes for data forwarding.

Encryption Schemes

Here describes how the secure exchange in wireless sensor networks with energy efficiency. It considers link layer security of WSNs, providing both the data ciphers and the encryption, including aspects such as the cipher mode establishment and operation by initialization vectors. Here calculates the computational energy efficiency of different cipher algorithms considering both the characteristics and the effect of channel quality on cipher synchronization [37].

Data Management

Data management in WSN includes both data collection and data processing. Energy efficiency can be achieved by switching on and off the node depends on the data collected by the neighboring nodes. For the purpose of improving the precision of estimation there are estimation models such as Data Estimation using a Physical Model (DEPM), Data Estimation using Statistical Model (DESM) etc. There is another approach called distributed historical data query processing which is an upcoming research area. In this approach, an Index based Historical Data Query Processing scheme which stores historical data locally and processes queries energy-efficiently by using a distributed index tree is used. Area query processing is significant for various applications of WSNs [38]

Compression Techniques

Sensor nodes are capable of performing some processing of information and communicating with other connected nodes in the network [42], [43]. Data compression before transmitting increases energy efficiency. However, employing data compression optimizes the Data Transfer rate (DTR), because reduction in the effective size of the data to be transferred on the network leads to reduction in the effective file transfer time and hence preserves the network energy.

Specific Study

Data Compression

Energy efficiency is necessary in all layers of WSN operations. In the conventional view, energy consumption in WSNs is dominated by radio communications [41-43] The energy consumption of radio communication mainly depends on the number of bits of data to be transmitted within the network [44] In most cases, computational energy cost is less significant with cost of the communication. In particular, the energy cost of transmitting one bit is typically around 500–1,000 times greater than that of a single 32-bit computation [45]. The data compression can be done locally so that the resulting data to be send to the header noade should be in relatively compressed size. Thus through an efficient data compression algorithm life time of the sensor node may increased by letting the transmission limited to smaller data packets. Therefore, by compression we reduce the number of bits to be transmitted there by significant reduction in communication energy and increase network lifetime. Battery is the main power source in a sensor node.

Data compression is a process that limits the amount of data to be transmitted because the size of the data is reduced. However, the limited resources of sensor nodes like processor power constraint or limited RAM have resulted in the revision of existing compression algorithm to WSN’s constraint. [46][47]

There are lossy and lossless techniques. Lossless techniques are very important in applications where precision is valued, such as in medical image processing or space research. The most known techniques for lossless compression in popular are 'Eugene Pamba Capo-Chichi' and 'Jean-Michel Friedt' [47] mentioned about Run Length Algorithm (RLE) as lossless algorithm where as the modified version of RLE called K-RLE is lossy compression algorithm.

'P. Rachelin Sujae' and 'S. Selvaraju' [48] described about Huffman encoding requires prior knowledge of the probabilities of the source sequence. Otherwise Huffman coding becomes a two pass procedure; the first pass the statistics are collected and the source is encoded in the second pass. But its difficulty in constructing the binary tree is become the limitation of this algorithm, which makes it unsuitable for sensor nodes.

'S.R. Kodituwakku' And 'U.S.Amarasinghe' concluded that [50]The Lempel Zev Welch Algorithm Dictionary based algorithms are uses a dictionary rather than based on a statistical model. In this method, the previously seen string patterns may used to store and indexed in a dictionary table. In the compression process, instead of repeating string patterns, those index values are used. This algorithm is an adaptive compression algorithm.

The popular LZW data compression algorithm is a dictionary based algorithm. It requires considerably use of RAM is large. Such algorithms cannot be applied to most sensor platform due to limited RAM.[46]

'Anmol Jyot Maan' [51] said about arithmetic coding in his paper. There they said Arithmetic Coding is useful for small alphabets with highly twisted probabilities. In this approach, a code word is not used to symbolize a symbol of the text, instead it generates a code for an whole message. In their paper there proved that Arithmetic coding compression ratio is too good compared to Huffman encoding. But the compression speed is slow with respect to Huffman encoding. Lossy techniques are more widely used in the area web development to personal everyday use.[52][62]

Deployment and coverage

Deployment

Setting up sensor network nodes in a real world environment is termed as Deployment. Nodes may be deployed in predetermined locations or place them randomly dropping sensors from a plane would be an example of random placement. The coverage schemes can be quite effortlessly determined in deterministic placement than in random placement. However in many deployments, it is impractical and difficult to deploy sensor nodes in a deterministic way. If the sensor nodes are deployed in an area in high density it is termed as dense deployment while a sparse deployment would have fewer nodes. The model of dense deployment is used in circumstances where it is significant for every event to be detected or when it is important to have multiple sensors cover an area. The sparse deployment is cost effective and it should be properly managed and localized with maximum coverage with minimum nodes. In most of the work studying coverage it is assumed that the sensor nodes are static, they reside in constant place once they are deployed.

There is extensive research in the development of algorithms for deployment of nodes, ad hoc routing and power management in the context of wireless sensor networks. As the algorithms for wireless sensor network are developed, they must be a low-power, highly efficient and adaptable to various hardware platforms. Setting up sensor network nodes in a real world environment is termed as Deployment [53]. Nodes may be deployed in fixed sites (deterministic placement) or place them aimlessly (random placement); dropping sensors from a plane; would be an example of random placement. The coverage schemes can be easily determined in deterministic placement rather in random placement.

Other deployment approaches are dense deployment and sparse deployment. If the sensor nodes are deployed in an area in high density it is termed as dense deployment while a sparse deployment would have less quantity of nodes. The intense deployment model is used in situations where every events may critical to be analyzed so it is important to have several sensors cover a region. The sparse deployment is cost effective and it should be properly managed and localized with maximum coverage with minimum nodes. In most of the work studying coverage, it is assumed that the sensor nodes are immobile; they inhabit in the same place once they are deployed. A more sophisticated deterministic deployment method is given in [54]. The authors suggest a pattern of arranging the sensors in diamond pattern which would correspond with a Voronoi polygon[55]. This pattern accomplishes full coverage with four way connectivity from every nodes by dividing the communication range with the sensing range; which is greater than the square root of two.[58] However the pattern is too difficult to practical deployment. It assumes that the sensing and communication ranges of every node are a perfect circle.

Coverage

Energy efficient Coverage is the one of the most active areas of research in wireless sensor networks. WSN coverage s is defined as a measure of "how successfully and for how long the sensors are able to examine" the physical space. It is Coverage is how well a sensor node(s) will monitor a given environment. It can be thought of as a measure of quality of service (QoS). Connectivity between the nodes and the sink can be maintained only by the effective and standardized coverage. Connectivity can be defined as the ability of the sensor nodes to reach the data sink. Each node has a range where which another node can be located in order to receive data and is defined as the nodes communication range and it is different from the sensing range which defines the area a node can observe. The two ranges may be equal but are often different.

Cardei and Wu [56] survey recent sensor coverage problems proposed in literature and ordered them according to the following design criteria:

1. Problem definition: maximize network lifetime or minimize the number of sensors deployed
2. Deployment approaches: deterministic versus random
3. Relationship between Rs (Sensing range) and Rc (Communication ranges) (e.g. Rc = Rs; Do all sensors use the same Rc and the same Rs (homogeneous network))
4. Addition requirements energy efficiency and connectivity

5. Algorithms characteristics: localized versus centralized, distributed

The coverage problems can be classified in the following types [56]

- area coverage where the main objective is to cover (monitor) an area, [57-59]
- point (or target) coverage [60], where the objective is to cover a set of points (targets)
- coverage problems that have an objective to determine the maximal support/breach paths that traverse a sensor field [61][63]

Coverage protocols such as CCP, OGDC, ASCENT, PC are compared with coverage, connectivity, data processing and energy conservation [65] and the Table 2 is given bellow

Table 2 Comparison of coverage algorithms

Protocol	Coverage	Connectivity	Data Processing	Energy conservation
Coverage Configuration Protocol (CCP)	Good	God	Decentralized	Fair
OGDC (Optimal Geographical Density Control).	Good	Good	Distributed	Good
ASCENT (Adaptive Self-Configuring sEnsor Networks Topologies)	Fair	Bad	Decentralized	Bad
Sleep + Power Control (PC) Protocol	fair	Not Considered	Decentralized	-

Table 3 Comparison of various compression algorithms

Algorithms	Description	Data Mode	Approach	Compression
Run-length encoding	Runs of the same byte	Streaming mode.	String-based compression	Loseless
Burrows-wheeler transform	Rearrange (by adding and sorting)	Block mode	Statistical method	Loseless
Move to front transform	-	Streaming mode.	Arranging	Loseless
Arithmetic coding	-	Streaming Mode	Statistical method	Loseless / Lossy
LZW	-	Block Mode	Dictionary based	Loseless

From the Table 3 the CCP protocol is being suggested as the best coverage protocol followed by OGDB because even ASCENT protocol gives a better coverage it has less energy efficiency compared CCP and OGDB..

CONCLUSION

WSN nodes are operate in a collaborative manner. Fair utilization of networking recourses at node level equally important like accomplishing the overall goal. An energy aware data manipulation and aggression is important in Wireless sensor network applications. The measure of the efficiency of a network is also defined with respect to how efficient in sensing the given physical ambience. Energy efficient coverage and data compression in Wireless sensor network is essential and have lots of scopes in the area for research. This paper generally discuss the characteristics of sensor nodes and WSN and talk about approaches of gaining energy efficiency based on reducing the communication overhead by data compression and node deployment methods. This paper gives a detailed comparative study of applications, data compressions, coverage and deployment of WSN.

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