A Study on Approaches for Enhancing WSN Lifetime and Contribution of AI

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***Abstract*-This paper exhibits intelligent approaches for efficient energy consumption motivated by theory of artificial intelligence (AI). Intelligence is the ability to perform abstraction and conceptualization, and it refers to the ability to collect information, make decisions, and implement actions that lead toward the accomplishment of some goal. AI technology has been applied extensively in the research of wireless sensor networks to aggregate and disseminate the messages more efficiently along with the optimization of routing protocols to conserve the limited resources in a large collection of sensor nodes.**

INTRODUCTION

Advances in wireless communication made it possible to develop wireless sensor networks (WSN) consisting of small devices, which collect information by cooperating with each other. These small sensing devices are called nodes and consist of CPU (for data processing), memory (for data storage), battery (for energy) and transceiver (for receiving and sending signals or data from one node to another). The size of each sensor node varies with applications. For example, in some military or surveillance applications it might be microscopically small. Its cost depends on its parameters like memory size, processing speed and battery. Today, wireless sensor networks are widely used in the commercial and industrial areas such as for e.g. environmental monitoring, habitat monitoring, healthcare, process monitoring and surveillance. For example, in a military area, we can use wireless sensor networks to monitor an activity. If an event is triggered, these sensor nodes sense it and send the information to the base station (called sink) by communicating with other nodes. The use of wireless sensor networks is increasing day by day and at the same time it faces the problem of energy constraints in terms of limited battery lifetime. As each node depends on energy for its activities, this has become a major issue in wireless sensor networks. The failure of one node can interrupt the entire system or application. Every sensing node can be in active (for receiving and transmission activities), idle and sleep modes. In active mode nodes consume energy when receiving or transmitting data. In idle mode, the nodes consume almost the same amount of energy as in active mode, while in sleep mode, the nodes shutdown the radio to save the energy. The following steps can be taken to save energy caused by communication in wireless sensor networks.

To schedule the state of the nodes (i.e. transmitting, receiving, idle or sleep). Changing the transmission range between the sensing nodes.Using efficient routing and data collecting methods.Avoiding the handling of unwanted data as in the case of overhearing.

In WSNs the only source of life for the nodes is the battery. Communicating with other nodes or sensing activities consumes a lot of energy in processing the data and transmitting the collected data to the sink. In many cases (e.g. surveillance applications), it is undesirable to replace the batteries that are depleted or drained of energy. Many researchers are therefore trying to find power-aware protocols for wireless sensor networks in order to overcome such energy efficiency problems as those stated above. All the protocols that are designed and implemented in WSNs should provide some real-time support as they are applied in areas where data is sensed, processed and transmitted based on an event that leads to an immediate action.Recent advances in micro-electro mechanical systems (MEMS) have made the sensor networks possible which are highly distributed networks consisting of small, lightweight wireless nodes. These tiny sensors, which consist of sensing, data processing, and communication subsystems, are deployed randomly and redundantly to monitor environment parameters such as temperature, humidity, speed, pressure and characteristics of objects in precedented detail. Nowadays, wireless sensor networks (WSNs) have been widely deployed in physiological and environmental monitoring, intelligent home appliances, forest fire and flood detection, military surveillance, transportation and inventory tracking. Energy management is a key issue in the deployment of sensor networks, because sensors only reply on the battery for the power which cannot be recharged or replaced. The available energy is considered a major factor when designing protocols in a sensor network. The lifetime of the battery operated nodes may be extended in some way by adopting appropriate energy conservation mechanism for efficient communication.

AN OVERVIEW OF WIRELESS SENSOR NETWORKS

Wireless sensor network is to create a robust and fault-tolerant network to cover a large area. Each node usually has three components: the sensor component to sense the environment for the data, the process component to perform simple computation from the collected data, and the communication component to exchange messages with neighboring sensor nodes. Each sensor network has the ability to disseminate the data through the network, and aggregate the local data from nodes to a sink node (gateway or cluster head). Recent advancement in wireless communications and micro electro-mechanical systems has enabled the development of low-cost wireless sensor networks. Akyildiz has argued that sensor networks represent a significant improvement over traditional sensors. The design challenges of sensor networks lie in three key areas. Firstly, energy consumption is a common problem. Secondly, how sensors sense and interact with the physical world is of great interest. Finally, with tens, hundreds, or even thousands of sensor nodes, the network and applications as a whole must be self-configuring and intelligent. The architecture of sensor networks can be either layered or clustered. In the layered architecture, the nodes that have the same hop-counts to a sink node form a layer or circle. The nodes will be responsible to relay messages to and from neighboring nodes in a multi-hop manner. UNPF is an example of a layered architecture which consists of a set of protocols for the implementation: network initialization and maintenance, MAC, and routing protocols. To facilitate scalable operations within sensor networks, sensor nodes can be aggregated to form clusters based on their power levels and proximity. In a clustered architecture, sensor nodes are organized as a cluster in which one node is selected as the cluster head. The message exchanges of sensor nodes are directed by the cluster head to the sink node and vice versa from the sink node to sensor nodes. Due to the loose structure of sensor networks, the form of a cluster and the election of cluster head should be autonomous and self-organized through network protocols. Shen et al. introduced a sensor information networking architecture called SINA to facilitate querying, monitoring, and tasking. In this architecture, SINA plays the role of middleware that abstracts a network of sensor nodes as a collection of massively distributed objects. The SINA's execution environment provides a set of adaptive configuration and communication primitives that enable scalable and energy-efficient organization of and interactions among sensor objects. On top the execution environment is a programmable substrate that provides mechanisms to create associations and coordinate activities among sensor nodes.

Users then access information within a sensor network using declarative queries, or perform tasks using programming scripts. Talukder et al. presented a new maximum discriminating feature (MDF) neural network for data discrimination in pattern recognition applications. In the MDF neural network, the weights are obtained in closed-form and neuron activation functions are dynamically chosen based on the application. A generic optimization algorithm is used to control the system in the presence of dynamic events, while ensuring that system constraints are met. This tight integration of control optimization and machine learning algorithms results in a highly efficient intelligent sensor network.

Network Design Challenges and Routing Issues

The design of routing protocols for WSNs is challenging because of several network constraints. WSNs suffer from the limitations of several network resources, for example, energy, bandwidth, central processing unit, and storage. The design challenges in sensor networks involve the following main aspects:

Limited energy capacity: Since sensor nodes are battery powered, they have limited energy capacity. Energy poses a big challenge for network designers in hostile environments, for example, a battlefield, where it is impossible to access the sensors and recharge their batteries. Furthermore, when the energy of a sensor reaches a certain threshold, the sensor will become faulty and will not be able to function properly, which will have a major impact on the network performance. Thus, routing protocols designed for sensors should be as energy efficient as possible to extend their lifetime, and hence prolong the network lifetime while guaranteeing good performance overall.

Sensor locations: Another challenge that faces the design of routing protocols is to manage the locations of the sensors. Most of the proposed protocols assume that the sensors either are equipped with global positioning system (GPS) receivers or use some localization technique to learn about their locations.

Data Aggregation: Since sensor nodes may generate significant redundant data, similar packets from multiple nodes can be aggregated so that the number of transmissions is reduced. Data aggregation technique has been used to achieve energy efficiency and data transfer optimization in a number of routing protocols.

Diverse sensing application requirements: Sensor networks have a wide range of diverse applications. No network protocol can meet the requirements of all applications. Therefore, the routing protocols should guarantee data delivery and its accuracy so that the sink can gather the required knowledge about the physical phenomenon on time.

Scalability: Routing protocols should be able to scale with the network size. Also, sensors may not necessarily have the same capabilities in terms of energy, processing, sensing, and particularly communication. Hence, communication links between sensors may not be symmetric, that is, a pair of sensors may not be able to have communication in both directions. This should be taken care of in the routing protocols.

ENERGY OPTIMIZATION METHODS

The methods in which energy savings can be affected or can be classified under two heads:

Device Level: Hardware component selection and their configuration to achieve low energy consumption in a wireless sensor node.

Network Level: Choice of communication methods and protocols to minimize energy consumption. In a sensor node there are four essential parts: 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 to transfer in the wireless communication channel.

In reality sensor unit is the medium to communicate between the physical world and the conceptual world of processing unit. The sensor unit is the one of the vital part of wireless sensor mode, it sense and detect the physical state of environment and sends the data to processor. Processor manipulates data and decides where it has to promote or else transmit the data to base station. Sensor converts energy from one form to another form. In reality sensor acts as the transducer where energy is convert into analog signal or digital signal. Sensor can be distinguished based on what kind of energy they detect or transfer to the system. A wireless sensor node can be built with different type of sensor, and different types of sensors use different amount of energy. Some of them require a significant large amount of energy than others. For example, gas sensor requires a comparatively higher amount of energy than temperature sensors, pressure or image sensor because it requires active heating elements. Table 1 shows power requirement of different sensors. Image sensors also require a higher amount of energy because thousands of conversions (analog to digital) are require for producing images.

Table 1: various types of sensors' power consumption

Sensor Type	Power Consumption
Gas sensor	500mW-800mW
Pressure sensor	150mW
Image sensor	10mW-15mW
Acceleration sensor	3mW
Temperature sensor	0.5mW-5mW

Efficient Energy Consumption in Wireless Sensor Networks

Wireless sensor nodes have limited energy resources. Advance in battery technology has been very much limited compared to the development of sensor networks. Energy conservation is essential in many scenarios due to the impossibility of extending or replacing the battery power. In addition, the multi-hop routing in a typical sensor network from the layered or clustered architecture has introduced a large portion or relay traffic which depletes the power quickly as in a traditional wireless network. Deployment of mobile sensors in a wireless sensor network is an energy consuming process and it should be carefully designed. Simunic et al. analyzed the potential power saving in the micro-controlled unit. It discussed the choice of different processors for specific applications. The dynamic power management (DPM) technique can be used to shut down some components in a sensor node to conserve energy when it becomes idle for a period. The software part in a sensor network such as the operating system, network communication protocols, and application protocols should also be optimized to reduce the consumption of energy by reducing the unnecessary broadcast messages for the handshaking or other redundant design in a traditional wireless network protocols. The Directed Diffusion (DD) is a data dissemination paradigm in that all communications is for the named data. The sink node requests named data of attribute-value pairs. Data aggregations and disseminations are determined locally among the neighbor node message exchanges within the vicinity. This paradigm does not need to keep track of global network topology and thus it is very efficient as an on demand query schedule. The query is disseminated (flooded) throughout the network and gradients are set up to draw data satisfying the query toward the requesting nodes. Events (data) start flowing toward the requesting node from multiple paths. Heinzelman et al. proposed the low-energy adaptive clustering hierarchy (LEACH) to reduce energy consumption in sensor networks. The idea is the randomization of cluster head nodes in the lifetime of a sensor network to balance the communication traffic loads across all the nodes in the network. In the initial setup, some nodes will become the cluster-head depending on the random number generated locally by comparing to a predefined threshold value. In the steady phase of longer duration, the cluster head will perform the message relay between the sensor nodes in the cluster and the sink node. Cluster heads are elected again after a certain period of time to avoid the energy depletion of these nodes. The energy consumption is minimal considering the fact that the sink node only communicates with cluster heads instead of a large number of sensor nodes in the network.

In sensor networks, the communication cost is often much higher compared to the computation cost. Ding proposed energy aware distributed aggregation tree (EADAT) for the in-network data aggregation. In a tree topology of the sensor network, the non-leaf nodes collected and aggregate the data from leaf nodes and forward to the sink node. Each node waits for some time before sending data depending on the remaining energy level. The more the energy, the shorter time a node needs to wait. This is to ensure the proper equal depletion of energy of non-leaf nodes and thus extend the total life time of the network.

Intanagonwiwat et al. proposed a novel approach of using a greedy incremental tree (GIT) in to adjust aggregation points to increase the amount of path sharing, reducing energy consumption. The greedy approach constructs an energy-efficient aggregation tree using data-centric reinforcement mechanisms and prunes inefficient paths using a greedy heuristic for weighted set-covering problems. Pham et al. proposed a new metric, data aggregation quality (DAQ), for the performance evaluation of in-network data gathering and aggregation. They presented two new protocols: the enhanced LEACH and the clustered PEGASIS, enhanced from two major existing protocols: the cluster-based LEACH and the chain-based PEGASIS. The paper concluded that chain-based protocols are more energy efficient than cluster-based protocols though they suffer from poor data aggregation quality. DAQ does not assume any prior knowledge on values or on statistical distributions of sensing data and thus the author argued that DAQ may be applied to most data gathering protocols.

Fan et al. proposed a data aggregation protocols to reduce the communication cost and thus conserve the energy for a longer network lifetime. Tree-based or cluster-based data aggregation protocols incur high maintenance overhead. Two mechanisms - Data-Aware Anycast (DAA) at the MAC layer and Randomized Waiting (RW) at the application layer are proposed as packets need to converge spatially and temporally. DAA is based on anycasting at the MAC layer to determine the next-hop for each transmission. In the Randomized Waiting, nodes send packets along the shortest path to sink with random delay at the source. In contrast with the traditional random deployment, Heo et al. proposed an intelligent energy-efficient deployment algorithm for cluster-based wireless sensor network by a synergistic combination of cluster structuring and a peer-to-peer deployment scheme. The key idea of the algorithm is the introduction of local clustering during the deployment process so as to increase the amount of local control over a fraction of the entire region of interest (ROI). Each node decides its own mode to be either in a clustering mode or a peer-to-peer mode based on its local density and the remaining energy level in a distributed and adaptive manner. The goals are the realization of largest possible coverage, the formation of an energy efficient node topology for a longer system lifetime, and the organization of a hierarchical structure for easier management and scalability that supports collaboration among nodes. Kulik et al. designed a family of adaptive protocols called SPIN (Sensor

Protocols for Information via Negotiation), which disseminate the information among all the nodes in an energy-constrained wireless sensor network. Nodes running a SPIN communication protocol name their data using high-level data descriptors, called metadata. They use meta-data negotiations to eliminate the transmission of redundant data throughout the network. In addition, SPIN nodes can base their communication decisions both upon application-specific knowledge of the data and upon knowledge of the resources that are available to them.

This allows the sensors to efficiently distribute data given a limited energy supply. Lindsey and Raghavendra have proposed power-efficient gathering for sensor information systems (PEGASIS) to transmit the collected data from sensor nodes to the sink node. It is based on the assumption of a relatively static network topology in which each node knows the location of other nodes in the network. Any node that is within the transmission range to the sink node in one hop will be selected as a leader. A chain is constructed from the farthest nodes to the sink before the data is transmitted. The message will be passed from one node to the next until the leader transmits the message to the sink. Since efficient energy consumption is a key problem in the sensor networks, lots of work lies in the algorithms for energy efficiency, less attention has been paid in area of providing QoS (Quality of Service). Perillo et al. conducted research on how to balance the application QoS and energy consumption through intelligent sensor management. They argued that the network should be designed to provide enough data to their application so that a reliable description of the environment can be derived, while operating as energy-efficiently as possible to meet bandwidth constraints. The joint optimization of sensor scheduling and data routing is proposed to extend the lifetime of a network considerably. Bandyopadhyay et al. presented an energy efficient hierarchical clustering scheme to enable nodes communication within long distance. The sensors are organized into groups and communicate information only to cluster heads and then the cluster heads communicate the aggregated information to the processing center. The processing center determines the final estimates of the parameters in question using the information communicated by the cluster heads. Since the sensors are now communicating data over smaller distances in the clustered environment, the energy spent in the network will be much lower than the energy spent when every sensor communicates directly to the information processing center.

INTELLIGENT APPROACHES FOR WIRELESS SENSOR NETWORKS

The functionality of an intelligent sensor includes self-calibration, self-validation and self-compensation. In a broad category, an intelligent agent can be a mobile application able to move from one node to another for information acquisition. Team of such agents can solve a wide range of tasks related to information acquisition and delivering it to the customer. The self-organization of collective mobile intelligent agents is proposed by Botchkariov. Each sensor takes the role of a functional agent and the basic tasks of multi-agent information acquisition are distributed sensing, mapping, searching, and tracking. Petriu developed a wireless network of mobile autonomous Robotic Intelligent Sensor Agents (RSAs) deployed in the field for active investigation of multiple environmental parameters. The collected sensor data are fused in a model, which is available to remote human supervisors as an interactive virtualized reality environment model. The intelligent, autonomous RSAs use a combination of intrinsic reactive behaviors with higher-order world model representations of the environment.

A forward model-learning method is used to recover explicit structural representations of the dynamic environments from the sensor data and robot navigational experience. Srisathapornphat et al. proposed the use of Genetic algorithms for real-time control of sensor network system. They proposed a new machine learning architecture with integrated system control and resource management capability for use in autonomous sensing applications with limited resources. A genetic optimization algorithm is used to control the system in the presence of dynamic events, while ensuring that system constraints are met. This tight integration of control optimization and machine learning algorithms results in a highly efficient intelligent sensor network. Genetic algorithms do not require computation of a gradient and/or inversion of complex, large matrices, which makes them suitable for applications with limited computing power.

CONCLUSION

Efficient energy consumption and conservation is a key problem in the sensor networks, lots of work lies in the algorithms for energy efficiency, less attention has been paid in area of alternative intelligent sensors. This research is trying to conduct a survey of intelligent approaches which could be applied in wireless sensor networks considering the capabilities and collaborating of mobile sensors to aggregate information and make decisions.

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