A SURVEY ON ENERGY CONSERVATION TECHNIQUES IN WIRELESS SENSOR NETWORKS

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ABSTRACT

In the last years, the research community and actual users have enabled to increase the attention of Wireless Sensor Networks. The lifetime of the sensor node is based on battery powered devices. Several authors discussed the different energy consumption techniques for different layers. Consolidated efficient energy consumption techniques are missing. This paper provides a detailed study about all the existing energy conservation techniques and also explains about limitations available in the techniques. In this paper, the energy conservation approaches and its algorithms for computing the optimal transmitting ranges in order to generate a network with desired properties are discussed. Finally this paper concludes with insights for research techniques about energy conservation in Wireless Sensor Networks.

Keywords: energy conservation, wireless sensor networks, power management, data driven.

1. INTRODUCTION

Wireless Sensor Network contains a number of sensor nodes that are deployed over a geographical area to sense the desired physical phenomena. Typically, a sensor node includes the following basic components: Sensing subsystem, Processing subsystem, Communication subsystem and a power unit. Sensing subsystem (E.T.-H. Chu. H.J. Lee, *et al*., 2011) acquires data from the geographical area. A processing subsystem encapsulates data processing and storage, and a wireless communication subsystem to transfer the data. D.P. Agarwal. Q. -A. Zeng, (2011) says that sensor nodes typically exhibit limited capabilities in terms of processing and communication, and they especially run on battery power. Energy consumption (Giuseppe Anastasi, *et al*., 2009) in WSN can be broadly classified into duty-cycling, data-driven and mobility based.

In this paper, a study on various protocols coming under power management and data-driven approaches has been done. This paper also discusses the main approaches based on the different layers of energy conservation in wireless sensor networks. This paper is organized as follows; Section 2 discusses various cost factors in wireless sensor nodes. Section 3 deals with Power management technique protocols. Section 4 deals the data-driven technique protocols.

In Section 5, future research directions have been discussed.

2. GENERAL APPROACHES TO ENERGY CONSERVATION

Several energy conservation approaches have been proposed for WSN, Power management techniques to reduce processing cost, data driven approaches for mitigating communication cost, restricting the number of data samples to reduce sensing cost.

2.1. Processing subsystem cost

Power management is mainly focused on the processing subsystem and puts the transceiver in sleep mode whenever communication is not required. Nodes are alternatively gone to sleep and active periods depending on the network activity. A sleep/wake-up scheduling algorithm thus accompanies any power management scheme.

2.2. Communication subsystem cost

Communication diminution is not enough when the sensor itself is power hungry. Data-driven improves the energy conservation in a way of sensing subsystem.

2.3. Sensing subsystem cost

In unneeded samples, sample data having well built spatial and/or chronological correlations. The sampling has the issue as: unneeded sample data is inadequate.

3. POWER MANAGEMENT TECHNIQUES

Power Management increases the energy life time of sensor network by putting the radio transceiver in the sleep mode whenever the communication is not required. This section described the techniques which reduce the energy consumption by the local network characteristics and the residual energy of neighboring nodes.

3.1. Receiver-driven medium access control (RMAC)

RMAC (Wee LumTan, *et al*., 2011) is a type of TDMA based scheduling scheme. Unlike other MAC protocol, each node in its time slot will receive message from other nodes. To avoid simultaneous message transmission from multiple nodes to the receiver node, each receiver node will have a sender node on its scheduled time period. When compared with other Receiver MAC protocol, it is having time stealing mechanism. If the sender node is not transmitting any message on the time slot of receiver node, then the allotted time slot will be traced up by nearby sender node to transmit its message to the receiver node.

3.2. Multi-layer MAC (ML-MAC) protocol

ML-MAC (Manish Kumar Jha, *et al*., 2011) is a distributed contention-based and self organizing MAC protocol, where nodes discover their neighbours based on their radio signal level. ML-MAC divides sensor nodes into layers. Layers are randomly chosen by nodes and its time period of each layer is divided into number of frames. Each frame decides its listen and sleep periods. The listen periods of nodes in different layers are non-overlapping. A node in the ML-MAC protocol wakes up only at its assigned layer's listen period. ML-MAC reduces the energy consumption than other protocols by reducing the wake up time of each node through layered architecture.

3.3. Optimal wake-up frequency assignment algorithm (OWFA)

OWFA (Ungiin Jang, *et al*., 2012) exhibits both centralized and distributed mechanism. OWFA assigns optimal wake up frequency to all nodes in the data gathering tree. OWFA has three procedures as: Alpha procedure, Combine-Node procedure and Assign frequency procedure. Alpha calculates optimal wake-up frequency by summing the overhead energy values and data transmission energy values of all child nodes. Combine-Node procedure recursively calculates the combined energy consumption coefficient of the root node. The root node assigns the wake-up frequency of each node.

3.4. Adaptive service provisioning mechanism

N Chien - Lian Fok, *et al*., (2011) proposed the adaptive service provisioning for enhanced energy efficiency. The flexibility of wireless sensor networks is achieved through novel service binding strategies that automatically adapt application behavior. Adaptation mechanism is divided into three parts: energy-aware selection, shared service invocations, and adapting the network topology changes. Selecting the provider is to choose the one that result in the application having the smallest energy footprint. Service sharing enables multiple service execution requests can be combined into one execution of the service. An adaptation mechanism is responsible for switching providers to enhance service availability.

3.5. Memetic algorithm (MA)

MA (Konstantinos P. Ferentinos, *et al*., 2010) is a dynamic optimal design algorithm. Memetic algorithm optimized the design based on the battery level threshold values for each operating modes of sensors. The MA approach is materialized through local search and threshold update schemes. Local search initialize the threshold values of battery levels for each three possible operating modes are CH, Higher Sensor Range (HSR), and Lower Sensor Range (LSR) defined. If battery level is below its threshold, then operating mode is changed to lower mode until its corresponding threshold value becomes lower. Threshold update scheme determines updated threshold as reduction rate using reduction scheme.

3.6. Time division multiple access (TDMA) -based algorithms

A TDMA scheduling scheme has balanced energy and end-to-end delay of wireless sensor networks. This balance achieves with appropriate scheduling of the wake-up intervals. From sensors to gateway it takes one sleep interval for data transmission.

3.6.1. TDMA scheduling algorithm

TDMA (Nikola A. Pantazis Dimitrios J. Vargados, *et al*., 2009) scheduling reduces sleep mode delay in WSN. TDMA algorithm initially builds the transmission schedule. Transmission schedule is flooded back to the sensor nodes, allowing them to know when they can transmit or receive a packet. Energy-saving phase determines sleep and wake-up periods using initial transmission schedule. At the wake-up time wake-up (WU) message is forwarded to all sensors that are located in the path from sensors to the gateway. Path wake-up aggregation techniques are maintaining a low end-to-end delay from the sensors to the gateway.

3.6.2. Low energy adaptive clustering hierarchy (LEACH)

LEACH (W. Heinzelman, *et al*., 2000) is the cluster based algorithm. LEACH forms the clusters based on the received signal strength and without any centralized control. The CH is determined with probability that can reach using least communication energy. CH localized the data processing of all the fusion and aggregation. The role of CH is assigned to some other node in order to balance the load. The rotation of CH role is assigned through choosing random number between 0 and 1. A node becomes a CH for the current rotation, if the random number is less than the threshold. Data from cluster nodes to BS achieves through CH.

3.6.3. Energy efficient cluster node (EECL) data transmission

EECL (Venu Madhav and N.V.S.N. Sarma, 2012) is distributed over the sensors which forms optimal clusters. The cluster has been created and the data transmission is fixed with TDMA scheduling. Sensors nodes have to send the data during its allocation transmission time to the CH. After allocating transmission time for each node, the radio of CH node is turn to off. When wake-up time CH receives data from remaining nodes and the data has been aggregated. The data has sent through energy efficient CH to BS.

3.7. Network coding-based cooperative ARQ (NCCARQ MAC) protocol

NCCARQ MAC (Angelos Antonopoulos *et al*., 2012) is a network coding technique. NCCARQ correlates the transmissions between a set of relay nodes that supports a bidirectional communication among pair of nodes. NCCARQ-MAC enables wireless workstations to request cooperation of neighbouring nodes for correct reception of a data packet. It allows the helper nodes to perform network coding techniques to the packets to be transmitted before relaying the packets. The relay store, a copy of any captured data packet until it is acknowledged by the intended destination. The error mechanism, such as Cyclic Redundancy Code is applied to perform error control for receiving messages.

3.8. Geodesic sensor clustering (GESC)

GESC (N. Dimokas, *et al*., 2010) is a Distributed clustering algorithm and designed for multi-hop networks. Clustering creates the hierarchical base structure. Network management technique uses the residual energy for selecting cluster head. The clustering protocol is divided into two major procedures: the clustering formation procedure (CFP) and the network operation procedure (NOP). The duration of the clustering formation procedure is the time interval needed to cluster the network, while the duration of the network operation procedure is the time interval between two subsequent intervals. The clustering protocol is divided into rounds where at the beginning of each round CFP is triggered. The NOP follows the CFP when data transferred from the nodes to cluster heads and it will forward through multi-hop paths to the information sink.

3.9. Cluster based routing protocol (EADC)

EADC (Jiguo Yu, *et al*., 2012) is a cluster-based routing protocol. EADC calculates average residual energy and waiting time of each node. If a node has not receive any header message from remaining nodes within the waiting time, then it elects as a CH. The other nodes are joined as members to CH. CH broadcast the schedule to its cluster members. During its schedule, nodes transmit the data to CH. If the distance between the CH to BS is less than the calculated threshold, then it will have BS as next hop. Otherwise, it will forward to next CH node having higher residual energy.

4. DATA-DRIVEN APPROACHES

The data-driven techniques aimed to deliver the shrink data to BS. The information from the source node is to be compressed using Data compression technique and through intermediate nodes aggregated data reached BS. This section described the techniques to increase the network life time by reducing the amount of data.

4.1. Directed diffusion

Directed Diffusion (Chalermek Intanagonwiwat *et al*., 2000) is a data-centric protocol. Each node will sense its environment and stores it as its interest. When the Query is flowing through the network, each node will receive the Query and check with its own interest. If it get matched it will send its data to sink node, otherwise the Query will be forwarded to its neighbor node. When the source node sends its data to sink node it chooses the path contain in the Query itself. After sending the reply (or) forwarding the Query to neighbor node if it receives the Query of same interest it rejects it.

4.2. Maximizing energy utilization routing protocol (MEURP)

MEURP (Yunsheng Liu, Zheng Wang, 2012) avoids global flooding, whereas it uses local flooding for route discovery. Back-off waiting scheme mechanism have been used to ensure that the data from source node ‘S’ reaches the sink node ‘D’ with minimum hop count. Furthermore it avoids global reconfiguration, due to energy depletion of nodes by using additional new nodes among energy depleted nodes. It becomes the responsibility of the new node to relay packets without any loss

4.3. Energy-balanced sampling workload allocation (SWAP)

Sampling Workload Allocation Problem (SWAP) (Edward T.-H. Chu, 2012) algorithm has been assigned for the application where large number of sample data is needed to construct the original phenomena. But large data volume will cause rapid energy depletion in the network. Here the rapid energy depletion is compensated by providing sampling schedule to each node by its parent node for each request from the root node. The intermediate parent nodes assigns different sample scheduling period to its child nodes (leaf nodes. Using this centralized energy balancing algorithm energy is conserved and at the same time required numbers of samples are given to the root node.

4.4. Distributed energy-efficient clustering with improved coverage (DEECIC)

DEECIC (Zhixin Liu, *et al*., 2012) works with four control messages. Each node in the network will update its existence to the nearby nodes. Then the nodes will inform its neighbors about its node degree (number of neighbor nodes) using DEGREE_MSG. The node which is having higher node degree is elected as Cluster Head (CH). After this, the CH elected nodes broadcasts STATE_MSG to nodes within the range R_c. The cluster member nodes will respond to its CH node with JOIN_MSG. The unclustered nodes after receiving STATE_MSG from 1-hop clustered nodes will check its node degree. If its node degree is less than 1-hop clustered hop it joins the cluster as 2-hop member node. Otherwise it elects itself as CH. Each CH nodes have been given a threshold energy level. If its energy level becomes less than that threshold level, it issues ABDICATE_MSG to its 1-hop member node. The member nodes in the cluster elect its new CH who is having higher residual energy and node degree. Thus it tries to avoid packet loss due to energy depletion of CH nodes.

Table-1 summarizes the survey of energy conservation in wireless sensor network.

Table-1. Summarizes the survey of energy conservation in wireless sensor network.

Layers	Energy conservation schemes	Location-driven	Connection-driven	Asynchronous sleep/wake protocols	Contention based MAC protocol	Data compression	Energy efficient data acquisition with clustering	Energy efficient data acquisition with adaptive sampling
Physical layer	SWAP							✓
Data link layer	R-MAC				✓			
	ML-MAC				✓			
	OWFA			✓				
	Adaptive service provisioning		✓					
	Memetic algorithm			✓				
	TDMA-based scheduling				✓			
	LEACH				✓			
	EECL				✓			
	NCCARQ				✓			
	EADC				✓			
Network layer	GESC	✓						
	Directed diffusion					✓	✓	
	MEURP							✓
	DEECIC						✓	✓

5. CONCLUSIONS

In this paper, different techniques of energy conservation in wireless sensor networks have been surveyed This paper have some importance on different approaches of power management technique's protocols as, R-MAC, ML-MAC, OWFA, Adaptive service provisioning, Memetic algorithm, TDMA Scheduling, LEACH, EECL, NCCARQ, GESC, EADC and data-driven techniques such as Directed Diffusion, MEURP, SWAP, and DEECIC algorithm.

Energy conservation approaches are based on some attributes such as power management and data-driven. Many of the researchers follow this paradigm in order to avoid the overhead of forming clusters, the use of specialized node. The time taken for sampling phase will be long especially when compare it to the time needed for communication. Hence the sensors itself will consume high energy. Therefore the target of energy conservation has not been fully yet in data acquisition. Finally, it observes that many practical applications such as network can be very efficient and robust if the communication protocol exists power managing.

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