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Research Article

A Comprehensive Survey on Energy Efficient Adaptive Cluster Based Algorithm for Multihop Heterogenous Wireless Sensor Networks

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Abstract: Wireless sensor network has been emerged as a most powerful technology in which many sensor nodes are deployed for various monitoring applications. Wireless sensor network uses battery-operated computing and sensing devices. The sensor nodes use battery as a source of energy and these batteries cannot be recharged or changed very often. It is vital requirement in wireless sensor networks that node's energy need to be efficiently utilized. In this study, a literature survey on various methods for energy efficiency in wireless sensor networks is discussed. The study also provides energy issues in wireless sensor networks and various sources of wastage of energy in WSNs.

Keywords: Broadcasting, data cycling, data driven methods, energy efficiency, energy wastage, MAC, topology issues, wireless sensor networks, WSN

INTRODUCTION

A set of spatially dispersed, wirelessly enabled and dedicated sensors which monitors and records the physical conditions of the environment is referred to as Wireless Sensor Networks (WSN) (Mohamed and Kemal, 2008). The recorded data is organized at a central location. The sensors in WSN measure physical conditions such as temperature, pressure, sound, humidity, pollution levels, wind speed, wind direction, etc in their given environment. Wireless sensor networks are having wide applications in areas like disaster relief operations, bio-diversity mappings, intelligent building, precision agriculture, medicine and health care, machine surveillance and preventive maintenance, (Mohamed and Kemal, 2008).

Because of WSNs embedded construction and distributed nature, it is having many advantages than traditional sensing technologies. The wireless sensor network uses low power, small, inexpensive micro controllers and transceivers which reduces the cost notably. This allows many commercial and military organizations to use WSN technology for their applications (Wheeler, 2007).

Another advantage of WSN is the use of mesh networking scheme. Transmission of data from one point to another with mesh network consumes less energy than direct transmission between two points. This is the nature of RF communication and overall energy consumption is much lesser than point-to-point communication (Suzhi *et al*., 2014). Wireless sensor network also provides better coverage than centralized architecture. Wireless sensor networks reduce SNR (Signal to Noise Ratio) thereby increasing the amount of usable data. Since wireless sensor networks offer more advantages, which are not available with traditional sensor technology, WSN networks are widely used in many applications (Suzhi *et al*., 2014).

A set of sensor nodes with different abilities like variable sensors used, different communication and sensing scope, are called heterogeneous wireless sensor networks. Usage of many low-priced, low-capability devices along with expensive, high capability devices can appreciably increases the duration of network's sensing performance. The deployment and control mechanism of heterogeneous WSN are more complex (Chun-Hsien and Yeh-Ching, 2007).

LITERATURE REVIEW

Minimizing energy consumption is an important requirement in wireless sensor networks. Care must be taken such that energy minimization should not affect the functioning of WSN like affecting the quality, etc. There are number of issues that arises while designing the energy efficient wireless sensor networks and they are broadly classified into three categories:

- Broadcasting issues
- Clustering issues
- Monitoring issues
- Topology issues

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To address the above problems, it is optimal to design distributed algorithms that are executed in individual nodes of WSN to compute the solution for the problems of global nature. The individual nodes are allowed to make decisions after executing the distributed algorithm without the knowledge of global topology (Hebden and Pearce, 2006). In certain cases, nodes are allowed to know little knowledge about the global network structures and in few cases, nodes are allowed to communicate only with its neighbours to make decisions during the execution of distributed algorithm. This distributed scheme relieves sensor from sending information to a central base station which runs the algorithm and return the results to sensor (Al-Karaki and Kamal, 2004).

Generally flooding technique is used for broadcasting in wireless sensor networks. Broadcasting is used to forward a message to all the other nodes in the network and flooding technique is a type of routing technique in which node sends the data to its neighbours only. This forwarding of data is carried out in all the network links, including shortest path (Yun-Wei *et al*., 2010). Flooding is very simple to implement and if a packet can be delivered, it will. But flooding can waste the allocated bandwidth of the network because messages are duplicated in the network and forwarded to its neighbours. This increases the load on the network. Duplicate packets may go on circulate in the network (Yun-Wei *et al*., 2010). Hence it is important to design energy-efficient algorithms that can address the above unwanted transmission problem.

Another way to implement broadcasting in wireless sensor networks is to use virtual backbones. A backbone often connects large networks and larger transmission lines that carry data collected from smaller lines. Backbones are widely used in wired networks and its variant, virtual backbones can be used in wireless sensor networks for broadcasting process (Datta and Gopinath, 2006). Virtual backbones allow small portions of nodes to perform transmission thereby reducing the number of retransmissions. In wireless sensor networks, virtual backbone is assumed as a subset of nodes which are responsible for relaying message throughout the subset (Datta and Gopinath, 2006).

Often these subsets of nodes are known as Connected Dominant Sets. The size of the connected dominant sets is directly proportional to the number of transmissions in the network. Hence it is important to find small sized connected dominant sets in wireless sensor networks (Ji *et al*., 2008). To accomplish broadcasting, we can depend on flooding or virtual backbone techniques. It is better to use virtual backbone technique which reduces the usage of energy in a substantial way.

Clustering divides the wireless sensor networks in to a number of clusters. Each cluster is represented with a node called cluster head. These cluster head nodes are always active and performs sensing, gathering and transmitting data to the base station. The other nodes in the cluster can go to sleep mode (Zhang and Wang, 2011).

The issue with clustering is that number of clusters need to be minimized. This can be accomplished by imposing the condition that any node in the wireless sensor network will be either a cluster head or connected to at least one cluster head. If we have minimum number of clusters, then most of the nodes will be in sleep mode there by achieving energy efficiency. This problem is said to be minimum dominating set problem (Zhang and Wang, 2011).

Since cluster head nodes are busy in sensing, gathering and processing data, they run out of energy very often. The other nodes which are in sleep mode contains substantial amount of energy with them. This disproportion in energy distribution among clusters head nodes and other nodes in wireless sensor network can be tackled by locating a family of disjoint sets of cluster heads and allow them to change regularly so that energy consumption can be balanced among other nodes (Liu *et al*., 2009).

Finding the maximum number of disjoint sets from a given WSN is a difficult task and the problem is said to be Dominating Partition Problem. This problem is NP-hard in nature and a dominating set of a graph is used to identify disjoint set of nodes

In wireless sensor networks, it is sometimes observed that only a small set of sensors alone is used to do the same monitoring activity. Though all the sensors are designed and fixed for monitoring purpose, few are rarely used where as small group of sensors are continuously used. It is a good idea to make unused sensors in sleep mode and small set of sensors to monitor continuously. This will result in enormous energy saving in wireless sensor networks (Wu *et al*., 2014). The idea is that only few nodes are made active while others are in sleep mode.

The set of sensors which monitors stationery targets are said to be monitoring sets and each monitoring set monitors all the targets. The monitoring sets are always active in monitoring targets. It is good to maximize the number of monitoring sets and minimize number of sensors in each monitoring sets to achieve high energy efficiency.

Sensors provide monitoring information about the targets and it is necessary to protect these sensors from certain actions that attack sensors (Padmavathi and Shanmugapriya, 2009). One way is to monitor each sensor by its neighbor sensor and inform to the base station when there is an attack. This type of networks are said to be self protecting wireless sensor networks. Moreover, it is also a requirement to know whether all the sensors contribute their task. Bad sensors, malfunctioning or dying out sensors may exist in the wireless sensor networks and it cannot inform its condition to the base station (Padmavathi and Shanmugapriya, 2009). The targets monitored by such bad sensors are unprotected and system is not having any provision to know this danger.

It is always a good idea to have a set of sensors whose duty is to monitor other sensors. And whenever there is any failure or malfunction among sensors, it will notify this situation to the base station. Then base station can take suitable action to the vulnerability and the action may be deployment of additional node in replacement of malfunctioned node.

To enhance the performance of networks, it is good to obtain the sub graph of the underlying network architecture. The sub graph removes redundant links to achieve performance and the sub graph is expected to have certain features like connection information, planarity, sparseness, spanner property, (Ababneh *et al*., 2009). Finding this type of topology allows us to apply routing algorithm such as GPSR which needs network topology to be planar.

Reducing the links can substantially reduce the burden of keeping all the nodes and allow only a subset of their neighbours. Keeping few neighbours reduces the number of transmissions which helps to elongate the life time of network. The sub graph also removes longer links in the network by keeping smaller ones as such in order to achieve energy efficiency.

One of the scarce resource for wireless sensor networks is energy and it has to be utilized in a wisely manner to elongate the duration of sensor for a particular mission. Sensor consumes energy for useful activities such as transmitting or receiving data, processing query requests, sharing data to neighbour nodes, forwarding queries, (Patil and Biradar, 2012). However, energy can also be consumed for dissipate activities. The various ways by which energy is wasted in wireless sensor networks are.

Idle listening: Listening an idle channel for a long time to receive a possible traffic is a biggest way of wasting power. Wireless sensor networks which follow CSMA mechanism generally prove to be inefficient because of idle listening (Cardei *et al*., 2005).

Over hearing: In wireless sensor networks, sensor nodes may over hear few packets transmission whereas these sensors are not the deliberate recipients. These unwanted receipts of packet transmission may result in wastage of energy (Cardei *et al*., 2005).

Collision: When sensor nodes receive multiple packets simultaneously, packed colloid each other and collision occurs. All the collided packets are discarded by the sensor nodes and new transmission is needed. The new transmission causes wastage of energy (Chen and Na, 2006).

Control packets: Packets that are used to monitor and keep network healthy are said to be control packets and these packets carry control information rather than sensor data. If too much of control packets flow in wireless sensor network, that much of energy is wasted (Tiwari *et al*., 2004).

Over emitting: Failure in data transmission among neighbor nodes in wireless sensor networks is also a major source of energy waste. This occurs when the target machine is not ready to receive sensor data and source continuously transmitting (Tiwari *et al*., 2004).

METHODOLOGY

Before discussing about the methods used for saving energy in wireless sensor networks, it is important to consider the architecture of generic sensor nodes. It consists of four important components (Kawahara *et al*., 2003). The first one is a sensing sub system that acquires data and it includes one or more sensors. Architecture also contains processing sub system for data processing which includes micro controller and memory. Next it contains radio sub system for wireless data communication and a power supply unit which maintains power to sensor nodes (Giuseppe *et al*., 2009). Apart from this, a sensor node may have location finding sub system, mobilize, etc. However, these components are optional and its inclusion is based on the specific application.

Duty Cycling is a type of energy saving is mainly used in networking sub system. Among four modes of sensor node operation, more power is consumed for data transmission. The power consumption is same for a sensor node in idle mode as well as in reception mode. However, energy consumption in sleep mode is much lesser. Hence the effective way to conserve energy effectively is to put the sensor node to sleep mode when there is no data to transmit (Huan-Chao *et al*., 2011). Preferably, the sensor node should be switched off as soon as no data is available to send or receive and should be switched on when the data is ready. This switching of modes from active to sleep and vice-versa is said to be duty cycling. This is a distributed scheme and sensor node decides when to transform from active to sleep mode (Huan-Chao *et al*., 2011). This method is obvious to data that are sampled by sensors.

Data driven approaches try to compress the data. The idea is to use any compression technique to compress the data before sending it to the base station. The variations of this method include directed diffusion, maximum energy utilization routing protocol, energy-balanced sampling work load allocation and distributed energy-efficient clustering with improved coverage (Lehsaini *et al*., 2008). All the variations work with two basic principles. The first is that, sampled data has spatial or temporal correlation and hence there is no need to communicate the redundant information to the sink. Reducing transmission is not the only way for energy conservation since sensor requires huge energy. Data driven techniques reduces the sample data quantity by maintaining sensing accuracy with preferable level of threshold (Lehsaini *et al*., 2008).

Since the network is wireless, nodes are free to move across the network. In such cases, nodes follow a multi-hop path towards the sink. If nodes are mobile, the data flow path needs modification (Nesargi and Prakash, 2000). Hence static nodes can save energy because of minimum path length, contention and lower overheads. Mobile nodes more consume energy and hence too much mobility needs to be avoided for energy conservation.

The Medium Access Control (MAC) protocols that define a mechanism that creates an infrastructure and establish link for data transfer. It also defines how to share common resources between sensor nodes. The MAC layer is responsible for accessing the shared medium i.e., it guides the nodes when to access the shared medium. Since time of accessing the medium plays a vital role in energy conservation of wireless sensor networks, it is necessary to design a proper MAC protocols (Yan-Xiao *et al*., 2010). Few protocols used in wireless sensor networks are given below.

Abbreviated as Timeout MAC, transmits all the packets in a burst of variable length period. There is a gap between bursts and said to be sleep time. In this type, listen period ends when no activity is recorded for specific threshold time. The basic idea is to reduce the idle listening (Vuran and Akyildiz, 2006). The node awakes at time TA to communicate with neighbor nodes and it uses RTS and CTS signal to provide collision free reliable transmission. The advantage of T-MAC is that it can easily handle variable load due to dynamic sleeping schedule. But early sleeping problem in which nodes can sleep during activation time is the disadvantage as this problem will result in loss of data (Bhavana *et al*., 2011).

S-MAC uses effective mechanism to solve energy wastage between listen and sleep period. It is a contention-based protocol which follows CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) principle. All the nodes follow periodic sleep and listen schedule and during sleep period, the nodes sleep by turning off their radios. In listen period, the node senses the medium and if found idle, continues its listening and communicate with neighbours (Wei *et al*., 2002). It uses RTS, CTS and ACK signals to communicate with neighnours. If a sensor node does not find RTS or CTS signal, it goes to sleep mode. At the end of sleep mode, the node wakes up and looks for some event. If no event is found, it goes to sleep mode once again.

By this way, a large amount of energy conservation is achieved. The unnecessary listening is also avoided in S-MAC protocols. The advantage of S-MAC is that energy utilization increases because of sleep schedules (Wei *et al*., 2002). Moreover, the method is simple to implement, long messages can be efficiently transferred by message passing technique. But fixed listen and sleep period is not suitable for variable traffic load and this makes S-MAC algorithm inefficient (Wei *et al*., 2002). And adaptive listen can also cause overhearing hazard.

Stands for Pendulum MAC, organizes the system into layers and nodes are assigned with time slots. The nodes can be awake only in this time slot and report to the base station and it will go to sleep mode during remaining time (Besem *et al*., 2012). The sensor nodes decide when to wake up and when to sleep based on current location of node. But the drawback of this system is that there is a delay in data collection for extended periods of time. Moreover, P-MAC can be applied only in large networks with 250 or more nodes (Besem *et al*., 2012).

In this approach, a transmission ends at a scheduled listen time or scheduled sleep time. If the transmission ends at the scheduled sleep time, the node will keep listening till next scheduled sleep time. U-MAC provides various duty cycles, utilization based tuning and selective sleeping after transmission (Shih-Hsien *et al*., 2005). Piggy backing is done to avoid unnecessary retransmission of RTS frames.

The MAC based protocols deliver high rate of energy conservation. Apart from the methods discussed above, μ-MAC, DEE-MAC, Spare-MAC, Z-MAC, A-MAC, Wise-MAC, etc., are also available which proves good energy conservations.

CONCLUSION

Major area which many of the researchers pour their attention is the extension of network life which is dependent on utilization of battery with as much efficiency as possible. The difficulty of wireless sensor network in terms of energy is that nodes cannot be recharged after deployment. The nodes cannot be removed from the wireless network infrastructure for the sake of energy diminishment. Major usage of battery is at the MAC Layer level where radio module is utilized. MAC Layer protocols needs to be developed efficiently. In this study we have summarized various MAC protocols used in wireless sensor networks for efficiently using energy. SMAC protocol preserves energy by using sleep and active modes, with only few necessary nodes are active on a particular area where as other nodes are in sleeping mode. But problem with SMAC is static sleep schedule which leads to sleep delay. TMAC overcomes this problem by using dynamic sleep pattern. TMAC change patterns of network like inclusion of new node, deactivation of deliberated nodes. This variable sleep schedule increases the energy conservation of nodes. But TMAC protocol's performance gets decreased because of early sleeping problem. Other variations of MAC protocols such as PMAC, UMAC, etc., are also discussed which is having its own merits and demerits.

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