Sink and Relay Mobility Based Energy Conservation Techniques for WSN: A Survey

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Abstract - Wireless Sensor Networks are gaining more and more importance in present era. Recent Advances in WSN have extended the applicability of these to wide range of real time applications. One of these recent advances in WSN is invention of Heterogeneous Wireless Sensor networks (HWSN). Compared to Homogenous, Heterogeneous have large curve of applicability. However, whether it is Homogenous WSN or Heterogeneous WSN consumption of energy is un-avoidable. In most of the sensor applications energy is one of the scarce resource. Hence, the main goal of any application using WSN is to spend less energy and extend the lifetime of the WSN. Broadly, the energy conservation techniques in Wireless Sensor Networks are classified as Data driven based, Mobility based and Duty cycle based. In this paper, we are presenting a survey on mobility based energy conservation techniques for sensor networks (both homogeneous and Heterogeneous WSNs). Mobility of nodes could be in the form of sink mobility, relay node mobility or sometimes sensor node mobility. We are discussing in more details on sink mobility and relay node mobility based energy conservation techniques. Present works concentrate only on one aspect of energy conservation. We are also identifying some research gaps in the field of energy conservation in sensor networks considering mobility of nodes in the sensor network.

Keywords - *Wireless Sensor Networks(WSN);Heterogeneous Wireless Sensor networks (HWSN); Mobile-sink based Energy-efficient Clustering Algorithm (MECA); Residual energy aware routing(REAR); Load based sink movement(LBM).*

1. Introduction

1.1 Heterogeneous Wireless Sensor Network

Wireless sensor networks(WSNs) are broadly classified as Homogeneous and Heterogeneous Wireless sensor networks. Homogeneous WSNs are identified with nodes in the sensor network having similar resource capabilities except the base station. Compared to Homogeneous WSN HWSNs have nodes with different communication capabilities, different levels of power and different computational capabilities.

1.2 Resources in Sensor Networks

Most of the sensor networks have some of the common resources. These resources have typical features that make the sensor to loose or gain them. Following is the list of those key features and resources:

- Power(in the form of batteries): This includes availability of energy, capacity to store energy and capacity to regenerate energy.
- Memory: Consists of small capacity on chip memory for storing sensed data and restoring after memory becomes full.
- Communication: Types of communication protocol/s used, bandwidth available, antennas used, receiving and transmission power, range of coverage.
- Computation: Types of processors and electronic components used in circuit, Energy consumed by every component of circuit including the processor.
- Base station: distance between the sensing node and sink node, capacity of all resources of sink node.

It is understood from aforementioned key features that they have requirement for energy. Every resource consumes different amount of energy making the battery of sensors to drain out very fast. This makes energy management as important part of any sensor and then, in turn for whole sensor network. Presently sufficient research works(as added in references) are done to efficiently manage energy consumed by every resource in the form of Clustering Algorithms, efficient Routing protocols/techniques, Efficient MAC layer protocols/techniques to consume less energy, Memory management techniques/protocols. In summary, energy conservation in Sensor networks becomes an important issue to be addressed. Presently number of solutions are proposed by researchers across the globe to conserve energy in sensor networks. These energy conservation techniques for WSNs can be classified as Duty cycle based, Data driven based and Mobility based [4]. As shown in Fig. 1 mobile-based energy conservation techniques are dependent on mobility of relay & sink nodes.

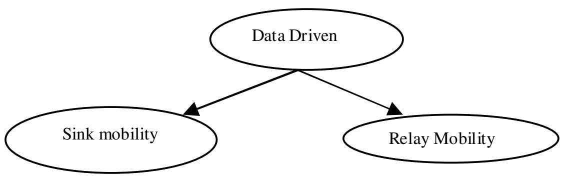

Fig. 1: Classification of mobility based energy conservation techniques

In this paper we discuss different sink node and relay node mobility based energy conservation techniques as applicable to both homogeneous and HWSNs. We also propose some research gaps from these techniques to improve the energy conservation in WSNs.

2. Mobility in WSNs

Mobility is a general word used to represent movement of nodes in a sensor network. Any wireless node in a sensor network will make the network as mobile wireless sensor network. Most of the sensor networks have sensing node, sink node (Base station) and relay nodes. Hence depending on the mobility of these nodes the mobility based energy conservation techniques are classified as:

- Mobile sensing node based techniques
- Mobile sink node based techniques
- Mobile relay node based techniques

In above-mentioned techniques, mobile sink and mobile relay node based techniques are important as they are actively involved in collecting and routing the sensed data.

2.1 Mobile Sink based techniques

2.1.1 Mobile-Sink-based Approach

Many approaches proposed in the literature of sensor networks with mobile sinks (MSs) rely on a Linear Programming (LP) formulation, which is exploited in order to optimize parameters such as network lifetime and so on. Proposed model consisting of a MS which can move to a limited number of locations (sink sites) to visit a given sensor and communicate with it (sensors are supposed to be arranged in a square grid within the sensing area). During visits to nodes, the sink stays at the node location for some period. Nodes not in the coverage area of the sink can send messages along multi-hop paths ending at the MS. The path till MS are obtained using shortest path routing [7].

2.1.2 Load Based Sink Movement (LBM)

A major problem affecting network lifetime is because energy dissipation becomes highly concentrated on the sensor nodes, which are closer to the sink node(one hop away). The main goal of most energy-efficient routing and/or data gathering protocols is to solve "Hotspot problem". This problem becomes particularly acute with a single stationary sink node. Since, the same set of sensor nodes close to the sink must be responsible for transmitting all the data to the sink. However, when sink mobility is introduced, different sensor nodes have higher data loads at different times, as the sink moves from one location to another. Process of LBM starts with an sink node in its initial position, and the "heavily loaded" sensor nodes around the sink in some region. If the sink is stationary, these same sets of nodes always remain heavily loaded; but, if the sink is allowed to move to a new location, the load is transferred to a completely new set of nodes. Over time, as the sink moves around, the set of heavily loaded sensor nodes changes, and the energy dissipation is more evenly distributed among all the nodes. Problem with this LBM is that it does not keep in memory about any old data transmissions done by nodes i.e. it may select same nodes based on the distance leading for repeated selection of same nodes [15].

2.1.3 Residual Energy Aware Routing (REAR)

The goal of this algorithm is to avoid using low-energy nodes, when calculating the routing paths from each sensor to the sink. The low-energy nodes can still be used, if there are no other alternatives; however, there is an increased cost for using such nodes. The main objective of REAR algorithm is that the edge costs are calculated differently, to account for the energy levels in each node. These updated edge costs are then used in to create the routing paths. The purpose of REAR is to avoid using sensors that are running low on residual energy. Instead, it attempts to first utilize sensors with higher residual energy to set up alternative routing paths so that the energy dissipation may be balanced. As a result, each individual sensor node can achieve a longer lifetime and extend the lifetime of the network[15].

2.1.4 Mobile-sink based Energy-efficient Clustering Algorithm (MECA) and Static and Multi-mobile-sink Clustering Algorithm algorithm (SMCA)

In MECA, the moving velocity V of the sink is predetermined. A sink node only needs to broadcast across the network to inform all sensor nodes of its current location(sayP0) at the very beginning for just one time. Later on, as sensor nodes keep record of the original location of the sink, they can reduce the changed angle(say θ) after some time interval Δt . As P0 is known, the new location (P*Δt) can be determined. After the broadcasting finishes, the mobile sink is ready to collect data. Then, the mobile sink is assumed to stay at a site for a period long enough to complete a round of data collection, and then moves to the next position. In SMCA both multiple mobile and static sink nodes are deployed. Suppose whenever sink node appears near to it then cluster head it can directly forward packet to sink node. In this case sink node is both static and mobile. Thus, energy is saved. Sensor nodes will calculate least distance which is required to forward the packets. Sensor nodes calculate the minimum energy required with the help of this formula [6].

2.1.5 Multi Mobile Sink nodes (MME)

MME assumes a cluster structure for arrangement of the sensor nodes in the network. Some special nodes, called Rendezvous Point (RP) nodes. These RP nodes collect the data from sensor nodes, store it and wait for travelling agent kinds of nodes called Mobile Element(ME) nodes. These ME node will move in the network across the different clusters and collect the data from these RPs and free there memory. The moment RP hands over the data to ME, RPs will free its memory. After ME completing its travelling, the application will then act upon collected data. However, this approach creates the problem of consuming lot of time and energy. However, it may be addressed by deploying more numbers of MEs in appropriate places in the network [13].

2.2 Mobile Relay Node Based Techniques

2.2.1 Aggregation Routing (AR) Algorithm

This approach is designed for HWSNs. In this method, some static and low capacity (low computational, low communication and low transmission capable) nodes are deployed in a sensing area. This deployment would be either densely or very sparsely distributed in the sensing area. After the low capable static sensor deployed into the area some high capable mobile nodes(also called as mobile relay nodes) are allowed to move in the deployed area that collects, the sensed data from the already deployed low capable sensor nodes. In this scheme, mobile relay nodes have to be connected with sink nodes via two-hop connections only. An aggregate algorithm is applied to collect the data and send it to sink. Algorithm works for both finite and random distribution of the nodes in the network. This approach also claims to achieve four times increase in the lifetime of whole network. Problem with this approach is that it assumes that network is running a data logging application, sensors are in-capable of power control and it ignores event-based networks where direction based mobile relay nodes movement can be beneficial[8].

2.2.2 Message Ferrying Scheme

Message Ferry(MF) are special mobile nodes which are introduced into a sparse mobile ad hoc network to offer the service of message relaying. These nodes act like a mobile relay nodes that move in the network. These MFs nodes have more capabilities than other nodes. MFs move around the network area according to known routes, communicate with other nodes and collect data from all deployed nodes. They carry stored data and forward them towards the base station node. Thus, MFs can work as a moving communication infrastructure, which accommodates data transfer in sparse wireless networks. This approach also defines the concept of stable message ferrying scheme that can bound the data at any node in the network at any given time. This approach solves the afore mentioned problem of stability and addresses Min-Max buffer problem of nodes in the network[3].

2.2.3 Data Mule System

A similar scheme has also been proposed in the context of sparse wireless sensor networks through the data-MULE system. Data mule is any mobile entity in the network that catches the data from sensors, buffers it and delivers the same to wired access point. Hence, a wired access point is must. This system assumes 3-tier architecture to collect data from sparse sensor networks. The first tier is for sensor nodes, second for data Mules and third for access points. This technique starts by pre-deploying the sensor nodes in the fixed network. When moving Data mules come near the sensor nodes then, they collect the data from sensor stores it and pass it to the wired access point when it comes near [3].
The problems with this method are: No purely mobile relay node is considered, Wired fixed access point is must and no guarantee of delivery of data if data mule is not approaching a sensor node.

2.2.4 Optimal Tree Construction Strategy

This strategy addresses Optimal Mobile Relay Configuration (OMRC) in data-intensive WSN's for fixed topology. This strategy works by iteratively refining the configuration of mobile relays by improving the tree topology by adding new nodes. Improve the routing tree by relocating nodes without changing the tree topology.

This approach attempts to improve WSNs performances such as coverage, connectivity, reliability and energy efficiency by applying the concept of mobile relay to minimize the total energy consumed by both wireless transmission and locomotion of nodes. The drawback of this approach is, identifying optimal topology is not guaranteed and movement cost of mobile nodes is neglected for energy consumption calculations [7].

2.2.5 Multi-Hop Communication

This technique tries to apply three different types of deployment strategies for multi-hop relay nodes in multi-hop HWSN. These strategies are connectivity oriented, network oriented and hybrid deployment oriented. The basic principle behind these strategies is to deploy many relay nodes at different locations in the hybrid network or in randomly deployed network. In group of neighboring sensor nodes, one relay node becomes the Cluster Head(CH) and other sensor nodes become members of the cluster that transmit to this CH. When CH depletes its energy then, it is discarded from network communication and new relay node is given a chance for becoming CH. Any deployed relay node not elected as CH will go for sleep mode to save energy. After a CH is elected then bellman ford algorithm is applied to find the path for base station and pass the data to the base station. This work also calculates the weighted density function for every deployment and compares the performance of all three strategies. Out of three strategies multi-hop lifetime oriented strategy shows more performance than other deployment strategies, especially when number of nodes goes beyond 750 to 1500 along with consuming less energy than others [1].

2.2.6 Fault-Tolerant Relay Node Placement in HWSNs

This technique considers HWSNs for experimentation. This Technique addresses the issue of full and partial fault tolerant relay node placement, which aims to provide less number of relay nodes between any pair of sensor nodes or any pair of sensor node and relay node. An interesting problem on which this technique concentrates is single direction and multiple direction transmission of sensor and relay nodes. The problem turns to become NP-hard with different directions of transmissions. Afore mentioned problems are solved to some extent by applying the approximation algorithms to one-way and two-way fault tolerant relay node placement algorithms. This algorithm also shows good performance with k-vertex connected spanning graph identification. Although this technique claims to achieve fault tolerance in the HWSN but, fails to provide energy conservation and amount of approximation done in this technique is difficult to predict [12].

3. Challenges in The Field of Mobility Based Energy Conservation for WSNs

Lot of work is done to save energy using mobility-based techniques. However, general observation is, any technique tries to solve one problem and neglects the other. Following are some of the challenges in the field of WSNs to conserve energy using mobility of nodes in the sensor network:

1. Mobility of nodes- considering the mobility of sensor nodes, sink nodes, base station or relay nodes.
2. Topology- The best topology to be followed.
3. Range- the transmission range to be considered for sensor nodes, sink nodes, base station or relay nodes
4. Energy- Following are some issues to be considered:
   - Availability of energy for sensors, sinks, base station and relay nodes.
   - Energy consumed by movements of different nodes, by transceivers for transmission and receiving data, by different components of circuitries inside sensor nodes.
   - If nodes are having rechargeable batteries then, method of recharging and source of energy recharge.

Energy consumed due to underlying software / programs to perform following tasks:

- Routing – Algorithms/Logic used to route the data packets to next hop.
- Sensing – Mode of accessing sensed data from sensing device of sensor.
- Computation – involves any in circuit processing and computations for sensed data.
- Memory – Management and proper usage of memory devices embedded on sensor.
- Location – Storing location information of sensor in the deployed area and updating the same as and when sensors change their positions
- Controlling – Overall co-ordination of all the devices inside the sensors .
- Security – working of software security related tasks like authentication, confidentiality, integrity etc.. (Size of key in RSA algorithms)

5. Waiting time – sometimes Sensor nodes have to wait for following reasons:
   - Wait for relay node to acquire sensed data and then sensor node can free the buffer.
   - If sleep mode of node is not implemented then, sensors have to wait even when there is nothing to sense.
   - If base station or sink is not ready to receive sensed data then, wait until they become ready to receive data.

4. Conclusion

Presently WSNs are constrained by many resources like memory, computation and energy in the network. Out of these, energy is very vital because without which any other tasks cannot be accomplished. This makes conservation of energy as critical for sensor networks. In this paper, we have done a survey of some of the mobility-based techniques for energy conservation in wireless sensor network. Relay based mobility techniques show better performance compared to sink based mobility techniques as relay nodes go near the nodes that have some sensed data. All these techniques try to utilize the energy in sensors and other nodes in the network to extend the lifetime of network. However, these techniques fail to consider the energy spent in the movement of either sink or relay nodes. From the study of these techniques, we have also identified some of the research issues like mobility of nodes, topology consideration, range, waiting time and different ways of energy consumption inside the nodes that may be addressed in future by mobility based energy conservation.

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