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Data Collection Strategies Using Static Sink and Mobile Sink: A Review

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***Abstract*— Wireless sensor networks fundamentally comprise of low cost sensor nodes which gather data from environment and convey them to a sink, where they will be subsequently processed. As sensor nodes are severely power-constrained, the key concern is how to conserve the nodes energy so that network lifetime can be prolonged significantly .Efficient data collection schemes are crucial in effectively utilizing the available energy. This paper defines about various techniques of data collection that are adopted in wireless sensor networks. The data collection schemes are broadly classified into two major classes: one approach which uses static sink for data collection and the other approach which uses mobile sink for data collection. Various techniques that are adopted in both the schemes are defined.**

***Keywords* — Wireless sensor networks, data collection methods, static sink, mobile sink.**

1. INTRODUCTION

Wireless sensor networks are one among the ten influencing technologies that have emerged in the 21st century. Wireless sensor networks (WSNs) have obtained universal attention in recent years particularly in Micro-Electro-Mechanical Systems (MEMS) technology which has aided the development of smart sensors. A wireless sensor network is basically an infrastructure less network. It comprises of hundreds or thousands of tiny sensor nodes that are deployed in a random fashion in an environment with varying topology. The application specific sensor nodes once deployed, self-organize among themselves by listening to each other. They are deployed randomly without a fixed pattern in the environment. These sensor nodes collectively collaborate together on the common task of sensing an event, processing the collected data and transferring this data to a remote sink node. They are widely used in habitat monitoring, battle fields, object tracking, chemical field, home automation and other commercial applications [1].

The tiny sensor nodes comprise of a sensing unit to sense the event, a processor and a transmitting antenna to transmit data to the remote sink node. They are limited in memory, power and computational capabilities. As the sensor nodes are large in number, once deployed, it is almost impossible to replace their batteries. Battery power is a major concern in the case of sensor networks. Recent researches are being done in the sensor network area in order to find new solutions to effectively utilize the available energy in a fair manner.

Energy consumption by sensor nodes takes place in three cases i.e. when these nodes sense an event, when the sensed data is processed, and finally when this processed data is transmitted to a remote sink node. Energy is mostly consumed when the processed data is transmitted to remote sink node. Data collection by the sink node is a prime concern. Data collection should be effectively done so as to efficiently balance the energy consumption in the sensor nodes. The later section of this paper is organized as follows: Section 2 describes about the two major types of data collection in wireless sensor networks, Section 3 describes about various methods of data collection when the sink node is static, Section 4 describes about the problems encountered when the sink node is mobile and Section 5 and 6 describes about the various methods of data collection schemes when the sink node is given random and controlled mobility.

II. DATA COLLECTION METHODS IN WSN

Effective data collection techniques have a drastic effect on the performance of wireless sensor networks [2].Data collection strategies in sensor networks are mainly grouped into two categories namely, static sink based approach and mobile sink based approach. In static sink based approach, the sink node is considered to be static. After gathering relevant information from the area to be monitored, the sensor nodes transfer data to this remote sink node. In this approach, the selection of effective routing protocols for forwarding the information to the sink is most crucial. The routing protocols should be effective in balancing the energy consumption during data transfer as the data packets have to travel large distances to the sink node. A large number of routing protocols are introduced which efficiently deals with the routing process. A particular problem called hotspot problem is encountered in static sink based approach. As all the sensor nodes forward data to the sink node, the nodes that are placed around the stationary sink experience an onslaught of traffic. Even the data that is forwarded from the farthest sensor node, passes through the nodes placed nearer to the sink. This can significantly increase their energy consumption, thereby causing a problem called hotspot problem.

A significant solution as a remedy for this problem is by giving mobility to the sink node [3], [4].This leads to the second category of data collection strategy. In mobile sink based approach, instead of remaining stationary in a particular area, the sink node moves around the sensor network there by collecting significant data from the sensor nodes. This avoids the risk of energy consumption caused by the hotspot problem. A lot of researches are being done in this area; so as to find an effective strategy to optimize the path of the mobile sink node. Sink mobility causes some challenging issues in wireless sensor networks .It becomes almost impossible to use the classic routing protocols of WSNs with static sink. Therefore, new routing protocols are to be developed or existing ones are to be extended.

III. STATIC SINK BASED APPROACH

Routing protocols are hosted in wireless sensor networks so as to attain energy efficiency. As the sensor nodes are randomly deployed in an environment with varying topology, some of the parameters such as battery power, memory capacity, energy, bandwidth etc. are restricted. Each sensor node should maintain a routing table that describes an energy efficient path to the sink node. Deployment of sensor nodes in the adhoc manner prevents the programmers from pre-configuring the routing tables of each sensor nodes. To maintain the routing paths, various techniques are developed.
Once a region that is to be monitored is fixed, sensors are deployed in that area, along with a static sink node. This was the scenario in earlier days. The module that consumes maximum energy is the communication module. As single hop communication can result in much higher energy consumption, multihop communication is introduced. One way to effectively reduce energy consumption is by using more than one static sink scenario. The sensor nodes can effectively communicate with the sink which is closest to it. The average distance from source to sink is diminished in this case. Routing load that is experienced by the sensor nodes around a single static sink gets dispersed once more than one stationary sink is introduced [5].

Efficient routing strategies have been used in the case of static sink scenarios so as to effectively reduce the energy consumption and to find an optimized path to the static sink. Routing of data to the static sink can be done either based on the sensor network nature or the sensor network architecture.

A. Routing protocols based on nature

A proactive routing protocol (e.g. DSDV(Destination Sequence Distance Vector), OLSR(Optimized Link State Routing protocol)) creates a route before transferring the data or traffic flow at a time whereas in reactive routing protocols (Ad hoc On-demand Distance Vector (AODV)), path is established according to the need. The collaboration of both reactive and proactive routing protocol [6] is called hybrid routing protocol (TORA (Temporally Ordered Routing Algorithm)).

B. Routing protocols based on architecture

Based on the sensor network architecture, there are two types of routing protocols namely flat based routing protocols and hierarchical routing protocols.
In flat routing protocol, a node desires to direct the data to the sink through numerous intermediate node or multi hops. Each node characteristically plays the same role and sensor nodes work together to accomplish the sensing task [6]. Due to the huge number of such nodes, it is not possible to allocate a global identifier to every node. This deliberation has led to data centric routing, where the BS directs queries to certain regions and waits for data from the sensors located in the designated regions. Since data is being demanded through queries, attribute-based naming is necessary to specify the properties of data. Primary works on data centric routing are SPIN and directed diffusion. AODV, DSDV etc. are also flat based routing protocols that are effectively used.
Hierarchical or cluster-based routing, enable a much better performance to sensor networks compared to flat based approach in terms of energy consumption and life time. In this approach, the entire network is divided into hierarchical clusters in which only the higher level nodes communicate with the base station.

C. Hierarchical Clustering

If each sensor node has to communicate with the remote sink node individually, in can significantly enhance the energy consumption of these nodes. As the furthest node from the sink has to forward the data to a much larger distance, its energy reduces considerably. In spite of these matters, there occurs a problem of redundant information being transmitted to the sink node. The sensor nodes which are deployed around an area sense the activities of that area. The data collected by these sensor nodes will be almost similar. When all these nodes try to transmit this information to the sink node, it causes high traffic in the network. As the data transmitted is redundant, energy is wasted unnecessarily. An efficient solution to this problem is done by partitioning the whole sensor nodes into smaller clusters. A cluster head is elected for each cluster based on the residual energy of the sensor nodes. Once the cluster head is elected, the member nodes transfer their data to the cluster heads. The cluster heads aggregate this data and forward it to the remote sink node. This is one approach of efficient routing in static sink scenario. Wendi B. Heinzelman et al [7] proposed a protocol architecture called low-energy adaptive clustering hierarchy (LEACH), for wireless networks that associations the notions of energy-efficient cluster-based routing and media access along with application-specific data aggregation to attain virtuous performance in terms of system lifetime. The operation of LEACH is distributed into rounds. Every round initiates with a set-up phase when the clusters are structured, followed by a steady-state phase when data are transmitted from the nodes to the cluster head and then to the base station.

D. Chain based approach

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is an improved routing protocol compared to LEACH. The protocol, called Power-Efficient Gathering in Sensor Information Systems (PEGASIS), is an optimal chain-based protocol [8]. The major aim of the protocol is to enhance network lifetime. Here nodes require communicating with their nearest neighbors .Then they take turns in interacting with the base-station. When the round of all nodes interacting with the base-station ends, a new round will start and so on. This diminishes the energy needed to communicate data per round as the power exhaustion is spread regularly over all nodes.

E. Grid based clustering

Seifemichael B. Amsalu et al [9] proposed a routing protocol called Grid Clustering Hierarchy (GCH) that offers an efficient energy management for wireless sensor networks.. This protocol splits the network into a variable number of virtual grids based on the existing average energy of the network to construct optimum clusters in terms of energy consumption. Once the nodes inside the grids are recognized, a cluster head node is nominated from each grid. In addition, the cluster head role alternates within the nodes in the grid in a round-robin manner. The base station calculates the average energy of the network subsequently. Then, if the average energy of the network is less than a definite threshold rate determined apriori ,the number of virtual grids will be altered and the above procedure continues.

IV. MOBILE SINK BASED APPROACH

Sink mobility has been used to reduce and balance energy consumption among sensors. Sensor nodes transfer their data to one or more base stations for analysis and processing .Sink node assembles the received data from sensor nodes and when data aggregation is not used, each sensor node transfers its own packet to the sink, and also imparts the packets of its children. The main stimulus behind sink mobility is to alter these neighboring nodes intermittently by moving the sink to different locations. A node which was a neighbor of the sink in a particular round will have a large packet load in that round. But if sink is mobile, it moves to another location there by reducing the packet load of the earlier described node in the next round. In this way, on the average each sensor node will possess nearly similar collective packet load and residual energy levels at an arbitrary time.

The concept of sink mobility into WSNs has become a very effective technique to ease the hot spot problem defined above and balance energy depletion .To attain sink mobility, sink nodes actually travel throughout the network. The mobility is attained when the sink is attached to vehicles, animals or people so that they can travel all over the sensing field to gather data from sensors using very short range communications. Latest results show that network lifetime can be extended further by involving sink mobility.

The challenges of sink mobility have been addressed in different categories: random and controlled mobility. In the random mobility, MS can move freely in the network field and gather information from sensor nodes in the network [19].Though the random mobility schemes can be applied simply in the network, the unrestrained movement of mobile sink effects in poor performance, in case of packet loss, delay, network lifetime, etc. Recent algorithms are employed in the second category. In fact, the controlled mobility methods can be classified into two main classes: restricted and unrestricted.

In the former class, optimum trajectory has been defined through some predefined spacial locations [11],[16], or spacial nodes [1],[7] called rendezvous points (RPs).Some approaches in this class has controlled the velocity and data harvesting strategy of mobile sink on a fixed and predefined path [4]. The locations and the number of rendezvous points have a superficial influence on the performance and the value of the solution [19]. Consequently, in the latter class, the trajectory of mobile sink has been controlled based on the location of mobile sink and sensor nodes.

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V. RANDOM MOBILITY

Subsequently in random mobility schemes, the trajectory of mobile sink is uncontrolled. The issues of sending data and informing the current location of mobile sink to the sensor nodes have been considered as key challenges in this approach.

In [10], the authors proposed an algorithm in which data is collected by certain mobile agents, called data MULEs (mobile ubiquitous LAN extensions) that are attached on uncontrollable objects like human beings, animals or vehicles. MULEs take up data from the sensors when in adjacent range, process it, and drop off the data to wired access points. This leads to considerable power savings at the sensors as they only have to communicate data over a small range. The key drawback of this method, however, is higher latency because sensors have to wait for a MULE to approach for transferring the collected data to wired access points. This scheme is appropriate for delay tolerant applications. Also the sensor nodes take up huge amount of energy because they have to incessantly sense the channel for the impending MULE for transmitting their data.. The nature of Data MULEs are expected to be serendipitous in nature ie their movements cannot be predicted. Instead of random movement of a mobile node, the authors of [28] define a path which is constructed along the sensor field by optimizing the possible errors and helps to locate the sensors in the network.
Ye et al. in [23] proposed TTDD, a Two-Tier Data Dissemination algorithm as an appropriate approach for information gathering in a large WSN. To diminish the communication overhead in sending data from nodes that identify event to the unrestrained mobile sink, TTDD partitioned the network field by exploiting a virtual grid. Instead of broadcasting query messages from each sink to every sensor node to update forwarding information, TTDD constructs a grid structure such that only sensors positioned at grid points have to obtain the forwarding data. Upon triggering a stimulus, instead of inactively waiting for data queries travelling from sinks the information source proactively constructs a grid structure all over the sensor field and groups up the forwarding data at the sensors closest to grid points .These grid points are called dissemination nodes. By using this grid structure, a query from a sink crosses two tiers to reach a source. The lower tier lies inside the local grid square of the sink's present location, hence they are called cells. The higher tier consists of the dissemination nodes. The sink floods its query inside a cell. When a dissemination node acquires a query message from the sink, it further broadcasts this query to the upstream dissemination node, which in turn forwards this query to the source nodes. This query forwarding process helps to reveal the path to the sink node.
Liu et al. in [24] proposed a round based algorithm called SinkTrail for mobile sinks to yield data effectively. The present position of MS was updated using a trail-based approach in which mobile sink broadcasts a message containing its ID and time tag at certain precise locations. Upon getting such a trail message, a sensor node creates its route and distance from mobile sink, and then transmit the trail message which includes its updated elements. As the SinkTrail is a broadcast based protocol, it can cause significant communication overhead.

VI. CONTROLLED MOBILITY

Most of the studies in sink mobility are planned for controlled mobility. The controlled mobility schemes can be classified into two major classes: restricted and unrestricted. In the restricted category, optimal trajectory for a mobile sink has been determined using certain predefined spacial locations or spacial node, literally known as rendezvous points (RPs).Performance and the quality of the solution is mainly influenced superficially by the location and the number of rendezvous points .In the category of unrestricted controlled mobility, the trajectory of MS has been controlled concerning the position of mobile sink and sensor nodes which have collected data to transmit, specifically in the case of event-based applications.

For determining movements of the sink, the authors of [16] defined a Mixed Integer Linear Programming (MILP) analytical model whose solution defines the sink path that enhance network lifetime. MILP models offer centralized solutions. The paths that are defined by the MILP model drive the sink nodes towards areas which are energy rich. More precisely, the sink keeps observing adjacent locations with respect to the energy of the nodes around them. During this monitoring process, if the sink detects any site which is more energy rich than its current site, it greedily moves towards that location. As the LP model has a typical characteristic of using a centralized way for finding solution, this scheme offers best possible approach to enhance network lifetime. Here the sink voraciously journeys toward those zones whose nodes have the highest residual energy. One major drawback of centralized solutions is that, for most of the WSN applications, they consume unbearable time and energy.

A delay tolerant mobile sink model was recommended by Yun et al. [11]. This paper mainly focuses on applications which are delay tolerant. An enhanced framework is proposed here for such applications, to prolong the network life time. In this approach, the sensor nodes need not immediately forward its sensed data to the sink. Within a defined delay limit, nodes can wait until the mobile sink node reaches a favorable position to transfer this data. Until then the data is stored temporarily in each sensor node. A delay tolerant mobile sink model (DT-MSM) is developed for this approach. When the mobile sink reaches a particular position to collect data, a group of the sensor nodes can take part in the data exchange. For achieving best results for this delay bound model, node energy parameters, flow conservation parameters etc. have to be considered. This scheme is more complex than most previous lifetime-enhancement approaches.

Wang et al. in [13] defines an algorithm which specifies an optimal trajectory for multiple mobile sink nodes moving around the sensor network for collecting data. In this approach, the sensor network consists of both static and mobile sensor nodes. Static sensors act as a back bone of the network for determining events in the network field, where as mobile sensors are used for more in depth analysis. Events are unpredictable, so it is inefficient to wait for an event to happen for dispatching the mobile sink. So in this scheme, total time is divided into multiple rounds and mobile sensors traveling path is scheduled in a round by round manner. The main aim of this approach is to effectively utilize the available energy by choosing an efficient path for mobile sensors. A centralized and a distributed dispatch algorithm is effectively utilized for scheduling mobile sensors moving paths After each round ,the centralized dispatch algorithm reduces the energy of the mobile sink there by keeping the overall energy consumption balanced. Distributed approach utilizes a grid structure. The sensing field is partitioned into grids and a sensor is nominated as a grid head in each grid. The grid heads are notified about the mobile sensors location and residual energy. Once the events are detected, static sensors informs their grid heads about these events. The total time is partitioned into multiple rounds and each round is further separated into three phases .In the dissemination phase, each grid head gathers the locations of events and mobile sensors in the grid. In the competition phase, invitation messages are sent to mobile sensors by event grids. Dispatch schedules are calculated by mobile sensors after determining their target grids. Final phase is the dispatch phase, in which the mobile sensors travel according to their dispatch schedules for collecting data from the event grids.
Konstantopoulos et al. in [20] considered the fixed and predefined path for addressing the issue of sink mobility. The algorithm defines a method which clusters the sensor nodes and routes the collected data. This algorithm is appropriate for environmental monitoring applications. This scheme mainly focuses on enhancing the network life time and balancing the energy consumption by addressing multihop data gathering process. Here, the entire network is divided into clusters and cluster heads are elected for each cluster. The member nodes transfer the data to cluster heads which aggregates this data and transfer this to specific nodes called rendezvous nodes. These nodes will have high residual energy and will be located in close proximity to the trajectory of mobile sink. The selection of rendezvous nodes mainly depends upon network life time. Also its location is mainly in areas close to mobile sink trajectory and location of cluster heads .An efficient rendezvous node will have sufficient energy supplies and it will remain in the mobile sink's trajectory range for a relatively long time. Authors of [29] define about a weighted rendezvous point approach for mobile nodes which improves the performance of the sensor network than that of the clustered rendezvous point based approach.

Most of the studies in controlling sink mobility involve construction of a grid structure or by defining rendezvous points. Yun and Xia in [11] showed that the efficiency of algorithms and quality of solutions mainly depends upon the selection of rendezvous points. As the rendezvous points in a network field increases, it can cause considerable time complexity.

Some of the other latest approaches used for finding optimized path for mobile sink are defined below:
Neng-Chvng Wang et al [25] proposed a Power efficient data dissemination (PEDD) scheme for wireless sensor networks (WSNs) with mobile sinks. To save power, this scheme constructs a virtual grid structure which is source based. The dissemination points are defined at specific locations. Only the dissemination points need to forward data. The other sensor nodes just fall into sleep mode, there by conserving power. In this scheme, a message from one grid point is forwarded to its eight neighboring grid points. When an event is detected, the source nodes forms a grid structure. Dissemination points are selected based on minimum cost. When sink requires data, it simply broadcasts message to find the closest dissemination point so that it can forward the query. The dissemination nodes further broadcasts this query upstream until it reaches the source node.

The authors of [27] define a new technique - Mobisink that uses Intelligent Mobility Pattern based Routing Protocol (IMPR) for efficiently collecting data from the sensor nodes. Based on the convergent location, the IMPR protocols proactively construct optimal trajectories for mobile sink.

Convergent locations are areas of the sensor field from which the mobile sink nodes acquire the highest response. The convergent locations are effectively computed by using Minimum Spanning tree (MST) algorithm. Convergent Location Points (CLP) recognized during route discovery phase is mostly used for Mobisink's traversal. IMPR process is efficiently used by mobile sink for collecting data as it traverses the sensor field.. Sensing and communication range of Mobisink is exploited based on the response it receives from sensor nodes.

CONCLUSION

The Wireless Sensor Networks (WSN) and embedded devices have a great significance in our day to day life. The old-fashioned approach of a base station always attached to the end-user in order to collect queried information has become a severe limitation for common user applications. A scenario in which mobile users move through the environment querying information from the users embraces great importance in a lot of applications such as Intelligent Transport Systems. The idea of making the sink node mobile has tremendous impact on solving the energy consumption issues in wireless sensor networks .Providing controlled mobility to the mobile sink enhances the network life time by adopting an optimized path for the sink node.

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