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MOBILITY CHARACTERISTICS AND ROUTING PROTOCOLS FOR WIRELESS SENSOR NETWORK WITH MOBILE SINK - ENERGY PERSPECTIVE

Sameena P, Dr. Binu G.S

Student ECE Department, HOD at ECE department
NSS College of Engineering, Palakkad, Kerala

Abstract: Wireless sensor networks(WSN) provides information from physical world can be access remotely. Traditional WSN consist of large number of static sensor nodes deployed in a sensor field, forward the sensed data towards static sink or base station. Sensor nodes are battery powered small devices, hence there is chance of quick depletion of battery due to the operational overhead. Similarly increased data traffic concentration of the single-hop neighbors of static sink lead to the creation of hotspot at these single-hop neighbors. Mobile sink are the recent solution for reducing energy consumption in the network by providing uniform energy distribution throughout the network. This work deal with mobility characteristics and routing protocols used in a mobile sink scenario in order to enhance energy efficiency of the network.

Index Terms **- Mobile Wireless sensor network(MWSN) · Mobile sink(MS) · Energy efficiency · Hot spot problem**

I. INTRODUCTION

A network with large number of small sensor nodes deployed in a specific region for the purpose of monitoring is called wireless sensor network(WSN). In WSN distributed nodes monitor the sensing field and forward the sensed data towards a base station(BS) or sink either through single-hop or multi-hop. Now WSNs are very much established for verity of applications ranging from simple monitoring to surveillance. The typical applications includes environmental monitoring, health care, animal tracking, smart buildings, habitat monitoring and surveillance. The main objective of sensor nodes is to sense a particular area, process the generated data, and forward to sink through single-hop or multi-hop. Multi-hop communications involves intermediate nodes to forward data to sink or BS from source node, although in single-hop communication source node directly transmit data to BS.

Since sensor nodes are battery powered small devices, their battery get easily depleted. Therefore achieving energy efficiency is an important consideration in WSN. WSN must be operate for a long time without human intervention in most of the applications. Replacement of batteries in an unattended environment need significant effort. Hence routing protocols for WSN must be designed in such a way that they increase the life time of sensor nodes as well as maximizing network performance.

Mobile sink(MS) is the most recent solution for reducing energy consumption in WSN. Without much effort they can provide efficient load balancing. According to the sink motion, hotspot over sink also changes and the energy drainage at hotspot node happen uniformly in the network. Thereby achieving uniform energy consumption and increased life span of network [1]. Advantages of WSn with MS include:

- Eliminate hotspot or energy hole problem: In multi-hop communications, nodes that one hop away from sink have more involvement in sending and receiving of data. But energy of sensor nodes are limited, energy of such nodes deplete quickly and they get removed from network. Thereby further communication between nodes and sink get interrupted. This is called hotspot or energy hole problem. In WSN with MS approach, sink moves through the network and its neighbors changes accordingly. Also nodes need to transfer data to a short distance thereby reduces energy consumption at nodes. Ms help to get a balance in energy consumption in the whole network and enhance network lifetime.
- Increased connectivity: MS can collect data from isolated network areas and MS can be used in disconnected network as well as sparse network as compared to static sink.
- Reduction in cost: Mobility features doesn't add more cost, because it is possible to utilize the service of mobile elements that already present in the sensing field such as car, bus, train etc.
- There is a chance of packet loss, collision, interference in static WSN due to multi-hop data transmission. While in MWSN it can be eliminated to an extent. Because mobile sink can collect data via single-hop.
- Reduction in the number of hopes increases reliability and throughput. Also it is well suited for delay-tolerant applications.

- Security features: it is very difficult for an attacker to locate and pursuit MS for compromising MS.

The routing protocols used in WSN with MS should follow some performance criterion's:

- Energy consumption: Mobile sink require frequent advertisements about their location. This advertisements lead to an increase in overall network energy consumption. Hence routing protocol used should take care about energy consumption.
- Reliability: Reliability can be defined as the delivery ration of data to the sink. In WSN with MS, if source node send data to outdated sink position then data become lost. Hence routing protocol should be designed in such a way that it eliminate packet loss.
- Latency: Latency is defined as the time taken between generation of sensor data and reception of data by sink. There is already some delays exist in case of static sink, like queuing delay, congestion, re-transmission delay etc. In case of MS there exist an additional delay because source node have to find the location of sink. While dealing with time sensitive applications, efficient protocols which reduce latency have to be used.

II. MOBILE WIRELESS SENSOR NETWORK(MWSN)-MOBILITY CHARACTERISTICS

2.1 Classification based on Mobile elements

A typical WSN consist of mainly three elements, normal sensor nodes, base station or sink and anchor nodes. Mobility feature can be added in either of these three elements.

2.1.1 Mobile nodes

Sensor nodes are responsible for sensing a specified area and they act as source of information. Mobile nodes can be used in WSN.

Underground pipeline inspection is used to detect cracks, pipe corrosion and any other defects in pipe that cause failure of the system. Dalei et al. considered a robotic sensor node for pipeline inspection [2] carries sensor nodes to monitor the plastic pipeline. Similarly this system consist of above-ground Relay nodes (RN) and BS. RN send beacon packets to source node. There are multiple RNs, each RN covers a specific section of the pipe in order to mitigate signal attenuation.

A robust ad-hoc sensor routing(RESeR) protocol is suggested by T Hayes et al. with low latency packet delivery and high reliability in highly mobile situations [3]. Here assuming nodes appended with some mobility features. Which uses a technique of blind forwarding to transmit data to sink, hence the receiving node take forwarding decision on a hop by hop manner. Using a hop count gradient that permit node to blindly transmit data to sink. The protocol can be used in verity of future applications due to its high throughput, low delay and low energy consumption.

2.1.2 Mobile peers

Mobile peers are the normal sensor nodes they generate their own data as well as collected data from other peers. When they are in contact with the BS data transfer occurs.

Mobile peer concept mainly used in wildlife monitoring. Philo et al. proposes a ZebraNet system, in which animal carries a tracking collars(nodes) and these collars act as peers [4]. They collect their own data and peers data then forwarded to BS. The peer concept is more useful because it is not necessary that all animals are come within the range of BS. If some collars get missed, then data loss occurs. But using peer concept this situation can be avoided.

2.1.3 Mobile data collectors

Any moving element they collect data from the source node by visiting the network is called mobile data collectors. Mobile sink collect data from the source node and send to BS. The most recent energy conservation is based on mobile sink. They help to avoid hotspot problem as well as help for the uniform distribution of energy along the system.

A Cluster-chain mobile agent routing was proposed by Selvakumar et al. which utilize the advantages of both PEGASIS (Power Efficient Gathering in Sensor Information Systems) and LEACH (Low Energy Adaptive Clustering Hierarchy) [5]. Firstly the network is divided into clusters and all nodes within the created clusters form chain. In each cluster a cluster or chain head(CH) is selected which perform data aggregation. A mobile agent is used to get data from CH to sink. Thereby reducing hotspot problem at CHs. Also using cluster chain instead of long chain it is possible to reduce transmission delays.

2.2 Classification based on mobility type

Sink mobility can be achieved using robots, pedestrians or vehicles which carry the sink.

2.2.1 Pedestrian mobility

In pedestrian mobility type the persons who walk through the sensing field carries sink node.
WSN can be deployed in buildings for getting report during fires [6]. Such an approach in which firefighters carrying mobile sink was proposed by Thuy et al. these MS provides shortest path for relying data as well as it is possible to provide connections to the disconnected areas.

A hybrid adaptive protocol is suggested by Giuseppe et al. with pedestrian as mobile sink [7]. The mobile user visit the network for data collection and they act as data destination. These mobile user either consume data for their own needs or forward to remote user. In these type of application sensor nodes have limited amount of collected data. Data collection occurs when mobile user is in contact with the sensor nodes. But these mobile users visiting time is unpredictable. Hence nodes remain in discovery state always. MS (Mobile user) broadcast control beacon packets to inform their presence. nodes receive this beacon and start transmission of data.

2.2.2 Vehicular mobility

In this type, sink is carried by a vehicle including unmanned areal vehicles(UAV).
A method for measuring water quality parameters and emission of greenhouse gases is proposed by Matthew et al. by using WSNs [8]. The sensing field considered here is dynamic in terms of wind speed, waves etc. Water quality is monitored by using an autonomous surface vehicle, specifically a robot boat. Which autonomously navigate and water quality parameters are monitored continuously. The measured data is relay back to shore in real-time.

Carlos et al. deal with marine environment monitoring using UAV [9]. This type of sensing field is directly influenced by human activities, Flora, fauna and local climatic conditions. Sensors are placed in drifting buoys which are scattered in wide area. Buoys collect data such as wind speed, water temperature, humidity, pressure etc. UAV periodically search for buoys and after finding them it send data acquisition packets to collect stored data in buoys. Then forward data to ground station at the beach.

2.2.3 Robotic mobility

Data collection from a partitioned/islanded area can be done using mobile robots. A data collection scheme using mobile robots are presented by TzungCheng et al. The proposed algorithm find the isolated locations in WSN and direct the mobile robot [10]. For identification purpose of such locations, this protocol employs global and local based methods. Similarly in order to direct the robot towards the desired location time based, dynamic motion based and location based scheduling strategies also introduced.

2.3 Classification based on mobility pattern

Moving pattern determination for MS is the major challenge in MWSNs. Mobility patters can be divided into Random mobility, Predictable mobility and Controlled mobility. Different applications chooses different mobility pattern as per their need and also by considering network size.

2.3.1 Random mobility

Random mobility pattern allows the mobile sink to move randomly in the sensing field. This pattern is simple and future sink position is unpredictable. A simple data collection method from sensors by using a mobile sink is proposed by Ioannis et al. In which four randomized mobility pattern is proposed and also combine sink motion with various data collection schemes [11].

Increased latency will create major problems in time critical applications of WSN. A rendezvous based routing protocol in which Ms moves randomly in the network to collect data was suggested by Suraj et al. at the middle of the network a virtual cross area is created called rendezvous region and form a tree within that region. The protocol proposes two approaches for data transmission, firstly through rendezvous region, source node transmit data to sink. Secondly, sink advertise its location to created rendezvous region and source node acquire sink location from there and direct transmission occurs. The proposed method able to reduce energy consumption and end-to-end latency [12].

2.3.2 Predictable mobility

In predictable mobility pattern, the mobile sink moves through a certain pattern that can be determined. Such a motion can be periodic along the predefined path. The source node which have data to transmit, learn the time at which sink reach adjacent to them and will optimize sensing process and data collection.

A QoS-aware data gathering protocol is considered by M.Faheem et al. with multiple MS and predictable sink mobility pattern [13]. This scheme proposes a hybrid mobility pattern, in which sink moves exactly deterministic manner initially, then uses self-learning to address coverage issues and buffer overflow problems in nodes. By scheduling sink movement latency in the network get reduces. Energy consumed during long distance communication in smart grid applications is solved by using aggressive data collection. Along with QoS improvement this scheme also minimize packet error rate as well as end-toend delay.

Hui et al. deal with an asynchronous WSN [14] in which each node have an independent duty cycle and they have their own schedule for sleep and awake. MS moves in a straight or circular trajectory. In this design the coverage information of nodes exchanged before starting transmission, thereby eliminating redundant transmission. The proposed moving strategy reduces network broadcast delays.

2.3.3 Controlled mobility

In controlled mobility the path selection is based on some constrains such as delay, power consumption, throughput, hop count etc. Also it is possible to dynamically adjusting the MS path according to the change occurring in the network state. Ratijit et al. proposes a virtual grid based routing in which MS path selection consider both data production rate of nodes and hop counts, mainly used for multi-hop communication environment to reduce energy consumption [15].

An energy density based path design for MS was considered by Kumar et al. for the purpose of collecting data, MS visit certain predefined locations called rendezvous points(RPs) [16]. This proposed design select RPs based on sensor node energy density. This method decreases energy imbalance and enhance network lifetime. After finding position of RPs TSP(Travelling Salesman Problem) algorithm is used to find the MS trajectory.

Incidental data created in situation like water pollution detection, forest fire, wildlife monitoring, occurs suddenly, such a burst traffic creation was suggested by Ling et al. in order to improve energy efficiency and quick responds to these situations use a dynamic path planning algorithm [17]. Before sink collect data from CH, it plan a shortest path for travelling using TSP algorithm. Same way using TSP algorithm it compute time required to collect data from CH. During absence of burst traffic sink follows predetermined path. If burst traffic occurs it quickly answer to the burst event by considering two cases. If the cluster including the burst node is already visited by the sink, then burst node send data using multi-hop. Otherwise after completing the data collection from the current CH, MS moves to the burst produced region.

2.4 Classification based on mobility control

Motion control of MS can be divided into stop point constraint schemes and trajectory constrained schemes.

2.4.1 Stop point constrained schemes

In stop point constrained, Ms have pause time during their journey. MS enter the communication range of nodes which have buffered data to send and wait there for certain time for collecting data. For example in battle field surveillance applications, there is some defined safe locations at which MS can operate. Similarly in habitat monitoring, MS can access only limited space.

Controlled sink mobility and nomadic type of control was suggested by Stefano et al. to achieve uniform energy consumption [18]. In the proposed greedy maximum residual energy protocol nodes are randomly deployed in the sensing field and sensing field divided into grids. There are certain sites, which are the pause point for sink to collect data. when sink visit a new site it flood a message to all nodes. It help the nodes to find fresh location of sink and data transmission occurs. Upon leaving the current site it again flood another packet to indicate that sink has been moved to next site. The process are repeated in each round.

A cluster based routing algorithm for both energy conservation and load balancing was proposed by A.Karimi et al. consider the sensing field as a hexagonal shape which composed of three rhombuses [19]. Each rhombus is a cluster and Ms move through the internal triangle created by connecting large diagonals of the rhombuses. Sink moves in a predefined path hence covers all the clusters. Here two MS are moving per each diagonal, hence total six MS are there. Also included stopping points in the trajectory to collect data from selected CHs.

2.4.2 Trajectory constrained

Trajectory can be constrained in some applications regions like urban areas. In such applications normally Ms is carried by some vehicle like bus or car. Hence trajectory have to use road network for their journey.

Delay in the data delivery is not tolerated by the user if his primary concern is freshness of data. Hailong et al. proposes such a scheme which consider collection of emergency messages within a permittable latency level. Mobile element is fixed on a bus and collect data only bus stop at bus stops [20].

Hybrid of stop point constrained and Trajectory constrained is also possible.

III. ROUTING PROTOCOLS USED IN WSN WITH MOBILE SINK.

3.1 Classification based on network architecture

3.1.1 Hierarchical routing protocols

Hierarchical routing protocols used in MWSN is an efficient approach for energy saving, for enhancing scalability and for increasing lifetime of the network. Hierarchical approaches used in MS based WSN also minimizes the load causes due to the advertisement of sink position to the network. The hierarchical structures consist of two or more tiers. The high tier nodes attain sink location and low tier nodes acquire sink location from high tier node as per their need.

3.1.1.1 Cluster based methods

Routing protocols belongs to this category uses clustering technique to divide the network. A cluster head is selected in each cluster, they act as high tier nodes.

A sensing field may consist of moving and static obstacles [21]. Hence the MS must find an shortest obstacle avoiding path for its journey was proposed by Guangqian et al. cluster based method is used for achieving energy efficiency. Selected CH gather data from their corresponding cluster and forward data to sink. Obstacle avoiding path for MS is found by using heuristic algorithm

by creating a spanning graph and finding obstacle avoiding path in the whole network. The shortest obstacle avoiding routes can be obtain from these path.

Verity of approaches can be adopted for selecting CH in each cluster. A Fuzzy TOPOSIS method [22], utilizing multi criteria decision making was suggested by Bilal et al. Residual energy, distance from MS, rate of energy consumption at nodes, average distance of neighbor nodes are criterion's considered for CH selection. Energy efficiency is achieved by fixing a threshold for inter-cluster and intra-cluster communication. Octagonal trajectory and predictable mobility of MS help to minimize load distribution.

A different scheme for selecting CH was proposed by Vinith et al. The sensing field is divided into rectangular regions and select CH for each cluster based on nature-inspired firefly optimization algorithm. Which consider parameters such as residual energy, distance to sink and distance between sensor nodes. Sink determine centroid point of CH and move to the location for gathering data. Initially sink located at the middle of the network. This protocol compared with many other alternative protocols and its enhanced energy efficiency has been proved [23].

3.1.1.2 Grid based methods

Grid shape can be rectangle, hexagons, triangles etc. An uneven grid-based routing protocol was presented by Xiaodong et al. which applicable for smart home environments [24]. Establishment of a virtual uneven grid include two phases. Firstly in normal operation phase, partition the sensing field into uniform grids. Nodes which are closest to the grid centre selected as main CH (MCH). MS moves through network edge in counter clockwise direction to collect data from MCH. Secondly in dynamic adjustment phase, The grid cell having hard energy resource again divided into smaller grid cells. The nodes which closest to the centre of the small grid selected as assistant CH (ACH). ACH collect information from environment and forward to nearest MCH. sub-clusters with poor resource status does not engage in the selection of upper level headers. Hence they are not included in moving path of sink thereby saving energy of sensor nodes in the sub-clusters.

Traditional Flooding can be employed to transmit data to MS. But flooding techniques such as SPIN, direct diffusion introduce additional overhead due to broadcasting all over the network. In order to avoid the overhead created due to updating of MS fresh position, a grid based hierarchical division of sensor field was proposed by Ayush et al. Sensor field is divided into grids of equal size, Grid cell head (GCH) for each grid is determined by considering distance from cell centre and node residual energy. An interior and exterior cycles are formed for the communication between GCHs. Sink sends location packet to nearby GCH to inform its location and pausing time. The GCH is connected to another GCH via cycle. Hence this GCH share the information with others [25].

A.Waheed et al. deal with a virtual grid based data dissemination protocol, Which minimizes the virtual infrastructure establishment cost [26]. A grid based virtual structure formed in the sensing field and select CHs in each grid. MS send queries to the closest CH, also it mention about ROI (Region of Interest) in that queries. The query propagate towards the CH in ROI. Then the corresponding CH transmit data to the MS. MS follows a predefined path through the periphery of the network. Hence it cause burden for CH at the border grids.

Square grid approach allows the grid head to communicate only with four grid neighbours. Hence an hexagonal approach was proposed by V.Bibin et al. which includes six neighbouring grids are available for each grid head [27]. This dynamic hexagonal grid routing protocol divides the network to hexagonal grids to share latest location of MS. In case when MS move to a new position or congestion in data transmission then select a dynamic path for MS. The proposed protocol organized as two phases, initially dividing network into hexagonal grids which can cover more area as compared to square/circular grids. Then GH is selected and create a virtual line among GHs. At the last phase sink transmit query to its closest GH. As response to this query, data get forwarded to sink.

3.1.1.3 Tree based methods

In tree based methods create a logical tree is formed by all nodes. An energy-aware and scalable data dissemination approach for environmental monitoring was suggested by Zeeshan et al. called quad tree based data dissemination [28]. Nodes detect mobile stimulus(workers) and they determine set of RPs by dividing network into equally sized quadrants. The source nodes send sensed data to the nodes situated at centroid of quadrants. MS initiate querying the immediate RPs until it get required data. The proposed protocol reduced energy consumption as well as maintain data delivery ratio.

Tree structure based approach discussed by Jau-Yang et al. help to reduce the data forwarding distance of nodes [29]. The protocol create an energy efficient routing structure by considering distance nodes, MS location and sensor nodes residual energy. This design organized as two phases. Setup phase includes tree structure formation, determining hop nodes and selecting CH nodes. The tree-cluster members are assigned with TDMA schedule based on number of nodes in the tree-cluster. This scheme minimizes data forwarding distance of nodes thereby achieving improvement in energy saving and increased network lifespan.

3.1.1.4 Rendezvous-based methods

Rendezvous-based methods construct a rendezvous region. Rendezvous nodes in the rendezvous region collect data packets form source nodes. When sink request for data, these rendezvous nodes forward the stored data.

A Rail based virtual infrastructure was suggested by Jeong-Hun et al. which is used in applications like habitat monitoring, target tracking etc [30]. A rectangular area(rail) was formed at the middle of the network and act as rendezvous area. The source node send metadata to the nodes in the rail. Upon receiving this metadata rail nodes create a station and share the meta data among nodes situated on the station. Sink initiate uni-cast query to rail for the meta data, it propagate and reaches to the station nodes. The station node share sink position with the source node, source node directly send data to sink. This protocol possess better energy efficiency and scalability but suffers due to high latency and data loss.

To overcome data loss created from a source node failures in rail based approach a line based data dissemination protocol was suggested by Elyes et al. here a virtual vertical line divides the sensing area into two portions [31]. This line was created at the centre of the field hence it is easier to accessible by nodes. This line area is called rendezvous region and nodes at the boundary of

the line is called in-line nodes. The source node generate data and transmit it to closest in-line node. MS forward query to line and it is propagated through the line until it reaches the data storing in-line node. Then direct transmission of data to sink occurs. This protocol is very simple and overhead reducing but for large network due to broadcasting queries through the line increase energy consumption.

Aysegul et al. deal with a honeycomb architecture, which divide network into hexagonal grids and can be used in emergency situations [32]. This protocol is called hexagonal cell-based data dissemination which utilize the idea of rendezvous area for queries and events. These areas lie on main direction of the sensing field, hence sink can access fastly. The protocol also make the network against node failures and quick coverage hole recovery is possible.

3.1.1.5 Backbone-based methods

In backbone-based methods, the source node find the fresh sink position through the backbone structure, then forward data packet to the MS using multiple hops.

A fish-bone structure based backbone construction was introduced by Ashok et al. the backbone structure was formed by using distinct level of aggregators. Source node forward data through backbone in a multi-hop fashion. This method is efficient in terms of communication infrastructures but resulted in higher latency due to multi-level aggregation [33].

A novel strategy for the formation of routing backbone which was inspired from water vascular system of star fish was proposed by Md.Ahsan et al. the routing backbone includes several radial canals along the network and a central ring canal. In this approach [34] nodes can be accessed by source nodes in a single hop. The source node transmit data to MS through the backbone nodes. The backbone nodes collect data from sensor node using single hop and forward to MS. This approach improves network performance, reduce energy consumption and decrease delay in data delivery.

Minjae et al. deal with a multi-ring routing scheme which employ solar powered sensor nodes [35]. The sensor node use part of harvested energy to build a ring. The ring nodes only utilizes surplus energy to provide sink location information. This is not effect the general operations of nodes such a s sensing, processing and forwarding. Sink node select the closest node having higher energy as anchor nodes, they inform their location to the ring. If a source node wish to deliver data to sink then these node acquire anchor position from ring nodes. By using location based routing source node deliver data to anchor node. Due to the existence of multiple rings, overhead for attaining sink position reduces but if network size is larger, overhead get increases.

3.1.1.6 Chain-based methods

In chain based approach sensor node are connected like a chain. A selected chain leader collect data from the other members of the chain.

Communication distance and energy consumption is directly proportional. So multi-hop techniques can be used but more hops create latency issues. An enhanced PEGASIS algorithm suggested by Jin et al. improves network life time, reduce latency and energy consumption [36]. In order to avoid energy consumption during data transmission an optimal communication distance wass computed. Also MS concept was used for uniform distribution of energy. Similarly it protect dying nodes by setting a threshold value.

3.1.1.7 Agent-based methods

This type of approach relay the network traffic between nodes and sink by using agents. Agents act as representative of sources or sink.

Intelligent agent based routing was discussed by Jae-Wan et al. provide efficient data transmission to sink [37]. Sink select closest node as its agent. Then sink transmit query to the selected agent and agent broadcast the query by flooding. Hence as the propagation of query each node able to find its next hop to the agent. Agent forward gathered data to MS when Ms reaches its radio range. If sink passed out of its range, then agent forward data by relying. The protocol also address link failures and reduce triangular routing problem. MS periodically finds the distance between itself and present immediate relay. Also immediate relay node able to receive the lossed data when sink passed out of its coverage area. The protocol reduces packet loss and keep path between source sink pairs. Hence the protocol can be used in verity of applications.

3.1.1.8 Hybrid methods

This method consist of combination of virtual structures. Industrial applications contains large quantity of heterogeneous data. In order to avoid hotspot problem during these application Chuan et al. proposes tree-cluster based algorithm for data gathering [38]. Here weight based tree is constructed. The root node of this tree constitute RPs. By eliminating the number of hops to the root node and traffic load , sub Rps also selected. These RPs and sub RPs are res-electable and act as pause point for MS. The protocol reduce energy consumption and enhance network life time.

Cluster-chain mobile agent routing was proposed by Selvakumar et al. which combine chain based network structure of PEGASIS and cluster based network structure of LEACH [5]. In order to increase energy efficiency a mobile agent is used for data collection. The network was divided to clusters and all nodes within the created clusters form chain. In each cluster a cluster/chain head is selected which perform data aggregation. Mobile agent gather data from CH and transfer to sink. Thereby reducing hotspot problem at CHs.Also using Cluster chain instead of long chain it is possible to reduce transmission delays.

3.1.2 Non-hierarchical routing protocols

These type of routing protocols does not divide the network into high tier nodes and low tier nodes. Hence there is no overhead creation due to the virtual infrastructure construction. But here it is necessary to use various another mechanisms for advertising latest position of sink.

3.1.2.1 Flooding based methods

Flooding is the process of broadcasting of data/control messages along the network. Since flooding is a energy consuming process, the protocol must to be designed in such a way that it will reduce unnecessary broadcast, restrict the broadcast into confined areas and minimize its frequencies.

sink is continuously moving across the network and it also needs to broadcast its own network information along the network. It will increase energy consumption at nodes due to the repeated position updates. Guojun et al. solve this issues by broadcasting sink location only within a certain area rather than the entire network [39]. Source node send data to the nodes in the destination area. These nodes forward data to MS. When movement of sink occurs, but not beyond the destination area, it only require to broadcast position information in the destination area. Otherwise a new destination area is formed. The protocol reduces energy consumption in nodes as well as problem of collision.

In order to minimize transmission overhead and needless redundant packet flooding Guisong et al. proposes cluster based proactive data collection routing protocol [40]. MS randomly move along the network and broadcast its position information not to the entire network but only to some limited hopes. The nodes called watchers, receives this message and deduce the number of hops between themselves and MS. Watchers stores this location information as clue's. MS moves randomly across the network, hence more and more watchers are created. By using clue's sensed data can be forwarded to MS. This method can minimize redundant transmission thereby reducing energy consumption at the network.

3.1.2.2 Overhearing based methods

Overhearing is the process of receiving packets by the indented nodes as well as some another neighboring nodes. That is neighboring nodes overheared the packet that is not destinated for them. In these type of protocols sink advertisement occurs through the overheared packets.

An elastic routing scheme in which overhearing feature is exploited for propagating position of MS was suggested by Fucai et al. here sink moves freely along the network [41]. In order to inform the fresh location to its singlehop neighbors, sink broadcast beacon packets periodically. Once sink motion occurs, the neighbors in the second-to-last hop receive beacon message and first learn the fresh position of sink. It reset the position of sink in its packet and transmit it. The new location of sink is learn by the predecessors through channel overhearing. Hence as per sink motion new position information propagate backward to the source node. In order to maintain freshness of location information time stamp or sequence number is also added in multi-sink case.

Ke Tian et al. deal with a trail based data gathering protocol [42]. When sink motion occurs trail of the Ms utilized for directing packets. During movement of MS it leaves a trail by broadcasting beacons to its single-hop neighbors. If a node have data for transmission it use combinations of random walk and trail based forwarding for data reporting. Random walk is used when no new trail of MS is found. Otherwise packet forwarding occurs through trail.

A data driven routing protocol was proposed by Lei et al. which minimizes protocol overhead occurring due to sink mobility [43]. This protocol combines random walk and data driven message forwarding. For rout learning the protocol uses broadcast method of wireless transmission. Each packet carry hop distance of the source node to sink as additional information. Overhearing of these packets gives other sensor nodes in the coverage, along with route to MS. Thereby more number of sensor nodes acquire rout information. The protocol is very simple and cause less overhead.

3.2 Classification based on protocol operation

Hierarchical routing protocols can be divided on the basis of protocol operation.

3.2.1 Multi-path routing protocols

For the enhancement of network performance and fault tolerance multi-path routing protocols use multiple path between source and destination.

A similar approach which use immune orthogonal learning particle swarm optimization algorithm was suggested by Yifan et al. for providing alternate path during path failures caused due to movement of sink [44].

An intelligent routing fault tolerance method based on artificial bee colony (ABC) Particle swarm optimization was considered by Yinggao et al. the faulttolerance method is based on multi-path routing, is used to create multiple transmission path between sink and sensor node. This lead to increased reliability in data transmission. The proposed system perform fast re-routing the path failure caused by the sink movement to a new position. The nodes having higher QoS parameters used to form alternative path, hence it is more energy efficient and increase network life time [45].

3.2.2 Query-based routing protocols

In query based routing protocols source node forward data to sink as a response to the query received from sink. In query based data collection it is necessary to consider delivery latency and energy consumption of query and response packets. Long et al. address these problem by using MS, which was aware about its mobility features through GPS(Global Positioning System) [46]. MS send query packet to ROI in the sensing field. The packet contain position information of ROI. The sensor node nearest to the centre of ROI select itself as CH. CH aggregate data and through multi-hop send to MS. In order to solve the problem of delivery latency and energy consumption this protocol uses two main approaches. Firstly find packet delivery velocity and predict the location at which MS meet response packet. Hence by using geographical routing response packet can be send to the determined meeting position. Secondly, finding optimum opportunity for transmitting query packet by MS. Through these approaches this scheme attain reduced delivery latency and reduced energy consumption.

A mobile sink based routing protocol was proposed by Babar et al. MS moves through a clustered network and its movement is based on residual energy of CH. The protocol consist of set-up phase and steady state phase. set-up phase include clustering and MS location advertisement to CH through broadcasting of beacon messages. In steady state phase MS allocate

TDMA schedule to the selected CH, CH collect data from cluster members and forward to MS. Then based on residual energy of CH, MS select next CH for data collection [47].

Aircraft is mainly used for applying pesticides and fertilizers in the agricultural field. But there is a chance of causing damage for crop due to overlapped spraying at some areas, spraying process may not cover some areas etc. Similarly wind speed during spraying is an important consideration. Bruno et al. proposes a unmanned areal vehicle (UAV) and WSN based pesticide spraying system in agricultural field [48]. UAV routing are self adjustable by considering wind direction and intensity. UAV work based on the feedback acquired from sensors deployed in the clustered agricultural field. UAV broadcast control messages to the sensing field in order to find the amount of pesticides being perceived. The sensor measures the necessary chemical amount in the crop field. Upon receiving the broadcast message, sensors reply with the sensed amount of chemicals and its position. Based on this received data UAV decide the necessity of rout changing. There is a predefined threshold assigned on amount of pesticides. UAV change its rout when the threshold does not match with perceived amount of chemicals.

In query-driven applications, delayed data or partial data may lead to improper decision making. Similarly it is necessary to reduce overhead caused due to sink motion. Shubhra et al. uses a virtual infrastructure based approach. This protocol consist of four phases [49]. Firstly, a virtual infrastructure(wheel) is created. The nodes included in this virtual wheel is called wheel nodes. Secondly position information of sink is advertised to wheel nodes. Thirdly, sink forward queries to the ROI. These queries carried through the wheel nodes to the corresponding ROIs. Finally through the wheel nodes, source node send data to the MS.The protocol minimize overall energy consumption same time maintain low delay and increased data delivery.

3.2.3 QoS-based routing protocols

The algorithm used in this type should meet QoS requirements such as bandwidth, reliability, delay etc.
A different approach [50] which use static sink for delay sensitive message and MS for delay-tolerant message was suggested by Babar et al. In addition to delay the protocol consider QoS parameters such as packet loss and traffic prioritisation based on bandwidth and delay. The protocol identifies the various traffic with different bandwidth and delay requirements through dividing of node traffic into various traffic types. Also based on content type in the packet, node traffic get prioritised, thereby sensor node transmit only important data. Static sink suffers hotspot problem, in order to mitigate this issue, static sink only forward high priority messages. Similarly MS suffers long delay , because sensor node hence to wait for MS to transmit data. Hence this scheme introduce the concept of prioritised traffic and according to traffic priority, movement was scheduled. The protocol provide reduced end-to-end delay using static sink and achieve energy efficiency using MS.

Delay is a major QoS parameter in time critical applications. A QoS aware routing protocol was proposed by Bhaskar et al. which consider QoS parameters such as delay and reliability [51]. Two MS moving through the field in opposite direction to each other, from diagonally opposite corner. MSs pause their tour at sojourn points to broadcast their position information. The protocol operation includes two main phases, firstly network configuration. In this phase sensor node find their neighbors by using Acknowledgement(ACK) and HELLO packets, as well as they compute delay by using time interval taken between transmitting HELLO packets and receiving ACK packets during the previous phase. The next phase is data forwarding, data forwarded by the source node to the sink based on local information. The proposed protocol minimizes end-to-end delay between source node and MS as well as balance sensor node energy consumption.

3.3 Classification based on applications

Today MWSN used in verity of applications. Depending upon application WSN can be classified into time driven applications, event-drive applications and query-based applications.

3.3.1 Time-driven applications

The applications included in this category are monitoring of environmental parameters, weather monitoring, crop monitoring in agricultural field etc. Here sensor nodes always monitor the sensing field and measurements are continuously reported to MS.

WSN deployed in animal farm, monitor environmental conditions of the farm as well as health condition of animals thereby increase productivity [52]. Through this approach farmers can control the farm environment from remote locations. The proposed approach consist of two parts. Firstly, measure and monitor animals health parameters in pasture field and secondly monitoring occurs at farms. Monitoring at pasture field done through nodes mounded on animals and these sensors form cluster. Several representative sensor nodes are mounted at the border of the sensing field. They act as rendezvous points and collect data from neighbor nodes. Then MS collect data from these RPs.

Real-time precision agricultural model was proposed by Ashish et al. in which a tractor was used as MS [53]. Tractor can perform both its duty as well as collection of data. Thereby reduce additional cost. Here less number of sensors deployed in a deterministic manner, upon sink reach the nodes coverage area data transmission take place either through WiFi or Bluetooth.

Equal clustering of sensor field lead to hotspot problem at cluster heads. Similarly in continuous monitoring needed applications the usage of static sink leaded to the death of clusters closest to the sink. MS concept also cause problems in such scenarios because it cause delay and more time taken for communication. A solution for this problem considered by Mukhil et al. suggests unequal clustering and usage of both static and MS [54]. Here two process involved in CH selection, tentative(TCH) selection and final selection(FCH). TCH selection is based on energy based timer and trust value. FCH is by competition range, node degree and residual energy.

In underwater WSNs nodes are deployed in different depth, it cause an unbalance in energy consumption. Also in water nodes use acoustic channel for communication, which have low bandwidth and speed as compared to radio signals. Another problem is collision , when several nodes try to transmit data simultaneously. Delay also increases in transmission and reception of data. Protocol proposed by Fatemeh et al. solve these problems by several methods [55]. Energy consumption balanced by grouping the nodes and the smaller group area managed by forwarder(F) nodes. These F nodes collect data from their assigned set by using single-hop. Collision and packet loss reduced by using MAC protocol in which the source nodes use assigned time slot for

forwarding data to F nodes. Ms collect data from the F nodes according to their degree. Degree is the number of sensor nodes in their respective sets.

3.3.2 Event-driven applications

In these type of applications the sensor node deployed in the sensing field are inactive during most of the time and upon detection of an event the gain active state. Examples of these type of applications includes tracking of animal movements, intrusion detection , monitoring of seismic activities etc.

WSN can be used to reduce mine disasters and can ensure the safety of mine workers [56]. Cedrick et al. deal with a mobile gateway node (MP) collect data from static node placed at the underground tunnels. MP was carried by the mine workers. The received data process in real time and find the strength status of surrounding infrastructure and quality of air. The nodes in the system is categorised into three hierarchy. Initially the level 3 nodes called mobile gateway node, find whether the static node (level 2) is in its communication range, also stor its address in an array. From these stored node MP acquire data. MP again store the received value in an another array and compare the value with a predefined threshold. If any abnormal situation is detected MP will alert the super node (level 1) by broadcasting. Then an alarm system get activated to alert workers.

Forest fires creates great damage. WSN can be deployed in the forest for the timely detection of forest fire [57]. Forest fire detection by using a mobile agent was proposed by Kartik et al. two type of sensor deployment is considering here, it is homogeneous with regular pattern for deployment and non-homogeneous without a regular pattern.In clustered network, if any abnormal change in temperature detected by cluster members then they inform CH by creating alert message . CH send alert message to the other CHs and sink. Sink then reduces the time period for sending mobile agent. The protocol also addresses the problem of damaging CH in fire.

A harbor monitoring application of WSN was suggested by Madhuri et al. this method can be used for tracking of ships that reaches harbors by using areal MS [58]. Sensors are densely deployed in shallow water. Network get clustered and select CH after deployment. Relay nodes placed at the sea surface convert received acoustic signal to wireless signal and transmit to the aerial MS. Relay nodes are aware about the velocity, path and time of sink arrival. Sink frequently contact relay nods in order to avoid missed data. There is a chance nodes drifted away due to the water current and topology changes. Hence here use two algorithms one for relay nodes and other for sensor node to form clusters. It is possible to reduce jitters, delay in packet delivery through this scheme. An animal tracking system composed of WSN and UAV as MS is considered by Jun et al. this system monitors animals without any attachment devices. Firstly it create a prediction model for getting animal appearance pattern from the previously sensed data. By using this information introduce a path for UAV that reduce delay [59].

Proper understanding of weather conditions of farm land solve farm related problems and give high yield. MS based ambient crop field monitoring system was proposed by TH.Feiroz et al. which use ambient intelligence containing nodes for sensing and give response to farmers [60]. Sensors sense events like smoke, temperature, pressure, light, humidity etc. at the constant time and transmit sensed data to farmers by comparing the sensed value with a predefined threshold. Actually the sensed data was stored in a database and it is liked with IoT(Internet of Things) hence farmers can access the data remotely using their personal devices.

3.3.3 On-demand applications

In some applications, MS take data from some specific node of interest only. This is done by sending queries to the region of interest.

Examples of these type of applications includes post-emergency monitoring applications, in which a savior who carries MS was searching in a particular area for any survivor. Same way in military applications, a soldier who carry MS detect any intruder or for tracking any objects. These situations need sudden response reporting.

A human existence detection system was proposed by Gurkan et al. which can be used in disaster areas [61]. A group of mobile robots move through the field under observation and find presence of human by using passive infrared sensors. They take photos for verifying whether it is human or not. After verification rescue team visit the corresponding area suddenly.

CONCLUSIONS

This paper provides a brief view about the existing mobility characteristics and routing protocols that can be used in mobile sink scenario. Mobility features like mobility type, mobility pattern and mobility control can be selected depend up on the application. The routing protocols should be selected in such a way that they meet the required performance criterion's. Non-hierarchical routing protocols avoids the need of construction of a virtual structure but they suffer due to high energy consumption. Hierarchical protocols provides an easy way for attaining sink position information but leads to the formation of hotspot at head nodes. The rendezvous based protocols provides a solution for this problem by distributing load uniformly along the created virtual structure. In this paper also provide real time applications of mobile sink concept.

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