Chapter 1

Mobile Wireless Sensor Networks: An Overview

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Abstract

Mobile wireless sensor networks (MWSNs) have emerged and shifted the focus from the typical static wireless sensor networks to networks with mobile sensor nodes that are capable to sense the various types of events. Also, they can change their position frequently in a specific sensing area. The applications of the MWSNs can be widely divided into time-driven, event-driven, on-demand and tracking based applications. Mobile sensor node architecture, residual energy utilization, mobility, topology, scalability, localization, data collection routing, Quality of Service (QoS), etc., are the key factors to design an energy efficient MWSNs for some specific purpose. This chapter deals with an overview of the MWSNs and a few significant phenomena to design an energy efficient MWSNs to the large-scale environment.

Keywords: mobility, mobile sensor node, routing, topology, data collection, MWSNs

1. Introduction

Mobile wireless sensor networks (MWSNs) play a vital role in today's real world applications in which the sensor nodes are mobile. MWSNs are much more versatile than static WSNs as the sensor nodes can be deployed in any scenario and cope with rapid topology changes. Mobile sensor nodes consist of a microcontroller, various sensors (i.e., light, temperature, humidity, pressure, mobility, etc.), a radio transceiver, and that is powered by a battery [1]. The major applications of MWSNs are economics, environmental monitoring, mining, meteorology, seismic monitoring, acoustic detection, health care applications, process monitoring, infrastructure protection, context aware computing, undersea navigation, smart spaces, inventory tracking and tactical military surveillance [2]. There are two sets of challenges to MWSNs; hardware and environment. The main hardware constraints are limited battery power and low-cost requirements. i.e., the mobile sensor nodes should be energy efficient, low complexity algorithms required for microcontrollers and use of only a simplex radio [3].

The mobility models to define the movements towards/away the sensor nodes, and how the mobile sensor nodes location, velocity and acceleration change over time, also predicts the future node positions.

In MWSNs, the major environmental factors are the shared medium and varying topology. The shared medium denotes that channel access must be regulated in some way. Hence, the network topology plays a significant role in routing protocol design and also decides the transmission path of data packets to reach the desired destination [4, 5]. While the sensor nodes on mobility, the performances of the network topologies such as flat/unstructured, chain, tree and cluster topologies are inadequate for large-scale MWSNs. To solve these kinds of issues a hybrid network topology is the best option for large-scale environments. Furthermore, the hybrid topology plays a significant role in data collection as well as the network performance is also good. Also, the routing protocol decides the efficient and reliable data transmission path. Therefore, this chapter deals with the various types of WSN as well as the design challenges, mobile sensor node architecture, mobility entity and mobility models, network topology and several routing protocols for MWSNs [6, 7].

2. Types of WSNs

Usually, the sensor nodes are deployed on land, underground and under water environments and that forms a WSN. Based on the sensor nodes deployment, a sensor network faces different challenges and constraints. Types of the WSNs are terrestrial, multimedia, underground, multi-media and mobile WSNs. In this chapter, we are discussing the overview of the mobile WSNs. According to the resources of the sensor nodes on an MWSN, it can be classified into homogeneous and heterogeneous MWSNs [3]. Homogeneous MWSN consists of identical mobile sensor nodes and they may have unique properties. But, heterogeneous MWSN consists of a number of mobile sensor nodes with different abilities in node property such as battery power, memory size, computing power, sensing range, transmission range, and mobility, etc. Also, the nodes deployment of heterogeneous MWSN is more complex than homogeneous MWSN [8, 9].

2.1. Why are mobile nodes considered in WSNs?

Kay Romer and Friedemann Mattern investigated the design space of the wireless sensor networks and suggested many applications such as bird observation on great duck island, zebranet, cattle herding, bathymetry, glacier monitoring, cold chain management, ocean water monitoring, grape monitoring, power monitoring, rescue of avalanche victims, vital sign monitoring, tracking military vehicles, parts assembly, self-healing mine field, and sniper localization. Among 15 different applications, 10 applications are purely mobile and one of them is partially mobile. Therefore, mobile sensor nodes play an important role in humans real world applications [10, 11].

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3. Design challenges of MWSNs

The major design challenges to the MWSNs are hardware cost, system architecture, deployment, memory and battery size, processing speed, dynamic topology, sensor node/sink mobility, coverage, energy consumption, protocol design, scalability, localization, data/node centric, network heterogeneity, node failure, QoS, data fusion/redundancy, self-configuration, cross layer design, balanced traffic, fault tolerance, wireless connectivity, programmability and security [12–14].

4. Mobile sensor node architecture

Usually, the sensor nodes are designed with one or more sensors (i.e., temperature, light, humidity, moisture, pressure, luminosity, proximity, etc.), microcontroller, external memory, radio transceiver, analog to digital converter (ADC), antenna and battery. Again, the nodes are limited on-board storage, battery power, processing and radio capacity due to their small size [15]. However, the mobile sensor node architecture is almost similar to the normal sensor node. But, some additional units are considered on mobile sensor nodes such as localization/position finders, mobilizer, and power generator. The architecture of the mobile sensor node is shown in **Figure 1**. The location or position finder unit is used to identify the position of the sensor node and the mobilizer provides mobility for a sensor node. The power generator unit is responsible to generate a power for fulfilling further energy requirements of the sensor node by applying any specific techniques such as the solar cell.

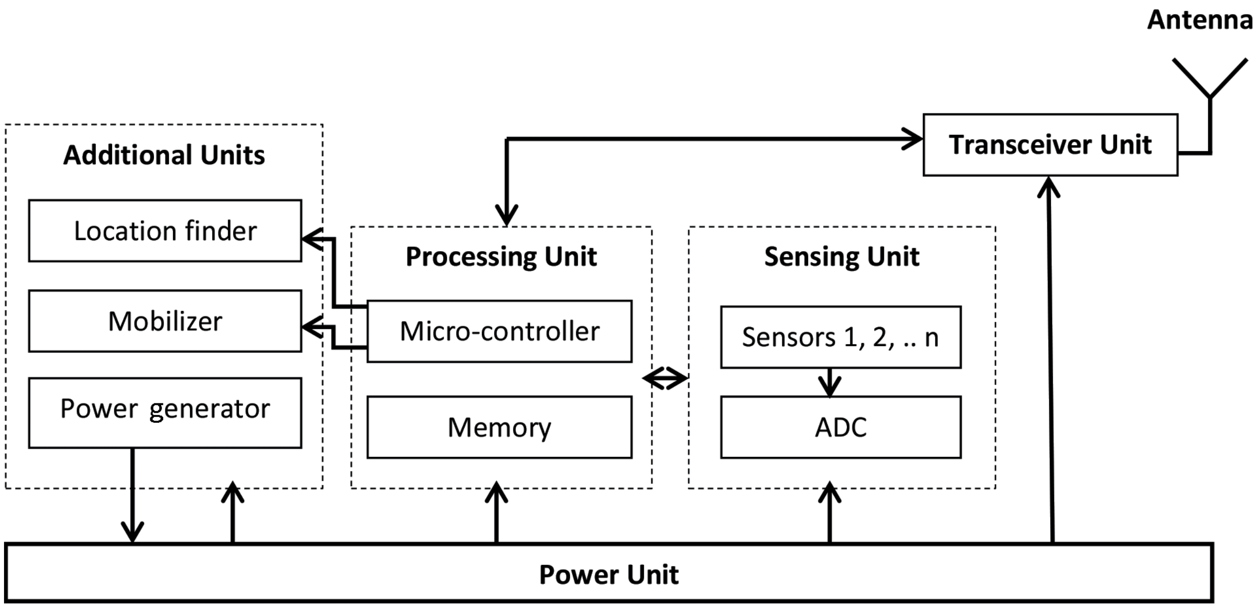

Figure 1. Architecture of the mobile sensor node.

5. Mobility entity

Nowadays, the researchers considering the MWSNs for large scale applications and that consists of a large number of sensor nodes and sink nodes. Here, the mobility can be applied to the sensor nodes or sinks depending on the application requirements.

5.1. Why are mobility models considered in MWSNs?

Usually, the MWSN is a self-configuring and a self-healing network which consists of mobile sensor nodes connected wirelessly to form an arbitrary topology. A good coverage network ensures the reliable communication, higher network connectivity, lower energy consumption and consequently longer lifetime of sensor nodes [16]. Mobility models characterize the mobile sensor nodes movement patterns, i.e., the different behaviors of the nodes. Several mobility models have been considered in MWSNs to set the mobility of mobile nodes. Here, the sensor nodes movements are considered as an independent or dependent of each other respectively.

5.2. Mobility models

The mobility modeled to describe the movement towards/away mobile sensor nodes, and how the mobile sensor nodes location, velocity and acceleration change over time. Mobility models are frequently used for simulation purposes and that is used to investigate the new communication or navigation techniques. Mobility management schemes for mobile wireless sensor networks describe the use of mobility models to predict the future positions of the sensor node [4].

In mobility modeling, the sensor nodes movement can be defined using both analytical model and simulation model. Here, the input of the analytical mobility model simplifies the assumptions of the movement behaviors of the sensor nodes. Also, the analytical model will provide the performance parameters for the simple cases of mathematical calculations. These models can offer the functioning constraints for simple events through scientific calculations. In contrast, simulation models are considered as a well-defined realistic mobility scenario, and that derives the constructive solutions to more complicated cases. Again, the mobility models accurately represent the mobile sensor nodes in the MWSN which is the key to examine the designed protocol is beneficial in a specific type of mobile scenario [17].

The modeling of the mobility patterns can be considered into (a) *trace models*: a deterministic mobility pattern of real-life systems; (b) *syntactic models*: represents the movements towards/away mobile sensor nodes realistically. It can be classified into individual mobile movements and group mobile movements. The mobility models can also be considered by mobility patterns and histories such as directional, random and habitual mobility models. Various mobility models are classified into four major categories which are based on their specific characteristics and that includes random models, models on temporal dependency, models on spatial dependency and models on geographical restrictions. **Figure 2** shows the classification of mobility models based on their areas.

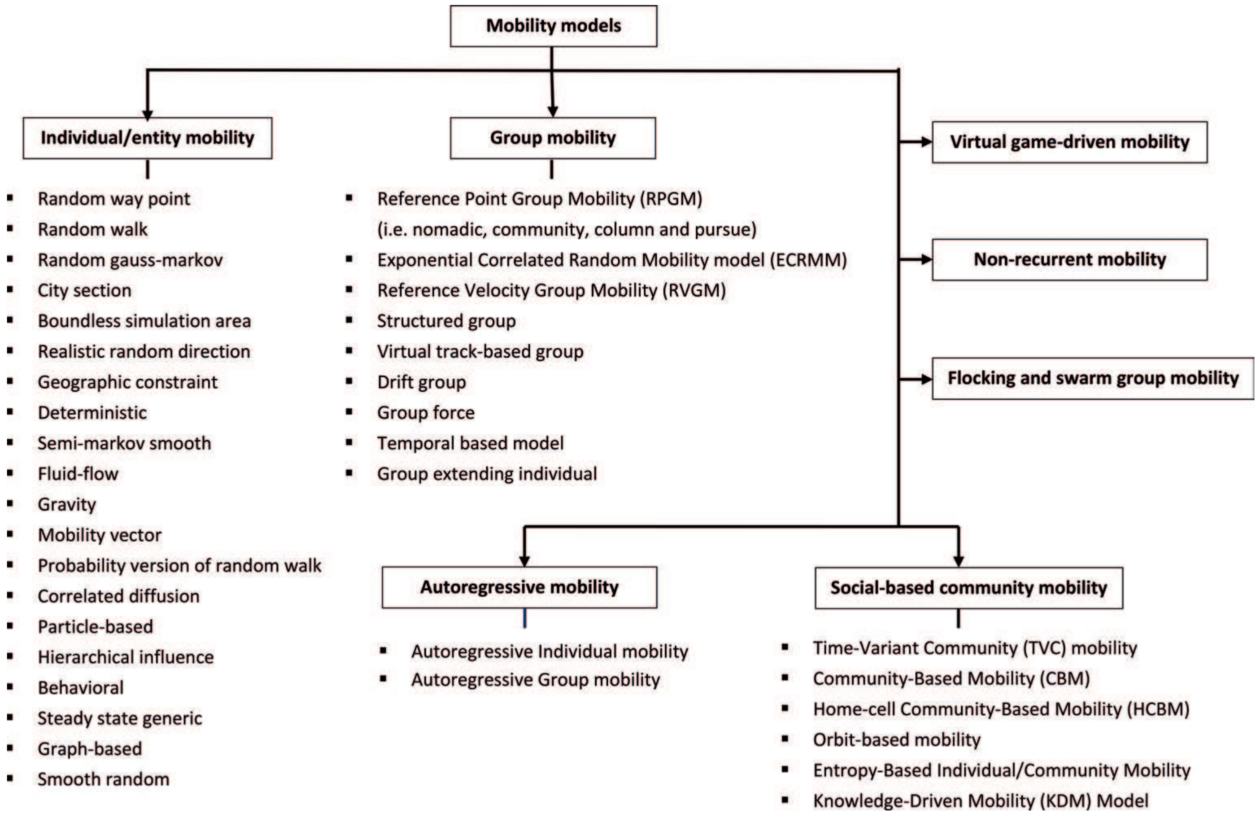

Figure 2. Classification of mobility models based on their areas.

The mobility models can also be classified into the following areas [18]:

- **Individual/entity mobility models:** represents the mobility pattern of the individual mobile node. e.g. random waypoint, random walk, random Gauss-Markov, city section, boundless simulation area, realistic random direction, probability version of the random walk, geographic constraint, deterministic, semi-Markov smooth, fluid-flow, gravity, mobility vector, correlated diffusion, particle-based, hierarchical influence, behavioral, steady state generic, graph-based and smooth random mobility models.

- **Group mobility models:** co-operative groups movement towards/away the mobile nodes acts in synchrony as a group. Here, the movements of the mobile nodes are not independent of each other. Also, the function defines the group behavior or the mobile nodes are somehow connected with a target or a group leader. Many group mobility models are exist such as reference point group mobility (RPGM) (i.e., nomadic community, column and pursue), exponential correlated random mobility model (ECRMM), reference velocity group mobility (RVGM), structured group, virtual track-based group, drift group, group force, temporal based model and group extending individual mobility models.

- **Autoregressive mobility models:** the mobility pattern of individual sensor node/group of sensor nodes correlating the mobility status and that may consist of position, velocity, and acceleration at consecutive time instants. e.g. autoregressive individual mobility model and autoregressive group mobility model.

- **Flocking and swarm group mobility models:** a collective action of a massive number of cooperating mobile agents with a mutual group objective. Examples of the agents are ants, bees, fish, birds, penguins, and crowds. In a flocking mobility model, a coordinated movement task performed by dynamic mobile nodes or mobile agents over self-organized networks of nature. Self-organizing features of the flocks/groups/schools provide a deeper insight into designing MWSNs. Since random walk (RW) and random way point (RWP) models are not suitable for realistic environments, swarm group mobility model is introduced to generate the realistic movements of living organisms or objects led by living organisms by psychological behaviors, physics, and mimicking perceptions is explained.
- **Virtual game-driven mobility models:** based on the user requirements, an individual/group of mobile sensor nodes are characterized from the real time to virtual agents cooperating with each other groups of mobile users. It models the real-world characteristics of the user, group, communication, and the environment. Here, a virtual world is used for the simulation of mobility and that includes all features of mobility models.
- **Non-recurrent mobility models:** nodes mobility on the unknown way of unrepeatable the previous patterns. Let, the mobile nodes can be moving data objects which continuously changing its topology. Here, kinetic data structures (KDS) is considered to capture a continuous moving data objects in an information database when the mobility of the data object can be defined as a polynomial of time to collect the non-recurrent mobility pattern of the object. KDS is fully or partially imaginable. Further, random mobility is captured by soft kinetic data structures (SKDS). KDS and SKDS maintain an approximate geometric structure which is updated by property testing and reformation.
- **Social-based community mobility model:** each mobile sensor node is considered as a member of a cluster of a community whereas different communities may be a part of an overall society. The model must capture the non-homogeneous activities in both space and time normally known in certainty with mathematically tractable. e.g. time-variant community (TVC) mobility, community-based mobility (CBM), home-cell community-based mobility (HCBM), orbit-based mobility, entropy-based individual/community mobility and knowledge-driven mobility (KDM) model.

6. Network topology

The network topology plays an important role in MWSNs to transfer the data onto the mobile sensor nodes to the sink/base station. Then, the sink and the remote user/server are connected by the internet. The effectiveness of large scale mobile wireless sensor networks purely to depend on the data collection or topology management scheme. Therefore, the topology provides a guaranteed reliable network and better QoS in terms of mobility, traffic, end-to-end connection, etc. In addition, topologies in MWSNs define the dimension of the sensor node group, manage the addition of new members of a group and deal with the withdrawal of members that leave the group. With considering such aspects in network topology may provide an efficient data collection of low energy utilization and form superior MWSN. The existing network topologies of WSNs are flat/unstructured, tree, cluster, chain, and hybrid. Various network topologies are followed to achieve the maximum data collection and network performance, which depends upon the nature of the MWSNs. Depend upon the nature of the network, various network topologies are followed to obtain the maximum data collection.

7. Routing protocols for MWSNs

The routing approaches to the MWSNs can be centralized, distributed or hybrid. An efficient and reliable routing protocol design for MWSNs considers the network topology, sensor node mobility, energy consumption, network coverage, data transmission methods, QoS, connectivity, data aggregation, sensor node and communication link heterogeneity, scalability, and security. The existing routing protocols are grouped based on their routing structures such as flat, hierarchical and location based routing protocols. Again, the hierarchical based routing can be broadly categorized into classical and optimized hierarchical based routing. Furthermore, the path establishment discovers the route from the source to the destination which follows the proactive, reactive, and hybrid based routing [5, 19, 20]. **Figure 3** shows the taxonomy of the mobile wireless sensor networks [21–26].

7.1. LEACH variants

LEACH is one of the most popular dynamic clustering algorithms for the hierarchical routing based sensor networks, which is absolutely designed for the distributed environment and there is no global knowledge required about the network. The sensor node uses the received signal strength as well as the threshold values to select the cluster head and that forms a cluster. Here, the round or topology updates interval are considered for the data transmission, which is divided into fixed time intervals with equal length. Each sensor node on a network has an equal probability to act as a cluster head by selecting a random number between 0 and 1, and therefore, the sensor nodes die slowly [27]. The total network operations are considered as a round. Each round consists of a setup phase (i.e., forms a cluster and makes a multi-hop communication between the cluster head and the sink) and a steady state phase (i.e., transfer the data of the cluster members to the sink through the cluster heads). The data transmission phase of the LEACH protocol consists of the intra-cluster and the inter-cluster communications. In an intra-cluster communication, the cluster head collects data of the cluster members and aggregate that data instantly. After the completion of the intra-cluster communication, inter-cluster communication is started to forward the data of the cluster heads to the sink.

Even dynamic clustering improves the lifetime of the network; the static LEACH is not suitable for the large scale mobile wireless sensor networks; therefore, LEACH with mobility must be considered for the dynamic networks. The LEACH variants such as T-LEACH, mobile LEACH, and LEACH-mobile-enhanced are considered for the mobile sensor networks [29–32].

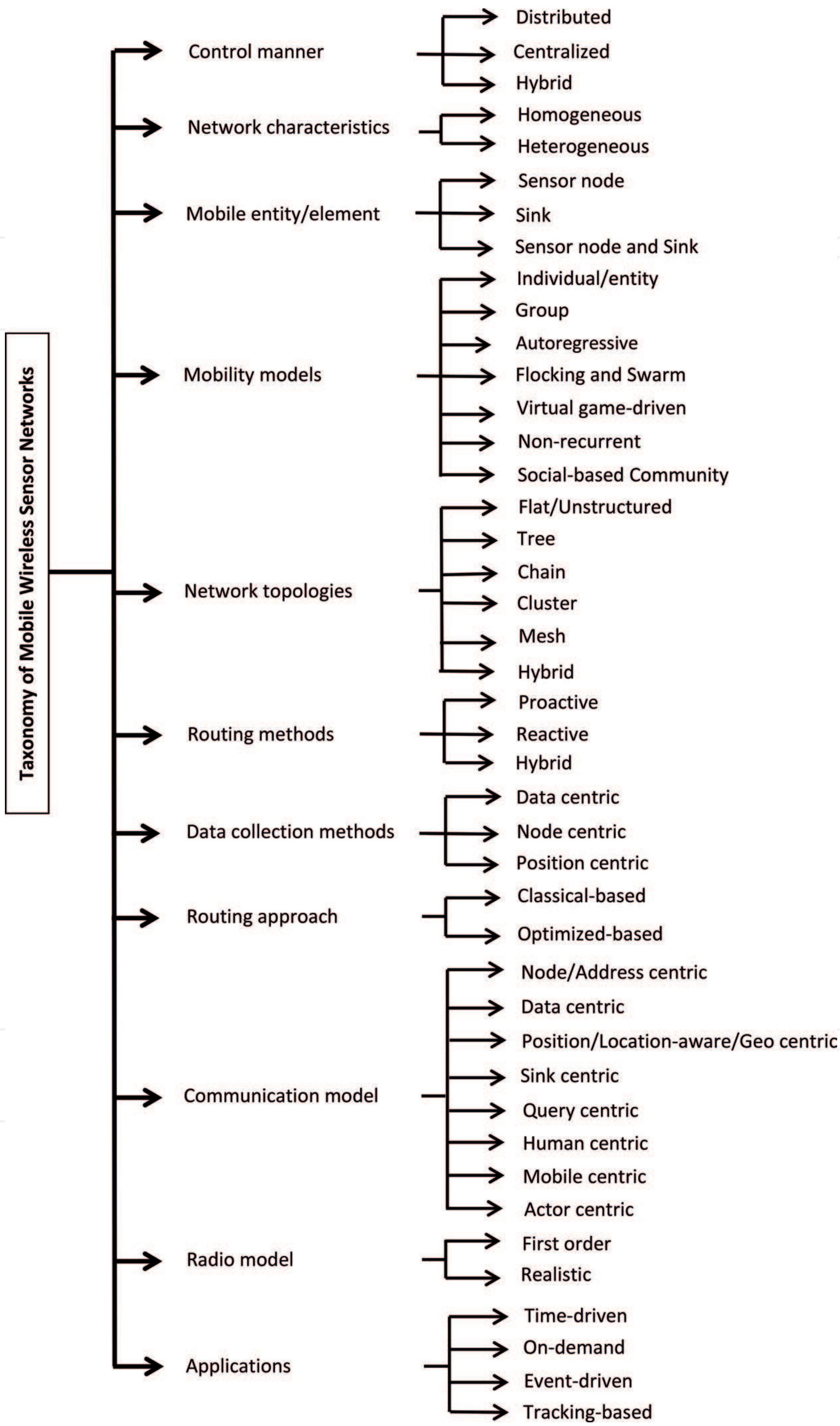

Figure 3. Taxonomy of mobile wireless sensor networks.

7.1.1. T-LEACH

Like LEACH, T-LEACH protocol [28] establishes a hierarchical topology for the large scale, dynamic and uneven distributed mobile WSNs. It uses the tree topology; power consumption mechanism and multi-hop transmit scheme to balance the whole network energy consumption as well as to increase the packet delivery rate. T-LEACH is implemented in two phases such as the topology construction stage and topology maintenance stage. On first, the topology construction stage establishes a data aggregation tree, cluster structure, and multi-hop transmit mechanism. Secondly, the topology maintenance stage follows the multi-hop transmits scheme, member nodes mobile reaction mechanism and cluster mobile reaction mechanism to establishes the stable network. From the simulation results, the T-LEACH protocol can effectively establish and maintain the topology structure of the dynamic and uneven distributed large-scale MWSNs in terms of packet delivery ratio and average energy consumption when compared to LEACH and cluster based routing (CBR) mobile LEACH.

7.1.2. Mobile LEACH/LEACH mobile

Mobile LEACH [29] is a mobility-centric protocol which is designed for mobile wireless sensor networks. Mobile LEACH operations are very similar to the static LEACH operations. But, the mobile LEACH allows the inclusion of the mobile sensor nodes with non-cluster heads on a setup phase and also rearrange the cluster of minimum energy consumption. After the cluster formation, the cluster head assigns a time slot for all the sensor nodes in its cluster. Also, the cluster members turn off the radio except during its transmit time to minimize the energy dissipation of the individual sensors. From the experimental results, Mobile LEACH outperforms LEACH by reducing the data packet loss for the mobile nodes. But, Mobile LEACH has the trade-off that it increases the unwanted energy dissipations while compared to LEACH.

Mezghani and Abdellaoui [30] proposed mobile mono-hop LEACH and mobile multi-hop LEACH for improving the lifetime of the mobile LEACH for the MWSNs. In mobile mono-hop LEACH, each mobile sensor node may directly communicate with the sink which is suitable for the small-scale indoor environment. Then, the mobile multi-hop LEACH is designed to support for some large-scale outdoor applications. Simulation results proved that the proposed protocols (mobile and static LEACH for the mono and multi-hop architecture) improve the performance of the heterogeneous MWSNs as in terms of network lifetime, exchanged packet rate, delay and loss packet rate [31].

7.1.3. LEACH-mobile-enhanced (LEACH-ME)

LEACH purely considers the sensor nodes residual energy level for selecting the cluster head on each round, therefore, LEACH is not suitable for dynamic networks. But, LEACH-ME elects the cluster head based on the sensor node mobility and energy level [32]. Also, LEACH-ME maintains some information about the sensor nodes such as role of the node, mobility factor, cluster members list and TDMA schedule. Even the sensor node maintains all these four information, the mobility factor is a prime key to select the cluster head. Let, the mobility factor is calculated based on the transition count and the concept of remoteness. Because of these pieces of information, each cluster head can form a group of cluster members of minimum node mobility. Also, LEACH-ME ensures that the clusters are distributed minimally while the cluster heads on mobility. Simulation results show that LEACH-ME performs well than mobile LEACH in terms of average successful communication, normalized performance, computational overhead, and energy overhead with respect to mobility factor.

7.2. Mobile sink-based routing protocol (MSRP)

MSRP [33] is proposed to prolong the network life time of the cluster based wireless sensor networks. Usually, the sensor nodes very close to the sink should forward a large number of data packets when compared to far away sensor nodes, and they may drain their residual energy very quickly. This problem is termed as hotspot problem. To avoid such kind of issues, the sensing region is the portion of clusters and that prolongs the lifetime of the network. In MSRP, the mobile sink is considered instead of static sink, and that visits each cluster to collect the sensed data onto their cluster head. Now, the mobile sink collects the residual energy information about the cluster heads and that moves to the higher energy cluster heads.

The MSRP protocol operations consist of the setup phase and the steady state phase. In the setup phase, the whole network is portioned into clusters and the mobile sink advertises its location to cluster heads by broadcasting the beacon message for the registration process. Further, it is divided into three sub-phases such as initialization, mobile sink advertisement, and cluster head registration. After completion of the setup phase, the steady state phase is initiated. In the steady state phase, sink collects the data onto the registered cluster head and the cluster head collects the date from the cluster members. Then, it can be divided into three sub-phases such as TDMA scheduling, forwarding to sink and sink movement. Based on the residual energy of the cluster head, the mobile sink frequently visits all cluster heads in a network and that collects the data from among them. Simulation results proved that the MSRP reduces the energy consumption among the mobile sensor nodes and solves the hot spot problem due to changing the one-hop neighbor nodes of the mobile sink.

7.3. Mobility adaptive cross-layer routing (MACRO)

The MACRO [34] is developed to meet some essential requirements of the MWSNs such as end-to-end reliability, minimal power consumption, and packet delay. A single layer protocol development cannot provide some optimal solutions to the large scale MWSNs. Therefore, the authors developed a cross-layer interaction MACRO protocol, which combines five open systems interconnection (OSI) reference layers features such as application, transport, network, media access control (MAC) and physical layers into the all-in-one protocol. The MACRO protocol design consists of route discovery, data forwarding, and route management algorithms, which provides reliable quality links to frequent topology changes. Also, it reduces the node failures, unwanted control packets flooding and serious congestion of the MWSNs. However, the route discovery process of the large-scale mobile sensor networks may cause more delay due to the higher number of mobile sensor nodes as well as frequent topology changes. The simulation results prove that MACRO performs well rather than the classical CBR-mobile and LEACH-mobile in the aspects of packet delivery ratio (PDR) and end-to-end packet delay.

7.4. Energy management algorithm in a WSN with multiple sinks (EMMS)

An EMMS [35] is proposed to improve the residual energy utilization and the quality of data transmission of the MWSNs. EMMS protocol operation for the energy management MWSN with a multiple mobile sink is considered into two stages. (i) Find a closed tour of each mobile sink. i.e., a length of the closed tour of each mobile sink is roughly equal. (ii) Determine the sojourn locations of each mobile sink on the found closed tour. Then, build a routing tree rooted at each sojourn location as well as the sojourn time of the location for the mobile sink.

In EMMS, there are two types wireless transmission interfaces are used on each mobile sink: (i) low power wireless interface—communicate with sensor nodes within a sensor network; (ii) high bandwidth wireless interface—communicate with a third-party network for remote data transfer purpose. Like LEACH, EMMS energy management operations are considered into rounds. Each round consists of a routing tree construction, a sojourn time calculations at each sojourn location, and a data collection and sensing data transmission. Based on the residual energy of the sensor nodes, routing tree construction phase initiates a routing tree at each sojourn location on the closed tour of the mobile sink. Then, the sojourn time-calculation starts to calculate the members of the constructed tree and that estimates a sojourn time at each sojourn location on the closed tour of each sink. In a data collection and sensing data transmission phase, the sensor nodes forward their sensed data onto the mobile sink via the constructed routing tree and that transmits the sensed data to the remote monitoring center. At the end of the data transmission stage, the mobile sink collects the residual energy information about the sensor nodes in the neighbor set and then travels through its next sojourn location. The simulation results proved that the EMMS improves the residual energy usage as well as the data transmission quality of the MWSN significantly.

7.5. Artificial bee colony (ABC) based data collection for large-scale MWSNs

Zhang et al. [36] proposed the ABC algorithm, which considers three “bee” (i.e., onlookers, scouts, and employed bees) groups in the “colony”. The ABC algorithm represents the population of bees to identify the optimal path and each bee represents a position in the search space. A bee always waits on the “dance” area to pick a honey source in an onlooker, randomly searches a scout and return to the previously visited honey source is represented as an employed bee. Let, the position of the honey sources signifies the possible solution to the optimization problem. In addition, the amount of “nector” of a honey source relates to the quality (i.e., fitness) of the correlated problem. Furthermore, the first half of the ABC algorithm denotes the employed bees and the second half signifies the onlooker bees. The ABC algorithm operation is divided into four main steps: initialization, population updating, bee source selection and population elimination.

Yue et al. [37] proposed an optimization based ABC mechanism, which uses the mobile sink to identify the optimal moving path as well as the routing path to collect the data onto the mobile sensor nodes of the large-scale MWSNs. Also, the ABC algorithm is designed to investigate the data latency of the mobile sink on three aspects: data collection maximization, mobile path length minimization, and network reliability optimization. Like LEACH, the ABC algorithm operation consists of an initial phase and a data collection phase on each round. In the initial phase, the mobile sink uses the network topology information to identify the optimal clusters of the best cluster head nodes as well as to establish a routing tree among the cluster head nodes. After the completion of the initial phase, the data collection is initiated. Here, each cluster head collects the sensed data from their cluster members. Then, the mobile sink responds immediately to the cluster head, which collects the data from the cluster head.

Further, the mobile sink identifies and picks the next cluster heads position according to the current network environment parameters along with the mobility, and that helps to identify the shortest path to each cluster head. The simulation results show that ABC is compared with the random walk and ant colony algorithms, the ABC algorithm can effectively improve certain metrics of the MWSNs such as data collection efficiency, residual energy utilization, reliability, and that prolongs the lifetime of the MWSNs.

7.6. Mobility-based clustering (MBC) protocol

Deng et al. [38] developed a mobility-based clustering (MBC) Protocol to improve the performance of the MWSNs. Like LEACH, the MBC protocol operation consists of a setup phase and a steady-state phase on each round. In the setup phase, all the sensor nodes have an equal chance to elect the cluster head based on the threshold value (i.e., residual energy and mobility). Also, MBC considers the connection time for cluster formation process, which builds a more reliable path based on the stability or an availability of each link between the cluster members and the cluster head.

7.7. Cluster independent data collection tree protocol

Velmani and Kaarthick developed a cluster independent data collection tree (CIDT) scheme [39], to provide reliable guaranteed end-to-end communication for large-scale MWSNs. CIDT is a unique methodology of the hybrid logical scheme, which utilizes to intra-cluster communication and data collection tree (DCT) communication for cluster and tree topologies respectively. The protocol design helps to improve the QoS parameters in terms of data collection, energy consumption, delay, PDR, throughput and network lifetime for large scale mobile WSNs. In CIDT, each sensor node picks the cluster head with better connection time, then the cluster head collects the data packets of the cluster members in an allocated time slot. After the cluster head election, base station initiates the DCT to elect one-hop neighbor DCN or current DCN which picks one-hop neighbor DCN or another cluster head with good coverage distance, maximum connection time and minimized network traffic.

The protocol operation consists of set-up phase and steady-state phase. During the set-up phase, a sensor elects itself as a cluster head among them based on its threshold value (i.e., flag, residual energy, and mobility). Furthermore, the cluster member joins with the one-hop cluster head during cluster formation based on the estimated connection time, received signal strength (RSS) and robustness in the connection.

Subsequently, the DCT communication is initiated by the base station to construct a data collection tree, which selects the data collection node (DCN) for covering the entire cluster heads. Here, the DCN does not participate in sensing for this particular round, which simply collects the sensed data and aggregates the data packets belonging to one-hop cluster head and the DCN, thereby forwarding the data packet to the base station through DCT. In order to keep the lifetime of the entire network to be well-balanced, new cluster heads and DCNs are elected for every round. Even when the sensor nodes are on high mobility, the DCN keeps communication with the cluster head, and CIDT no needs to update the tree structure for that particular round. Moreover, CIDT reduces energy consumption, link failure, end-to-end delay and traffic of cluster head due to forwarding the data with DCT. Minor complexity is involved in a sink to create a tree structure which reduces the energy consumption of cluster head. Also, CIDT helps to minimize the frequent cluster formation and maintain a cluster for a considerable amount of time.

In steady state phase, each cluster member sends its gathered data to the cluster head during its allocated time slot, and the cluster head aggregates the data and forwards it to the base station via intermediate cluster heads by direct sequence spread spectrum (DSSS) technique. Simulation results prove that CIDT achieves outstanding performance when compared to LEACH, HEED, and MBC in terms of PDR, throughput, delay and total energy consumption even in mobile sensor ambiance.

7.8. Velocity energy-efficient and link-aware cluster-tree (VELCT)

VELCT [40] is a hybrid topology (i.e., cluster and tree topology) based energy efficient routing scheme, which has been particularly designed to improve the network performance, data collection and lifetime of large scale mobile WSNs. VELCT is an enhancement of CIDT technique, which effectively mitigates the existing issues in network topologies such as residual energy consumption, coverage problem, critical node occurrence, RSS, traffic, connection time, tree intensity, scalability, fault tolerance, delay, throughput, PDR, mobility and network lifetime. The proposed VELCT scheme constructs the data collection tree (DCT). In DCT, a few sensor nodes in a network have been assigned as the data collection node (DCN) based on the position of the cluster head and that does not participate in sensing on this particular round. Here, the purpose of the DCN consideration is to be collecting the data packets of the cluster head and delivers it to the sink. The VELCT protocol minimizes residual energy consumption and reduces the end-to-end delay and traffic in cluster head in large scale MWSNs due to the efficient usage of the DCT. The major strengths of the VELCT algorithm are: reduce the residual energy consumption of the cluster head, constructs a simple tree structure, avoiding frequent cluster formation and maintains the cluster of a considerable amount of time.

The overall operation of the proposed protocol is partitioned into set-up phase and steady-state phase. The set-up phase consists of intra-cluster and DCT communication, which estimates the node position, threshold value, RSSI, connection time and robustness of connection. Moreover, DCT estimates the traffic, tree intensity, delay, mobility and throughput for every round. The DCN of the DCT does not participate in sensing for this particular round, but simply collects the data packets of the cluster head or adjacent DCNs, further to deliver the data packet of the sink through DCT, thereby the DCN acts as an ordinary sensor node from next successive rounds. The steady state phase is similar to that of CIDT.

The strength of VELCT protocol is, constructing a simple tree structure of cluster heads that maintain the cluster of a considerable amount of time, which reduces the energy consumption and control packet overhead, thereby avoid the bottleneck problem with the cluster head level and frequent clustering on mobility ambiance. Simulation results demonstrate that VELCT could yield better performance in terms of energy consumption, throughput, delay and PDR with reduced network traffic when compared to energy-efficient data collection protocol based on tree (EEDCP-TB), chain oriented sensor network (CREEC), cluster-tree data gathering algorithm (CTDGA), MBC and CIDT even in high mobility ambiance.

8. Conclusions

This chapter presented in detail the research carried on the large-scale mobile wireless sensor networks. Also, analyzed the major technical challenges as well as the research issues in designing hardware architectures, mobility, algorithms, and protocols for the large-scale MWSNs. We discussed most of the existing literature works of the MWSNs such as mobile sensor node architecture, mobility, topology, and routing protocols. Finally, we classified the existing mobility models and the taxonomy of MWSNs.

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