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A review of Mobility-Based Wireless Sensor Networks

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***Abstract*—A wireless sensor network is composed of a large number of sensor nodes and one or more sink nodes (base stations). The sensor nodes are deployed inside the area of interest to collect useful information from the surrounding environment and report it to a base station located generally at the extremity of the area of interest. Wireless sensor networks are widely used to deliver observations at low cost over long phases of time. Allowing disparate devices and appliances to communicate with each other or a centralized controller already ensures a good level of communication. Communication is one of the essential functionalities of these networks but at the same time power and computational resources in each sensor are limited resources. To optimize these factors there are three major techniques namely: duty cycling, data-driven approach, and mobility-based techniques to conserve the power in WSNs. Mobility based communication can prolong the lifetime of WSNs and increase the connectivity of sensor nodes and clusters For this reason using mobility control to minimize energy consumption in WSNs has recently grabbed attention. Hence this paper reviews emphasizing the WSNs based on controlled mobility.**

Keywords-Wireless Sensor Network, Energy Conservtion Scheme, Mobility, Controlled Mobility.

I. INTRODUCTION

Wireless sensor networks (WSNs) have been proposed as observation of events and environments over a large number of small and simple sensor devices to communicate over short range wireless interfaces to deliver observations over multiple hops to central locations [1]. WSNs are considered for several critical application scenarios including battlefield observation, territory observation, traffic observation, and security applications. Sensor nodes and hence these applications, are subject to constraints such as limited processing, storage, communication capabilities and limited power supplies. One of the great visions of wireless sensor network (WSN) research is the idea of a ubiquitous and seamless interface between the physical and online worlds. WSN research aims to soak our surroundings with small, cheap, multi-functional nodes that can sense, process and communicate [2]. Generally, the base station is much more powerful in terms of resources than the sensor nodes. Sensor node is a small device that includes four basic components: a data sensing unit, a processing unit, a wireless communication unit and an energy unit. The sensor node is equipped with low-power batteries suitable for its small size, which limits the ability of the sensor node in terms of development, storage and communication [3].

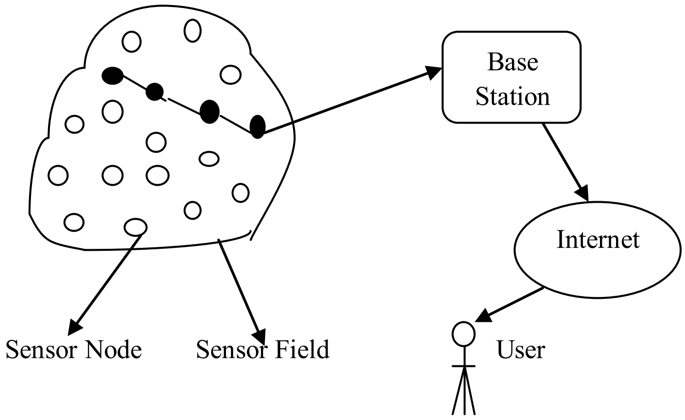

Fig. 1 A Typical Wireless Sensor Network

II. DESIRABLE FEATURES OF WIRELESS SENSOR NETWORK

Some of the general characteristics of wireless sensor network are like:

A. Scalability

In some applications wireless sensor network can grow. The number of sensor nodes deployed in sensor is may be in the order of hundred or thousand.

B. Energy Consumption

Most of the sensor use battery power as their energy source. Energy Consumption depend upon the three major operations of the sensor nodes which are sensing, communication and processing, power control, etc.

C. Security

It must achieve all safety goals which are privacy, accessibility, reliability, verification, approval, non-denial.

D. Fault Tolerance

Sometime a node may fail due to various reasons. Failure of nodes should not affect the overall performance of wireless sensor network.

E. Data Gathering

Data gathering is a task of collecting the data from sensors node and removing the redundant data. The

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information collected should be transmitted to the sink node or base station without loss.

III. Schemes of Energy Conservation in WSN

Energy is one of the most important resources for wireless sensor networks, but one problem general to most of these WSNs is lack of reliable power for each sensor node in the network. The go down of the energy consumed in the network depends on the specific sensor node. There are three major techniques namely: duty cycling, data-driven approach, and mobility-based techniques.

A. Duty-cycling approach

Duty cycling can be achieved through two dissimilar and complementary approaches. From one side it is possible to utilize node redundancy, which is usual in sensor networks, and adaptively select only a minimum subset of nodes to remain active for maintaining connectivity. Nodes that are not currently needed for ensuring connectivity be able to go to sleep and save energy. Finding the best subset of node that guarantee connectivity is referred to as topology control1. Thus, the basic idea behind topology control is to utilize the network redundancy to prolong the network long life, typically increasing the network lifetime by a factor of 2-3 with respect to a network with all nodes always on [4][5][6]. On the other hand, active nodes (i.e., nodes selected by the topology control protocol) do not need to maintain their radio all the time on. They can switch off the radio (i.e., put it in the low-power sleep mode) when there is no network activity, thus discontinuity between sleep and wakeup periods. Throughout we will refer to duty cycling operated on active nodes as power management. Thus, topology control and power management are complementary techniques that implement duty cycling with unlike granularity. Warrier et al [6], designed and analyzed a topology control scheme whose major components are similar to those of existing protocols but the difference lies in the definition of a rule of thumb that determines the energy gain obtainable in a network of given density.

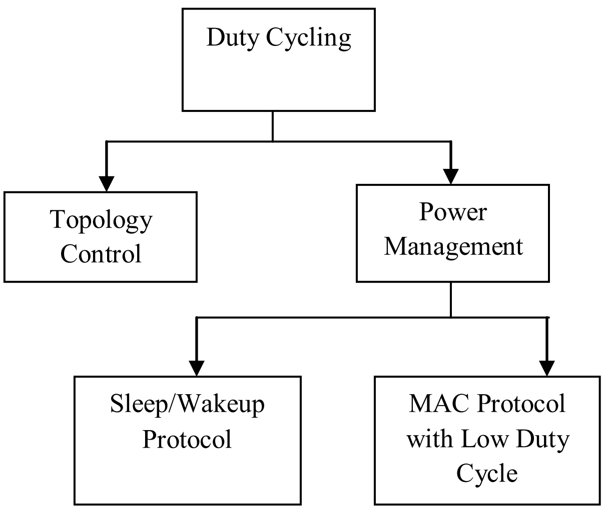

Fig. 2 Taxonomy of Duty-cycling Approach

B. Data driven approach

Data-driven approaches can be divided according to the problem they address. Specifically, data-reduction schemes address the case of unneeded samples, although energy-efficient data acquisition schemes are mainly aimed at reducing the energy spent by the sensing subsystem. All these techniques aim at reducing the amount of data to be delivered to the sink node. Data compression can be applied to reduce the amount of information sent by source nodes. This scheme contains encoding information at nodes which generate data and decoding the data at the sink. There are different methods to compress data [7][8][9][10]. Data prediction consists in building an abstraction of a sensed phenomenon, i.e. a model telling data evolution. The model can forecast the value sensed by sensor nodes within certain error bounds and resides both at the sensors and at the sink. Energy efficient data acquisition techniques are not focused on reducing the energy consumption of the sensing subsystem but they highly reduce radio energy consumption (Alippi et al [19]). They aimed at reducing data samples thereby minimizing the number of communication as well.

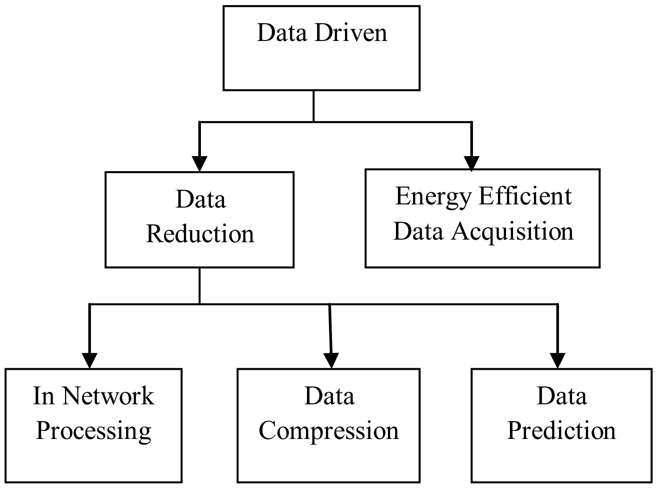

Fig. 3 Taxonomy of Data-driven Approach

C. Mobility based approach

Mobility-based schemes can be classified into two types: mobile-sink and mobile-relay, which depends on the type of the mobile entity. When considering mobile schemes, an important subject is the type of control the sensor-network designer has on the mobility of nodes. A detailed discussion on this point is presented in [11] and [12]. Mobile nodes can be divided into two broad categories: they can be specifically designed as part of the network infrastructure, or they can be component of the environment. When they are component of the infrastructure, their mobility can be totally controlled and are, in general, robotized. When mobile nodes are part of the environment they might be not controllable. If these nodes follow a strict schedule, then they have a completely predictable mobility [13]. Otherwise they may have a random behavior so that no reliable assumption can be made on their mobility. Wang et al [3] employed a linear optimization model to determine the node to be visited and the duration so as to prolong the lifetime of the first node in the network. With the help of this model, it was demonstrated that deploying a mobile sink has greater improvement over using a static sink.

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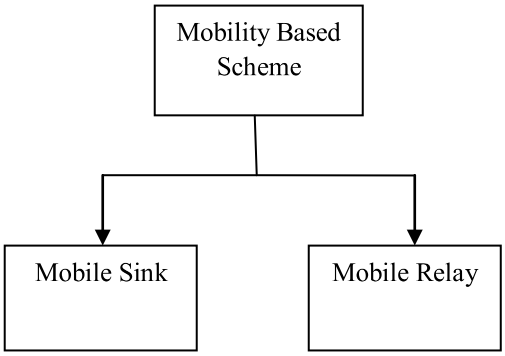

Fig. 4 Taxonomy of Mobility-based Approach

IV. Mobility in Wireless Sensor Network

Mobility is an inherent feature of WSN as either the nodes or the sensed event can be mobile based on the requirements of the specific application. The main reason for which mobility was introduced in WSNs is to reduce the number of hops required to deliver data from sensor nodes to the base station. Thus, reducing the delay and prolonging the network lifetime by reducing the amount of energy required to send and receive messages. Mobile systems are characterized by the movement of their components. The nature of movement, its speed, direction and rate of change can significantly affect the operation and the performance of the WSN and protocols have to be designed to support mobility.

A number of approaches exploit the mobility of nodes for data collection. The focus of these approaches can be generally classified into two types: sink mobility and node mobility. In sink mobility, the sink, which is the ultimate destination of sensed data in wireless sensor networks, moves and routes itself in the network to collect data from static nodes. However, a more complicated and challenging case is node mobility, where individual sensor nodes actively move from place to place and during their movement they attempt to maintain an end-to-end communication link. Based on the given classification, the node mobility can be treated as one of the four basic types:

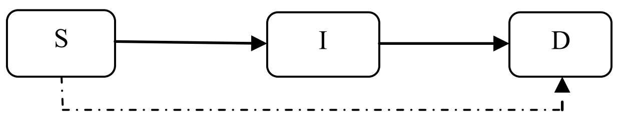

Fig. 5 Basic Communication in Wireless Networks

1) Stationary**:** A node doesn't move from its original location.

2) Random: A node moves in a random fashion. The motion may follow a probabilistic model characterized by some parameters [14].

3) Predictable: A node's future position is known but cannot be changed. Chakrabarti et al. [13] studied the case of an intermediary with predictable mobility. They analyzed the gain in power consumption of sensor nodes by modeling the data collection process as a queuing system.

4) Controlled: A node can be controlled by a user. There may be constraints on the motion such as maximum speed and maximum acceleration [15].

Eylem Ekici et al. [18] classified the approaches of exploiting controlled mobility into the following three types:

A. Mobile Base-station (MBS)-based Solutions

An MBS is a mobile sink that changes its position throughout process time. Data created by sensors are communicated to MBS lacking long term buffering. The primary objective of MBS-based solutions is to move the sink in the network to distribute energy consumption evenly.

1) *Base Station Relocation:* The base station relocation technique proposed in [2] aims to change MBS locations next to the periphery of the sensing field such that the energy consumption of individual sensors is balanced and overall energy consumption of all sensors is minimized. For this purpose, time is divided into rounds during which MBSs are stationary. At the end of every round, MBS locations are recomputed using inductive logic programming (ILP) methods minimizing an objective function.

2) *Joint Mobility and Routing:* Motivated by uneven energy consumption in WSNs among stationary sinks, the load balanced data transmission in WSNs has been investigated in [16]. In this work the authors develop an analytical model that describes the communication load distribution in a WSN.

3) *Move and Sojourn:* Network lifetime elongation using MBSs has also been investigated in [3].

B. Mobile data collector (MDC)-based solutions

MDC is a mobile sink to stays sensors. Data are shielded at foundation sensors until the MDC visits the sensors and downloads the information above a single-hop wireless transmission.

1) *Data Mules:* The MDC concept has been first introduced in [14], where MDCs are referred as Data Mules. In this scheme, data generated by sparsely situated sensors are buffered at sensors. MDCs move randomly and collect data opportunistically from sensors in their straight communication range. Collected data are then carried to a wireless access point.

2) *Predictable Data Collection:* In the predictable data collection scheme presented in [13], data is collected from sensors by vehicles that pass near sensors. Sensors are assumed to know the trajectory of MDCs (e.g., buses in a campus environment), which is leveraged to predict when data transfer will take place. Founded on the predicted data transfer times, sensors sleep until the time of data transfer to save energy.

3) *Mobile Element Scheduling:*In WSNs sensors may generate data at different rates. This manners is more pronounced when data collection is performed as events occur or when the sampling rates are determined according to rate of change of the observed phenomenon.

4) *Partitioning Based Scheduling:*The PBS algorithm computes mobile element (ME) trajectories based on

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knowledge of the data generation rate of sensors and their locations.

C. Rendezvous-based solutions

Rendezvous based solutions are hybrid solutions where sensor data is sent to rendezvous points close to the path of mobile devices. Data are buffered at rendezvous points until they are downloaded by mobile devices [18].

1) *Relayed Data Collection:* An autonomous mobile router (MDC)-based solution is pro- posed in [17] to collecting data from sensors. MDC traverses a linear path and transfers data from sensors when it enters their transmission range. Remaining nodes relay their data to the nodes closest to the MDC path by multihop transmission.

2) *Multihop Route to Mobile Element:* Being an MDC-based scheme, the primary objective of the PBS algorithm is to ensure that the data is collected before sensor buffer overflows occur. It is also possible that sensors generate urgent messages that must be delivered to MEs within given delay bounds in addition to regularly generated data.

V. CONCLUSION

In this paper mobility-based communication proposals for WSNs are discussed. Mobility based communication can prolong the lifetime of WSNs and increase the connectivity of sensor nodes and clusters. Mobility has been discussed for the purpose of improving communication performance in wireless networks. In a common communication pattern where there are one or more intermediary nodes between source and destination nodes, each of the participants can be mobile. We have classified the mobility into stationary, random, predictable and controlled mobility and reviewed the literature depending on the source, destination, and intermediary nodes, but our focus in this paper is on controlled mobility, where the users can find out the motion of mobile nodes. Hence this paper represents the review of mobility-based wireless sensor network. We propose a new approach in our future work and attempt to solve the different problems found in this study.

TABLE I :
Comparison of mobility-based communication proposals [18].

Class	Algorithm	Multihop commun.	Long-term buffering	Mobility	Message latency	Algorithm execution	Platform mobility	Energy consumption
MBS	Base Station Relocation	Yes	No	Controlled	Low	Online	Low	High
	Joint Mobility and Routing	Yes	No	Controlled	Low	Offline	Low	High
	Move and Sojourn	Yes	No	Controlled	Low	Offline	Very High	High
MDC	Data Mules	No	Yes	Random	High	Offline	High	Low
	Predictable Data Collection	No	Yes	Predictable	High	Offline	High	Low
	MES	No	Yes	Controlled	Medium	Online	High	Low
	PBS	No	Yes	Controlled	Medium	Offline	Medium	Low
Rendezvous	Relayed Data Collection	Yes	Yes	Controlled	Medium	Online	Medium	Medium
	MRME	Yes	Yes	Controlled	Medium	Offline	High	Low

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