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Information Collection in Multi-Application Sharing Wireless Sensor Networks

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ABSTRACT

A wireless sensor network (WSN) is made up of several autonomous spatially distributed sensor nodes that can be used to sense information about the physical or environmental conditions like pressure and temperature etc. and to cooperatively pass their data to the destination location through the network. Wireless sensor nodes are energy constrained and efficient techniques have to be employed while collecting data to maximize network lifetime. Energy is expended in two ways; in sensing the data and in sending the data to sink. This paper focuses on data collection and discusses about several ways in which data can be sent to the sink.

Keywords: *Data collection, mobile elements, power management, discovery, data communication.*

I. INTRODUCTION

Wireless Sensor Networks are used in a large variety of applications including military applications, environmental applications, health-care applications, home applications and other commercial applications. WSNs contain a large number of sensor nodes, which are tiny devices that work using a battery. These devices perform three functions: sampling a physical quantity from the surrounding environment, processing (and possibly storing) the acquired data and transferring them through wireless communications to a data collection point called sink node or base station. One of the ways to increase the network lifetime is by introducing mobility into the Wireless Sensor Network (WSN).

1.1 Advantages of Mobility in Wireless Sensor Networks

1. Sparse WSN – Since the nodes are mobile we can manage with fewer nodes. So sparse WSN becomes a feasible option.
2. Less Cost – Since fewer nodes can be deployed, the network cost reduces. We can make use of mobile elements already present like moving vehicles, public transport etc. to transport data,
3. More Reliable – Data loss is reduced as the mobile elements visit the nodes to collect data directly through singlehop transmission as opposed to multi-hop transmissions. Interferences and collisions are avoided.

4. Funneling effect avoided – In traditional networks, the nodes near the sink are overloaded as they have to relay the data to the sink node. By making use of mobile collectors we can ensure that energy consumption is more uniform, since the mobile element collects the information by visiting the node. 5. Improved Coverage – Since the data collector is mobile it has improved coverage and it also has the additional advantage of connecting disconnected networks.

1.2 Challenges faced in incorporating mobility in WSN

1. Node Detection - As communication occurs only when the nodes are in the transmission range of each other, the nodes have to be correctly and efficiently detected.
2. Mobility-awareness – The nodes must be aware of the mobility pattern so they can be awake only when they expect the mobile element to be in their transmission range
3. Policy– The elements are mobile so a policy must be used to ensure efficiency in movement in order to increase the lifetime of the network.
4. Efficient Data Transfer – Movement of nodes occur so the data exchange must have knowledge about the mobility pattern. The data that is transferred to the sink must be correct and optimized.

II. COMPONENTS OF WIRELESS SENSOR NETWORKS

Nodes – They sense data, they also forward and relay messages to other nodes in the network.

Sinks – They are the destinations of information. They can collect data either directly or indirectly using intermediate nodes. Sinks can use data coming from sensors autonomously or make them available on the Internet to interested users.

Mobile Data Collectors – They are neither sources nor destinations, they merely act as intermediate nodes to collect data.

A network is said to be mobile when at least one of the above components is mobile.

III. WIRELESS SENSOR NETWORKS MOBILE ELEMENTS (WSN-ME)

3.1 Re-locatable nodes – These nodes change their location to forward data to the destination. The architecture is depicted in Figure 1.

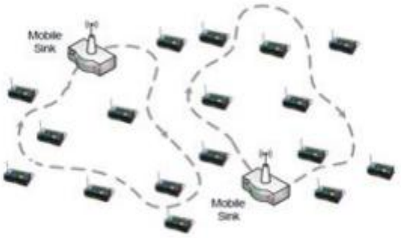
Fig.1. Architecture of a WSN with re-locatable nodes

They do not carry any information in contrast to mobile nodes. They change the topology of the network. Predefined Intelligent Lightweight tOpology managemenT (PILOT) nodes are used during link failure to re-establish connectivity in network. They act as bridges when nodes are unstable. Algorithms for placement of re-locatable nodes in order to improve the network connectivity have been discussed in [5][6].

3.2. Mobile Data Collectors (MDCs) – They visit each node and gather data. They can be mobile sinks or mobile relays.

3.2.1. Mobile Sinks – These mobile nodes are the destination and have high energy. They move around and collect data. The collected data can be made available to users using wireless internet connection. The path between the sink and node is not fixed and changes with time. Path between node and sink is multi–hop. The architecture is depicted in Figure2

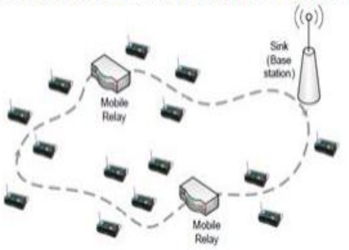
Fig.2. Architecture of WSN-MEs with MDCs - Mobile Sinks



3.2.2. Mobile Relays – They are not the source or destination of the data, but they are intermediate nodes used for data passing. The architecture is depicted in Figure3.

Fig.3. Architecture of WSN-MEs with MDCs - Mobile Relays

Fig.3. Architecture of WSN-MEs with MDCs - Mobile Relays



The data-MULE system was proposed [7][8]. This data-MULE system consists of a three-tier architecture, where the second tier is represented by relays, called Mobile Ubiquitous LAN Extensions (MULEs). The MULEs pass through the network collect the data from the sensor nodes and when they to near the sink they pass the collected data to the sink. The MULEs move in straight line and to reduce delay the data can be relayed by other nodes to reach the sink. If obstacles are present then the MULE will not be able to move along a straight line. When there are only a few MULEs and when all sensors are not connected, data MULEs may not cover all sensors by navigating along a straight line. A message ferrying scheme [14][15]provide the relaying of messages in sparse and mobile networks. Message ferries move through the field and get data from nodes. Message ferries can be thought of as a moving communication infrastructure which allows data communication in wireless networks that are sparse. Mobile Data Collectors called M-Collectors were proposed in [1]. Here M-Collector will move through the network and gather information. This is called as M-Collector tour and it is based on the optimal path as found out by a variant of the spanning tree algorithm called spanning tree covering algorithm. Since delay will be high if we use a single mobile collector, we can use many M-Collector to collect data in a parallel manner. But these techniques cannot be used to transfer emergency data. This problem can been addressed by the usage of long range wireless communication between the sink and MDC to transmit the emergency data as soon as it is sensed, instead of the MDC sending it to sink at the end of the tour. We can also use a technique where we design the topology as a minimum hop transmission. Certain nodes with high energy are designated as polling points. The sensors move the data from the sensor node to the polling point and the polling point sends control signals to base station. The base station will dispatch the mobile collector to get the data from the polling points. In this scheme the cost of having multiple data collectors is avoided by making use of a single data collector. 3.3 Mobile peers - Mobile peers are ordinary mobile sensor nodes in WSN-MEs. They can be the source or they can be used to relay the messages in the network. Mobile peers are depicted in Figure 4. Their interactions are symmetrical because the sink itself might also be mobile. When a peer node is in communication range, it can transfer its own data and it can gather data from the other peer nodes while moving in the sensing area. Mobile peers have been successfully employed in the context of wildlife monitoring applications, such as tracking of zebras in [9][10][11]. Sensor nodes are attached to animals and act as peers, so they generate data and also carry and forward all data coming from other nodes which they have been in contact with earlier. When mobile peers get near a base station, they push all the gathered data. Redundant data are discarded by peers in order to save storage. The problem with using animals to collect the data is that the movement is unpredictable. This can be avoided by using a predictable robot or vehicle as suggested in the [1].Mobile peers can also be used for data collection in urban sensing scenarios [2]. Sample applications include personal monitoring (e.g., physical exercise tracking), civil defense (e.g., hazards and hotspot reporting to police officers) and collaborative applications (e.g., information sharing for tourism purposes). Here, sensors are not used primarily for monitoring the environment, but are rather utilized to characterize people in aspects of interactions and context (or state) information. An example is represented by handheld mobiscopes [12] where handhelds devices –such as cell phones or PDAs – gather data from the surrounding environment and report them to servers, which give services to users.

Fig.4. Architecture of a WSN-ME with mobile peers

IV. OVERVIEW OF DATA COLLECTION

4.1 Terminology Contact - ME is in contact with a sensor when they can reach out each other through wireless communications. In general, a contact happens when two or more nodes are in their mutual communication range.

Contact Time - The amount of time the nodes are in contact is called as contact time. Contact Area - The contact area of a node is defined as the region where that node can possibly be in contact with other nodes.

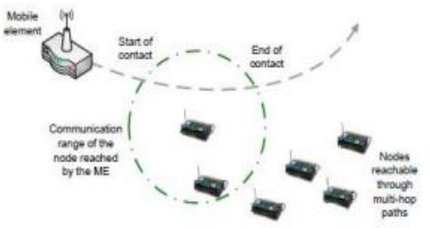
Discovery - Since nodes cannot communicate unless they are in contact, discovery is the process which allows a node to identify a contact, i.e., an ME in its communication range.

Data Transfer -Data transfer is the message exchange between nodes which are in contact. The data transfer covers only single-hop transmissions, which may involve several nodes, where at least one is mobile.

Residual Contact Time -The residual contact time is defined as the amount of time which is actually used for data transfer during a contact. The residual contact time is generally shorter than the contact time because the node has to find out the presence of an ME before starting the message exchange.

Routing - The process of data forwarding toward an ME, i.e., the selection of the path or the sequence of pair-wise message transmissions to the intended destination. The data collection is depicted in Figure 5.

Fig.5. Representative scenario for data collection in WSN- MEs



4.2 Phases

The phases for data collection in WSN-MEs are: discovery, data transfer and routing to MEs. Each phase has its own issues and requirements which we briefly described below. a. Discovery is the initial step for collecting data in WSN-MEs, since the presence of the ME in the contact area is generally not known at sensors. The aim of discovery protocols is to find contacts as soon as they happen, and with less energy expenditure. In other words, discovery must maximize the number of detected contacts and the residual contact time, while at the same time minimizing the energy consumption. Discovery permits the nodes to detect the presence of the ME while it is in the contact area. Since communication is possible only during contacts, discovery should not only be able to correctly detect the presence of the ME, but should also be timely, so that the contact time can be fully exploited. Indeed, contacts need to be detected even when they occur very infrequently. In order to reduce the energy consumption due to discovery, two complementary approaches can be used. First, it is possible to design (general) mobility-independent low-power protocols, which can detect MEs no matter what the mobility pattern is. Second, it is also possible to exploit some knowledge on the mobility of nodes, so that sensors can be active only when the ME is expected to be in contact. b. Data transfer immediately follows discovery. The goal of the data transfer protocols is to maximize the throughput – in terms of messages successfully transferred per contact – while minimizing the energy consumption. After the presence of an ME has been detected, actual data transfer has to be accomplished by using a data collection protocol. By data transfer, we mean the communication process between an ME and its one-hop neighbors. As a consequence, data transfer protocols have to be aware of the issues which result from mobility. In fact, the communication process is influenced, not only by the conditions prevalent in the channel, but also by the distance between the source and the receiver, which changes based on their speed. c. Routing to MEs is actually possible only when the density of the network is enough to allow (even partial) multi-hop routes. This is true for dense WSN- MEs, where routing to ME is always possible. This is also possible in case of sparse WSN-MEs, where nodes can organize as clusters that are disconnected. There are two main classes of routing techniques for uncontrollable MEs namely, flat routing and proxy-based routing. The routing paths to the ME are adaptively computed and updated in both the cases, so that it can be reached while navigating through the network. Flat routing is characterized by the fact that all nodes behave the same way, and, hence, there are no sensors with special roles. Proxy-based routing, on the contrary, selects a number of proxies or gateways among sensor nodes. Proxies bridge communications between the static sensors and the ME. In this case, routing is possible only when an ME is in contact with at least one node in the cluster. However, some nodes can be selected as bridges and act as gateways between the cluster nodes and the ME. In both cases, the aim of routing is to discover the best multi-hop paths – in terms of both delivery ratio and low energy consumption – towards either the ME or a node which can be in contact with the ME.

4.3 Impact of mobility

Different kinds of mobility can have significant impact on the phases of data collection. The aspect of mobility which has the most important impact on the data collection process is controllability, depending on whether the ME’s motion is autonomous or not. Two main patterns for uncontrolled mobility are deterministic and random. The deterministic mobility pattern is characterized by the regularity in the contacts of the ME, which enters the communication range of sensor nodes at specific and periodic times. This can occur when the ME is placed on a shuttle for public transportation, as in [3]. On the other hand, the random mobility pattern is characterized by contacts which take place not regularly, but with a distribution probability. For example, Poisson arrivals of a mobile element have been discussed in [4], while random direction ME mobility has been investigated in [13]. In general, anode should perform discovery continuously, so that it can ensure that the chances of detecting contacts is enhanced. However, when some knowledge on the mobility pattern of nodes can be exploited, the node can restrict discovery to the times where the probability of an ME being in proximity is high. Controlled mobility exploits nodes which can actively change their location, because they can control their trajectory and speed. As a consequence, motion becomes an additional factor which can be effectively exploited for designing data collection protocols specific to WSN-MEs. It should be noted that controlled mobility can make some issues related to data collection less relevant. For example, the discovery problem can be somewhat made simple, since MEs can be instructed to visit (individual) nodes at specific times. In addition, the duration of contacts has fewer issues, since the MEs can stop at nodes until they have collected all stored data. Anyway, different problems arise in this context, mainly related to how to schedule ME arrivals at sensors – which includes defining both the trajectory and the speed of the ME – while satisfying certain quality of service constraints (such as minimizing latency and buffer overflows) and keeping the energy consumption as low as possible.

V. CONCLUSION

In this paper we have discussed the techniques used for collecting data. The terminology concepts involved in mobile data collection were discussed and some of the advantages and disadvantages were also investigated.

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