Need For Energy Efficient Data Fusion in Wireless Sensor Networks

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Abstract

Wireless Sensor networks consist of large number sensor nodes that are deployed in some geographical area. The purpose of the network is to sense the environment and report the happenings in the area. With various potential applications wireless sensor network has many challenges. Energy is the main constraint of the wireless sensor network due to limited battery power supplied to each sensor node, so it is necessary to incorporate energy awareness into every stage of the network design and operation. In order to maximize the lifetime of sensor networks, the system needs aggressive energy optimization techniques, ensuring that energy awareness is incorporated not only into individual sensor nodes but also into groups of cooperating nodes and into an entire sensor network. The past few years have witnessed increased interest in the potential use of wireless sensor networks (WSNs) in applications such as disaster management, combat field reconnaissance, border protection and security surveillance. Sensors in these applications are expected to be remotely deployed in large numbers and to operate autonomously in unattended environments. To support scalability, nodes are often grouped into disjoint and mostly non-overlapping clusters.

Keywords: Wireless sensor networks; Clustering algorithms; Scalability; Network architecture; Energy aware design; Data Fusion, Cluster Head

1. Introduction

Wireless Sensor Networks (WSNs) are composed of a large number of sensor nodes (also known as motes), usually with reduced size. Each node has a processor, memory, sensors, a wireless communication module and a power supply. In the most common situations, the power supply is provided by batteries. These networks can be deployed in hazardous areas, where maintenance is a difficult task. Therefore, energy consumption is a major concern because in these situations it is very difficult to replace batteries. Recent advances in miniaturization and low-power design have led to the development of small-sized battery- operated sensors that are capable of detecting ambient conditions such as temperature and sound. Sensors are generally equipped with data processing and communication capabilities. The sensing circuitry measures parameters from the environment surrounding the sensor and transforms them into an electric signal. Processing such a signal reveals some properties about objects located and/or events happening in the vicinity of the sensor. Each sensor has an onboard radio that can be used to send the collected data to interested parties. Such technological development has encouraged practitioners to envision aggregating the limited capabilities of the individual sensors in a large scale network that can operate unattended [1]. Numerous civil and military applications can be leveraged by networked sensors. A network of sensors can be employed to gather meteorological variables such as temperature and pressure. Sensor networks are used to evaluate high temperature or pressure, or it could be used for object tracking or margin surveillance. It could be also deployed in factories in order to monitor poisonous or dangerous resources. It is also used to evaluate the weakness in building structures, or in vehicles and airplanes.

Figure 1 shows the architecture of a sensor node, it consists 4 major parts. Energy supply, sensor and analog to digital converter (ADC), processor and memory, last the transceiver .Basically transceiver are used to send and receive data simultaneously.

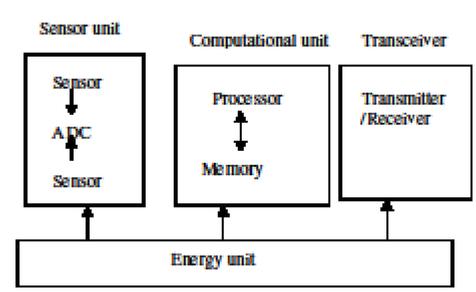

Figure 1 Sensor node architecture

The Energy supply is to power the sensor node. The sensor circuitry can convert physical quantities into an electric signal. The ADC changes the analog signal generated by the sensor into a digital signal and sends it to the processor. The processor can perform operations on the received digital signal, and stores it into memory.

Grouping sensor nodes into clusters has been widely pursued by the research community in order to achieve the network scalability objective. Every cluster would have a leader, often referred to as the cluster-head (CH). In addition, clustering has numerous advantages. It can localize the route set up within the cluster and thus reduce the size of the routing table stored at the individual node .Clustering can also conserve communication bandwidth since it limits the scope of inter-cluster interactions to CHs and avoids redundant exchange of messages among sensor nodes [2]. Moreover, clustering can stabilize the network topology at the level of sensors and thus cuts on topology maintenance overhead.

Data fusion is the process of combining observations from a number of different sensors to provide a robust and complete description of an environment or process of interest. Data fusion finds wide application in many areas of robotics such as object recognition, environment mapping, and localisation. As sensors are usually deployed in large numbers with high density, data fusion (or aggregation) offers a key strategy to curtail the network load, and hence, reduce energy consumption [3]. Besides energy; applications for WSN may also have to deal with time-constrained messages. The use of dense networks (i.e. with a high number of nodes per m2), with hundreds or thousands of nodes, may be an advantage. However, the usage of dense networks imposes more complex management approaches. Additionally, some data fusion techniques can deal with delays, message losses and discards, allowing greater flexibility in both the choice of the network technology and the communication approach used to disseminate data on the network.

The remainder of this paper is organized as follows: In Section 2, we opt to present the challenges of Wireless sensor network. Section 3 presents objectives of clustering in wireless sensor networks. Sections 4 describe Data Fusion in wireless sensor networks along with its advantages; disadvantages and parameters that measure the ability of data fusion Section 5 present Existing Data Fusion Techniques in Wireless Sensor Networks. Section 6 justifies the need for energy efficient data fusion. Section 7 concludes the paper.

2. Challenges in Wireless sensor network

Wireless sensor network assure a wide variety of application and realize these application in real world. Planning or designing a new algorithm or protocol address some challenges, these are as follows:

i. **Resource constraint:** Limited battery power of sensor node is an important constraint in a wireless sensor network, since Lifetime of sensor node is also recognizing by the power supply. Therefore energy (power) consumption is important design issue. Individual sensor node can store only small amount of data due to limited computation power and memory size constraints, hence there is a need to design lightweight and simple algorithm and protocols.

ii. **Ad – hoc deployment:** One of the advantages of wireless sensors networks (WSNs) is their ability to operate unattended in harsh environments in which contemporary human-in-the-loop monitoring schemes are risky, inefficient and sometimes infeasible. Therefore, sensors are expected to be deployed randomly in the area of interest by a relatively uncontrolled means, e.g. dropped by a helicopter, and to collectively form a network in an ad-hoc manner [4].

iii. **Quality of service*:*** Some applications of wireless sensor network are time critical. Which means the data should be delivered with certain period of time from the instant it is sensed, otherwise the data will become useless that’s why quality of service parameters is required for some applications.

iv. **Scalability:** Depending upon the application in wireless sensor network and the vast area to be covered, large population of sensors are deployed, it is envisioned that hundreds or even thousands of sensor nodes will be involved. Hence, Designing and operating such large size network would require scalable architectural and management strategies (algorithms/protocols).

v. **Fault tolerance:** In the hostile environment a sensor node may fail due to physical damage. If sensor nodes fails, the algorithm or protocol are working upon must accommodate these changes in network.

3. Objectives of clustering in wireless sensor networks

The very important feature of wireless sensor network is the need to correlated data. Grouping sensor nodes into clusters has been widely pursued by the research community in order to achieve the network scalability objective. The clustering techniques widely vary depending on the node deployment and bootstrapping schemes, the pursued network architecture, the characteristics of the CH nodes and the network operation model. Furthermore, a CH can aggregate the data collected by the sensors in its cluster and thus decrease the number of relayed packets. Clustering algorithms also varies widely in their objectives based on their applications requirements. For example if the application is sensitive to data latency, the length of the data routing paths and clustering are usually considered. The following are the popular objectives for node clustering:

i. **Load balancing:** Distribution of sensor nodes among the clusters is usually an objective for setups where CHs perform data processing or significant intra-cluster management duties, which further requires balancing of load to meet the expected performance goals [5]. CHs are picked from the available sensors to preferably form equal-sized clusters for extending the network lifetime, and also to prevent the exhaustion of the energy of a subset of CHs at high rate, which may result in prematurely making them dysfunctional. When CHs perform data aggregation, it is imperative to have similar number of node in the clusters so that the combined data report almost becomes ready at the same time for further processing at the base-station or at the next tier in the network.

ii. **Fault-tolerance**: WSNs will be operational in harsh environments in many of the applications, thus exposing the nodes to increased risk of malfunction and physical damage. Hence tolerating the failure of CHs is necessary to avoid the loss of important sensors' data. One of the most intuitive ways to recover from a CH failure is to re-cluster the network, but re-clustering not only places a resource burden on the nodes, but can also often destruct the on-going operation. Therefore, assigning backup CHs is the most notable scheme pursued in the literature for recovery from a CH failure. When the CHs have long radio range, neighbouring CHs can adapt the sensors in the failing cluster [6].

iii. **Increased connectivity and reduced delay**: Unless CHs have very long-haul communication capabilities, e.g. a satellite link, inter-CH connectivity, it limits the availability of a path from every CH to the base-station or be more restrictive by imposing a bound on the length of the path [7]. Hence some of the sensors assume the CH role, as one of the many variant of the connected dominating set problem. On the other hand, when data latency is a concern, intra-cluster connectivity becomes a design objective.

iv. **Minimal cluster count:** This objective is used only when CHs are specialized and resource-rich nodes [8]. In such network designs least number of CH's would be employed as they tend to be more expensive and vulnerable than other sensor nodes. For example, if CHs are laptop computers, robots or a mobile vehicle there will be inherently some limitation due to cost and complexity of deploying them e.g. when the WSN is to operate in a combat zone or a forest. In addition, the size of these nodes tends to be significantly larger than sensors, which makes them easily detectable, which is highly undesirable in many WSNs applications such as border protection, military reconnaissance and infrastructure security.

v. **Maximal network longevity**: Since sensor nodes are energy-constrained, the network's lifetime is a major concern; especially for applications of WSNs in harsh environments. When CHs are richer in resources than sensors, they are required to be placed close to most of the other sensor nodes in its clusters [9]. On the other hand, when CHs are regular sensors, their lifetime can be extended by limiting their load. In such cases Combined Adaptive clustering is a viable choice for achieving longitivity of network.

4. Data Fusion IN wireless sensor networks

The main aim of data fusion is to eliminates redundant data transmission and thus further enhance the life time of sensor nodes in wireless sensor network. Data fusion is the process of one or several sensors collecting the sensed result from other sensors and processes it (CH) to reduce transmission burden before they are transmitted to the base station or sink. The simplest form of data fusion function is duplicate suppression that is if two or more source sends same data to Data fusion node, then it will forward only one copy of the data. Data fusion is very necessary in wireless sensor network and basically involves direct transmission of fused data to the base station and is very expensive since base station may be located very far away and sensor nodes in a network needs more energy power to transmit data over long distance .Hence a better schemes is that fewer nodes can transmit data to this far distance and are called cluster head (CH) of individual cluster in wireless sensor network.

*A. **Advantage and Disadvantage of Data aggregation in wireless sensor network:-***

Advantage:

- Use of data fusion helps to enhance the robustness and accuracy of information obtained by entire network.
- Another advantage is that it reduces the traffic load and conserve's energy of the sensor nodes.

Disadvantage:

- The cluster head or the fusion node is responsible for fusing of data received from other nodes of the cluster and send this data to the base station .But if the cluster head or fusion node may be attacked by malicious attacker and is compromised, then the base station (sink) cannot ensure the correctness of the fused data that has been received by it.
- Another drawback is that in the existing systems, several copies of the fusion result may be sent to the base station (sink) by uncompromised nodes, resulting in increase power consumption at these nodes and may result in partial failure due to complete draining of energy along the path to base station.

***B. Performance measure**:-*

There are several important performance measures of data fusion algorithm, which are highly dependent on the desired application.

i. *Network lifetime*: The network lifetime is defined as maximum number of data fusion rounds possible before a specified percentage of the total nodes dies and the percentage depend on the application .If we consider an application, where all the sensor nodes is crucial and are working simultaneously, hence in such a case the lifetime of the network is number of round until the first nodes dies thus improving the energy efficiency of nodes and enhance the lifetime of whole network.

ii. *Latency*: Latency is also called as the delay and corresponds to how long it takes a data to travel from one end of the network to the other. It is used to evaluate time delay experiences by system in terms of data, means data send by sensor nodes and received by base station (sink).Basically delay involved in wireless sensor network is due to data transmission, routing and data fusion.

iii. *Communication overhead:* It evaluates the communication Complexity of the network fusion algorithm.

iv. *Data accuracy/Average data delivery ratio:* It is evaluated as the ratio of total number of reading received at the base station (sink) to the total number of generated.

v. *Average end-to-end delay:* The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

5. Existing Data Fusion Techniques in Wireless Sensor Networks

In sensor networks, data fusion is an essential service, which aggregates data from individual sensors in order to compute useful information, such as average of all the sensor readings, the maximum value among the sensor readings or the number of sensors that detect an event. For the purpose of energy-efficient in-network data fusion is mostly preferred in wireless sensor networks, where information flow from several sensors to a central server or sink. To effectively fuse the data, the data fusion techniques should be synchronized at various levels. Existing Data Fusion Techniques in Wireless Sensor Networks are as fallows.

i. ***Witness based data fusion**:* In this fusion technique, the data fusion node doesn't forward its result to the base station directly, but will compute the Message Authentication Code (MAC) of the result (they call the MAC a proof).

After receiving this information the data fusion node forwards the proofs to the base station. The data fusion node has to create false proofs on the invalid result if the node has to be compromised and wanted to send an invalid fusion result to the base station. [10].

ii. ***Dynamic data fusion****:* Fusion of data in dynamic applications is supported by an architectural framework known as DFuse and requires advanced fusion methods that bridge an important abstraction gap for such applications.

iii. ***Multi-sensor data fusion****:* Uses heterogeneous sensor nodes that can detect parameters like temperature, humidity, light, and Carbon Monoxide. The information about the environmental condition can be provided by using more than one sensor. These diverse sensor signals can be processed and fussed using the fuzzy rule based system. [11].

iv. ***Single Mobile agent (MA)-based autonomic data fusion:*** Here for autonomic data fusion, only one MA is used. In small scale WSNs this approach is effective but in the networks comprising hundreds or thousands of sensor nodes these solutions does not scale well.

v. ***Multiple MA-based autonomic data fusion****:* In order to fuse the data from WSN sensors, in this approach number of MAs are working parallel. Large scale WSNs also supports this fusion technique. The itineraries of individual MAs are derived using the relatively complex algorithms. [12].

vi. ***Mobile agent based clustering data fusion*****:** Here, two cluster head models are used to control the size of the clusters. All the sensor nodes in the detection region are divided into several clusters and the faulty nodes are removed through the partial results of data integration. The mobile agents are used in between the cluster heads for data fusion, and the path of the mobile agent is optimized. [13].

6. Need for Energy Efficient Data Fusion in WSN'S

i. By employing in-network processing and suitable data correlation, *redundancy* among sensed data and the network load can be reduced by exploring data correlation and employing in-network processing. [14]

ii. Though the wireless sensor networks have infinite scopes, they have limited node battery lifetime. Hence once a battery is deployed over an inaccessible area it is impossible, to replace the battery and this problem is off main concern. [15]

iii. Wireless sensor networks are also prone to failure, due to the effect of Sensors running out of energy, ageing or harsh environmental conditions. [16]Hence these issues of failure also need to be addressed.

iv. Consumption of energy in a sensor node is due to in-data acquisition, processing and communication for which the sensor nodes must rely on small, usually non renewable batteries, hence energy efficiency is considered as a most important design concern in sensor networks. The data transmission among the sensor nodes is reduced to a minimal level, So as to conserve energy in many of the applications. [17]

v. Due to the reason of limited detection range and reliability of each node, in wireless sensor networks, the monitoring range are made to overlap on each other, thus further increasing accuracy and robustness of the network, but resulting in sensor node maintaining redundant information. In order to save the energy and prolong the network redundant information should be reduced, hence each node transmits its detection data to the sink node in the routing. [18]

vi. The cost and continual power consumption of sensors are high since extra circuits are required in hardware based approach in order to detect or frustrate the compromised node. [19]

7. CONCLUSIONS

Wireless sensor networks (WSNs) have attracted significant attention over the past few years. A growing list of civil and military applications can employ WSNs for Increased effectiveness; especially in hostile and remote areas. Examples include disaster management, border protection, combat field surveillance. In these applications a large number of sensors are required, with careful architecture design and management of the network. The wireless sensor network consists of different sensor node that have very limited battery power, so main objective is to maximize the lifetime of sensor network by Grouping the nodes into clusters, and has been the most popular approach for support scalability in WSNs. Significant attention has been paid to clustering strategies and algorithms yielding a large number of publications. In this paper, we surveyed the need for energy efficient data fusion. We also study the desired cluster properties and clustering process. This paper gives the overview of current challenges in the wireless sensor network, In WSN the energy is basically consumed by data transmission, and approximately 70% energy is consumed by data transmission, hence data transmission should be optimized in wireless sensor network for maximizing the lifetime of network. Data transmission can be optimized only with the help of effective protocol and effective ways of data fusion (aggregation). In this paper we discuss various techniques of data fusion (aggregation) and also discuss the advantage and disadvantages of these techniques. With the help of these techniques we can reduce the transmission load and enhance the life time of the entire network.

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