Available online at http://www.journalijdr.com

International Journal of DEVELOPMENT RESEARCH

ISSN: 2230-9926

International Journal of Development Research
Vol. 07, Issue, 01, pp.11283-11286, January, 2017

Full Length Review Article

CIVIL AND ENVIRONMENTAL ENGINEERING IN WIRELESS SENSORS EXISTING IN EFFICIENCY CRITERIA USED IN GROUP1 AND GROUP2

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ARTICLE INFO

Article History:
Received 15th October, 2016
Received in revised form
20th November, 2016
Accepted 09th December, 2016
Published online 30th January, 2017

Key Words:
WSNs.

ABSTRACT

This WSN applications for civil and environmental engineering first of all deals with monitoring condition of the objects created by human, as well as the environmental objects. For a researcher these applications are interesting first of all because of a great number of various types of sensors used, and also because of variety of places where it is necessary to implement a network.

INTRODUCTION

Structural health monitoring

Structural health monitoring is the process of identification and localization of failures in different engineering systems with the help of the statistical analysis of the periodic measurements of various physical parameters. For the large objects where parameters have to be measured at the same time in a great number of places, WSNs are becoming indispensable. One of the most typical WSN applications for structural heath monitoring is bridges condition control. On famous Golden Gate Bridge in San Francisco Bay there is implemented a network of 64 sensors (piezoelectric accelerometers) which measure ambient vibrations with accuracy of 3 μ G sampled at 1 kHz [38]. The goal is to determine the response of the structure to both ambient and extreme conditions and compare actual behavior to design predictions. The network measures ambient structural accelerations from wind load at closely spaced locations, as well as strong shaking from a possible earthquake, all at low cost and without interfering with the operation of the bridge.

Volcanic Earthquake Timing

Predicting of eruption is a very difficult technical problem. One of the ways to solve this problem is monitoring of so called *primary waves* (P-waves) with the help of seismic sensors network. Specific algorithms are worked out which can detect hypocenter and seismic tomography, but they need fine-grained data to operate, more precisely sensor signals which are sampled at high frequencies (e. g., 50 to 200 Hz), collected upon a large territory; moreover, the data have to be transmitted in real time. It settles extremely stringent requirements to sensor network capacity that, in turn, has a negative effect at the cost and energy consumption of sensor nodes. Another problem is the difficulty of network deployment because sensors have to be installed in a volcano crater, what is not just costly, but also risky. Also, after installation sensors have to operate in a harsh weather conditions. In the project *Autonomous Space In-situ Sensor web* (OASIS) [39], where monitoring of the Mount St. Helens (Pacific Northwest region of the USA) was carried out, the problem of WSN deployment was solved due to sensor nodes being air-dropped and self-organizing a network. Also the researchers have used a special hardware design for sensor nodes. It were 3-leg "spider" sensor nodes, which are about 4-foot (122 cm) tall including the lifted antenna and weigh about 70 pounds (32 kg). Such design was able to support air-drop deployment and survive in the harsh volcano environment.
In the work [40] it was suggested to reduce the cost and increase energy efficiency of WSN in the following way. Instead of transmitting raw measurements to the central point, it was proposed to implement hierarchical architecture where a large number of inexpensive sensors were used to collect fine-grained, real-time seismic signals while a small number of powerful coordinator nodes process collected data and pick

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accurate P-phases. This approach was successfully implemented for the OASIS project, and made it possible to increase the sensor nodes lifetime from 2 to 6 months.

Decision making in sensor networks

While deploying a WSN, the system designer has to take care of many issues which require selection between several alternatives. He or she needs to determine:

- network topology,
- number of sensor nodes,
- relative position of elements,
- security model,
- hardware and software for both sensor nodes and servers.

The final goal of these choices is making the WSN solve all the problems that are set for it effectively. At the same time, the expense of the limited resources (e.g. financial costs of deploying and maintenance of a WSN) should be kept within established limits.

In the same way, during WSN maintenance many decisions have to be made, for example:

- placement of new sensors in case of WSN expansion,
- procedure of battery replacement in the sensor nodes,
- necessity of software update and hardware upgrade.

Moreover, while designing the WSN elements, it is also required to choose electronic components, modulation methods, cryptographic schemes, frequency channels, etc. Finally, the operating of every WSN itself is connected with decision making on the level of sensor nodes and servers:

- route selection for data delivery (routing),
- decisions about sleep mode or active mode transition,
- sensor node identification and evaluation of the trust level of the sensor nodes.

The algorithms able to make such decisions are built into the sensor nodes' firmware.

Thus, during designing a WSN, its deployment and maintenance various decisions have to be made at the following levels:

- **System level**: the decisions made while deploying, upgrading, modifying and maintaining a WSN;
- **Element level:** the decisions made by the developers of WSN elements' software and hardware;
- **Operation level:** the decisions made automatically by the WSN elements' software/firmware.

As these three levels have different *decision making units* (DMUs): it can be both people (system analytics, developers, designers) and software/firmware working automatically, — it is very important to provide the consistency of their decisions. For that reason, it is required that DMUs at all levels use the same set of efficiency criteria for assessment of alternatives. All the requirements to WSN or its individual components have to be expressed in terms of these criteria. As soon as this is done, different alternatives can be compared using the selected criteria to find the one that fits best for the task to be solved. Thus, working out the set of efficiency criteria allows to formalize the decision making process and, thus, to make it more objective. The set of efficiency criteria together with the rules of application of these criteria forms an *efficiency assessment system*.

Group 1. Network lifetime

Battery replacement is a complex and expensive operation almost in every WSN, because the sensor nodes are numerous and they can be situated in places that are difficult of access. That is why one of the most important WSN efficiency criteria is the network lifetime, i. e. the time the WSN remains alive after the deploying of [41]. Network lifetime can be defined in various ways, because the meaning of the statement "the network is alive" depends on the requirements for this network. In the [41] work some of the most frequently used definitions are given:

- The time before the failure of the first sensor node;
- The time before the failure of a certain fraction β of total number of sensor nodes;
- The time before one of the following events happen (which is earlier): failure of one of the so-called "critical" sensor nodes or failure of k "non-critical" sensor nodes.
- The time before the failure of one of the sinks;
- The time before the failure of all the sensor nodes;
- k-coverage: the time while the whole service area is covered by at least k sensor nodes. The "service area" can mean some area, volume or a discrete set of points which the DMU would like to monitor;
- α-coverage: the time while α percent of the service area is covered by at least one sensor node;
- An important special case of the previous two definitions: the time while the whole service area is covered by at least one sensor node;
- The number of successfully transmitted packets. As opposed to other definitions, this value is measured not in hours or days, but in dimensionless units;
- The time before the fraction of the sensor nodes that have a path to the base station is below some threshold value α;
- The time before the probability of some specified event detection by the WSN is below some threshold;
- The time while the maximal connected sub graph of the network graph contains more nodes when N.

Network lifetime, defined in any of the following ways, belongs to the system level of decision making. But network lifetime is related in many respects to the lifetime of individual components of the network, which, in its turn, depends on the energy content of batteries and power consumption in different modes: transmission, reception, idle and sleep. Moreover, network lifetime depends on algorithms and protocols for data transfer, processing, routing and other operations. For instance, the choice of more efficient routing protocol can result in significant increase in network lifetime without modifying the hardware implementation of the sensor nodes. That makes it possible to use different parameters related to network lifetime as efficiency criteria both on the element level and the operation level. In the former case that means that the firmware can take into account the amount of energy that should be needed to execute every action.

Group 2. Criteria related to data processing

In many WSN applications the sensor nodes do not just make measurements and send the results to the central node, they perform data processing, too. The algorithm of this processing strongly depends on the application, but it always involves two basic operations: data storage and retrieval. Thus, expenses to these operations can be used as efficiency criteria of a WSN.
To calculate the numerical value of the criterion, we can measure either the mean time needed for one operation of data storage and search, or the amount of messages sent to the network during the operations. Although all of these criteria are used for assessing the efficiency of data storage and processing in a WSN, there are differences between them: the meantime is directly connected with the speed of processing the users' requests, and the amount of messages mostly assesses the efficiency of spending the resources during the operations. To achieve the best values for these criteria the DMU should take care of choosing the best network topology and the best way of organizing data storage (e. g. indexing, data replication, optimization of requests), which would provide high speed of data reading and data recording. Moreover, there may be need of using or developing the request algorithms that minimize the amount of messages sent to the network. On the element level, one may need integrating faster storage devices into the WSN. On the operation level, the WSN elements can, for example, give priority to the packets related to storage or searching the data and their responses. That would reduce the mean time of data processing.

Conclusion

All the parameters of the *quality of service* (QoS) used for other networks could be applied to WSN: data throughput, the level of bit and packet losses and errors, the reliability availability ratios [41]. In a number of applications connected with real-time transferring and processing of information the delay variation (jitter) may be important. Among the efficiency criteria, the service area should be mentioned particularly. Depending on the problem, either the volume, area, or length of the service area can serve as an efficiency criterion; in some cases, it can be more convenient to choose several objects the WSN should observe and express the size of the service area through the amount of objects covered by the network. As in the previous cases, each efficiency criterion related to the QoS on the system level has a corresponding criterion on the element level. The WSN service area is a function of the service areas of single sensor nodes. The service area, the error probability, the reliability and availability indexes, the jitter can all be determined for single sensor nodes, for communication links between them, and sometimes for different algorithms. On the operation level different indicators can serve as corresponding efficiency criteria (the signal level, the distance between different sensor nodes, the level of battery charge, etc.). Such indicators serve for the automatized making of such decisions as choosing the best route, estimating the priority of different kinds of traffic or choosing the degree of data compression.

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