Wireless Sensors placement for Structural Health Monitoring-A survey

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Abstract- *Wireless Monitoring has emerged in recent years as a promising technology for environmental health monitoring. It is implemented for the structures (e.g., bridges, buildings) to monitor their operations and health status. Wireless sensors are predominant technology for SHM applications that are easily deployable than wired networks. The group of Wireless sensors (WS) installed in a structure could provide sufficient amounts of pragmatic data for monitoring structural health. SHM brings new challenges to WSNs: engineering-driven optimal deployment, a large volume of data, sophisticated computing, and so forth. The faults caused by sensors are communication errors, unstable connectivity; battery down due to large usage of the sensors without any placement planning may greatly affect the performance of sensors while monitoring. This paper surveys related research of placement of the sensors in the structure in order to capture the health status without any interruption.*

Keywords:- energy-efficient, sensor placement, Structural Health Monitoring, Wireless sensor networks

I. INTRODUCTION

A network is a group of two or more computer systems linked together. There are two types of computer networks. They are wired and wireless networks. The topology, protocol and architecture are the important characteristics of the networks. In wireless networks, the computers or any wireless devices are connected to form a network without wires. A wireless network is any type of computer network that uses wireless data connections for connecting network nodes. Each system may also acts as nodes or as sensors. Here comes a sensor networks. When sensor devices form a network is called a sensor networks.

Wireless Sensor Network (WSN) are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, vibration, etc. and to pass their data through the network to base station. Wireless Sensor Networks (WSN) consists of a large number of sensor nodes. The sensor nodes can be deployed either inside or very close to the sensed phenomenon. A sensor is the device which converts a physical phenomenon and also sound phenomenon to the electric signals e.g. heat, light, motion, vibration etc. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, structural health monitoring, and so on. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network.

WSNs should self-configure and be robust to topology changes (e.g., death of a node). It also maintains the connectivity between sensor nodes and the base station. It also ensures connectivity over certain range.

Some of the characteristics of the sensor networks are:

- ✓ Requirements: small size, large number, tether-less, and low cost.
  - ➢ Constrained by
    - ▪ Energy, computation, and communication
- ✓ Small size implies small battery
- ✓ Low cost & energy implies low power CPU, radio with minimum bandwidth and range
- ✓ Ad-hoc deployment implies no maintenance or battery replacement

Structural Health Monitoring (SHM) [1] is a developing technologies and systems that assess originality of structures such as buildings, bridges, aero-space structures. Most existing SHM deployment use wired sensor systems to monitor structures from various locations (induced by ambient sources *e.g.*, moving vehicles, winds) for analysis. Installing a large scale wired sensor system may sometimes take several weeks and may often turn out to be very expensive. A wireless sensor network based monitoring system promises enormous benefits such as ease and flexibility of deployment in addition to low maintenance and deployment costs.

The objectives of SHM are to monitor the health status (i.e., damage) of a structure, and supply both long-term monitoring and immediate response to unusual incidents, e.g., earthquakes. In real, it is often difficult to achieve these objectives in WSN-based SHM, due to requirements of SHM.

The performance requirements of wireless sensors intended for structural monitoring are more. First, the wireless sensors must be inexpensive in order to make economically reasonable dense arrays of sensing units, perhaps hundreds of nodes in a single structure. Because wireless sensors have a narrowed power supply, usually an on-board battery pack, they must be able to operate with low power consumption and be equipped with efficient power management techniques. More effective computing methods for damage detection can be achieved using wireless sensing nodes capable of distributed in-network computation. To be power efficient, such a device requires the minimization of communication between sensors as, generally, the radio is the greatest consumer of power within the unit. The wireless monitoring systems must be completely scalable, not restricted in terms of size or number of wireless sensor nodes. Finally, the survey on the placement of the wireless sensors networks without affecting in the monitoring process of the structure. The group of Wireless sensors (WS) installed in a structure could provide rich amounts of empirical data for monitoring structural health.

II. NEED FOR STRUCTURAL HEALTH MONITORING

The need of structural health monitoring is very important for the bridges and buildings to avoid the destruction. They are

- a continued deterioration of the infrastructure
- restoring serviceability of the bridge after an extreme event; and the introduction of new materials in bridge construction.

A health monitoring system that detects changes that may indicate damage or degradation in the civil structure does not go far enough to satisfy the needs of the user. SHM combines a variety of sensing technologies with an embedded measurement controller to capture, log, and analyze real-time data. SHM systems are designed to reliably monitor and test the health and performance of structures.

III. LITERATURE SURVEY

In this section, the sensor placement is the main issue for monitoring. Here various authors have been proposed the different methodologies for the wireless sensor placement issue in structural health monitoring.

A. Health Monitoring of Civil Structure using Wireless Sensor

In this study [9] increased knowingness of the economic and social effects of aging of the structure, deterioration and extreme events on civil infrastructure has been coupled by recognition of the need for advanced structural health monitoring and damage detection tools. Structural health monitoring techniques depends on changes in dynamic characteristics have been studied for the past three decades. When the damage is significant, these methods have some success in determining if damage has occurred. Most global health monitoring methods are centered on either finding shifts in resonant frequencies or changes in structural mode shapes. Early health monitoring found that loss of a single shape in a structure can result in changes in the fundamental natural frequency. Next level of sophistication of health monitoring approaches proposes to find the location of cracks based on the natural frequency drift. Most of these methods stipulate that the only form of damage is cracking, and by extension loss of cross sectional areas. These assumptions limit the method to some very special situations. These new sensors include Micro-electromechanical System (MEMS) devices for accelerometers and other application, nuclear magnetic resonance (NMR) encapsulates to detect chloride ions. LIDAR to capture 3D position of objects.

B. High Quality Sensor Placement for SHM Systems: Refocusing on Application Demands

It focuses [10] on the sensor placement on the civil requirements and on the computer science requirements. It provides the placement quality of the candidate locations of the sensors in step by step manner. Then optimize the system performance, by considering networking connectivity and data routing issues; with the objective on energy efficiency. For this, this process leads to the introduction of the new method called Sensor Placement using EFI method (SPEM). The deployment of the sensors must be in EFI method and not be in regular forms (i.e.) grids or tree form. The Effective Independence placement method gives the appropriate location of the sensors. It shows the topology control, data routing and energy efficiency which can be integrated with the SHM framework. But it have some disadvantages, is that the computer requirements constraints should be adjusted with the civil placement quality constraints which leads to missing of some optimal locations in the structure. It also fails to recover from fault in wireless sensors while monitoring.

C. Relay Node Deployment Strategies in Heterogeneous Wireless Sensor Networks

It focuses [13] on the sensor deployment issue in WSNs. The number and positions of sensors determine the usability of a sensor node in terms of coverage, connectivity, lifetime, cost, etc. Here, the impacts of random device deployment on connectivity and lifetime in a large-scale heterogeneous WSN. The deployment of the RNs can have a significant impact on connectivity and lifetime of a WSN system. The former solely aims at balancing the energy consumption rates of RNs across the network, thus prolonging the system lifetime.

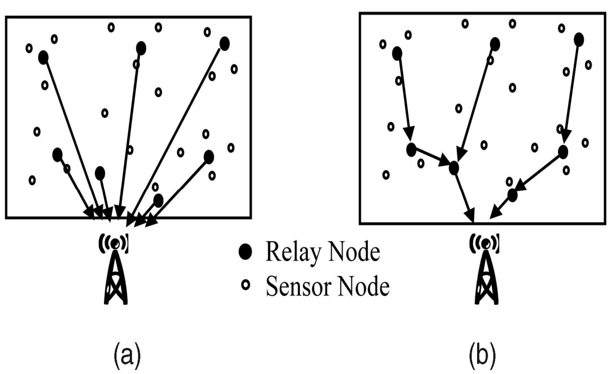

Fig a) [13] the RNs which are away from the BS will dissipate energy speeder than the RNs closer to the BS due to the larger transmission distance. As such, the nodes are away from the BS become unusable, while a large part of energy is still left on those close to the BS. In Fig b) [13] where RNs adopt a fixed transmission transmit data to the BS via multiple intermediate RNs in Fig. b, RNs closer to the BS will consume energy speeder than RNs away from the BS. The reason is because traffic is built up on RNs closer to the BS as it is relayed from far to near.

D. Traffic-Aware Relay Node Deployment: Maximizing Lifetime for Data Collection Wireless Sensor Networks.

It gives [12] where the sensors have to be placed at critical locations to fulfill civil engineering requirements. The raw data collected by the sensors can then be route to a remote base station (the sink) through a series of relay nodes. In the wireless communication, the processing time of the relaying nodes depends on the traffic volume and communication range. The deployment of the sensors have to not only ensure the connectivity among the neighboring sensors and sink nodes, but also accommodate the heterogeneous traffic flows from different sensors and many-to-one traffic pattern. It introduces the two strategies. First, in single traffic flow case, the optimal solution is to start from the source and evenly deploy the R-nodes (Relay) with a distance that should minimize the maximum energy consumption. Second, in multi traffic flow case, the solution is to start merge all flows into one and also apply the optimal scheme of single source with single traffic flow. But the disadvantage of the method is that the lifetime of a relay node is severely narrowed by its battery power, and the power consumption, in turn, closely depends on the communication distance. Fail to take over the drained out sensor while relaying. It is centralized approach. The performance of the Relay nodes may fail while monitoring the health status of the structure

E. Optimal Deployment Patterns for Full Coverage and k-Connectivity (k≤6) Wireless Sensor Networks

It gives [14] the study of deployment patterns to achieve full coverage and k- connectivity under different proportions of the sensor communication range to the sensing range. For the deployment introduces the polygon-based methodology to prove the optimal deployment patterns to achieve 3-connectivity, 4-connectivity, 5-connectivity and 6-connectivity under all ranges. When k is above the range of 6-connectivity range ($k > 6$), this patterns are complicated and cannot construct the networks that is disjoint union of the atomic deployment polygons. The k-connectivity patterns based on the constraints are coverage constraints and connectivity constraints. The coverage constraints are the area of atomic Polygons and the connectivity constraints are embodied in the polygons edge length. The deployment of sensors is the collection of individual deployment polygons, which form a tessellation over a region. The tessellation is the biggest area with the number of vertices constructing polygons. In this method there is the chance of missing some region when the placement of the sensors. It may affect the performance of the sensor while monitoring the health status.

F. Energy and bandwidth-efficient Wireless Sensor Networks for monitoring high-frequency events

[5] Wireless Sensor networks can be deployed to detect the events at high or low sampling frequency is easily detected by the sensor destination node or mote. The proposal of the new scheme event-sensitive adaptive sampling and low-cost monitoring used to address the two problems. By using adaptive e-sampling rate the intervals are switches between high frequency and low frequency intervals to reduce the resource usage. After analyzing the content of the frequency e-sampling gives the event identification algorithm which is suitable for decentralized computing. Using these approaches

unwanted/unnecessary data cannot be transmitted to the destination or Base station. This approach will decrease the energy consumption and prolong the life time of the wireless sensors.

G. Energy harvesting for Structural Health Monitoring Sensor Networks

The main issue [6] of the sensor networks is the placement with energy efficient sensors for structure monitoring. Here proposes the energy harvesting for the low-power structural health monitoring sensing systems. The SHM sensor networks give some of the paradigms related to the power requirements and power optimization methodologies. Some current SHM sensor modalities are acceleration, strain, Lamb wave, and electrical impedance for energy harvesting techniques. For these methods in SHM energy harvested techniques are implemented. Energy harvesting is the technique that extracts the energy from the environment and converting it into the electrical energy. If external energy in the surrounding space can be harnessed, this captured energy can be utilized to extend the life time of the power supply and extensively it also provide unlimited energy for the sensor device that will be involved in the monitoring process. This approach gives the state-of –the-art energy harvesting methods for some sensor modalities.

H. Energy-Efficient and Fault-Tolerant Structural Health Monitoring in Wireless Sensor Networks

Wireless sensor networks (WSNs) have become an increasing platform for structural health monitoring (SHM) due to relatively low-cost etc. But, the challenge of effectively monitoring structural health conditions using Wireless sensor devices and sensor faults has not been studied earlier. In this paper [2], focus on tolerating sensor faults in WSN-based SHM. Designs a distributed WSN framework for SHM and then test its ability to use with sensor faults. In distributed method all the sensors need to be synchronized. The sink node handles the faulty detection process based on the signals received from all other sensors finally; sink node chooses the sensor with signal with maximum independence for fault detection. Besides, the detection of the sensor should be immediate and online since a sensor does not need to wait for the signals from sensor nodes. Moreover, the detected faulty signal set is not forwarded toward the sink; thus, the communication cost is relative low. The energy cost becomes lower. This approach is used for the fault tolerance energy efficient structural health monitoring using wireless sensor networks.

I. Sensor Placement for On-orbital Modal Identification of Large Space Structure via a Genetic Algorithm

The placing sensor [8] is the challenging part in SHM for monitoring the status of the health. A discrepancy of the Genetic Algorithm (GA) is used to place sensors in optical location on a Large Space Structure (LSS) for the identification of the mode shape. Here, new operator is introduced for the reproduction schemes of the Genetic Algorithm. The new operator is forced mutation. These changes are introduced to improve the convergence of the algorithm and also to find the near optimal locations. The GA system is apply to the sensor modal identification by representing locations as an integer (the gene) and also the sensor locations are consolidated as an integer string (the chromosome). These are represented using Fisher Information Model (FIM). The GA modified the parent selection and children reproduction methods that have been successfully applied to the sensor placement for the modal identification of an LSS. Since the GA is a global method for finding the optimal location, GA can find to lead to the simple error between the real target mode response and the estimated response.

J. Energy – aware Node Placement in Wireless Sensor Networks

The main issues for the wireless sensor networks [3] are the placement of the sensor problem. Here, constrained multivariate nonlinear programming problem is introduced for the determination of both the locations of the sensor nodes and data transmission pattern. There are two main objectives [4] are to maximize the network lifetime and to minimize the application-specific total cost, in a given region. In this paper, examine many-to-one wireless sensor networks, where the information are collected from all nodes is aggregated to a sink node. It includes the collection of the traffic information and feeding the data to the traffic control center, and gathering the data from the individual sensor nodes and aggregating towards a central controller. Some nodes are closer to the sink nodes have heavier traffic load and these consume the uneven power consumption and it distribute among the different sensor nodes. Using this node placement scheme will have the considerable impact on the lifetime of the whole sensor networks. This approach can be applied to different levels in hierarchical sensor networks.

IV. CONCLUSION AND FUTURE WORK

There have been a several challenges in Wireless Sensor Networks for structural health monitoring. The placement of the wireless sensors on the structure is to collect the status of the health and to pass the status to the base station without any intervention in communication. Using wireless sensor networks, the communication among the sensors are efficient than wired sensor. The future work is to improve the wireless sensor efficient by handling the faults in wireless sensor.

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