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Condition Monitoring in Railway Using Wireless Sensor Network

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ABSTRACT

The range of sensing technologies has expanded rapidly, as sensor devices have become cheaper. It tends to a rapid expansion in condition monitoring of systems, structures, vehicles, and machinery using sensors. The core factors are the recent advances in networking technologies such as wireless communication and mobile ad hoc networking coupled with the technology to integrate devices. WSNs can be used for monitoring the railway infrastructure such as bridges, rail tracks, track beds, and track equipment also monitoring such as chassis, bogies, wheels, and wagons. Condition monitoring reduces human inspection requirements through automated monitoring, reduces maintenance through detecting faults before they escalate, and improves safety and reliability. This is vital for the development, upgrading, and expansion of railway networks. This paper surveys these wireless sensors network technology for monitoring in the railway industry for analyzing systems, structures, vehicles, and machinery. This paper focuses on WSN technology to reduce the accidents using sensor devices. It also identifies network topologies.

Index Terms: *Asset management, condition monitoring, decision support systems, event detection, maintenance engineering, preventive maintenance, railway engineering, wireless sensor networks (WSNs).*

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1. INTRODUCTION

A basic part of the management will be condition monitoring. Condition monitoring detects and identifies the process of becoming progressively worse in structure and infrastructure before it causes the failure or prevent rail operation. In recent year, networking technologies such as wireless communication and mobile networking coupled with the technology to integrate devices have rapidly developed. Wireless sensor uses monitor infrastructure, structure and machinery. Each sensor node generally has a radio transceiver, a small microcontroller and energy source, usually battery. WSNs and data analytics allow the railway to turn data into intelligence. They provide decision support through continuous data capture and analysis to identify faults. WSN monitoring can be used to maintain process tolerance, verify and protect machine, system and process stability, detect maintenance requirements, minimize downtime, prevent failure and save business money and time. Sensors are located away from energy supplies, thus require either batteries or some form of local energy generation to power them. If there is error in transmission across the WSN, then data may be missing. It describes WSNs for railway condition monitoring focusing on systems described in the academic literature. Node refers to whole sensor unit that comprises the sensor power supply a data transmitter/receiver.

Figure 1.1, shows a typical WSN setup for railway condition monitoring. Sensor devices are mounted on boards attached to the object being monitored; examples include track, bridges, or train mechanics. One or more sensors are mounted on a sensor board (node). The sensor nodes communicate with the base station via wireless transmission protocol; examples include Bluetooth and Wi-Fi. The base station collates data and transmits it to the control centre server possibly through satellite or GPRS. There are variations on this setup. In some systems, the sensor directly communicate with the server rather than via base station. In other systems, the user accesses the data directly via the base station. In simple condition monitoring, sensors monitor the condition of a structure or machinery. If the sensor reading reaches a fault condition, then an alarm is activated. However, this simplistic approach may lead to a large number of false alarms and missed failures. It only provides local analysis but does not take advantage of the superior capabilities when the sensors are networked and their data processed collectively.

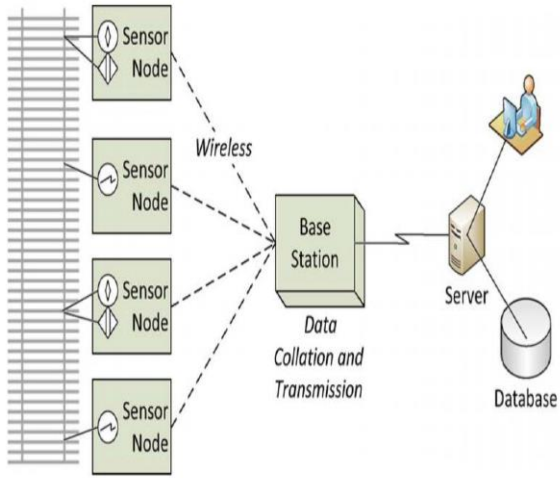

Fig-1.1:Typical WSN setup for railay condition monitoring

2. SENSOR DESIGN

There are a multiple types of sensors used in railway condition monitoring for analysing different aspects of structure, infrastructure and machinery. Device contains the transducers which convert energy from one form to another. Most railway sensors fall under the umbrella type micro electromechanical system (MEMS). MEMS are small, integrated devices, or system that combines electrical and mechanical components. They are cheap and efficient. Sensor deign required a trade-off between functionality and power consumption. Sensor must receive power from either batteries or local energy generation.

2.1 Measurement Sensors

It is one type of sensors that used in railway condition monitoring and the measurement produced. Sensor devices may also return additional measurements such as temperature and humidity and sensor data can be combined with the measurement from other systems.

2.2 Sensor Node

Sensor devices are mounted on boards. It from the platform combining mobile computing and wireless communication, (media access control (MAC), routing and error detection) with sensor devices. If the date sampling rate is low, then the memory and transceiver power can all be low.

2.3 Sensor Power

Sensor node use batteries as their energy source. Batteries have a finite life. Fitting and replacing batteries is not always possible in remote and inaccessible railway location. The node may also be embedded in the monitored structure or mechanics of a train, where no access to batteries or wired connection is possible. They stored the energy using super
capacitors and the sensors only drew energy when sufficient stored energy was available.

Solar power is easy way to generate energy. Solar panel used to generate energy. Sunlight varies on a daily basis, and sunlight is very limited in winter months in many global regions and power generation is affected by bad weather. So that they produced accelerometers and gyroscopes using power with battery backup.

3. NETWORK DESIGN

WSNs enable continuous real time capture of data. They use low power sensors powered by batteries although finder is investigating alternative power supplies such as local energy generation. Hence the network to enable data capture has to be carefully designed to overcome these factors and prevent transmission error, missing data or corrupted data.

3.1 Base Station

The base station controls the sensor node and act as a gateway for data transmission to a remote server. The sensor nodes use short range communication such as Wi-Fi or Bluetooth to transmit data to the base station. The base station uses long range communication such as GPRS or satellite to transmit

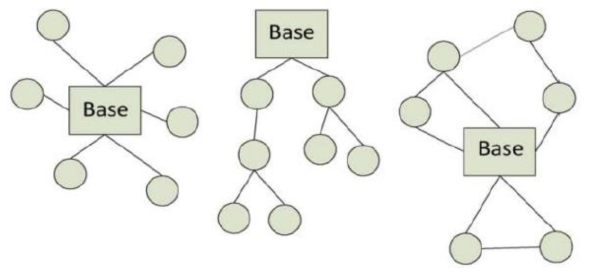

Fig-3.1: Star, Tree, Mesh Network Topology where circle represent sensor node and the boxes are base station.

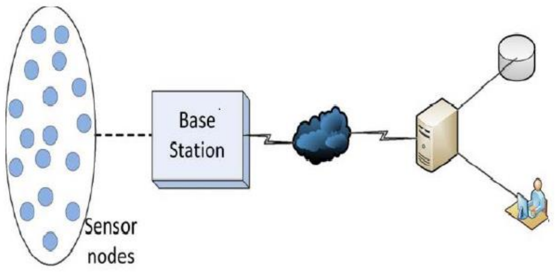

Fig-3.2: In typical WSN, the sensor nodes are arranged in a star, tree or mesh topology and transmit data to the control centre via longer range communications.

3.2 Relay Node

Sensor nodes are energy constrained, thus only having a short transmission range. If they cannot reach the base station, then relay node may be used. This is issue present in environment such as railway tunnel, along the length of trains or along the
railway track. Sensor nodes that function as relay node to transmit data.

3.3 Network Model

WSN has some layers and define their function to transmit data from the senor node to base station. The five layers from lowest to higher are the physical layer define how the sensors transmit their data to network. The data link layer specifies the network topology and connect node to each other. The network layer routes the data through the network as packets. The transport layer control the sending and receiving data. Application layer allow application software to access the data.

3.4 Network Topology

In network topology, star, tree, mesh topologies are present. In star topology, there is a single base station that can send or receive messages to or from a number of remote sensor nodes. The nodes can only communicate directly with the base station but not with each other. This topology is simple. A tree topology is a hierarchy of nodes, with the root node serving client node and it serves other lower level nodes. In a tree, node can be grouped at each level. Messages pass from the sensor nodes through the tree branches to the root. Sensor node can communicate with their parent. In mesh topology, any node in the network can communicate with any other node in a network that is within transmission range

3.5 Communication Medium

There are many communication techniques used in WSNs in railway[1]. The station transmits gathered data back to the control centre, and this required long range communication. WSNs can use technologies based on standard mobile telephony such as Bluetooth, GPRS or broadband techniques such as Wi-Fi, wireless personal area networks[7]. Both WPANs and WiMax can connect many devices in a mesh topology, where any node can communicate with any other connected node. Wi-Fi, WPANs and WiMax allow communication at much higher speeds and bandwidths than mobile telephony is cheaper to set up.

Mobile telephony has better coverage and range than Wi-Fi and WPANs. WiMax can operate long distances. GSM-R (Global system for mobile communications-Railway), is designed for information exchange between trains and control centres. Its main advantages are its low cost and worldwide availability. Another common for railway is the radio system which is stand for data communication for closed user groups. It is private mobile telephone system and is easily using a series of antennas at stations or control centre along the railway routes.

3.6 Transmission and Routing

Sensor nodes use the greatest amount of energy during data communication. The transceiver in the sensor node contains frequency synthesizers, mixers, voltage control oscillators, phase-locked loops, and power amplifiers. These all consume power. Thus, data transmission and routing has to be carefully designed to minimize the energy usage. When messages are transmitted through tree or mesh net- works, they have to be routed to ensure they pass from source to destination (sensor node to base station). If the base station fails in any topology, then the routing also fails. The sensor nodes need to transmit data reliably via the network despite having only limited power supply available. Hence, energy efficiency and reliability are both vital for WSNs.

4. MONITORING SYSTEM

The data from sensors is treated as a time series, where data are produced continuously. Where data is generated, for example generated every time a train passes. Condition monitoring can be performed continuously or periodically. Continuous monitoring should detect a problem straight away but it is often expensive, which is a problem for WSNs where the network components need power and the sensor node are very noisy. Periodic monitoring is cheaper, uses less energy and allows time for data cleaning and filtering but a problem will only be analysed at the next processing run. One very important factor in this topological variation is the mobility of sensor nodes. It subdivided the communication network for their WSNs into two: the fixed network relates to sensor nodes in fixed locations such as bridges, tunnels and special points, whereas the movable network relates to sensor nodes attached to locomotives or rail wagons. Movable sensors can monitor the whole track length travelled by the train but only monitor the section of the train where the sensor nodes are attached. In contrast, track mounted (fixed) sensor nodes can measure the whole train as it passes but only at specific points where the nodes are mounted on the track.

4.1 Fixed Monitoring

Sensors are objective and can provide data from all of the structure. Wired sensors can be used for monitoring. However, wired systems are expensive, inflexible, time consuming to
install, and the trains have to be stopped during installation. The early fixed WSNs is simple such as attaching sensor nodes to the rails to monitor the rail temperature or low-voltage warning sensors that monitor the power supply. These systems simply generated a binary output. For the temperature sensor, a rail expert uses alarm for rail temperatures to set the alarm levels for "amber" and "red" warnings. If an alarm level was reached, then the system sent an SMS alert. Modern WSNs provide sensor data to examine structural changes and to improve the durability of structures. Hence, WSN monitoring should reduce the overall maintenance costs.

4.2 Movable Monitoring

Movable condition monitoring is used to transport systems, allowing the early detection and analysing of problems. The sensor nodes used for movable monitoring are mounted on the train bogies or carriages. These locations are used in high levels of vibration thus, the sensor nodes have to be protected. They used shock absorbing material around circuit boards to protect them and also separate battery from the circuit board, mounted the antenna separately from the circuit board, and used flexible cables. Movable rail monitoring can transmit the data from the movable nodes to a static node when the static node is in range. Transferring data from the movable nodes to a static node it happens when a train stops in a station. The movable nodes can form a network with a base station within the network. If the nodes form a network on the train, then the base station is mounted on the locomotive, where power is available to power the data transmission. This transmits the data over a suitable mechanism, such as satellite or GSM.

5. FUTURE WORK

There are a number of promising directions for further research in condition monitoring in the railways which provide near real-time information and alerts. For example, train monitoring data can be combined with route data and GPS data. If multiple trains detect a vibration fault at exactly the same GPS location, then the fault is more than likely in the rail infrastructure such as uneven track. However, if only one train identifies a vibration at a particular GPS location, then the fault is more likely to be in the rolling stock[9]. As sensors become cheaper and easier to fabricate, then their availability and use will increase[7].WSN comprising many tiny wireless MEMS (smart dust), which are able to collect, process, and transmit data from light to vibrations. Vast numbers of these sensors can be placed inside a wagon, for example, where they can measure temperature, humidity, or vibrations. The number of sensors will increase in the future, and the number and distribution of monitored objects will expand.

The sensors are energy constrained with limited processing capability; thus, any security software needs to be carefully designed. In the future, ever more data will be collected from railway infrastructure and vehicles. In the future, condition monitoring will be able to exploit cheaper, more robust and more pervasive hardware. New data processing techniques will generate more accurate, robust, and reliable models from existing and new sensor data. Systems will be secure and provide clear and detailed decisions and recommendations.

6. CONCLUSION

This paper has reviewed the range of WSNs used for condition monitoring in the railway industry. Sensors devices are used for and identification of sensor node configurations and network topologies. A broad range of sensors are used in railway monitoring to provide an extensive range of data and allow monitoring of different structures, vehicles and machinery. The main challenge for WSNs in railway applications is determining the best measurement technologies to use. It must be possible to translate the sensor data from the WSN into relevant and clear information to enable decision support in the railway infrastructure maintenance lifecycle. In WSN data can also be stored and analysed over longer time periods to identify long term progressive faults such as a slowly developing crack. Many people die and several others get physically and mentally injured. Wireless sensor network which continuously monitors the railway track through the sensors and detect any abnormality in the track.

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