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DESIGN OF WSN SYSTEM FOR HUGE SPURT SENSING DATA REAL-TIME TRANSMITTING BASED ON STRUCTURE DETECTION

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ABSTRACT

Thousands of different types of sensors are deployed in large structural facilities. During the emergency, such as, the influence of the tsunami to hydraulic structure, heavy vehicles crossing bridges, the sensors will burst out massive data, which is significant to keep the structural safety and should be transmitted to the Sink node in real-time. However, the traditional wireless sensor network with a single channel can not meet the requirements of mass data real-time transmission
Therefore, this paper proposes a novel huge spurt sensing data transmission system and discusses the topology of system. The system includes 5 parts, which are Clustering, Channel negotiation, Data transmission within a cluster, Data fusion in cluster head node, Data transmission inter clusters.
The clustering structure is used to design the wireless sensor network system, cluster head node and the sink node are both using the multi-antenna, and ordinary sensor nodes in cluster are all using a single antenna. The system involves the inner-cluster transmission and inter-cluster transmission: inner-cluster transmission will study the matching mechanisms, the data of several ordinary sensor nodes will be simultaneously sent to the same cluster head node to form virtual MIMO system with pairing algorithm. Cluster head node adopts data fusion technology to send the fused data to the Sink node through inter-cluster transmission. OFDM and MIMO mechanism are used in inter-cluster transmission to send the data to the destination node with multi-hops networks.

KEYWORDS

Structural health monitoring, huge spurt sensing data, channel negotiation, MIMO (multiple input multiple output).

INTRODUCTION

The safety of offshore platform, bridges, dams and other structural facilities is important for people's life and property's safety, so structural health monitoring is paid more and more attention. Because the wired network requires the complicated field wiring, so the wireless networks of data detection have gradually become the main transmission modes of structure detection. At present, the main wireless transmission modes are: WLAN (Wireless Local Area Network), WSN (Wireless Sensor Network), 3G (The 3rd Generation Telecommunication), satellite communications, etc. Under normal circumstances the above transmission modes can be used. But in the case of disaster, such as overloaded trucks crossing bridges, offshore platforms during tsunami, dam conditions during the flood season and so on, the state of structure will change dramatically and instantly generate mass data which needs real-time transmission for the relevant management personnel to take contingency plans timely. While the traditional wireless transmission modes are difficult to meet the requirements of mass data real-time transmission. Therefore, in this paper we study the multi-hop wireless transmission system for huge spurt sensing data real-time transmitting based on structure detection under the conditions of disaster.

TRADITIONAL WIRELESS TRANSMISSION TECHNOLOGIES OF STRUCRURE MONITORING DATA

Existing wireless transmission modes of structural health monitoring are: WLAN (Wireless Local Area Network), WSN (Wireless Sensor Network), 3G (The 3rd Generation Telecommunication) and satellite communications.

WLAN (Wireless Local Area Network)

WLAN is a convenient wireless transmission system, which can transmit data, voice and video signals. In wired networks, the laying position of network equipment is restricted by cables, and WLAN can access the network anywhere in the wireless signal coverage area. WLAN users can move and keep connecting with the network simultaneously. WLAN technology is mature and has high data transfer rate and the theoretical rate of 802.11n can reach to 600Mbps. WLAN has been widely used in people's daily life. But main problems of WLAN technology applying to structural monitoring data transmission mode are: First, WLAN node has transmission capacity and cannot gather monitoring information. Second, WLAN system has only single-hop transmission capacity, and the transmission distance in WLAN will be greatly reduced by the shelter from structural facilities (such as bridge decks, steel of the large ships). Experiment shows that the effective transmission distance of WLAN is only 10m or so through a layer of steel, so WLAN technology is not suitable to transmit monitoring data to the sink node.

WSN (Wireless Sensor Network)

WSN has realized three functions that the data collection, processing and transmission. It is composed of a large number of stationary or mobile sensors with the way of self-organization and multi-hop. WSN nodes can collaborative sense, collect, process and transmit the information of the perceived object within the geographic area covered by network, and finally send the information to the network owner. WSN technology is mature and low power consumption. It can achieve multi-hop wireless transmission and has applied in the structure detection.

Since the energy consumption in wireless communication is proportional to communication distance to the 3 power. With the impact of external geographical conditions and natural environment, wireless communication performance may change frequently and the phenomenon of communication interruption may occur frequently, which limit the communication capability of WSN system severely. Existing WSN is based on Zigbee and its main purpose is to reduce power consumption. The transmission rate of WSN is low and the actual transmission rate is less than 10kbps, which is difficult to meet the requirements of mass data real-time transmission under the condition of disaster.

3G (3rd Generation Telecommunication)

3G is cellular mobile communications technology which supports high-speed data transmission. 3G system can transmit voice and data information simultaneously, the rate is general more than a few hundred kbps. 3G system combines wireless communications with Internet and other multimedia communications. 3G can transmit large amount of data through far distance, but there are some problems when 3G system is applied in structural health monitoring:

First, structure detection sensor must receive the signals from 3G base station, while the structure facilities may be at the place not covered by 3G signals. For example, offshore platform can not receive 3G signal for it is difficult to establish 3G base station on the ocean. In fact, even in the land the structure detection sensor node which is at the bottom of the facilities can not receive 3G signal affected by the block of the facilities. Second, even though the sensor nodes can receive the 3G base station signal, the distance form the sensor node to 3G base station is several kilometers, the cost and power consumption of sensor nodes to communicate with the base station is very high.

Satellite Communications

Communications Satellite is used in the communication between offshore platforms to land. But the sensor is laid in the bottom of the structure, such as the laying at the bottom of the bridge, at the bottom of the offshore platform, or the rooms of offshore platforms, because of the shelter from bridge, steel and other structures, the sensor is difficult to receive satellite signals. Moreover, communication satellites lie at an altitude of 38000 kilometers and the transmission delay is too long to meet the requirements of mass data real-time transmission.

As all of the existing wireless communication technologies are difficult to meet the requirements of mass data real-time transmission under the condition of disaster. It is necessary to study a new transmission system to transfer burst monitoring data of structural facility in real time. In this paper, we propose a novel multi-hop wireless transmission system called huge spurt sensing data transmission system for huge spurt sensing data real-time transmitting based on structure detection under the conditions of disaster

HUGE SPURT SENSING DATA TRANSMISSION SYSTEM

Figure 1 shows the huge spurt sensing data transmission system we proposed for huge spurt sensing data real-time transmitting based on structure detection under the conditions of disaster.
The huge spurt sensing data transmission system consists of lots of clusters and each cluster contains a cluster head node and a number of ordinary sensor nodes. Every detected structure is deployed a large number of wireless sensor nodes. When disaster happens, wireless sensors will collect the huge data about severe changes of structure state and compress the data. Then wireless sensors send the compressed data to the cluster head node. Cluster head node uses data fusion technology to process the received data, and forwards to other cluster head node. The cluster head node bears route forwarding function. Forwarded multiple hops through cluster head nodes, the data converges to the sink node. The sink node storages data, while part of the data is transmitted to remote structural detection center via satellite communications. We will describe the data transmission process of transmission system for huge spurt sensing data through five parts that are clustering, channel negotiation, data transmission within a cluster, data fusion in the cluster head node, data transmission inter clusters.

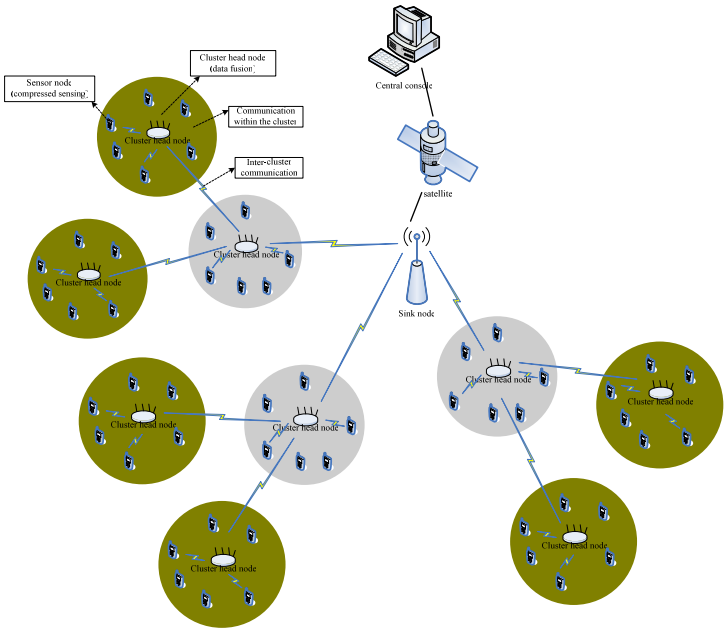

Figure 1. The topology of the huge spurt sensing data transmission system

In the huge spurt sensing data transmission system, we assume that:
(1) The location of sink node and sensor nodes are fixed after deployment. The location of cluster head node is fixed once selected and each cluster head is configured three antennas. Other sensor nodes is configured a single antenna. The sink node is not restricted by energy and it is configured three antennas.
(2) All nodes have a unique ID and the ID number of sink node is 0, the node with the smaller node ID has the priority during channel selection. All nodes have the capability of data fusion. The clock synchronization within the network has been completed.
(3) Wireless sensor nodes within the cluster can not communicate with each other and must be scheduled by the cluster head node
The system implementation as follows:

Clustering

After selected the sensor node as cluster head node, the cluster head broadcasts election information, the ordinary nodes join the nearest cluster according to the information received from the cluster head and send the

information to the cluster head, which contains ID number of the ordinary node, the distance to the cluster head and so on.

Channel Negotiation

To avoid the communication interference caused by multiple nodes using the same spectrum, channel negotiation is required before the data transmission. We use the spectrum sensing technology in cognitive radio to complete channel negotiation.

Spectrum sensing is an important prerequisite of protecting the primary users from harmful interference and improving cognitive radio network's utilization of spectrum resource. Its main function is continuous detecting the working frequency band assigned to the primary user in the time domain, frequency domain and spatial multidimensional space, detecting whether the primary users is using these bands, and getting the working condition of the entire working band.

Typical spectrum sensing algorithms are transmitter detection of primary user, multi-user cooperation detection, receiver detection of primary user. Transmitter detection of primary user is that cognitive user analyses whether the detection frequency band is in idle state. Unlike the primary user transmitter signal detection, receiver detection of primary user is that the receiver analyses the work state of the primary user to determine whether it is using the bands. The multi-user cooperative spectrum detection is an approach of combining multiple cognitive users to detect signal so as to determine whether the primary user exists.

Because of the huge spurt sensing data transmission system consists of many clusters. Each cluster contains a cluster head node, and spectrum detection based-on local single-user is constantly impacted by fading, shadows and other complex wireless communication environment, which makes the performance of spectrum sensing degradation. "Hidden terminal" phenomenon, which is impacted by severe path fading and shadowing effect, leads that cognitive users can not detect the primary user signal, so we use multi-user cooperative spectrum detection method.

Multi-user cooperative spectrum detection has mainly two different implementation methods: One is using distributed cooperative spectrum detection, which means cognitive users exchange detection information among them, and each user makes decision independently according to the same criteria. The other is using centralized spectrum detection, which means that all cognitive users send detected spectrum information to the central node and the central node makes a decision according to a fusion and decision rule.

Cooperative spectrum detection algorithm consists of two kinds of fusion detection methods: hard decision information fusion detection and soft decision information fusion detection. As the soft decision information fusion detection can fully utilize the cognitive user's perceived information, so we use the soft decision information fusion detection in the system, which means the cognitive user sends the perceived information to the central fusion node without processing and the central fusion node makes decision according to certain fusion rule. At present, typical soft decision fusion rules include likelihood ratio criterion and linear weighted criteria.

Likelihood ratio criterion is a soft decision method based on likelihood ratio, which is the optimal cooperative spectrum detection method, the disadvantages is that it requires high computational complexity and the decision threshold is difficult to determine. Therefore, we used linear weighted criteria. The main idea of soft decision algorithm basing on linear weighted criteria is that the central node will participate in detecting the primary user signal according to detection information sent by cognitive user and make a final judgment according to certain weighted criteria. Typical linear weighted fusion algorithms are gain weighted fusion and weight gain weighted fusion. Gain weighted fusion refers to the weighted value of each cognitive user is equal and joins the judgment with equal proportions. Compared to the gain weighted fusion, weight gain weighted fusion is a more reasonable weighting algorithm. Because it sets the different weighting coefficient according to cognitive user's different signal to noise and make full use of the cognitive user's detection information.

In short, we use centralized cooperative spectrum detection method, sensor nodes within the cluster send the detected spectrum status information directly to the cluster head node without any processing. The cluster head makes channels' allocation for each ordinary sensor node according to the weight gain weighted fusion criterion of linear weighted rule in the huge spurt sensing data transmission system.

Data Transmission within a Cluster

Before transmitting data, wireless sensor nodes within the cluster make effective compression for the detected huge data. Since traditional sampling technique leads to lots of redundant data, so we use compressed sensing techniques, whose sampling rate can be far less than that of Nyquist sampling theorem and it can reduce the transmitted data at the sensor nodes. The reconstruction work is handled by the sink node.

In order to handle large amounts of data, CDMA (Code Division Multiplexing Access) technique is used in data transmission within cluster, which means all nodes can use all spectrum at the same time and has high efficiency of the channel, large system capacity.
We use node pairing mechanism for communication within the cluster. Because the signal comes from the different nodes through different channels and the degree of interference among nodes is different. Node pairing mechanism can minimize the interference between the paired nodes and improve the wireless link transmission reliability after cooperation. The cluster head node chooses the right paired nodes within the cluster based on channel conditions and the cluster head node can communicate with two paired nodes simultaneously and the throughput increases by 1 times. Meanwhile, the paired nodes and the cluster head node constitute virtual MIMO. The two antennas on the paired nodes and two receiving antennas on the cluster head node constitute a 2×2 antenna array, which can increase the system capacity.

Data Fusion in Cluster Head Node

There are many wireless sensor nodes in huge spurt sensing data transmission system, and the cluster head node receives a large amount of data. Data from neighboring sensors has a large degree of redundancy. So we make data fusion in the cluster head node to reduce data traffic between clusters and improve the transmission efficiency of gathering data in the entire network.
Data fusion is a process of handling multiple copies of data and constituting the result which is more effective and more suitable for users. The basic idea is to use suppression redundancy, minimum, maximum, average calculations and other operations to combine with similar data which is come from different sensor nodes, and reduce the amount of data through simplifying data. In huge spurt sensing data transmission system, the cluster head node makes data fusion process for the data sent by sensor nodes within the cluster in order to reduce the amount of data transmission inter clusters.

Data Transmission Inter Clusters

In huge spurt sensing data transmission system, data from the cluster head to sink node goes through multi-hops and data transmission passes through several forwarding nodes, which are acted by the cluster head nodes. Multi-antennas are set in each cluster head node. We make use of OFDM and MIMO technologies in transmission inter clusters in order to improve the throughput in the multi-hops network.
With the maturity of FFT / IFFT fast algorithm, the implementation of OFDM technology becomes simpler. Meanwhile OFDM technology can effectively eliminate multi-path interference and improve the performance of communication systems.
MIMO technologies can be divided into spatial multiplexing technology, spatial diversity technology, smart antenna and beam forming technology. In order to improve the system throughput, we mainly use spatial multiplexing MIMO technology. Meanwhile, we mainly use Layered Space-Time Coding-BLAST to combine MIMO technology with OFDM technology. The transmitter structure of MIMO-OFDM system can be in Figure 2. First, cluster head node maps the forwarding data into different sub-channel. Second, data is input into the layered space-time coding module after serial-to-parallel converted. Third, the data modulated by OFDM module after going through the space-time coding module. Finally CP is inserted into the data and is sent to different transmitting antennas respectively. The data processing in receiver is exactly the inverse of launch system.

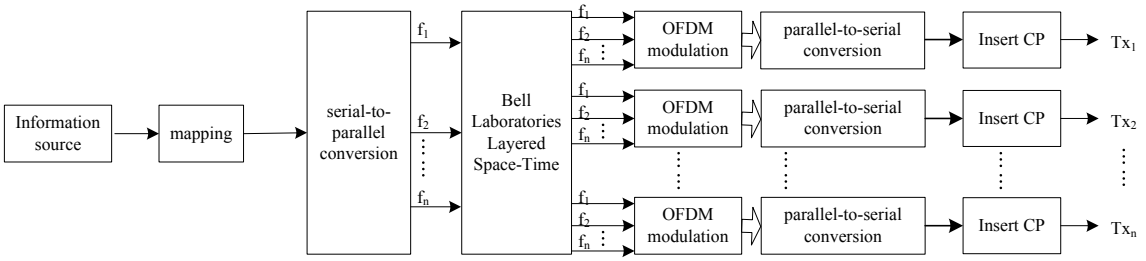

Figure 2. The transmitter structure of MIMO-OFDM system

CONCLUSIONS

According to huge spurt sensing data real-time transmitting problem based on structure detection. We give the topology of huge spurt sensing data transmission system. The system has five parts, that are, Clustering,

Channel negotiation, Data transmission within a cluster, Data fusion in cluster head node, Data transmission inter clusters. The appropriate solutions for each part of the system are discussed in this paper.
This paper gives a framework of huge spurt sensing data transmission system. There remain lots of issues. Such as, the reliability analysis of the system, the performance analysis of the system, the simulation of the system etc.

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