Artificial Intelligence Technology Monitoring Terminal for Mechanical Vibration Wireless Sensor

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Abstract. Wireless sensor network has the characteristics of distributed, self-organizing, strong expansibility, convenient and flexible deployment, which can effectively make up for the deficiency of traditional limited monitoring system in special application occasions such as closed, large displacement, rotation, etc., and has a huge application prospect in the field of mechanical vibration monitoring. This paper mainly studies the design of wireless sensor monitoring terminal for mechanical vibration with artificial intelligence technology. In view of the narrow wireless channel and low communication efficiency of the current mechanical vibration wireless sensor network nodes, this paper proposes a dual-core architecture node design method supporting IEEE 802.11 protocol, which provides the cohardware support for the low energy consumption and high efficiency transmission of large amounts of data.

Keywords: Artificial Intelligence, Mechanical Vibration, Wireless Sensors, Monitoring Terminals

1. Introduction

Wireless sensor network (Wireless sensor networks WSNs) is combined with Wireless network communication, embedded, microelectronics and sensor technology continuously developed new type of network information retrieval technology, it is composed of a large number of data acquisition, processing and Wireless network transmission functions of sensor nodes, ad-hoc network, easy installation and deployment, characteristics such as wide coverage, can collect real-time monitoring, awareness and monitoring object information, in transportation, environmental monitoring, agriculture, health care, industrial, military field has great use value [1]. At present, the universal ISM band (Industrial, Scientific and Medical) wireless network protocols include ZigBee, Bluetooth, WiFi, etc., with their respective features. In the field of mechanical vibration monitoring, the existing cable connection state monitoring system maintainability is poor, the lack of maneuverability and high cost of deployment, monitoring object and scope of the problems such as limited, wireless sensor network (WSN) while it is possible to make up for the inadequacy of cable machinery vibration monitoring system, but in the node energy, processor performance, data acquisition and storage efficiency of data transmission, limit conditions, in the face of high frequency, high precision mechanical vibration monitoring, there are still many problems to be solved, such as mechanical vibration of high frequency...
and high precision data acquisition, transmission, low power consumption, high efficiency and reliable node energy, etc.

At present, wireless sensor networks mainly collect slow variables such as temperature, light intensity, humidity and pressure, etc., with low sampling frequency, less data generated and less channel occupied. In the aspect of wireless sensor network node design for mechanical vibration, Khan developed a wireless sensor network acquisition node based on FPGA. NRF24L01+ was used as a wireless communication module, with the highest transmission rate only 2Mbps, and AD7476A was used as A/D converter, with only 16 bits acquisition accuracy, which could not meet the requirements of high-precision sampling [2]. Gelenbe designed the sensor node with dual core processor architecture combined STM32F103 and CC2430, and adopted the acquisition node of IEPE acceleration sensor, which avoided the noise problem under wide flat band of MEMS sensor, and realized the sampling frequency of 20K and the acquisition accuracy of 16bits [3].

The research content of this paper is to design multi-sensor integrated monitoring system based on the analysis of the existing wireless sensor monitoring system. The host-cluster design mode is adopted, and the acquisition module polling the sensor design scheme through modBUS-RTU protocol, which improves the number of sensor access and simultaneously combines analog signal sensor and digital signal sensor interface, thus solving the problems of large equipment, high maintenance cost and scattered monitoring points.

2. Wireless Sensor Monitoring Terminal

2.1. Hardware Design

Machinery vibration signal is relatively weak, low vibration amplitude, vibration signal of wide frequency band, so in order to solve the weak signal acquisition and wide-band vibration signal acquisition, which requires the nodes with high frequency and high precision acquisition function, at the same time, in order to solve a lot of data, the transmission time is too long, the problem of high energy consumption of the transmission, the nodes should be asked to support high bandwidth of IEEE 802.11 protocol communication. Node needs to perform in the process of collecting signal acquisition, data storage, network command recognition and data transmission function, in order to ensure accurate operation of each function, reduce the coupling between the various tasks, to ensure the precision of the acquisition, without interference is designed to support the IEEE 802.11 protocol of dual core processor architecture, each control high bandwidth network communication and high frequency and high precision mechanical vibration data acquisition [4, 5].

Core 1 of the processor is mainly responsible for power management, vibration acquisition, data storage and transmission, and data exchange with vibration acquisition module, data storage module and wireless transceiver module, which requires nodes to have strong computing and processing capacity and abundant external equipment resources [6]. This article core 1 based on ARM architecture (M4 kernel 32-bit high performance microprocessor STM32F405RG, its operating frequency is 168 MHZ, with floating point arithmetic unit, 1 MB of Flash, 192 KB SRAM and ART of the accelerator, the outstanding performance to ensure the nodes efficiently perform various tasks in a timely manner, and the core 1 with abundant peripheral interface, can be better and more efficiently exchange information and each function module. Core 1 uses an external active crystal oscillator to provide the clock. The internal timer divider can provide the clock sequence needed for each communication module. At the same time, the clock after the divider can control the Node A/D sampling, and SPI (serial peripheral interface) is used to exchange information between A/D module and core 1 to ensure the acquisition of high bandwidth of the collected data. In order to reduce the acquisition and transmission of data conflict, reduce data coupling, ensure the integrity of the data, this article adopts the mode of transmission after storage first, use large storage capacity Micro SD card, store a lot of vibration data, it is through the SDIO interface connection with the core 1, and controlled by the DMA control SDIO communication, to ensure that a large number of vibration data to be stored,
timely and complete guarantee storage tasks don't interfere with data acquisition tasks at the same time.

Processor core 2 is mainly responsible for command forwarding, data transmission and network maintenance. In order to support wireless transmission tasks with high bandwidth, improve transmission efficiency, reduce transmission time and save energy, core 2 adopts ESP8266EX low-power radio frequency communication chip. ESP8266EX support an IEEE 802.11 b/g/n WLAN MAC protocol specification of WiFi solution on system, idle current only 15 ma, on chip integrated with ultra-low power consumption 32-bit Tensilica L106 processor, low noise amplifier, antenna switch, rf balun, power amplifier and power management module, CPU running frequency of 160 MHz, at the same time, ESP8266EX have abundant peripheral resources: UART (synchronous/asynchronous serial receiver/transmitter), SPI, I2C bus, ADC, TIM timer and GPIO (General Input/output interface), etc. [7].

2.2. Energy Consumption Characteristics of Node Terminals

Wireless sensor network node vibration system with multiple tasks: networking, command to get and parse, acquisition parameter configuration, data acquisition, data processing, data storage, data reading, data transfer, data uploading and so on, usually the working state can be divided to different working stages: stage of network, the node to parse and networking and command to get work done; In the data acquisition stage, the nodes complete the configuration of acquisition parameters, data acquisition and storage. In the data processing stage, nodes complete the compression and packaging of data. In the data transfer stage, the node completes data reading, packs the data and sends it to the wireless module; In the data upload stage, the wireless module completes the data upload task at an appropriate time [8].

Different sub-modules of the node system need to be enabled at different working stages. Different sub-modules have different working power consumption and different working stages have different duration, so the nodes have different energy consumption at different working stages [9]. The following will analyze the energy consumption and real-time requirements of each working stage of the node.

(1) Networking Stage

In the networking stage, nodes need to complete networking and command acquisition and parsing tasks. ARM Cortex-m3 is in standby mode, and the wireless module is opened and in the transceiver mode. In this case, the node system power consumption is:

\[ P_1 = P_{\text{ARM,standby}} + P_{RF,\text{RTX}} \]  

Node periodically into line, set each time about \( \Delta t \) into online state, in this time period, node system energy consumption as follows:

\[ E_1 = (P_{\text{ARM,standby}} + P_{RF,\text{RTX}}) \cdot \Delta t \]  

In the network stage, while the power consumption of the wireless module is higher, working current up to 20-35 ma, but because of when this phase continuous \( \Delta t \) is short, therefore, networking phase total energy consumption is not high. The networking stage belongs to the online working state, with high real-time requirements, requiring nodes to respond to work in a timely manner.

(2) Data Acquisition Stage

In data acquisition phase, nodes according to the stage of network commands issued by the upper machine work, first configure acquisition parameters, including the constant-current drive, setting signal can zoom multiples, set anti-aliasing filter cutoff frequency, modulus conversion chip parameters, etc., and then enter the data collection work, and will be collected data is stored into the Flash chip [10]. At this stage, most of the molecular modules of the node system are enabled, and the power consumption of the node system is:

\[ P_2 = P_{\text{ARM,run}} + P_{\text{Drive}} + P_{\text{LTC6910}} + P_{\text{MAX7407}} + P_{\text{ADA4941}} + P_{\text{AD7766}} + P_{\text{Flash}} \]  

(3) Data Processing Stage
In the data processing stage, the node takes out the vibration data stored in Flash chip for compression processing and analysis. In this stage, only ARM Cortex-M3 and Flash are in working state, and the other sub-modules of the node system are in closed state. In this stage, the power consumption of the node system is:

\[ P_2 = P_{\text{ARM,run}} + P_{\text{Flash}} \]  

(4)

3. Multi-Node Transmission Performance Test

During mechanical equipment condition monitoring, more needs to be more monitoring nodes deployment, build the mechanical vibration of the wireless sensor network node, and the mechanical vibration acquisition node link of data transmission, involving more sections according to the above requirements, this article also puts forward the partitioned optimization of parallel concentration rotary transmission timing optimization scheduling method and blocking space parallel rotary transmission timing scheduling methods such as network transmission, and most of the mechanical vibration of wireless sensor network transmission method based on the IEEE 802.15.4 protocol is used, different transmission method for different network protocols were analyzed.

The node WSNs_WiFi designed in this paper and the node using CC2530 wireless module developed by the laboratory are experimental platforms, called ESP8266 node and CC2530 node, respectively, to test the transmission setup and transmission energy consumption comparison under various network modes and various transmission data lengths. Five groups of experiments were designed, namely single node 900KB data length, three node 300KB data length, three node 900KB data length, four node 300KB data length, four node 900KB data length, each group of experiments were compared for different transmission protocols and different transmission timing scheduling methods.

Multiple nodes of wireless sensor network node transmission experiment, the energy consumption of PC monitoring software displays the current four acquisition node star network topology model, network transmission energy consumption is simply a collection of network node transmission phase current is analyzed, and the use of dc voltage source for acquisition node power supply, the positive interface between the positive and acquisition node power supply voltage source in series 1Ω resistance, make NI9234 collection at the ends of the series resistance voltage, voltage waveform in the PC software of NI9234 showed that the resistance of Ω resistance value is 1,

Therefore, the value of the voltage is equal to the value of the current, and the voltage waveform is the same with the current waveform, so as to obtain the change of the working current of the node. Then, integrate and calculate the current in the transmission stage to obtain the transmission energy consumption data of the node in the transmission stage.

4. Multi-Node Transmission Performance Test Results

4.1. Transmission Rate Comparison

|          | 1N 900K | 3N 300K | 3N 900K | 4N 300K | 4N 900K |
|----------|---------|---------|---------|---------|---------|
| ESP8266  | 993     | 381     | 410     | 283     | 308     |
| ESP8266 optimization | 847     | 268     | 346     | 227     | 273     |
| CC2530   | 92      | 75      | 63      | 58      | 54      |
As shown in Table 1 and Figure 1, different network topology model and experiment, the length of the data transmission ESP8266 node network transmission rate is much higher than CC2530 node network, and network ESP8266 node block optimization space parallel rotary transmission timing scheduling method transfer rate is highest, four nodes in the network can still achieve 282.9 KBPS transmission rate, much higher than 31.14 KBPS CC2530 node.

4.2. Comparison of Transmission Energy Consumption

Table 2. Comparison of transmission energy consumption

|                  | 1N 900K | 3N 300K | 3N 900K | 4N 300K | 4N 900K |
|------------------|---------|---------|---------|---------|---------|
| ESP8266          | 6       | 6       | 14      | 8       | 16      |
| ESP8266 optimization | 7     | 8       | 17      | 11      | 19      |
| CC2530           | 41      | 29      | 83      | 37      | 87      |
As shown in Table 2 and Figure 2, although its low power wireless module CC2530 node, but due to the transmission rate, slow transmission takes too long, and communication rate affect the efficiency of transmission scheduling, cause it’s in groups of five experiments, the transmission energy consumption are much higher than ESP8266 node, and ESP8266 node network partitioning optimization space parallel rotary transmission timing scheduling method, used the space parallel design, improve the efficiency of the scheduling, optimizing the utilization of network channel and node transmission link, it has better effect of energy consumption, to ensure its transmission in all experiments are the lowest energy consumption. Even in the four-node 900K transmission length experiment, the node transmission energy consumption of space parallel and segmented nodes is the largest, but it is only 14% of CC2530 nodes, still lower than ESP8266 nodes of the blocking optimized parallel centralized rotation transmission timing scheduling method.

By comparing and testing different methods in different data transmission lengths and different network topologies, the effectiveness of the space parallel rotation transmission timing scheduling method with block optimization is verified, and the low energy consumption and high efficiency transmission performance of the nodes designed in this paper in the wireless sensor network for mechanical vibration is guaranteed.

5. Conclusions
In this paper, the wireless sensor network for mechanical vibration monitoring is taken as the research object, focusing on the problems of slow transmission rate and high transmission energy consumption existing in the wireless sensor network for mechanical vibration. First, in view of the problems existing nodes transmission belt width, on the premise of guarantee acquisition precision, the support of IEEE 802.11 protocol node design, dual core architecture are adopted to decrease the maintenance of the coupling nodes collection and network communication, using multiple power management, reduce the power consumption of the node selects the miniaturization ESP8266 high-bandwidth wireless communication module, low power consumption and verify network maintenance performance, low power consumption design acquisition front-end driver, filter and differential module, improve signal anti-jamming, using 24-bit ADC acquisition accuracy, and high speed data storage using SD card.

References
[1] Wei Y, Kin L, Terrence M, et al. A Survey of Wireless Sensor Network Based Air Pollution Monitoring Systems. Sensors, 2015, 15(12):31392-31427.
[2] Khan I, Belqasmi F, Glitho R, et al. Wireless Sensor Network Virtualization: Early Architecture and Research Perspectives. Network IEEE, 2016, 29(3):104-112.
[3] Gelenbe, Erol. Synchronising Energy Harvesting and Data Packets in a Wireless Sensor. Energies, 2015, 8(1):356-369.
[4] Wang H. Food Quality Monitor System Design Based on ARM11. Advance Journal of Food Science and Technology, 2015, 8(5):363-366.
[5] Gautam G, Sen B. Design and Simulation of Wireless Sensor Network in NS2. International Journal of Computer Applications, 2015, 113(16):14-16.
[6] Mohit P, Amin R, Biswas G P. Design of authentication protocol for wireless sensor network-based smart vehicular system. Vehicular Communications, 2017, 9(jul.):64-71.
[7] Huynh N T, Robu V, Flynn D, et al. Design and demonstration of a wireless sensor network platform for substation asset management. Cired Open Access Proceedings Journal, 2017, 2017(1):105-108.
[8] Park B H, Kim S H. A Study on the Energy Consumption Characteristics for Use and Operation Period in Office Buildings. Korean Journal of Air-Conditioning and Refrigeration Engineering, 2017, 29(11):605-611.
[9] Chao F, He Z, Pang A, et al. Path Optimization of Mobile Sink Node in Wireless Sensor Network Water Monitoring System. Complexity, 2019, 2019(10):1-10.
[10] Sujatha M, Bhuvaneswaran R S. An Efficient Beam Scanning Algorithm for Hidden Node Collision Avoidance in Wireless Sensor Networks. Lecture Notes in Electrical Engineering, 2015, 315(1335):627-639.