Design of verification platform for wireless vision sensor networks

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Abstract. At present, the majority of research for wireless vision sensor networks (WVSNs) still remains in the software simulation stage, and the verification platforms of WVSNs that available for use are very few. This situation seriously restricts the transformation from theory research of WVSNs to practical application. Therefore, it is necessary to study the construction of verification platform of WVSNs. This paper combines wireless transceiver module, visual information acquisition module and power acquisition module, designs a high-performance wireless vision sensor node whose core is ARM11 microprocessor and selects AODV as the routing protocol to set up a verification platform called AdvanWorks for WVSNs. Experiments show that the AdvanWorks can successfully achieve functions of image acquisition, coding, wireless transmission, and obtain the effective distance parameters between nodes, which lays a good foundation for the follow-up application of WVSNs.

1. Introduction

In recent years, wireless sensor networks (WSNs) have attracted widespread attention in academia. However, the traditional WSNs generally measure scalar data, such as temperature, light intensity, humidity, etc. The information collected and processed is limited. It is urgent to bring image, video and other visual information into the sensor networks to achieve more refined measurement, thus wireless vision sensor networks (WVSNs) came into being[1]. As most of the research of WVSNs only stay in the physical simulation stage, and simulation results have difference from the actual running status of WVSNs. It is urgent to set up a verification platform for WVSNs, which provides the physical support for the basic theory of WVSNs. The verification platform is composed of wireless vision sensor nodes through a specific way, it can reflect the large-scale network application environment. It supports the basic functions required for applications of WVSNs and provides physical support for specific protocols and algorithms.

At present, the typical verification platforms designed for WSNs at home and abroad mainly include Motelab of Harvard University[2], Kansei designed by Ohio State University[3], MoteWorks of Crossbow, MSRLab6 of Beijing Jiaotong University[4] and ComWSN of Central South University[5]. However the existing verification platforms for WVSNs are very few. Therefore, this paper puts forward the idea of constructing the verification platform for WVSNs. This paper designs a node for WVSNs at first, and then build a verification platform on this basis and runs it.

This paper is organized as follows: The first part briefly introduces the design scheme of the verification platform AdvanWorks designed in this paper. The second part introduces the routing protocol of AdvanWorks. The third part introduces the sensor node design of AdvanWorks, including hardware design and software design. In the fourth part, we test the AdvanWorks platform and analyze the experimental results. Finally, the last part summarizes the verification platform AdvanWorks.
2. Overall Program of Verification Platform

In order to realize the acquisition, processing, transmission of visual information, WVSNs have high requirements on performance of node processor and wireless communication capability of the network. Therefore, this paper designs a high-performance wireless vision sensor node to set up verification platform without additional configuration control system. In addition, only a communication protocol is used to simultaneously realize the data communication and transmission of PC configuration and monitoring information when the network is running. The basic framework of the verification platform AdvanWorks is shown in Figure 1, it consists of the source node, the intermediate forwarding node and the destination node. The number of nodes is less than that of actual network, and the nodes are distributed randomly. These nodes automatically set up the network in Ad-Hoc mode, in which the source node collects, processes and transmits the image data, the intermediate nodes forward the data packets, the destination node receives the data packets, and the PC acts as the network control center.

![Basic framework of AdvanWorks.](image)

3. Selection of Routing Protocol

The design of AdvanWorks only considers providing high-performance nodes with multimedia processing capability. For selection of routing route, it is possible to select the best transmission path by avoiding the communication between unrelated nodes outside the routing path and integrate coding and energy consumption during transmission, to reduce energy consumption during transmission and balance energy consumption of network. Since most nodes in the WSNs cannot communicate with the destination nodes directly, they need to communicate through the intermediate nodes, thus selecting an appropriate routing path to save energy has become an important goal of the network layer protocol. For the WVSNs with large amounts of data transmission, it is necessary to take energy efficiency into consideration when participating in the design of routing protocol.

Ad-Hoc On-Demand Distance Vector Routing (AODV) is an on-demand routing protocol that is based on the need of data transmission of the source node. The consideration of the distance is determined by routing hops between the source and the destination node [6].

The process during establishing AODV protocol routing involves three key packets: routing request packet (RREQ), routing reply packets (RREP) and routing acknowledgment package (RREP-ACK) [7]. During the sending of RREQ and RREP, each entry in the AODV routing table uses the destination sequence number created by the destination node in order to avoid the occurrence of routing loops [8]. In the process of route establishment, when the routing path has the same sequence number of the destination node, the smallest number of hops will be selected to shorten the distance of the data transmission and reduce the energy consumption. Therefore AODV can be selected as the routing protocol of WVSNs authentication platform.

4. Design of Sensor Node

The WVSNs are composed of multiple nodes. The functional requirements of the verification platform will eventually be transformed into the requirements of the design of nodes. The wireless vision sensor node in this paper has the function of the source node and the intermediate forwarding node at the same time. The node system is divided into hardware system and software system.
4.1. Design of Node Hardware

The node hardware system includes a microprocessor module, a wireless transceiver module, a visual information acquisition module and a power management module. The node hardware system block diagram is shown in Figure 2. The microprocessor module acts as the core module of the visual sensor node, exchanges information with other modules through the interface circuits and coordinates the node operation, and it also has the function of video processing. The wireless transceiver module controls the wireless communication between nodes and realizes exchange of information between the nodes. The visual information acquisition module collects the video information of the monitoring area and performs the preliminary processing on the data. The power management module uses the independent power to supply the function modules separately.

![Figure 2. Block diagram of node hardware system.](image)

4.1.1. Microprocessor Module. In the microprocessor module, RISC (reduced instruction set) architecture of the ARM11 microprocessor is used, and it is the hardware core of the wireless vision sensor node.

4.1.2. Wireless Transceiver Module. On account of the WVSNs transmit large amounts of data, and the transmission rate must reach the MB level, this paper uses WIFI technology to achieve data transmission[9]. The wireless transceiver module is composed of RTL8189ES WIFI chip, which supports IEEE802.11n / g / f standard and protocol, forms a wireless transceiver module with a maximum speed up to 11 Mbps. It supports the Ad-Hoc operating mode required for WVSNs, when it works, the distance of transmission outdoors is up to 150 m.

4.1.3. Visual Information Acquisition Module. The core of visual information acquisition module is the image sensor, considering wireless vision sensor node is one kind of device with large-scale layout, the cost of control is stringent and the node itself has limited energy. Therefore, it is more appropriate to use CMOS sensor which has small size and low power consumption to build the node system [10]. In this paper, OV9650 camera with 1.3 megapixel and low-power video decoder chip with highly integrated TVP5150 are used to achieve visual information collection.

4.1.4. Power Management Module. Power supply module’s function is to provide the required power supply for each modules. This system uses 3.7 V lithium battery-powered, battery capacity of 3.5 Ah, but the output voltage fluctuations with the remaining power, so it is easy to cause abnormal system work. In this paper, nodes use the DC boost circuit to convert Lithium battery output voltage to a stable 5V output voltage to supply node system, its maximum output current is 0.65 A.

4.1.5. Peripheral Interface Circuit. Peripheral interface of the microprocessor including UART0 debugging serial port, CMOS camera interface and WIFI interface are necessary to be designed to implement the exchange of information between the microprocessor with the visual information acquisition module and the wireless transceiver module.
4.2. Design of Node Software
The node software system is composed of the application layer and the Linux system layer. The Linux system layer contains the driver corresponding to the hardware system and provides the programming interface for the application layer through the system call. Application layer write the application program through the interface file to achieve the function of collecting and processing visual information, transporting wireless data, calculating and achieving the required physical parameters of routing protocol.

4.2.1. Building of Software development platform. This paper chooses the Linux operating system based on ARM as the node software platform. The software development platform is to install the Linux system on the host computer, establish the cross-compiling environment and the file sharing mechanism between the host Linux system and the node, and transplant the Linux system to nodes [11]. After the successful transplant, PC can be connected to node through the RS232 serial port, and can login node Linux system through the Secure CRT software to do the simulation of the terminal.

4.2.2. Development of Application software. The node application software adopts multi-threads scheme instead of single thread which is divided into visual information collection and processing thread, wireless communication between nodes thread, and parameter acquisition thread. Each thread occupies different resources at different times and improves system resource utilization rate. The visual information collection and processing thread sets the frame rate and the output format according to the user's request received by the wireless communication thread between the nodes. Wireless transceiver is in Ad-Hoc mode, the wireless communication thread between nodes needs to monitor information acquisition request sent by base station, collect image or video information, and realize the function of forwarding data collected by other nodes and transmitting data collected by itself. Based on the wireless transmission energy model, it can be seen that the data forwarding energy consumption is positively related to the distance between nodes. Therefore, it is necessary for the parameter acquisition thread to obtain the distance between nodes in the whole WVSNs.

5. Experiment and Analysis of Verification Platform

5.1. Test of Platform Basic Function
Firstly we set up the test scene, both the sending end and the receiving end have successfully transplanted the Linux system and are equipped with the user layer wireless network configuration tool (Wireless Tools.29). After the Linux system is started, a wireless self-organizing communication network must be established between the nodes. PC is connected to node through the RS 232 debug serial port, then uses the Secure CRT software to operate Linux system terminal of the node. Then the application software is executed at the sending end and the receiving end respectively, the image data are collected, processed and transmitted successfully, and the collected video information is decoded and displayed on the receiving end.

Tests are operated in 56 m long corridor indoors and square outdoors respectively. The distance between the transmitter and the receiver is changed in the long corridor, the average acceptance rate of 200 frames at 50 m is 98.55%, Although the image lose frame is occasionally present at 20 m, the frame loss rate is less than 50 m. The reason is that there are so many indoor corridor obstacles that wireless signal is unstable. In the case changing the distance between the sender and the receiver in the square, no obstacles in the range of 50 meters, the average acceptance rate of the 500 frames is 98.55%. When the range is more than 50 m, it begins to appear more obstacles so that acceptance rate decreases faster and the acceptance rate even drops to 15% in the range of 70 m.

In the receiving end decoding display with H.264, in the circumstances of long corridor, when the loss rate of frame is low, the displayed image at the receiving end is clearer as shown in Figure 3 (a). In the opposite, when loss rate is high, the displayed image at the receiving end is clearly blurred as shown in Figure 3 (b). In the open space environment, when the frame loss rate is low, the decoded image is clearer at the receiving end as shown in Fig 4 (a). When the frame loss rate is high, the decoded display of image is blurred as shown in Fig 4 (b).
5.2. Distance Parameter Acquisition between Nodes

The devices of the sending node and the receiving node are placed on the campus for testing, establishing a wireless Ad-Hoc network between two nodes and executing the receiving and receiving application program respectively. In the receiving program, there are some code about getting RSSI (Received Signal Strength Information). Put the two nodes at different distances, to obtain the received signal strength value from the receiving end. In order to simplify the process of solving the model’s parameters, the Equation 1 is used as the RSSI ranging model.

\[RSSI = -(10n \log 10r - k)\]  

In the formula, parameters \(n\) and \(k\) are related to the specific environment, \(k\) (dBm) is the value of RSSI (dBm) when the distance between nodes is 1m. It can be seen that \(k = -37\)dBm according to the actual test results. Using matlab to deal with the measured data to get the fitting curve. By fitting the matlab parameters, the signal attenuation factor \(n = 3.042\) is obtained. In the signal transmission environment, the more obstacles, the greater the signal attenuation factor, we can see that there is less obstacles in our test environment. The results are shown in Figure 5. The measured data fluctuating around the theoretical curve, the closer the wireless transmission distance, the higher the degree of data fitting. In the fitting results, the negative correlation coefficient R-square is equal to 0.9811 that is close to 1, we can see that the overall fitting results are better. It is feasible that the method of node distance measurement is used in wireless vision sensor network. Thus, Equation 1 can be convert to 2. And according to the received signal strength, that can be converted to Equation 3.

\[r = a \times 10^{\frac{RSSI}{b}}\]  

\[r = 0.045 \times 10^{27.47} RSSI\]
6. Conclusion
This paper designs a high performance wireless vision sensor node based on ARM 11 microprocessor, and builds an AdvanWorks verification platform for WVSNs. The results of different environmental experiments show that AdvanWorks platform successfully achieves functions of image acquisition, coding and wireless transmission, and obtains the effective distance parameters between nodes, which lays a good foundation for the follow-up application of WVSNs.

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8. References
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