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Research Article

DESIGN AND IMPLEMENTATION OF THE TIME-SLOTTED RANDOM MULTIPLE ACCESS SYSTEM IN WIRELESS SENSOR NETWORKS

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ABSTRACT

The time-slotted random multiple access protocol is briefly analyzed and simulated by Matlab, and the simulation results are consistent with the theoretical results. In order to implement the time-slotted random multiple access protocol in the wireless sensor network, CC2530 is selected as the hardware platform in the design process. Based on the change of the Zstack protocol stack, using the computer save the status of the data packets transmission and reception, and the saved data is analyzed and processed combine with python. The analysis using throughput as important indicators of the system. Compared with theoretical values , the actual experimental results are consistent with the theoretical results, laying the foundation for the realization of other more complex random multiple access protocols in wireless sensor networks.

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INTRODUCTION

Due to the limited channel resources in the communication network, the application of the multiple access technology enables multi-terminals to share a common channel for efficient communication in communication networks such as computer communication, mobile communication, and satellite communication[1-2]. In order to make the channel resources fully and efficiently utilized, experts and scholars have proposed a large number of multiple access communication protocols, among which the random multiple access protocol has been widely used in communication networks. With the development of science and technology, the Internet of Ting (IOT) technology has received more and more attention[3-4]. Make efficient use of random multiple access protocols in wireless sensor networks has also become an important issue. Many scholars have proposed different random multiple access protocol models and improvement measures, and use related software to simulate, but basically don't really apply them in the actual sensor network system. After comprehensive consideration, this paper chooses CC2530 RF chip as the hardware platform. Using the computer save the status of the data packets transmission and reception, and uses Python to analyze and process the saved data. In this way, the hardware simulation of time- slotted random multiple access is realized, which lays a foundation for the realization of other more complex protocols in wireless sensor networks.

MATERIALS AND METHODS

Time-slotted random multiple access system

The random multiple access protocol can be roughly classified into full random multiple access protocol and carrier sense multiple access protocol[5-6]. In the fully random multiple access protocol, each node in the network is in an equal position, and each node competes for the access rights of the channel. The fully random multiple access protocol system is shown in the figure 1.Each terminal nodes in the system randomly transmits data packets at the beginning of each time slot. The terminal node has two states of transmitting and not transmitting in each time slot. If two or more terminal nodes simultaneously send data packets in the same time slot, then these data packets will collide completely, and the receiving end will not receive the information. Only when one terminal node in this time slot sends data, the receiving end can receive the data packet normally. If no terminal device is transmitting a data packet in the current time slot, the time slot is idle.

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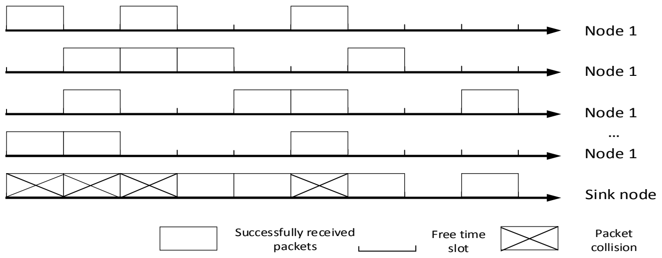

Figure 1 Time-slotted random multipleaccess system

The throughput theoretical expression of the time- slotted random multiple access model can be expressed as $S = Ge^{-G}$, where S represents throughput, G represents the arrival rate of the information packet, $G=Np$, N is the number of terminal nodes, and p is the probability that the terminal node transmits the data packet[7-8]. Take the derivative of both sides of this equation,

$$S' = e^{-G} - Ge^{-G} = (1-G)e^{-G}$$

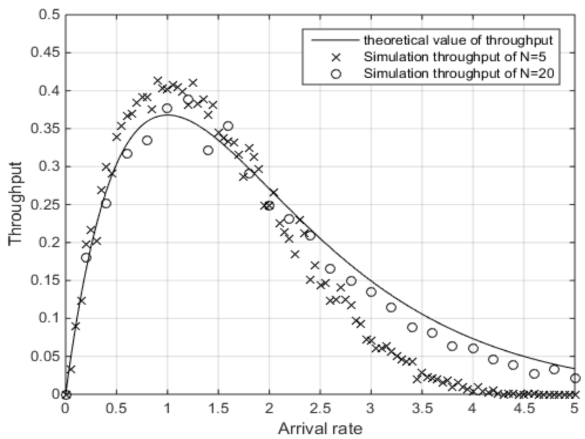

Figure 2 Matlab software simulation throughput of slotted random multiple access system

When G=1, the maximum throughput can be obtained, that is $1/e$, 0.368. Using Matlab to plot the theoretical curve of throughput and the simulation throughput curve when the number of simulated terminal nodes is 5 and the number of terminal nodes is 20. The throughput curve is shown in the figure 2.

As can be seen from the figure, the theoretical maximum throughput of the time- slotted random access protocol is 0.368 when the arrival rate is equal to 1. And when the number of terminal nodes is 5, the actual simulation value is 0.401, and the simulation throughput curve is close to the theoretical curve, when the number of terminal nodes is 20, the actual simulation value is 0.377, and the simulation value is basically consistent with the theoretical curve. When the number of terminal nodes is closer to infinity, the actual throughput curve is closer to the theoretical value curve.

Hardware simulation

Hardware node selection for wireless sensor networks

This paper chooses CC2530 as the sensor node. CC2530 is the zigbee system-on-chip solution introduced by TI. It can run the zstack protocol stack, and has successfully transplanted the 51-kernel popular sensor network operating system, the tiny os operating system and the contiki operating system. The CC2530 chip is equipped with an enhanced 8051 core CPU with 8KB RAM and 256KB of memory[9-10]. The low cost and high performance and high compatibility make the CC2530 fully meet the needs of this design.

This paper is modified on the basis of the zstack protocol stack to realize the time-slotted random multiple access system. zstack is a zigbee solution introduced by TI, which implements all functions of the physical layer, MAC layer, network layer and application layer[11-13]. The protocol stack defines three device types, namely the coordinator, the router and the terminal device. A zigbee network consists of a coordinator and several routers and terminal devices.

Hardware design

Select a node as the coordinator, responsible for the network construction, select five nodes as the terminal nodes, scan the channel and join the wireless network built by the coordinator. The coordinator is the sink node, the sink node and the terminal node start to run the protocol stack, and the terminal node starts to randomly send data packets to the sink node, and the sink node receives and processes the data packet. The network topology of the system is shown in the figure3.

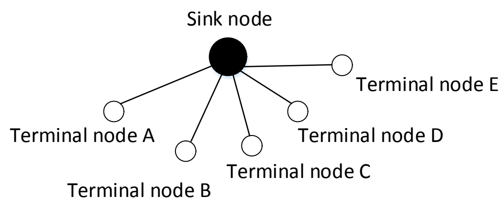

Figure 3 Hardware network topology

Software design

In the event processing function Sample App_Process Event(), the message event is received and processed accordingly. When the button message is received, the periodic transmission event SAMPLEAPP_SEND_PERIODIC_MSG_EVT is triggered for a period of 0.1 second. In the event, the terminal sends the data packet with a certain probability, 100 probabilities are set and the probability value is from 0.01 to 1, in steps of 0.01. The content of the data packet is the number of the terminal itself. In this paper, A, B, C, D, and E respectively represent five terminal stations. The sink node receives the data packet in one cycle and parses out the content. Receiving the content and add a receiving flag bit 1. Traversing the terminal number in the received content, if the terminal number is not found, it is considered that the terminal of the number does not send the data packet in the period, and the unreceived data flag bit 0 is added after the terminal number, indicating that the terminal does not send data packets during this period. Finally all of these data in a period are transmitted to the computer through the serial port for saving. The software flow chart of the protocol stack is shown in the figure 4.

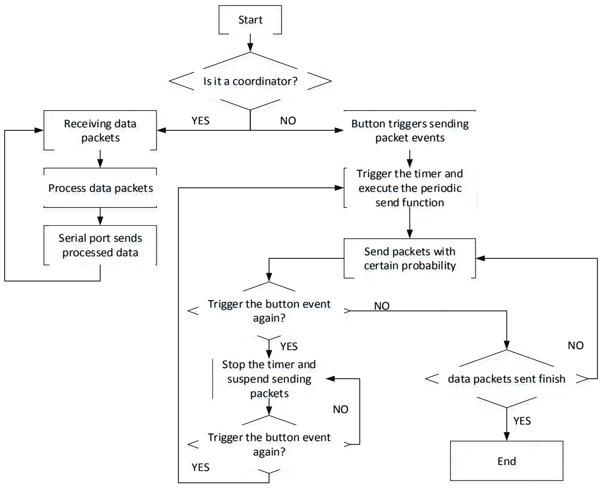

Figure 4 Hardware simulation software flow chart

Data processing and analysis

The computer reads the data transmitted by the serial port in python and saved it as a text file, and then reads the saved text file through python for data processing. Unify the data format in the text into one-digit terminal number plus one-digit receive flag. According to the terminal number, the data is classified into five matrices, and then each matrix is divided into a matrix of 100 rows. At this time, each row in the matrix is a case where the sink node receives the data packet under the same probability value, and each matrix represents the sink node receive the data packet sent by the corresponding terminal. The number of 0 in each matrix indicates that the data packet sent by the corresponding terminal has not been received, and 1 indicates that the data packet sent by the corresponding terminal is received. The length of the time slot is normalized, and the operation and statistics of the five matrices are performed. The final received data packet of the sink node can be obtained, and the actual throughput and actual average success delay are calculated as

$$\text{Actual throughput} = \frac{\text{total time slot length of successful reception}}{\text{total time slot length}},$$

The actual throughput is shown in the figure 5.

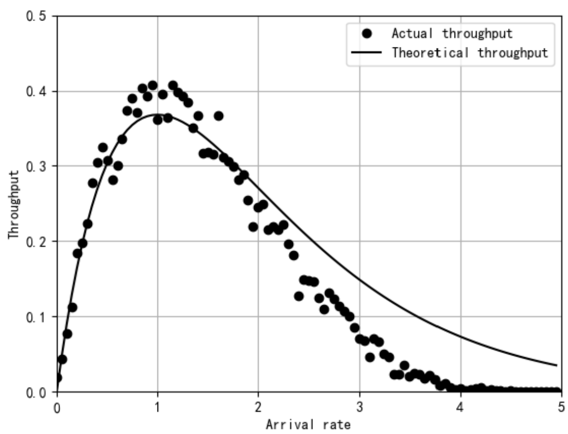

Figure 5 Hardwaresimulation throughput of slotted random multiple access system

It can be seen from the figure that when the arrival rate is 1, that is, when the transmission probability of each terminal node is 0.2, the terminal node transmits the data packet with a probability of 0.2, and the probability of 0.8 is not transmitted. At this time, the sink node can reach the maximum. At this time the system's performance is the best, in line with the theory. The theoretical value is 0.368 when the arrival rate is 1, and the actual value is 0.362, but the peripheral values are larger than the theoretical value. Considering the fact that the number of lost packets and the number of terminals in the actual transmission process is small, the error is within the acceptance range, compared to the simulation of five terminal nodes in Matlab, the actual system is closer to the theoretical value.

CONCLUSION

The time-slotted random multiple access protocol is implemented in the wireless sensor network by modifying and restricting the number of sub-devices and the maximum number of routing nodes in the sub-device, the network structure of the multi-hop ad hoc network is changed to a relatively stable single-hop cluster structure . And statistical calculations of important indicators such as throughput and average delay of the actual system, the results are basically consistent with the theoretical values. It lays the foundation for the application of more complex theoretical models to the actual wireless sensor network in the future and provides ideas. In the future research work, more complex random multiple access theory models will be practically applied to improve system performance, make full use of limited channel resources, and improve data transmission efficiency.

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