**Lab 5: 802.11a Image Transmission and Reception**

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| **Introduction**  In this lab, we have learned how to use MATLAB to implement the 802.11a image transmission and reception on the USRP platform. And in this process, we have got a better understanding of converting a three-dimensional array of images into a one-dimensional bitstream, and also how to change the size of the image for transmission. In addition, we have also learned the two channel competition mechanisms of MAC layer of 802.11a, DATA-ACK mode and RTS-CTS-DATA-ACK mode. Finally, we learned the random backoff mechanism, and completed the corresponding function part of the content of the code writing.  **Theoretical analysis**   1. **Introduction to functions** 2. **prmQPSKTransmitter.USRPCenterFrequency**   Define the center frequency of the USRP transmitter to transmit the radio signal, which is one of the properties of the prmQPSKTransmitter object.   1. **prmQPSKTransmitter.USRPGain**   Define the transmit gain of the USRP transmitter to transmit the radio signal, which is one of the properties of the prmQPSKTransmitter object.   1. **prmQPSKTransmitter.RxBufferedFrames**   Define the number of frames that the USRP receiver is allowed to buffer, which is one of the properties of the prmQPSKTransmitter object.   1. **prmQPSKTransmitter.Fs**   Define the IQ rate of the USRP transmitter to transmit the radio signal, which is one of the properties of the prmQPSKTransmitter object.   1. **prmQPSKTransmitter.USRPInterpolation**   Define the upsampling factor of the USRP transmitter to transmit the radio signal, which is one of the properties of the prmQPSKTransmitter object.   1. **prmQPSKTransmitter.FrameSize**   Define the size of the frame which will be transmitted from the USRP transmitter, which is one of the properties of the prmQPSKTransmitter object.   1. **prmQPSKTransmitter.USRPFrameLength**   Define the length of a frame USRP read at a time, which is the product of the number of frames buffered multiplied the size of each frame. And is one of the properties of the prmQPSKTransmitter object.   1. **prmQPSKReceiver.RxBufferedFrames**   Define the number of frames buffered, which is one of the properties of the prmQPSKReceiver object.   1. **prmQPSKReceiver.USRPDecimationFactor**   Define the decimation factor, which is the quotient 100e6 divided by the sampling frequency at the receiver. And is one of the properties of the prmQPSKReceiver object.   1. **Release(ThSDRu)**   Release the USRP transmitter object we have defined before. If the status of the USRP transmitter object is ‘Tx Busy’, then we need to use this function to release it so that we can transfer its status to ‘Success’.   1. **comm.SDRuTransmitter**   We can use comm.SDRuTransmitter to create the USRP transmitter object.   1. **comm.SDRuReceiver**   We can use comm.SDRuTransmitter to create the USRP receiver object.   1. **Channel competition mechanisms in MAC layer** 2. **DATA-ACK mode**   DATA-ACK mode is actually a simple ‘I ask, you answer’ interaction mechanism, and only two MAC frames are transmitted for the whole communication process: the transmitter DATA frame and the receiver acknowledgement frame ACK. This mechanism is also known as the two-handshaking mechanism. The transmitter detects the channel before communicating. If it hears that the channel is free, it waits for a DIFS. If the channel is still free at the end of this DIFS, it immediately sends a DATA frame. Upon receiving the DATA frame, the receiver sends back an ACK frame to inform the source station that the data has been received.    From the figure above, we can see that at the transmitter side, the first step for the DATA-ACK mode at transmitter side is Energy Detection. In this step, if the transmitter detects the energy E in the channel is less than the threshold ETH, then it will wait DIFS times, and when the countdown ends, the transmitter starts the Random Backoff, and when the countdown ends again, the transmitter will enter the next state, Data Transmission. And if the energy E in the channel is larger than the threshold ETH no matter it is waiting DIFS or entering Random Backoff, which means the channel is occupied by others, the transmitter will start detecting the energy in the channel again.  The second step for the DATA-ACK mode at transmitter side is Data Transmission. In this step, the transmitter will transmit the encapsulated packet to the receiver.  The third step for the DATA-ACK mode at transmitter side is ACK Receiving. In this step, the transmitter will first search SYNC in the ACK, then read the header, and if , then it will enter the last state, otherwise, it will enter the first step to detect the channel again.  The last step for the DATA-ACK mode at transmitter side is End of Transmission.    From the figure above, we can see that at the receiver side, the first step for the DATA-ACK mode at receiver side is Data Receiving. In this step, the receiver will first search SYNC in the DATA, then read the header and the payload of the packet. And enter the next state.  The second step for the DATA-ACK mode at receiver side is Wait SIFS. In this step, the receiver will wait SIFS times, and then enter the next state.  The last step for the DATA-ACK mode at receiver side is ACK Transmission. In this step, the receiver will transmit the ACK to the transmitter.   1. **RTS-CTS-DATA-ACK mode**   In this way, the sending station needs to reserve the channel before formally sending the data, and the data can be sent only after the reservation is successful. This method is also known as the "four-way handshake" mechanism, which is mainly used to solve the hidden station problem and exposed station problem in the basic access mode of CSMA/CA protocol.  In RTS-CTS-DATA-ACK mode, when a base station needs to transmit data,   1. The state of channel must be determined before sending. If the channel is idle, the base station first waits for a DIFS. If the channel is still idle at the end of this DIFS, the base station broadcasts a request to send an RTS control frame in which the address of the source station, the address of the destination station, and the time that the channel will be occupied by the communication process are written. The reason for waiting for a DIFS when the channel is idle is that if another station has a high priority frame to send, it will give the other station a chance to send the frame first, and the station will back off and delay sending. 2. When the destination station receives this RTS frame, it also sends back a CTS frame to the source station in the form of broadcast, and copies the value of the "duration" field in the RTS frame to the CTS frame if the channel is idle. When another station receives an RTS frame, it reads the value of time in it, compares the value with the value of its own NAV timer, takes the larger value of the two and sets the larger value to the NAV value. After setting, no other base station can use the channel during the timer time. 3. When the source station correctly receives this CTS frame, it indicates that the channel reservation has been successful, and the source station waits for another SIFS to start sending DATA frames. When other stations receive this CTS frame, they also read the value of time and set their NAV. 4. After receiving the DATA frame, the destination station sends an ACK frame to the source station to inform the source station that the data has been received. When the source station correctly receives the ACK frame, it means that the other party has received it, and the transmission process is successfully completed.     **Lab results & Analysis**   1. **Image sending and receiving on USRP**     The figure shown above is the image we transmitted at the USRP transmitter.  At USRP transmitter, we set the USRP center frequency to 2GHz, and change the image scaling factor to 0.1, so that we can get the new image size corresponding to the image scaling factor 0.1, which is [44 46 1], and also we can calculate the length of the image bitstream, which is , i.e., 16192. The specific configurations are shown as below:        The figure shown above is the image we received at the USRP receiver. From the figure, we can find that we have received the image we transmitted successfully.   1. **Random backoff mechanism**      1. **Flowchart of RTS-CTS-DATA-ACK mode**     The flowchart of the RTS-CTS-DATA-ACK mode is shown as above. | |
| **Experience**  **Experience**  孙逸涵:   1. In this lab, I first have learned how to use MATLAB to implement the 802.11a image transmission and reception on the USRP platform. Then, I also got a better understanding of the principle of the two channel competition mechanisms of MAC layer of 802.11a, DATA-ACK mode and RTS-CTS-DATA-ACK mode, which I have learned the basic concepts in the Computer Network lecture in the last semester. 2. When doing the 802.11a image transmission and reception on the USRP platform, I met some problems at first. So the first part I consider where there might be a problem is the image size mismatching between the transmitter and the receiver, and the second part I consider where there might be a problem is the center frequency and the gain of the USRP. Both of above are the problems of the code, but finally I proved that there is no wrong in the code. Instead, I tried to use ‘findsdru’ instruction to check the connectivity between the USRP and the computer, but there is still no wrong of that, the results always have been ‘success’. However, I find there was a warning on the receiver computer, which said that the center frequency and the gain of the USRP are both out of range, so I tried to use ‘probesdru’ instruction to see the appropriate range of the center frequency and the gain of the USRP, but the results are 0. Therefore, I find the problem is occurred at the receiver USRP, then I changed another one to try my codes, and it ultimately run successfully.   张旭东:   1. In this lab, I have known and mastered the principle of competition mechanism of RTS-CTS-DATA-ACK mode. 2. In this lab, I have understood the mechanism of random back off and simulated the mechanism of random back off. 3. I have mastered the flowchart of RTS-CTS-DATA-ACK mode.   **In-class lab screenshot**  孙逸涵:   * **Part3**      * **Part4**         张旭东:   * **Part3**      * **Part4** | |
| **Score** | 100 |