Wireless Networks and Mobile Systems, 598HH

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08/30/2016

Lecture: Rate Adaption

1. BitRate

BitRate is the number of bits that are conveyed or processed per unit of time. Every bit of the data is transmitted in the channel. Wireless channels are unstable and change over time. A good channel will have less noise to be added on the data signal. The SNR at the receiver will be higher. In this case, the transmitter is able to send more bits per symbol, resulting in the higher bitrate. In the other way, if the channel state is bad, more noise will be added on the data signal. SNR at the receiver will be decreased, which leads transmitter to transmit less bits per symbol.

Bits per symbol will change with different modulations. Assuming the bandwidth is 1 MHZ. With good channel state, BPSK can transmit 1 bit/symbol, the constellation diagram of BPSK is shown in the Figure 1. The number of symbols that can be transmitted in a unit time is 1M/sec. Therefore, the bitrate for BPSK is 1Mb/sec. 4QAM is able to send 2 bits at each symbol. The bitrate for 4QAM is 2Mb/sec. 16 QAM is able to send 4 bits at each symbol. The bitrate for 16QAM is 4Mb/sec.
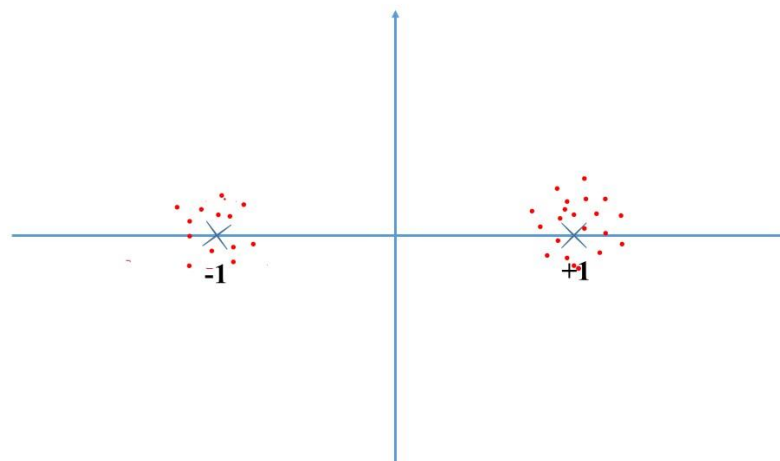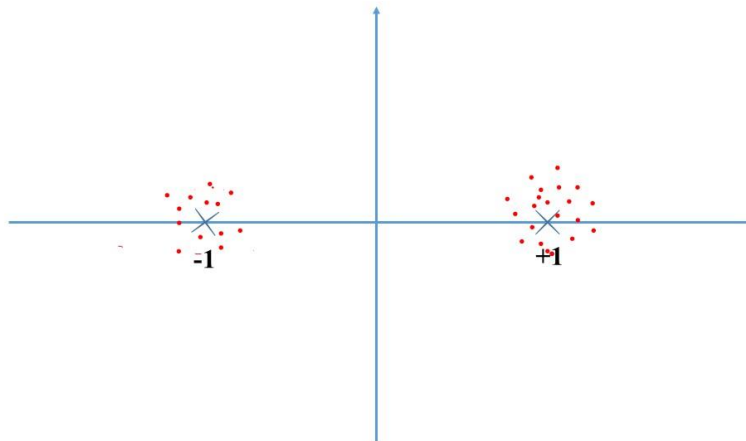

Figure1. Constellation for BPSK
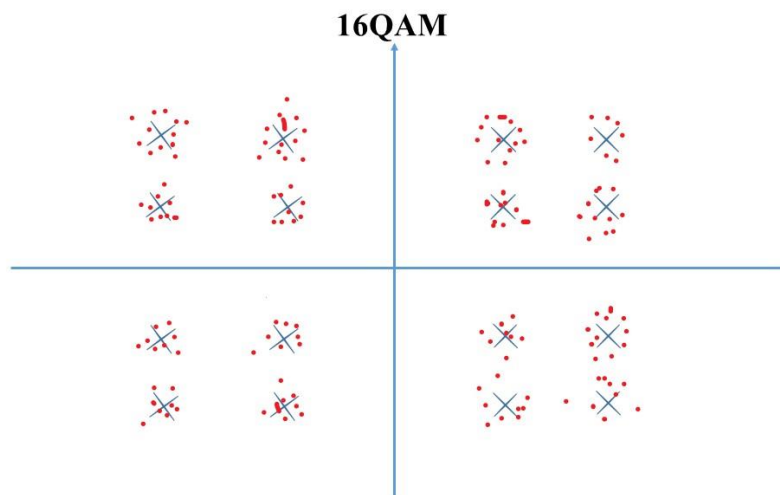
Figure2 Constellation for 4QAM

16QAM

Figure3 Constellation for 16QAM

For 4QAM, the SNR can be calculated by the following formula:

$$SNR_{dB} = 10 * log_{10}\left(\frac{|h|^2 P}{N}\right) = 10 * log_{10}(\frac{1}{\Delta^2})$$

Where, N is the power of the noise, h is the channel information and P is the transmit power of the signal.

Based on the SNR, the bit error can be calculated. BER will decrease as SNR increases. Because, it's easy to demodulate a signal correctly with less effect of the noise. The relationship between SNR and BER is shown in Fig4.
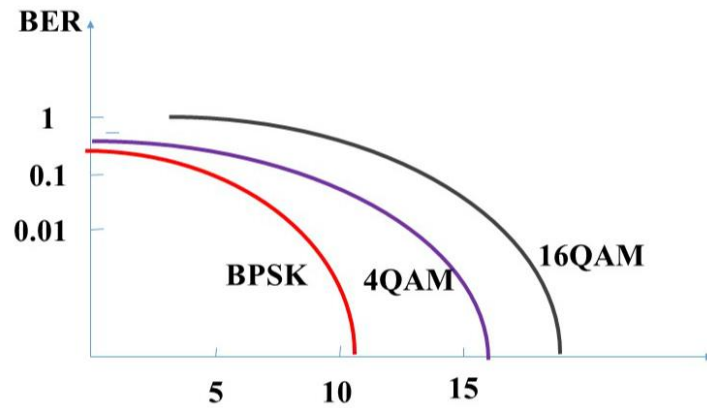
Fig4 Different BER at different SNR

2. Throughput

Forward error checking(FEC) is a technique used for controlling errors in data transmission over unreliable or noisy communication channels. For example, when we use the FEC, there will be redundant bits on the transmitted code. The redundancy allows the receiver to detect a limited number of errors that may occur anywhere in the message, and often to correct these errors without retransmission. For example, when the data is tranmitted with FEC, the code rate is m/n; bandwidth is B. Then the bit rate is B*rate/symbol. The efficient bit rate in FEC is B*rate/symbol*m/n.

The other way to measure the efficient bit rate is throughout. Throughput is the rate of successful message delivery over a channel. That is to say, throughput is the number of correct transmitted data bits per second. Throughput is always less than or equal to the bit rate. This is because throughput measures the time for transmitting a correct package. If the transmitter transmit a packet without any error for the firsttime, then throughput is equal to the bit rate. However, if errors occur in the first time, transmitter have to retransmit the packet. The number of bits the reciver received is the same, however, the tranmitting time is doubled, and throughput will be less than the bit rate. Bit rate is what transmit in the channel, while throughput is decided by the receiver. Therefore, throughput is influenced by SNR. When the SNR is very low, througput is always close to zero. As SNR increase and is larger than some threshold, throughput will be increase as the increase of SNR. And, when the SNR is larger than another threshold, throughput will remain an optimal value, which is bit rate. The relationship between throughput and SNR is shown in Fig5.
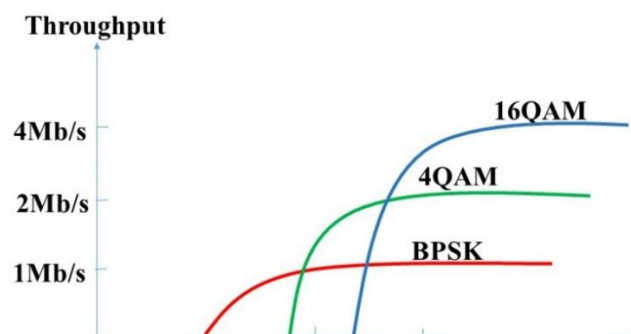

Fig 5 Relationship between throughput and SNR

That throughput is zero when SNR is too low is because the there will be correct transmittion only when the SNR is beyond a threshold. The best throughput curve is compose of the three modulation curves. The optimal value of the throughput is limited because of the bandwidth. Based on Fig5, we can select the modulation for transmitting signal.

3. Robust Rate Adaptation Algorithm

The drawback of RRAA is that it proposed that SNR is not a good metric in rate adaption. It said that SNR is unstable. Althrough in cases of fast mobility it can be very unstable, SNR is still a good metric in general. However, it is hard to measure. Because it is difficult to distinguish the signal when the power of noise is very high. You may misunderstand a signal and have no way to figure it out when you are decoding wrong.

The other metric used in the paper is frame loss, You can make a decision that a frame is lost in the channel when you don't receive a ACK for the corresponding packet.
Time interval will have an important effect on the metric. If the metric is measures on the small interval, it is inaccurate, while measured on large interval, the metric will change.

If there are signal collisons in the wireless network, the bit rate can't reduced. Because once the bit rate is reduced, the transmittion time of the data will be enlarged. Then more collisions may happen. The solution to the collisions in the wireless networks is the Request To Send/Clear To Send (RTS/CTS).

In the wireless networks, there are two famous collision problems. One is hidden terminal problem, and the other one is exposed terminal problem. Hidden terminal problem occurs when a nodes visible from a wireless access point (AP), but not from other nodes communicating with that AP. As shown in Fig6, before transmitting to aceess point B, C will hear on its channel, C can't hear A and begins to transmit signal to B. At the same time, A also can't hear B and starts to transmit to B. Then, A' signal and C's signal will collide with each other at B.
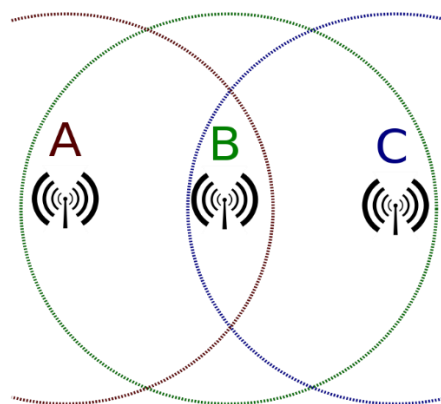

Fig 6 Hidden Terminal Problem

Exposed Terminal Problems occurs when a node is prevented from sending packets to other nodes because of a neighboring transmitter. As shown in Fig 7, terminal S1 is transmitting to

node R1. Terminal S2 wants to communicate with node R2. Although their signals will not collide with each other, S2 still have to wait for S1 to complete transmittion.

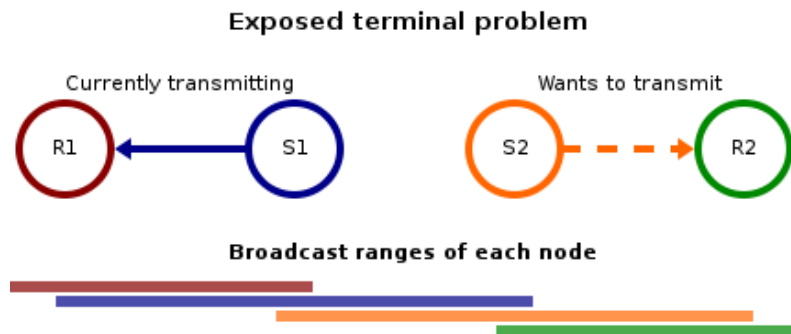**Exposed terminal problem**

Fig 7 Exposed Terminal Problem

RTS/CTS is able to solve these two questions. In the hidden terminal problem. When A and C want to communicate with B, they should send RTS to B at first. Then if B accept A's RTS first, it will reply CTS to A. Then B can hear the CTS and knows that it's not for itself. B will wait for the CTS. In the exposed terminal problem, when S2 want to communicates with R2, S2 can starts to transmit data after receiving the CTS from R2 and does not have to wait after S1's transmitting.

However, RTS/CTS also can introduce problems. RTS/CTS are using BPSK and thus transmitted at a low data rate. If data is tranmitted at high data rate, there will be high overhead. Paper RRAA introduced the adaptive RTS. If packets with RTS are lost in the channel, the system will decrease the number of packtes with RTS. On the other way, if packets without RTS are lost in the channel, system will increase the packets with RTS.

4. SoftRate

The idea for the paper is to use the PHY hints to compute BER, due to that SNR may lead to erroneous judgement for data. The formula is as following:

$$\text{LLR} = \log\frac{p(b_k = 1|r)}{p(b_k = 0|r)}$$

We can obtain from the formula that $S_k = |LLR|$. That means: $\widehat{b_k} = \begin{cases} 1 & LLR > 0 \\ 0 & LLR < 0 \end{cases}$. When the LLR is bigger than 0, the probability of bit to be 1 is higher. When LLR is less than 0, probability of bit to be 0 is higher.

The problem for the softrate is that they still need preamble to work. And it will cause overhead.