ECE442 Communications
Lecture 7. Adaptive Modulation and Coding

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In adaptive transmission systems, the system estimates the channel at the receiver and feeds back the estimation to the transmitter such that the transmission scheme can be adapted to the channel characteristics.

Adaptive modulation is first exploited in late 1960s.

Many wireless systems, such as GSM, CDMA and WLAN, are using or planning to use adaptive transmission techniques.
1. Adaptive modulation requires a feedback path between the transmitter and receiver.
2. If the channel changes too fast, the adaptation will perform poorly.
3. Hardware constraints determine how often the transmitter can change its rate and power.
4. It may not be feasible in fixed-rate applications with hard delay constraint.
System Model
Variable-rate Techniques

The transmission rate can be changed by

1. Fixing the symbol rate and using multiple modulation schemes or constellation sizes.

2. Or, fixing the modulation and changing the symbol rate.

3. For example, EGPRS in GSM systems can switch between 8PSK and GMSK; GPRS in TDMA can use 4, 8, or 16 level PSK.
We can do channel inversion:

\[
\frac{S(\gamma)}{\overline{S}} = \frac{\sigma}{\gamma},
\]

where \( \sigma \) equals the constant received SNR.

The channel inversion can be truncated.

We can also adapt the instantaneous bit error rate to an average BER constraint.
1. We can use a stronger code when the channel is bad and use a weaker code (or even no coding) when the channel is good. But we need to assume that the channel changes slowly within the codeword.

2. Rate-compatible punctured convolutional (RCPC) codes, which consist of a family of convolutional codes at different code rates. The correction capability can be modified by not transmitting certain coded bits (i.e., puncturing the code).
1. We use the following bound for the BER in AWGN channel:

\[ P_b \leq 2e^{-1.5\gamma/(M-1)}. \]

2. In a fading channel, the average BER is averaged over the random SNR \( \gamma \).
We consider adapting the transmit power $S(\gamma)$ and $M$ to maintain the target $P_b$.

The problem is formulated as an optimization problem:

$$\max_S E [\log_2 M(\gamma)]$$

subject to

$$\int S(\gamma)p(\gamma)d\gamma = \bar{\gamma},$$

where the objective function is the spectral efficiency and the constraint is the restriction on the average power.
Performance

- Shannon Capacity
- Adaptive MQAM (BER=10^-3)
- Adaptive MQAM (BER=10^-6)

Spectral Efficiency (bps/Hz) vs. Average dB SNR (dB)