Modulation Mapping

p	bits
0	0000
1	0001
2	0010
...	...
15	1111

$\xrightarrow{\text{Map}}$

$\xrightarrow{\text{Channel}}$
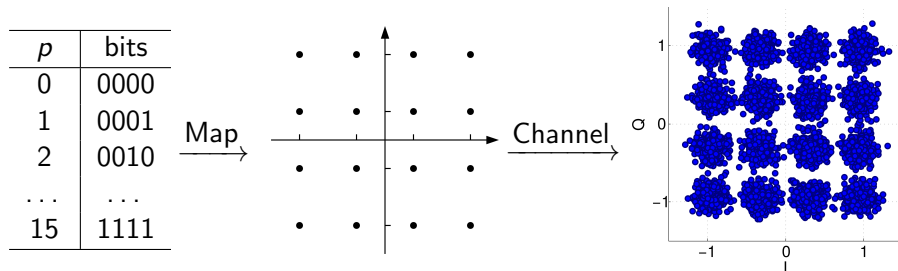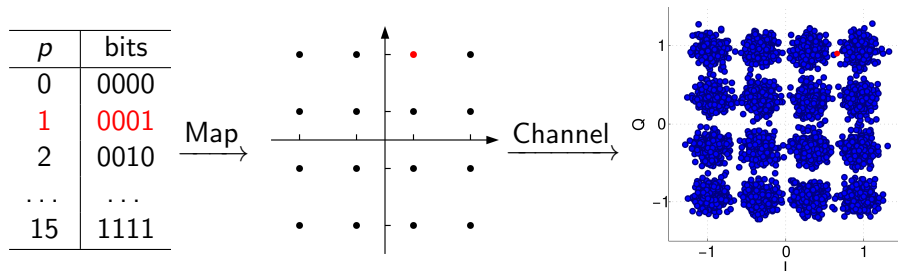
- Unideal wireless channel tends to cause demodulation errors.
- Constellation points closer to each other are more likely to be confused.

Modulation mapping needs to be carefully designed!

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Map → Channel →

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Single Transmission: Gray-mapping

Strategy (Gray-mapping)

Neighboring constellation points (horizontally or vertically) differ only by 1 bit, so as to minimize the Bit Error Rate (BER).

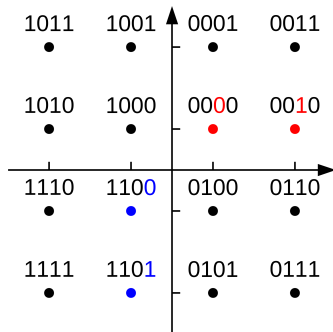Figure : Gray-mapping for 16-QAM, 3GPP TS 25.213.

HARQ with Constellation Rearrangement (CoRe)

Hybrid Automatic Repeat reQuest (HARQ)

- ▶ Same piece of information is retransmitted again and again, and combined at the receiver until it is decoded successfully or expiration.
- ▶ An error control scheme widely used in modern wireless systems such as HSPA, WiMAX, LTE, etc.

Constellation Rearrangement (CoRe)

- ▶ For each round of retransmission, different modulation mappings are used (explained next).
- ▶ Exploit the Modulation Diversity (MoDiv).
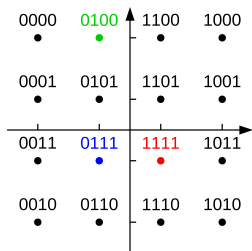
An Example of CoRe

Figure : Original transmission.

- Original transmission: 0111 is easily confused with 1111, but well distinguished from 0100.

An Example of CoRe
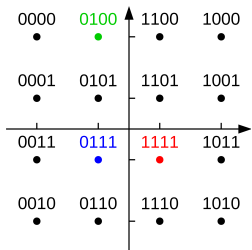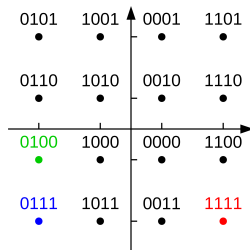

Figure : Original transmission.

Figure : First retransmission.

- Original transmission: 0111 is easily confused with 1111, but well distinguished from 0100.
- First retransmission: 0111 should now be mapped far away from 1111, but can be close to 0100.

General Design of MoDiv Through CoRe

Challenges

1. More than 1 retransmissions?
2. More general wireless channel models?
3. Larger constellations (e.g. 64-QAM)?

We formulated 2 different MoDiv design problems into Quadratic Assignment Problems (QAPs) and demonstrate the performance gain over existing CoRe schemes.

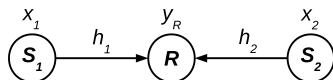# Two-Way Relay Channel (TWRC) with Analog Network Coding (ANC)

- System components: 2 sources (S_1, S_2) communicate with each other with the help of 1 relay (R).

$$\left(S_1\right) \qquad \left(R\right) \qquad \left(S_2\right)$$

Figure : TWRC-ANC channel.

Two-Way Relay Channel (TWRC) with Analog Network Coding (ANC)

- System components: 2 sources (S_1, S_2) communicate with each other with the help of 1 relay (R).
- Alternating between 2 phases:
  - Multiple-Access Channel (MAC) phase: the 2 sources transmit to the relay simultaneously.

Figure : TWRC-ANC channel.

$$y_R = h_1 x_1 + h_2 x_2 + n_R$$

Two-Way Relay Channel (TWRC) with Analog Network Coding (ANC)

- System components: 2 sources (S_1, S_2) communicate with each other with the help of 1 relay (R).
- Alternating between 2 phases:
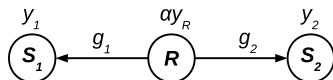   - Multiple-Access Channel (MAC) phase: the 2 sources transmit to the relay simultaneously.
    - Broadcast Channel (BC) phase: the relay amplify and broadcast the signal received during the MAC phase back to the 2 sources

Figure : TWRC-ANC channel.

$$y_1 = \alpha g_1 y_R + n_1,$$
$$y_2 = \alpha g_2 y_R + n_2$$

HARQ-Chase Combining (CC) Protocol

- Q: size of the constellation.
- M: maximum number of retransmissions.
- $\psi_m[p]$, $m = 0, \ldots, M$, $p = 0, \ldots, Q-1$: constellation mapping function between "label" p to a constellation point for the m-th retransission.

Due to symmetry of the channel, consider the transmission from S_1 to S_2 only. The received signal during the m-th retransmission of label p is:

$$y_2^{(m)} = \alpha^{(m)} g_2^{(m)} (h_1^{(m)} \psi_m[p] + \textcolor{red}{h_2^{(\tilde{m})} \psi_{\tilde{m}}[\tilde{p}]} + n_R^{(m)}) + n_2^{(m)},$$

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