Lecture 35: 4.6 MIMO Technology (Basic concept and Advantages)

4G and 5G Networks

DI05011011: Mobile Communication

Agenda for Today

- 1. What is MIMO?
- 2. Traditional Systems (SISO, SIMO, MISO)
- 3. Basic Concept of MIMO
- 4. Mode 1: Spatial Multiplexing
- 5. Mode 2: Transmit Diversity
- 6. Beamforming
- 7. Advantages of MIMO
- 8. Summary and Q&A

What is MIMO?

- **MIMO (Multiple Input Multiple Output)** refers to the use of multiple antennas at both the transmitter (eNodeB) and the receiver (Mobile Phone).
- - 'Input' refers to the signals entering the wireless channel (transmitter antennas).
- - 'Output' refers to the signals leaving the channel (receiver antennas).
- - It leverages multipath propagation—which used to be a problem—and turns it into a benefit.

Antenna Configurations

- Before MIMO, we had other setups:
- 1. **SISO (Single Input Single Output):** 1 Tx, 1 Rx. The traditional baseline. Vulnerable to fading.
- 2. **SIMO (Single Input Multiple Output):** 1 Tx, 2+ Rx. Uses 'Receive Diversity' to improve signal strength at the receiver.
- 3. **MISO (Multiple Input Single Output):** 2+ Tx, 1 Rx. Uses 'Transmit Diversity' to ensure the signal reaches a simple receiver.
- 4. **MIMO:** 2+ Tx, 2+ Rx. The ultimate configuration for modern networks.

How MIMO Works: The Magic of Multipath

- In a rich scattering environment (like a city with buildings), signals take multiple different paths from Tx to Rx.
- - Because the transmit antennas are physically separated, each path is slightly different (independent fading).
- - The receiver, with its multiple antennas and powerful signal processing, can separate these mixed signals mathematically.
- - This requires complex matrix mathematics to decode.

MIMO Mode 1: Spatial Multiplexing

- **Goal: Maximum Speed / Data Rate**
- - The transmitter splits a high-rate data stream into multiple independent data streams.
- - Each independent stream is sent out of a different antenna simultaneously, on the same frequency.
- - The receiver separates them.
- - **Result:** If you use a 2x2 MIMO system, you can potentially double the data rate without using extra bandwidth.

MIMO Mode 2: Transmit Diversity

- **Goal: Maximum Reliability / Coverage**
- - Used when the signal is weak (e.g., cell edge).
- - The transmitter sends the *same* data stream (or specially coded versions of it) out of multiple antennas.
- - The receiver combines these multiple copies to create one strong, clear signal.
- - **Result:** Does not increase peak data rate, but significantly reduces errors and dropped calls.

Beamforming (Related Concept)

- While not strictly basic MIMO, multiple antennas enable **Beamforming**.
- - Instead of broadcasting the signal in all directions (like a lightbulb), the antennas coordinate their phases to focus the RF energy into a narrow beam (like a laser).
- - Points the beam directly at the user.
- - Improves signal-to-noise ratio and reduces interference to other users.

Advantages of MIMO (Part 1)

- 1. **Increased Spectral Efficiency:** Spatial multiplexing multiplies data rates without requiring additional frequency spectrum.
- 2. **Improved Link Reliability:** Diversity techniques combat fading and improve coverage, especially at the cell edges.
- 3. **Higher Capacity:** The overall cell capacity is increased, allowing more users to be served simultaneously at high speeds.

Advantages of MIMO (Part 2)

- 4. **Reduced Interference:** Techniques like beamforming can steer nulls (areas of zero signal) toward interfering users.
- 5. **Synergy with OFDM:** OFDM flattens the frequency channel, making the complex matrix math required to decode MIMO signals much easier to calculate in real-time.

Real-World Application: Wi-Fi Routers

- Look at modern Wi-Fi routers at home:
- - Old routers (802.11g) had 1 antenna (SISO).
- - Modern routers (802.11n, ac, ax) have 4, 6, or 8 antennas sticking out.
- - This is MIMO in action! The router uses spatial multiplexing to stream 4K video to your TV while simultaneously handling a Zoom call on your laptop.

Lecture Summary

- MIMO utilizes multiple antennas at the transmitter and receiver.
- It turns multipath propagation into an advantage.
- **Spatial Multiplexing** splits data into parallel streams to multiply speed.
- **Transmit Diversity** sends copies of the same data to improve reliability.
- MIMO provides massive gains in spectral efficiency, capacity, and coverage, making it essential for 4G.

Next Lecture Preview

- In the next lecture, we will wrap up our discussion on 4G and introduce 5G.
- **Topics:**
- 1. Advantages and limitations of overall 4G technology.
- 2. Introduction to 5G technology.
- 3. The 5G Architecture.