Cooperative and Retransmission Diversity for Real-Time multiple antenna Communications
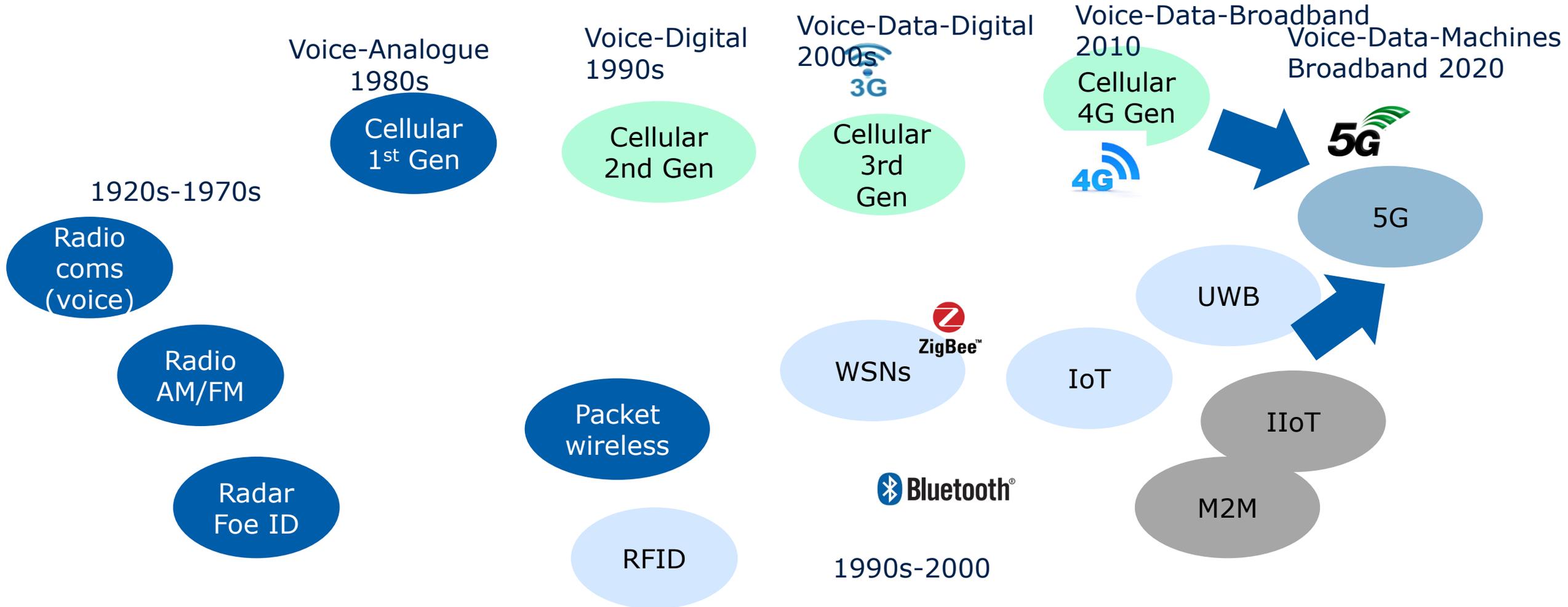
Ramiro Robles (ISEP)

Wireless communications (history)

Voice-Analogue
1980s

Voice-Digital
1990s

Voice-Data-Digital
2000s

3G

Voice-Data-Broadband
2010

Voice-Data-Machines
Broadband 2020

Cellular
1st Gen

Cellular
2nd Gen

Cellular
3rd
Gen

Cellular
4G Gen

4G

5G

1920s-1970s

Radio
coms
(voice)

5G

Radio
AM/FM

UWB

ZigBee™

WSNs

IoT

Packet
wireless

Radar
Foe ID

IIoT

M2M

Bluetooth®

RFID

1990s-2000

What is 5G?

- 5G is the next generation of wireless cellular infrastructure.

  ☐ Convergence of cellular, wireless sensor, IoT, M2M and CPS systems

- Main **objectives beyond 3G/4G systems**:

  ☐ higher capacity,

  ☐ ultra-low latency for machine-type traffic support, and

  ☐ dense object connectivity demand (IoT or Internet of things)

- **Motivations**:

  ☐ 50 billion devices will be connected to the cloud in 5-10 years time

  ☐ Industrial automation (M2M) and cyber-physical systems (e.g., automated driving and SHM)

  ☐ Current cellular technologies cannot cope with the scalability of large numbers of objects or "things" connected wirelessly with ultra-low latency

  ☐ 3G/4G solutions were designed for human users, not for machines.

 ☐ WSNs cannot achieve cellular coverage service for industrial IoT

Ultra low latency

Higher capacity

5G

Adaptivity

Dense object
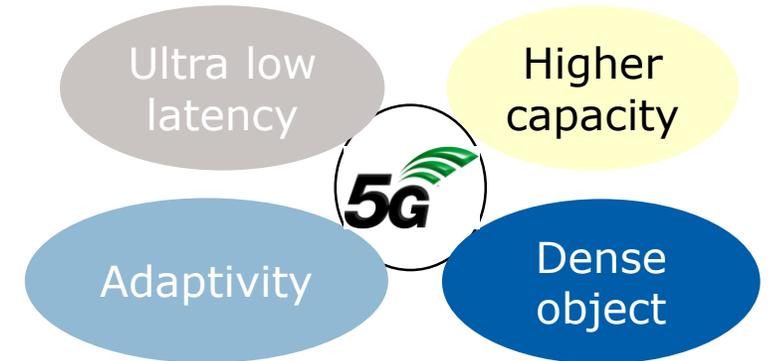
Wireless technologies (capacity vs range)
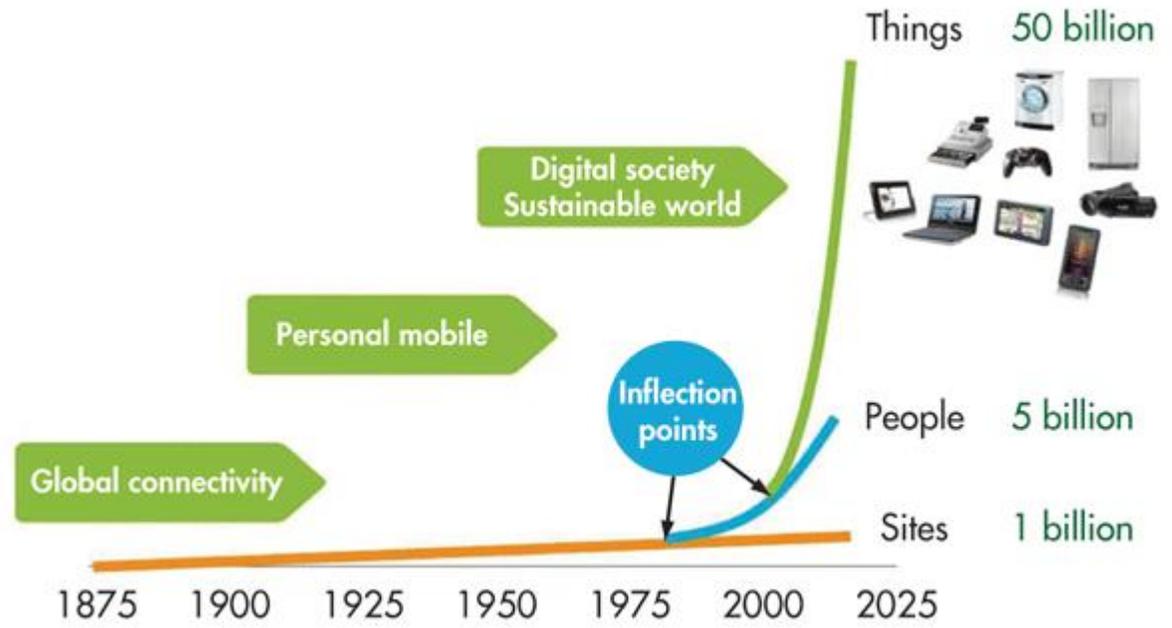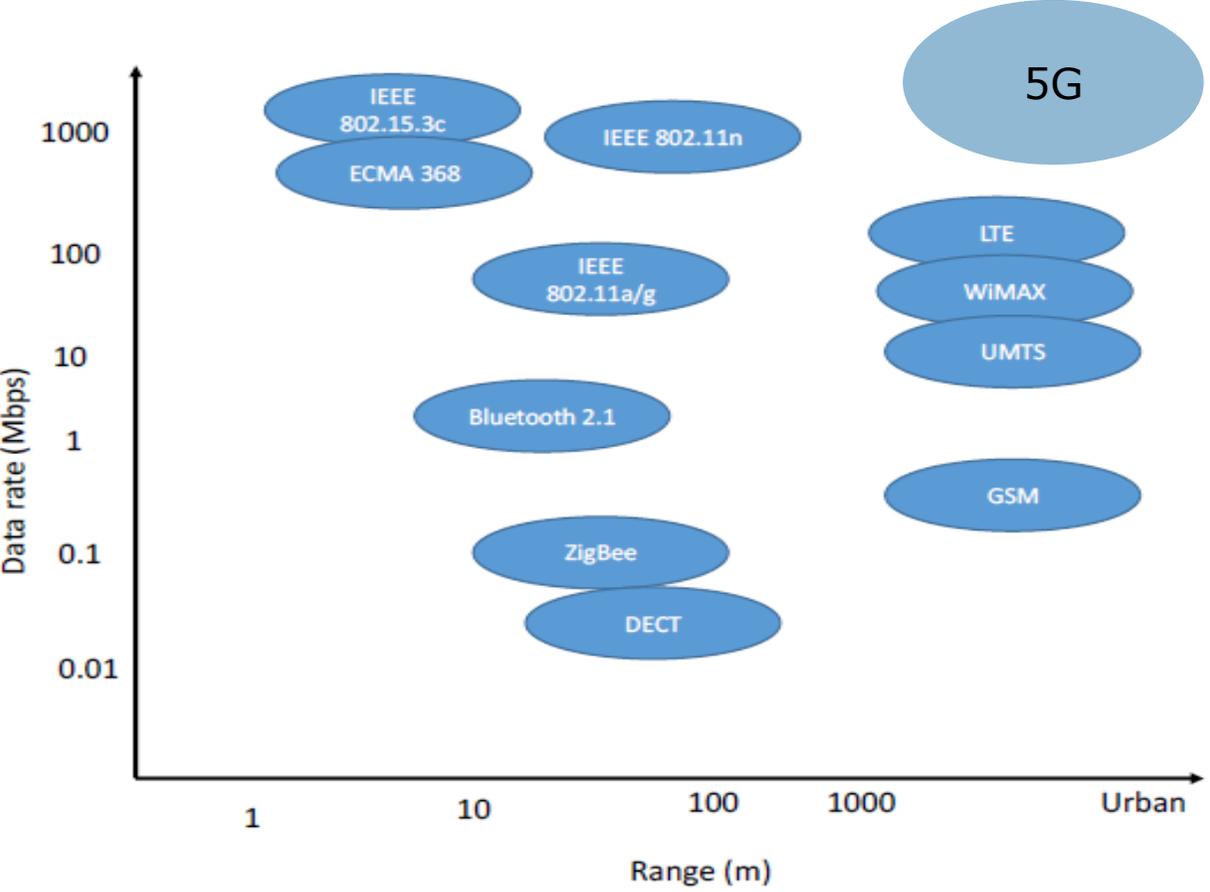
Why wireless has problems with real time traffic?

- Infinite number of reflections, diffractions, obstacles, etc.

- Propagation medium changes with temperature, vehicle, speed, etc

- Result is fading, inter-symbol interference, etc.

- Wireless is therefore random and the quality is potentially unpredictible
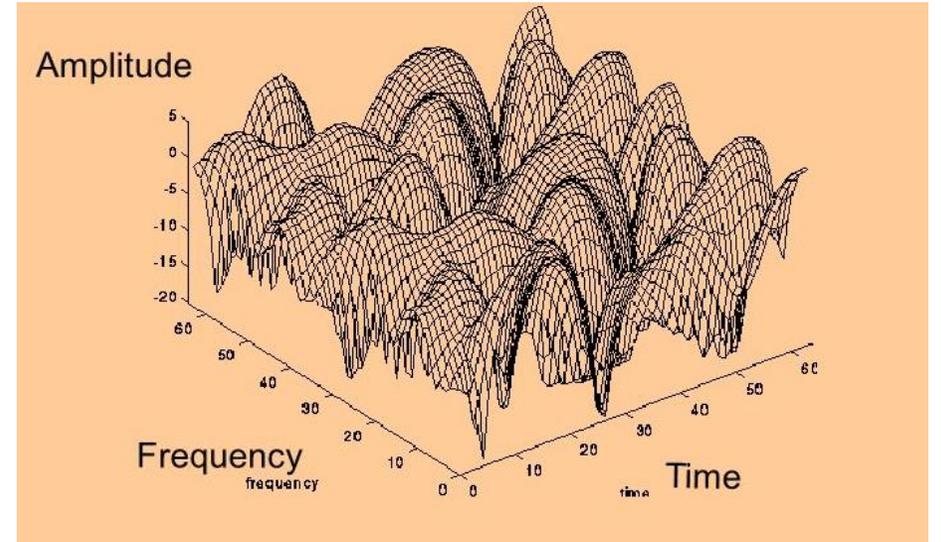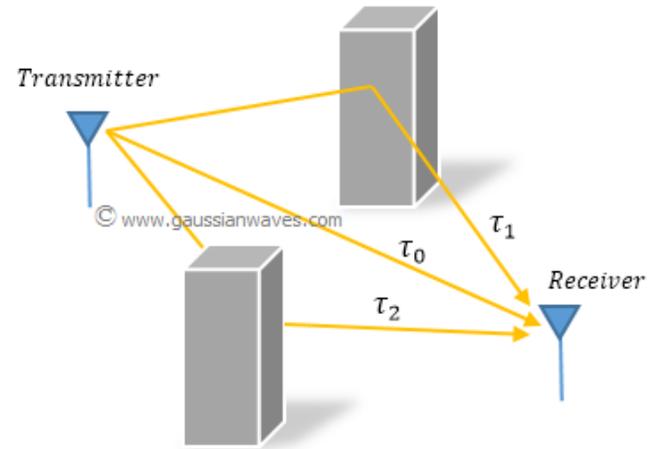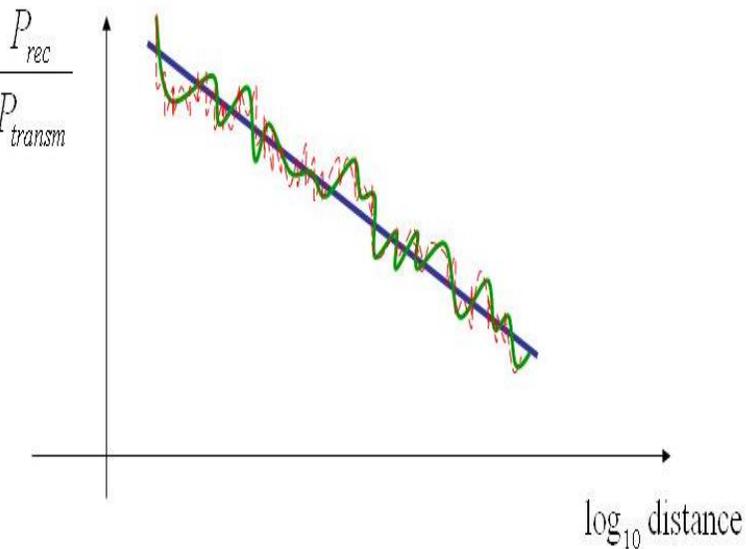
Spatial diversity

- Different antenna element suffer different fading phenomena

- Signals that in one antenna suffer fading, can be recovered from other antenna elements with less fading.

- Signal processing is key in multiple antennas

- MIMO systems are the base for 5G solutions

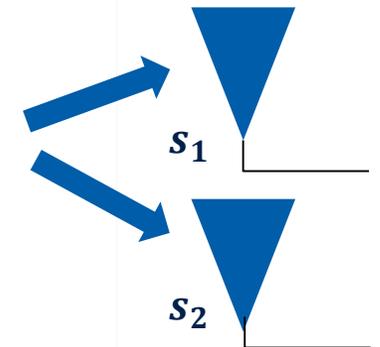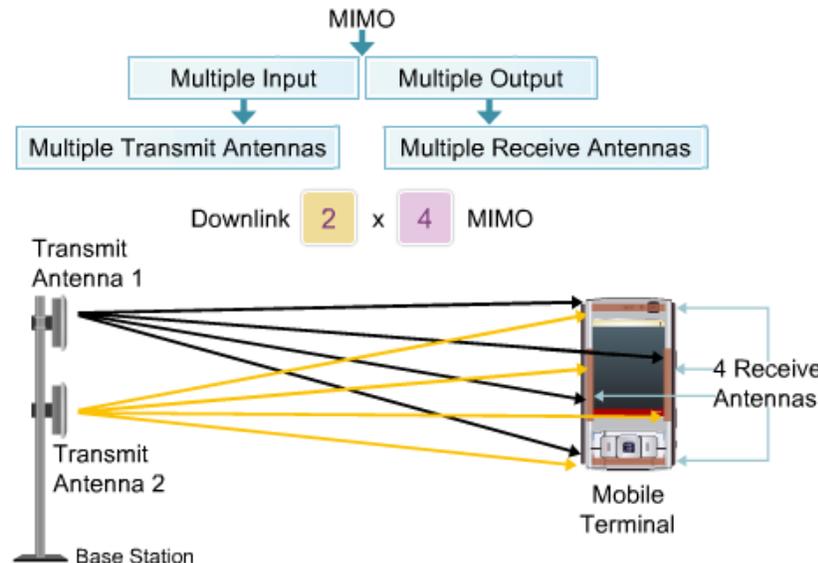- The suffer from **space correlation** (distance between antennas)
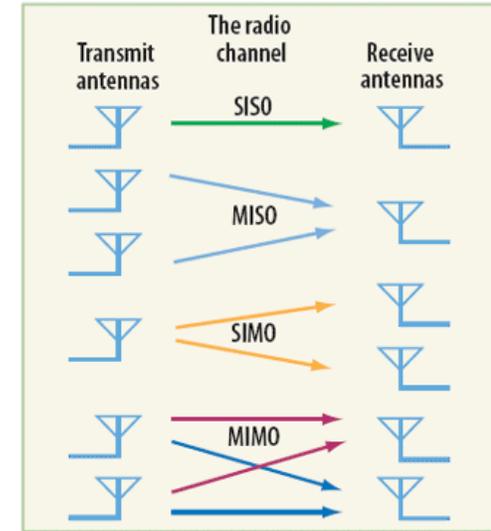
M Tx, N Rx

$$H = U^H \Delta V$$

H MIMO channel (MxN)

V Tx Beamforming matrix

U^H Rx Beamforming matrix

$$C \propto \min(M, N)$$

$$H = H_c + H_{null}$$

Induce noise+ interference rejection

MIMO

Multiple Input	Multiple Output
Multiple Transmit Antennas	Multiple Receive Antennas

Downlink 2 x 4 MIMO

Transmit Antenna 1

Transmit Antenna 2

Base Station

4 Receive Antennas

Mobile Terminal

The radio channel

Transmit antennas

Receive antennas

SISO
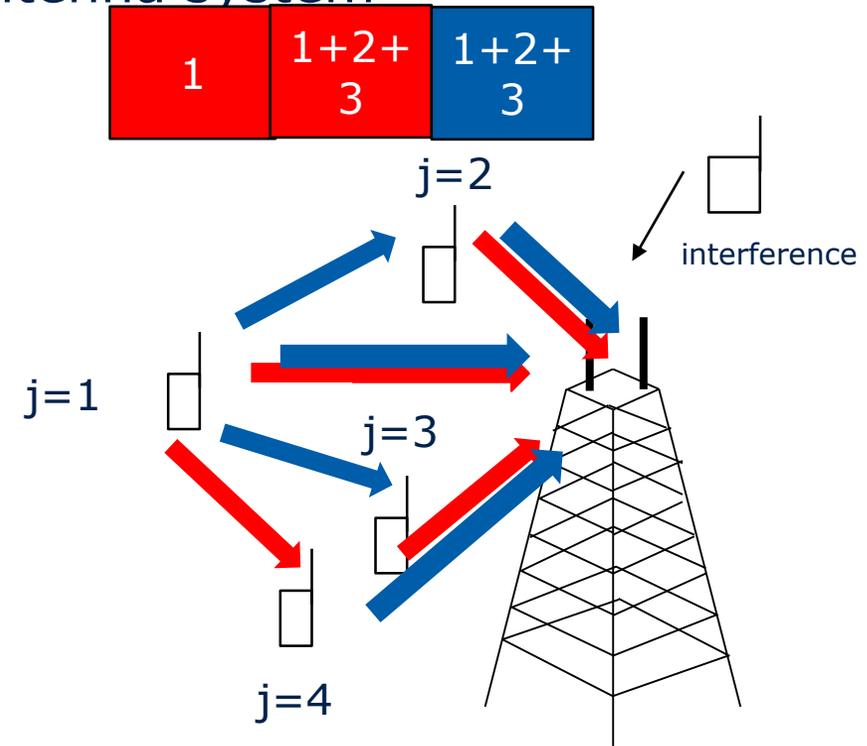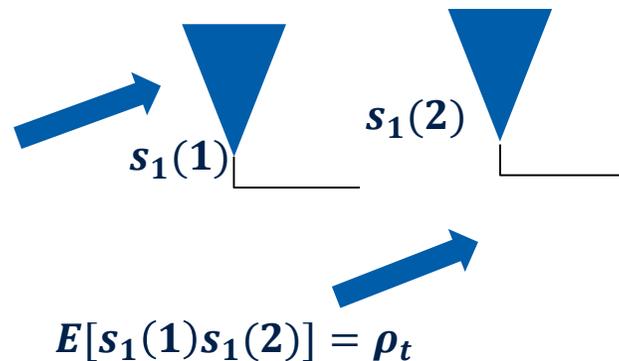
MISO

SIMO

MIMO

s_1

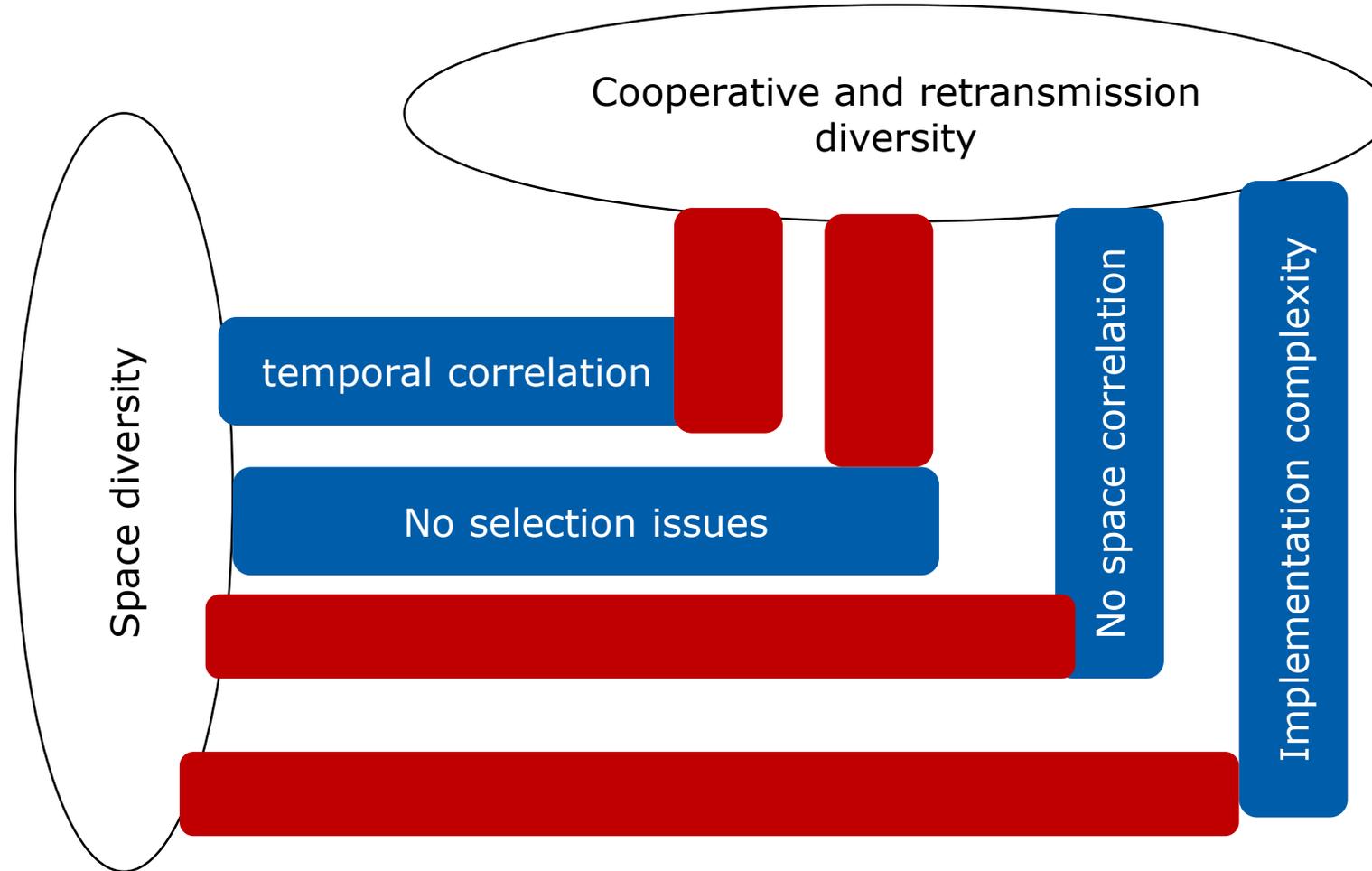s_2

$$E[s_1 s_2] = \rho$$

Cooperative and retransmission diversity

- Terminals relay the signals of other terminals in the network

- Retransmissions occur in different time slots

- Cooperative terminals form a macroscopic antenna system

- No spatial correlation

- Correlation between retransmissions

- Relay selection, coordination

- No need of multiple antennas

$$C \propto \frac{\min(M, N)}{E[l]}$$

$s_1(1)$

$s_1(2)$

$E[s_1(1)s_1(2)] = \rho_t$

| 1 | 1+2+3 | 1+2+3 |

j=2

interference

j=1

j=3

j=4

Cooperative vs spatial diversity

Cooperative and retransmission diversity

Space diversity

temporal correlation

No selection issues

No space correlation

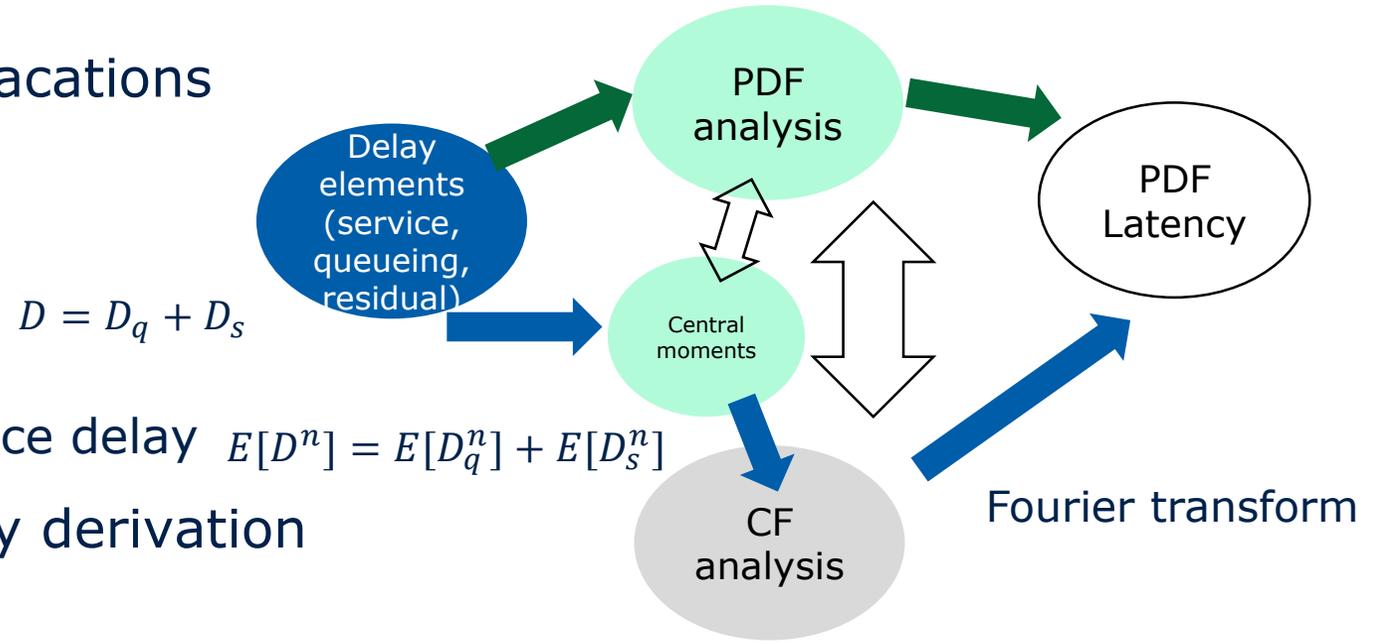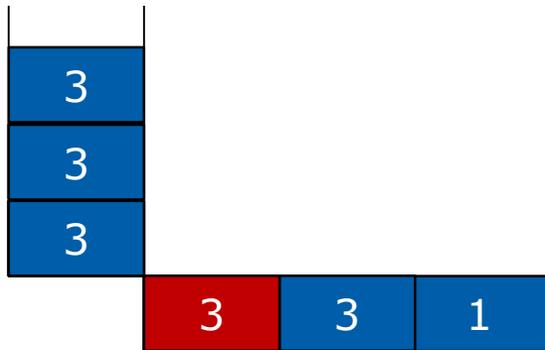Implementation complexity

Delay

- **Calculation using M/G/1 queue with vacations**
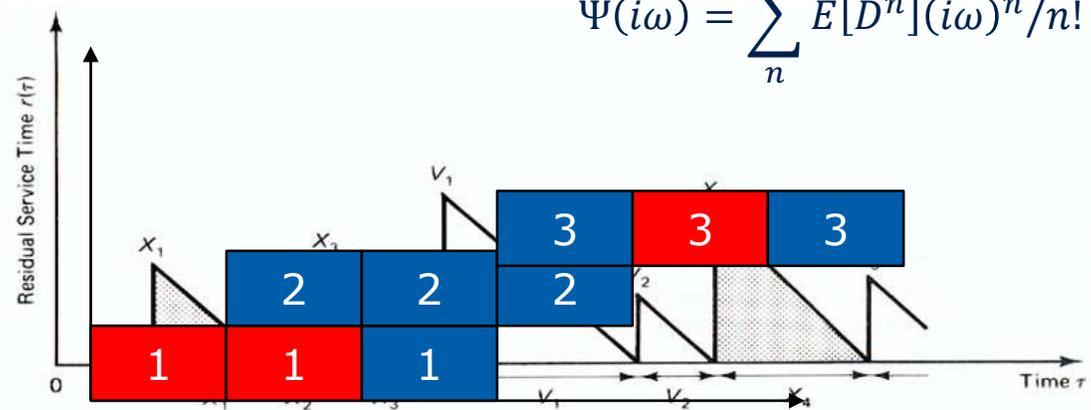 - ☐ M- Markov arrival
  - ☐ G- General distribution
  - ☐ 1- one server
  - ☐ Residual delay, queuing delay and service delay
- **Conventional approach: Average delay derivation**
- **For real time: full statistics of delay**

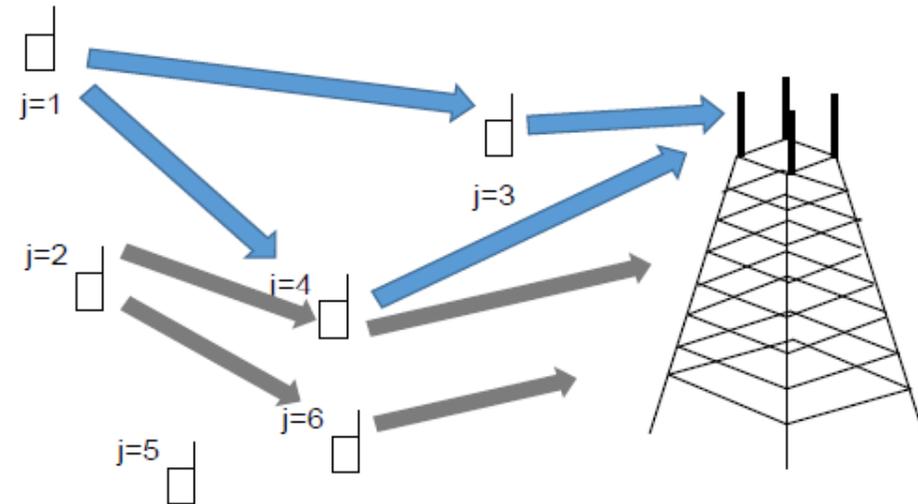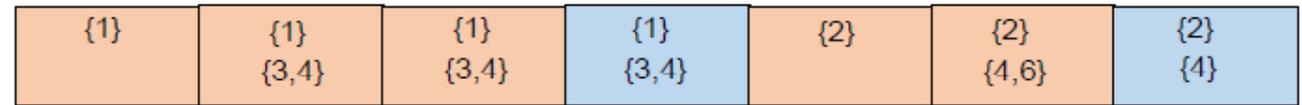$$D = D_q + D_s$$

$$E[D^n] = E[D_q^n] + E[D_s^n]$$

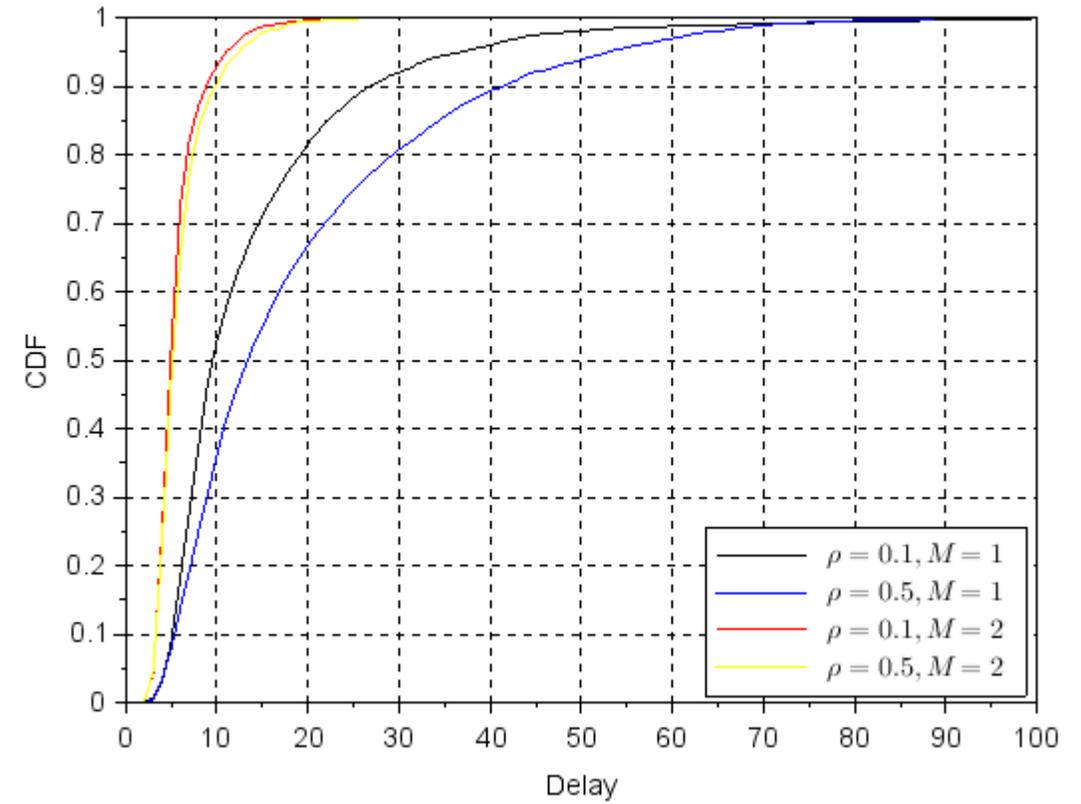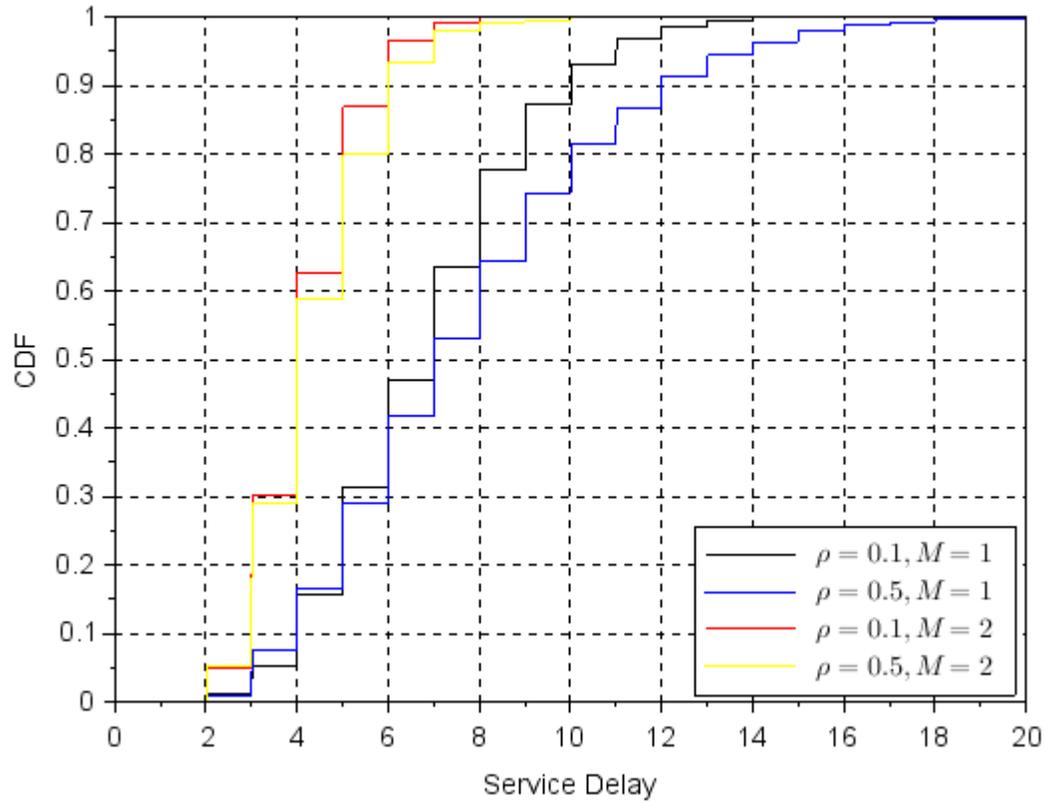$$\Psi(i\omega) = \sum_n E[D^n](i\omega)^n/n!$$

Simulation parameters

- Cooperative, restransmission and spatial diversity

- Fixed number of relays (uniform distribution)

- Single user analysis

- Poisson traffic distribution

- Ncoop=3

- SNRdir=3dB

- SNRrel=0dB

- Linear space-time correlation

Results

Questions?

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