Mobile wireless: 4G and beyond

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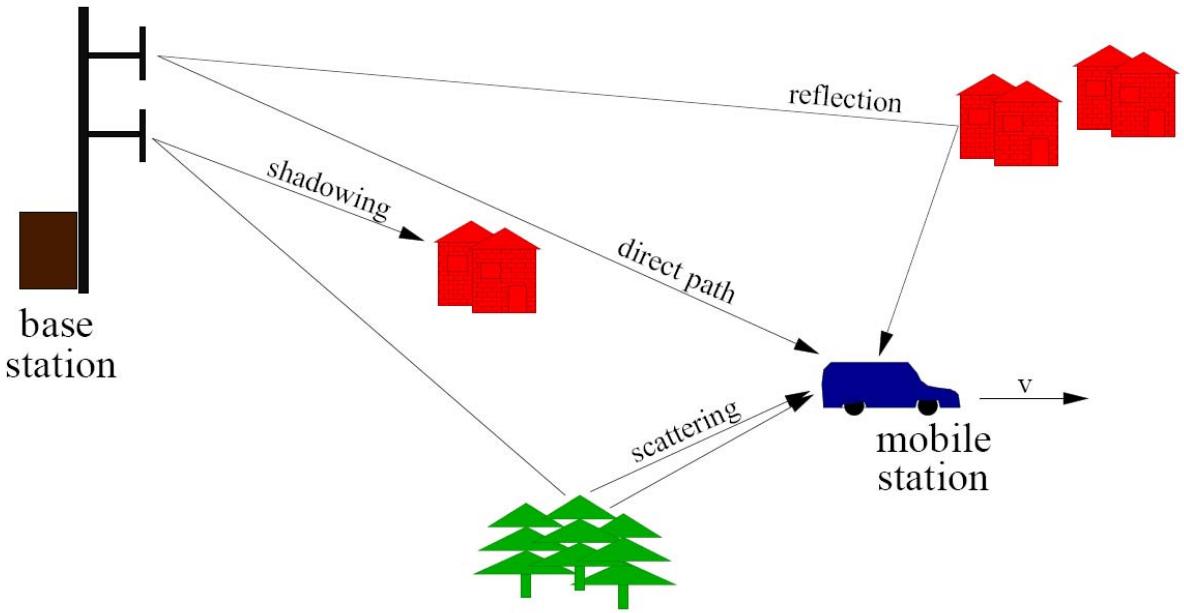
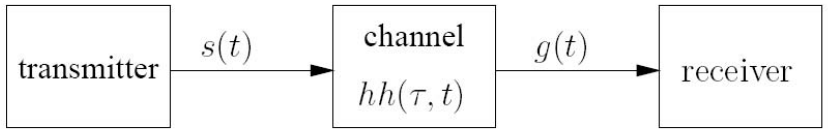
Outline

- Wireless mobile: introduction
- Standards evolution
- Standard development: requirements and issues
- New features possible in future standards

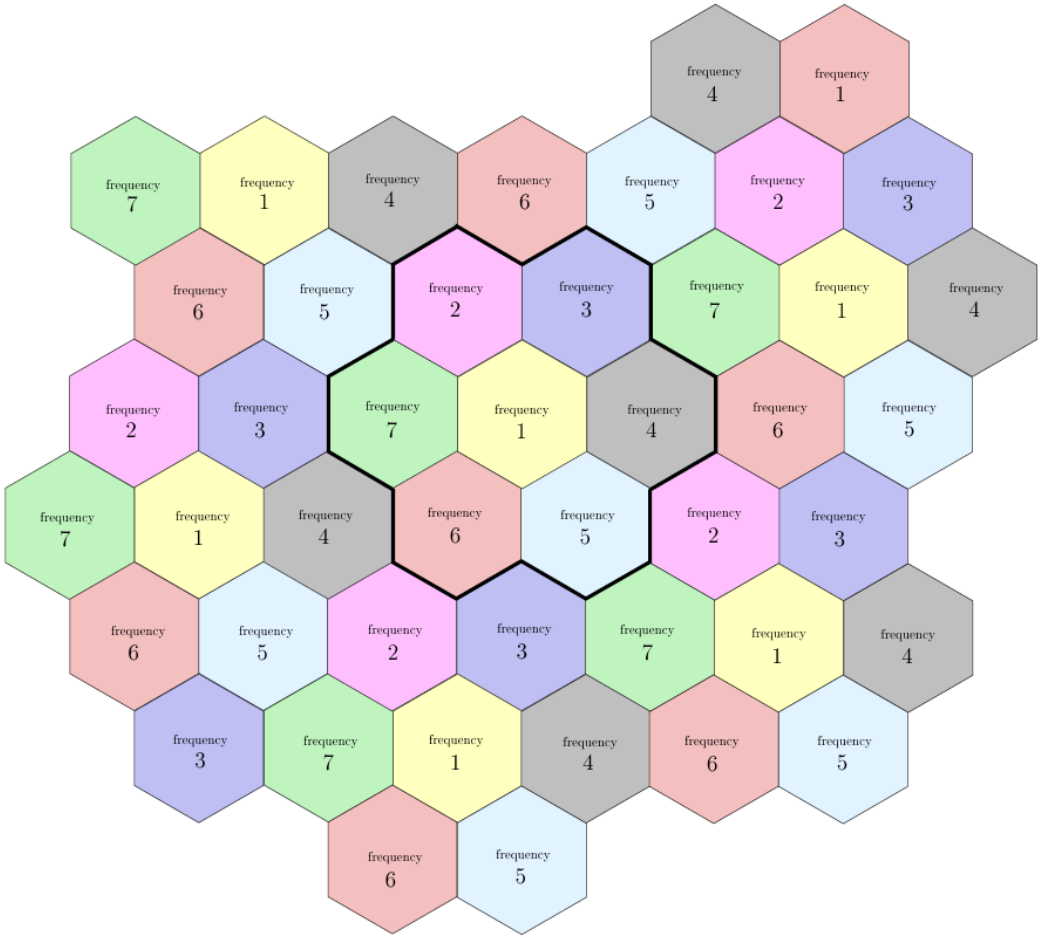
The mobile wireless channel





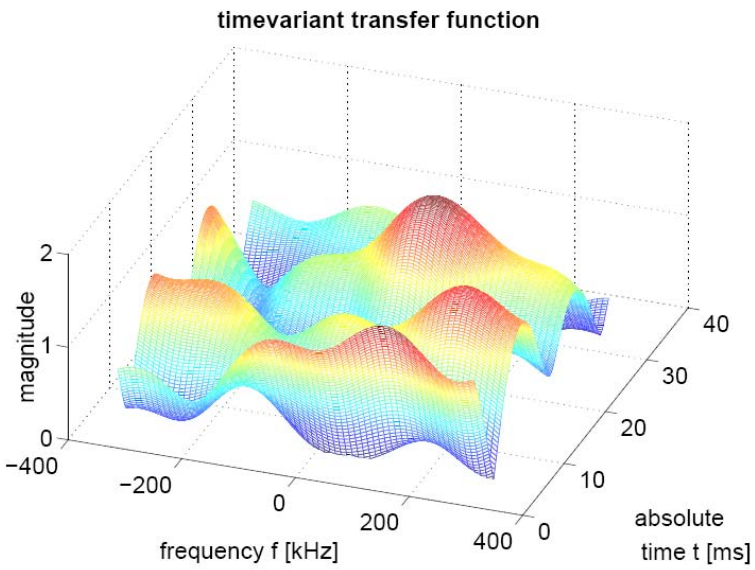
- Two type of objects:
  - Base station
  - Mobile station
- Channel is time variant:
  - Motion
  - “Weather”
  - Interference

Users, stations and location

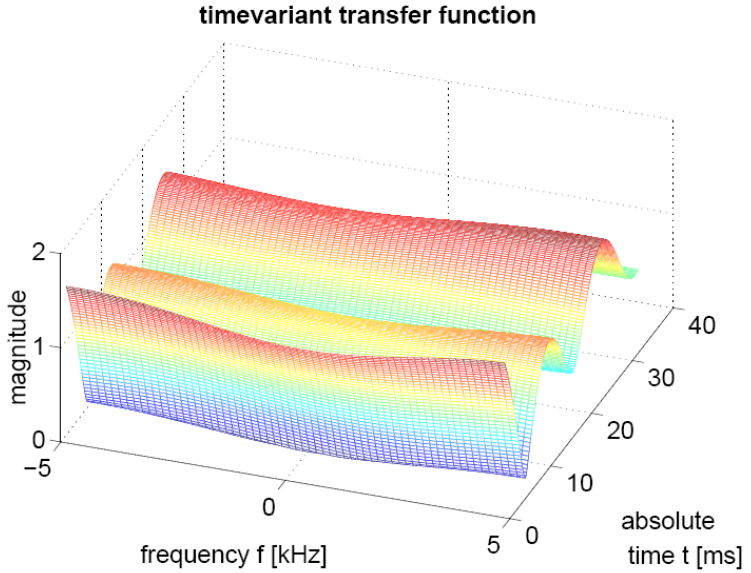


- Different users are connected to different stations:
  - Avoid interference
  - Easy handover
- How much frequency bands do we need?
  - Spatial reuse is possible

What does the channel transfer function look like?



Broadband



Narrowband

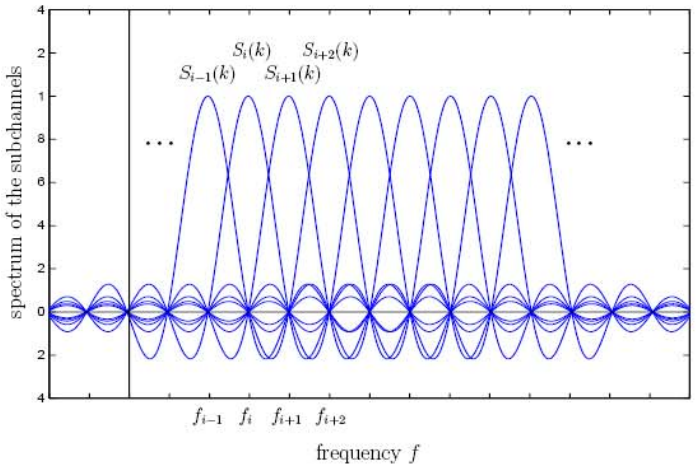
OFDM modulation

OFDM: multicarrier transmission with orthogonal subchannels, whereby the subchannels can be even overlapping

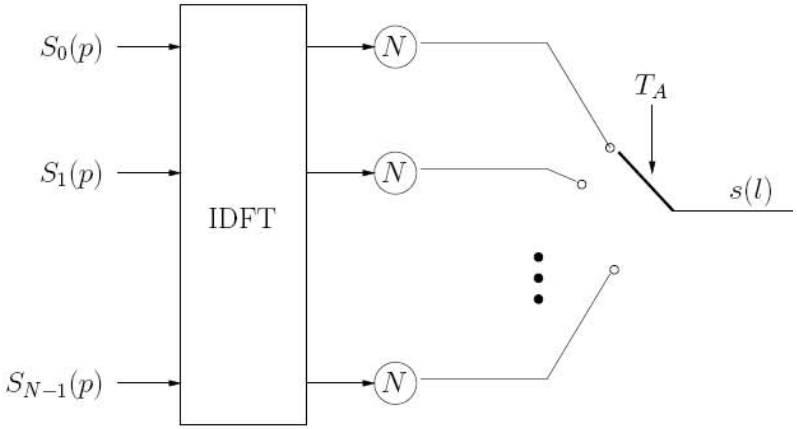
easy realization:

$g(l)$ rectangular: $g(l) = 1; \quad l = 1, \ldots, N-1$

overlapping orthogonal subchannels



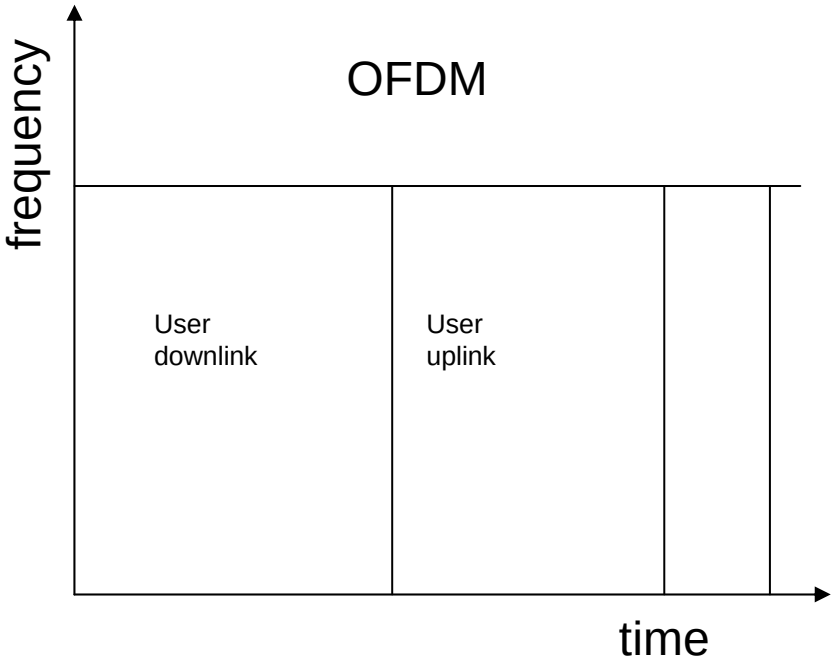
no filtering necessary after IDFT

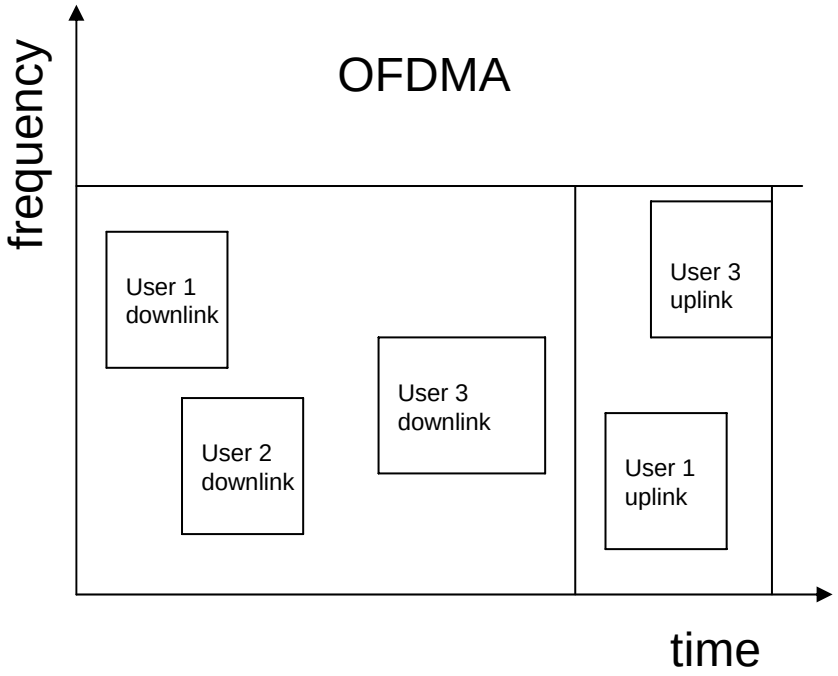


OFDM-Modulation: The N samples of the k-th OFDM-Symbol are calculated via an IDFT from the complex symbols $S_i, \; i = 0, \ldots, N-1$ of the N subchannels:

$\underline{s} = (s_0(k), \; s_1(k), \ldots, s_{N-1}(k))^T = \mathrm{IDFT_N}(S_0(k), \; S_1(k), \ldots, S_{N-1}(k))^T$

OFDM and OFDMA: current modulations for PHY





OFDM does not work without channel coding
FEC code design should match OFDM channel properties

OFDMA allows additional flexibility for users to channels mapping
OFDMA is now accepted as a modulation scheme for all recent Mobile wireless standards

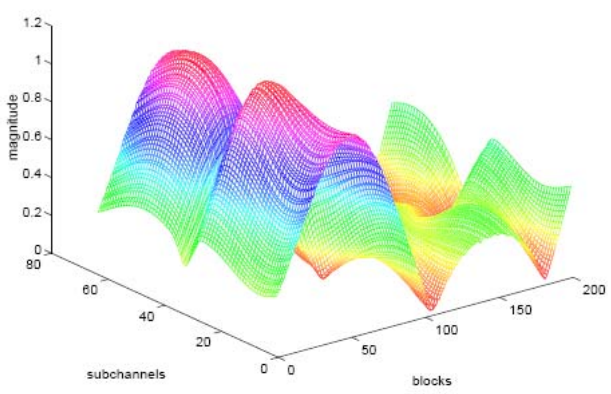
Standards evolution

- Mobility (MS velocity ~350kmph)
- Lower interference with others (older and newer standards)
- Working with different data sources (real time)
- Low power consumption/emission
- Throughput/Goodput becomes higher

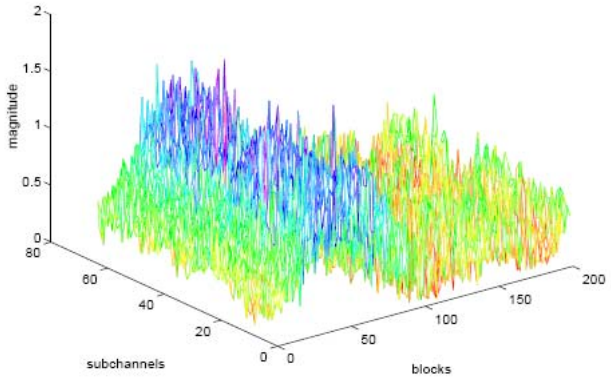
- What are the new problems and tasks to solve?

Mobility: problems?

- Channels are time variant:
  - Channel estimation becomes difficult



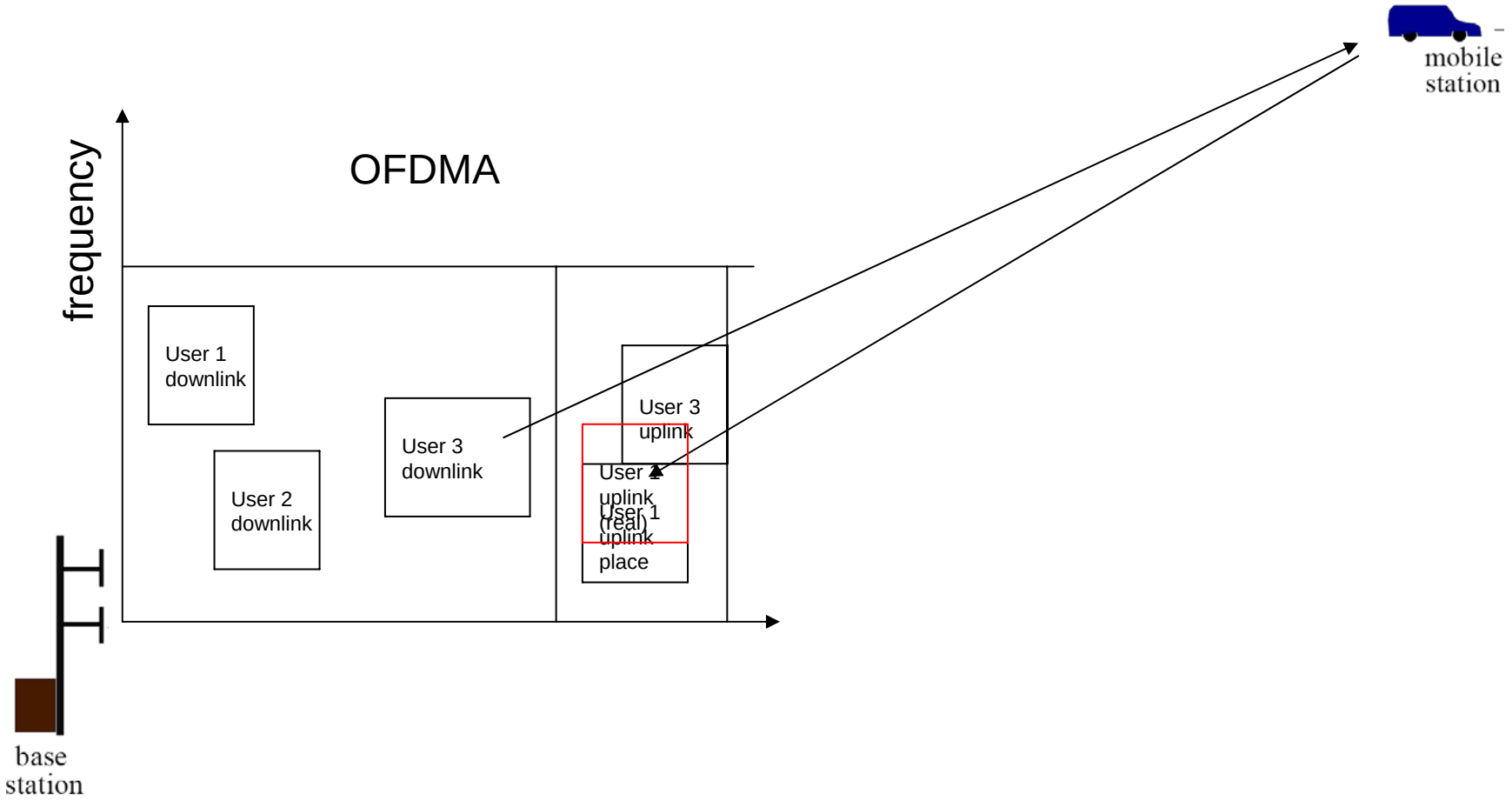
ideal



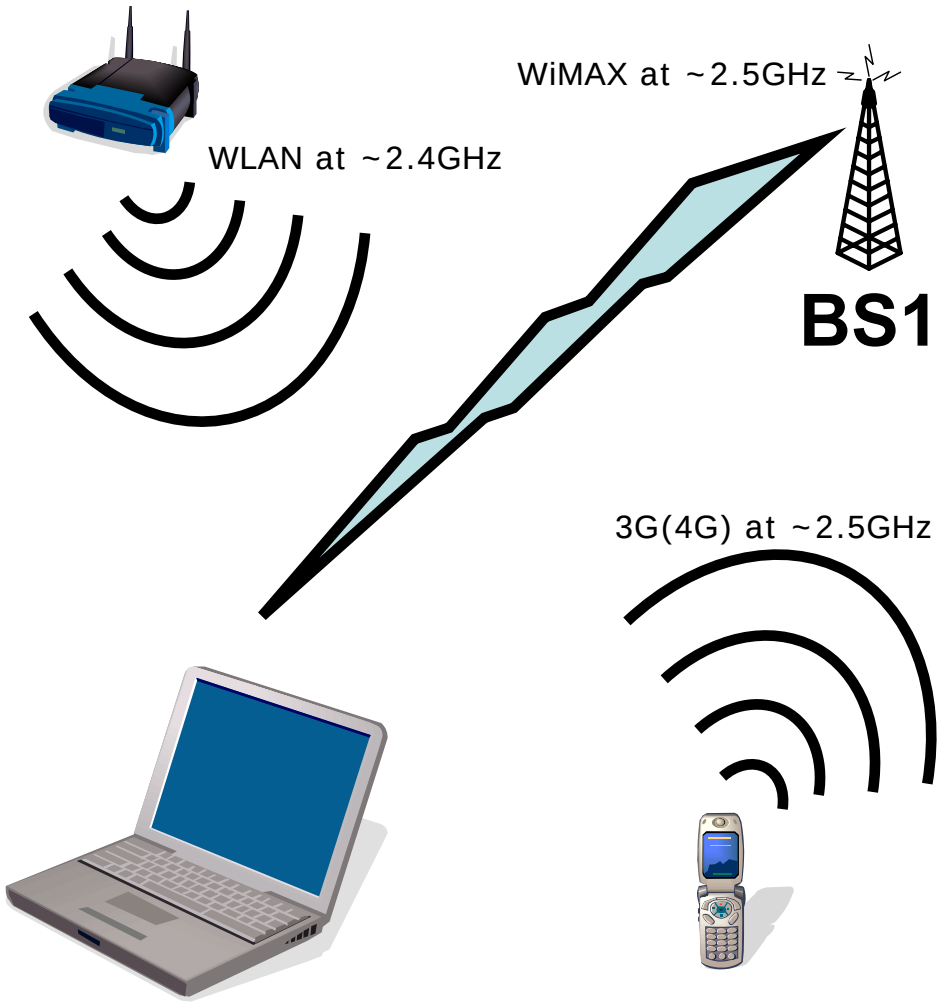
real

Mobility: problems? (2)

- Doppler frequency is a problem



Interference with others?



- Laptop user is connected to WiMAX base station
- Case 1: 3G(4G) collocated phone appears.
- Case 2: 3G(4G) collocated phone appears.
- Case 3: WiFi collocated TX appears.
- Case 5: All together: emissions at home or industry

Different data sources?

- File transfers
  - 100% reliable delivery
- Distributed databases (remote office, p2p)
  - Multiple connections at once
- Multimedia (VoIP, video)
  - Real time delivery, large sizes
- Other
  - Positioning, Banking, Identification, Sensors, etc

Higher data rates: problems

- Legacy (compatibility)
- Power emission/consumption and data rate trade-off
- New resources:
  - New modulation and coding
  - Smart link adaptation
  - Multiple antenna transmission
  - Cooperative transmission
  - Wireless oriented routing

FEC codes in mobile stds

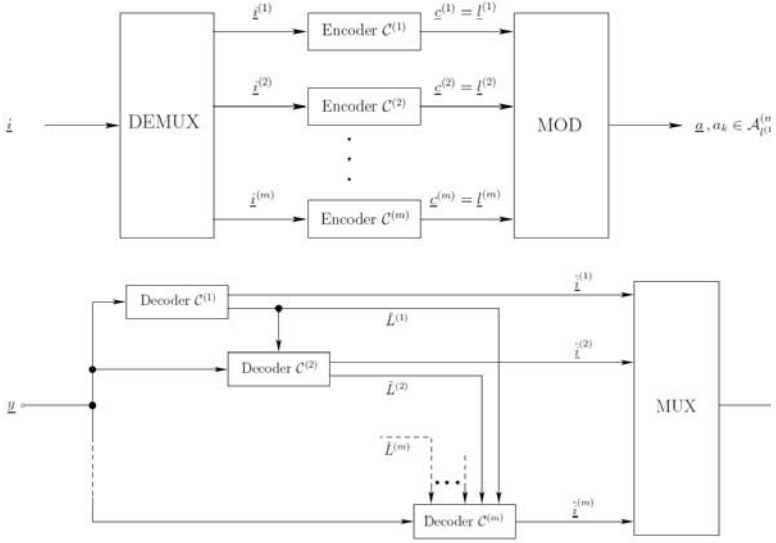
- RS (GSM, DVB)
- CC (GSM, WiMAX, WiFi, 3G)
- CTC (WiMAX, WiMAX-II, 3G, 3G/LTE)
- LDPC (WiMAX-I, WiFi (.11n))
- Code concatenations
- Coded modulation (future)
- Codes for multiple antenna transmission (future)

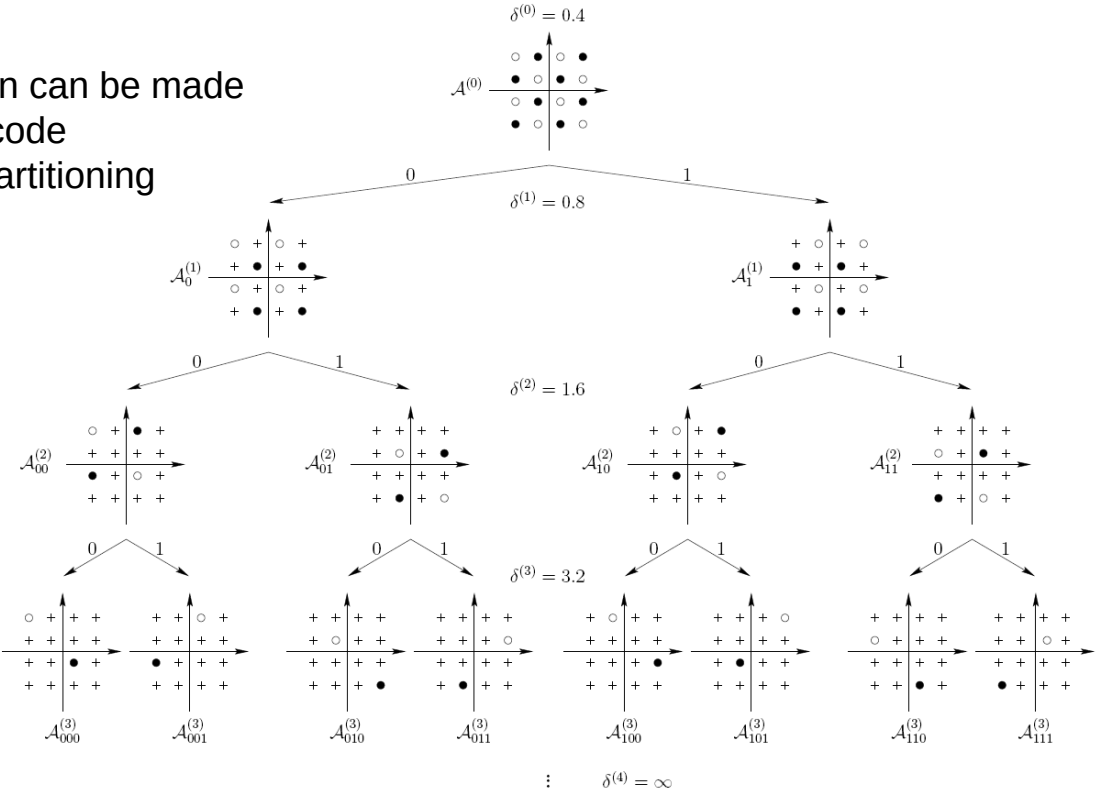
Coded modulation

Multilevel coding

Multilevel partitioning

Protection can be made
by FEC code
and by partitioning

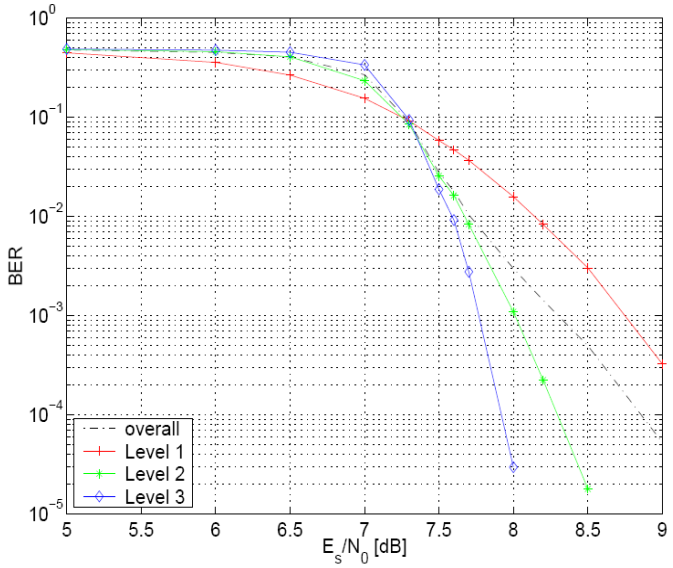




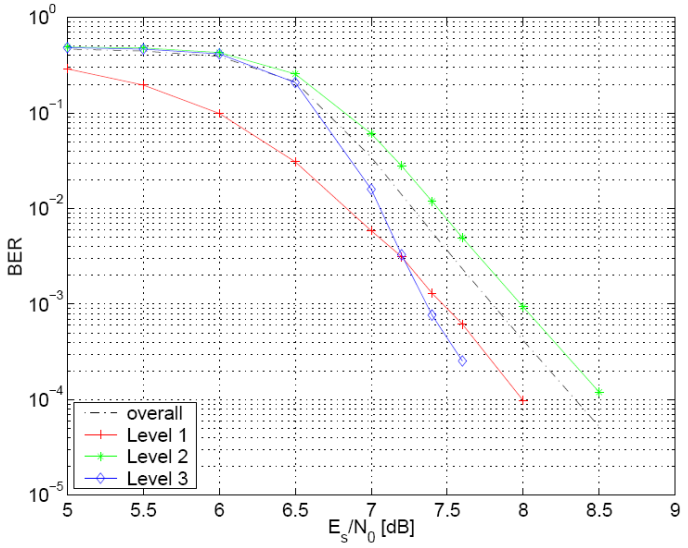
Coded modulation, cont'd

Coded modulation can give either energy gain
or datarate increasing

Balanced Distance Rule (BDR)



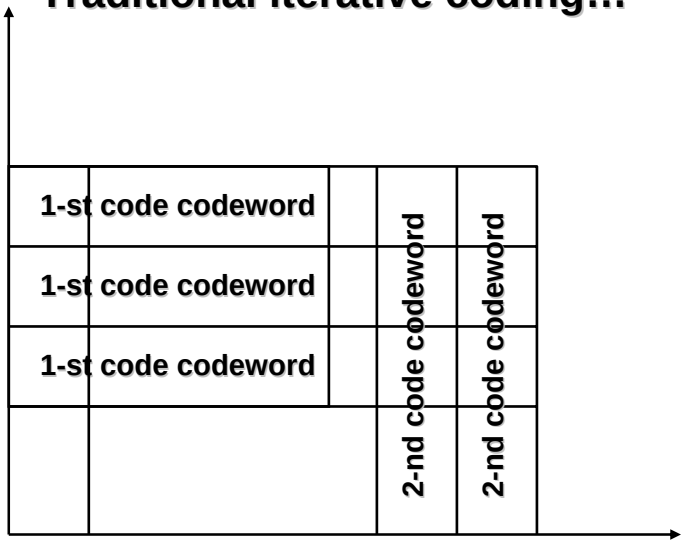
Unequal Error Protection (UEP)



Balanced distances rule is efficient for single stream transmission
Unequal error protection is efficient for multiple streams (multimedia or QoS)

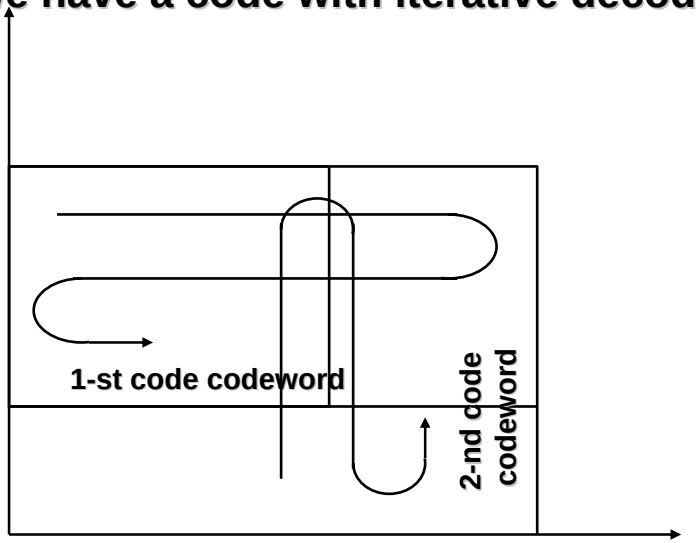
Codes concatenation

Traditional iterative coding…



…makes the whole codeword size very large

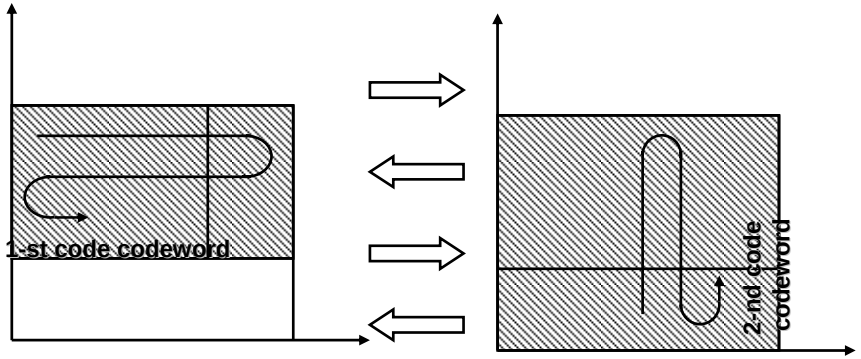
If we have a code with iterative decoding…



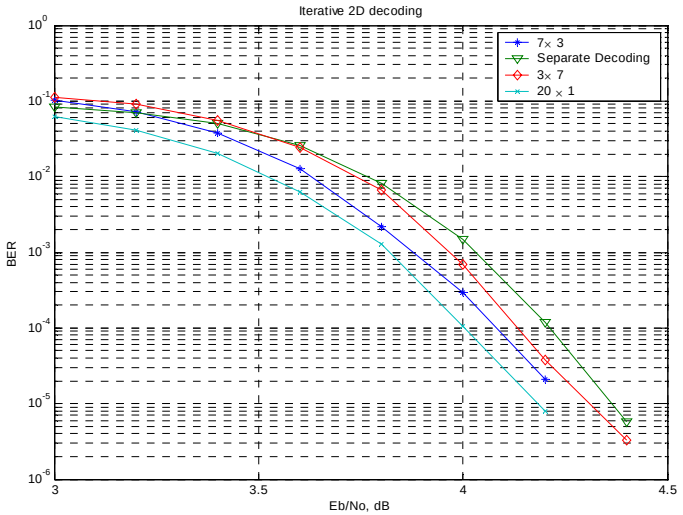
… allows to use symbol-by-symbol decoding properties In iterative scheme with shorter lengths

Codes concatenation, cont’d

LDPC iterative decoding:

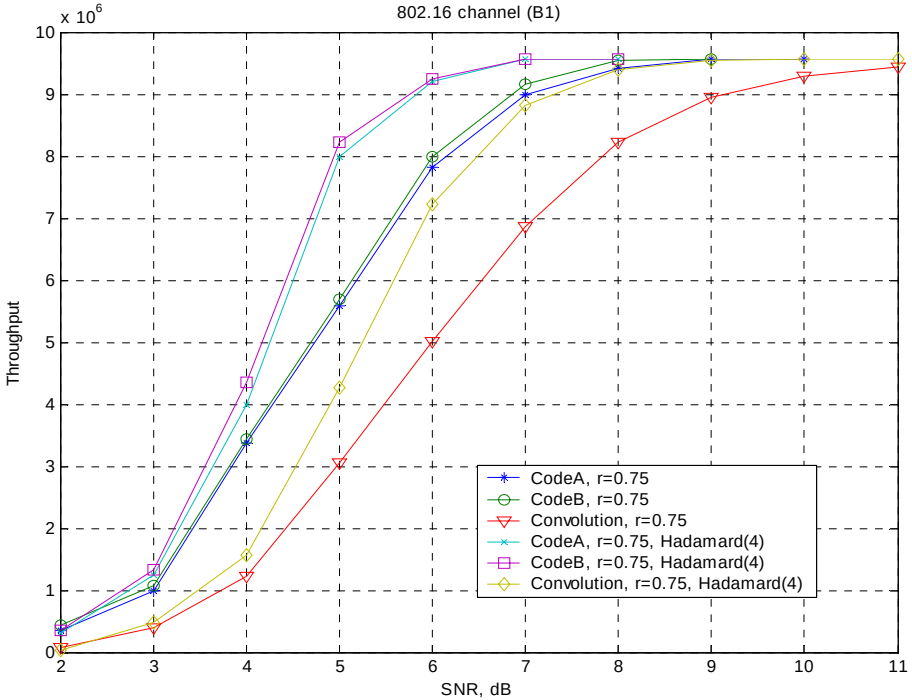


Do one decoding iteration in every code and change codes: 1-2-1-2….



Other modulations

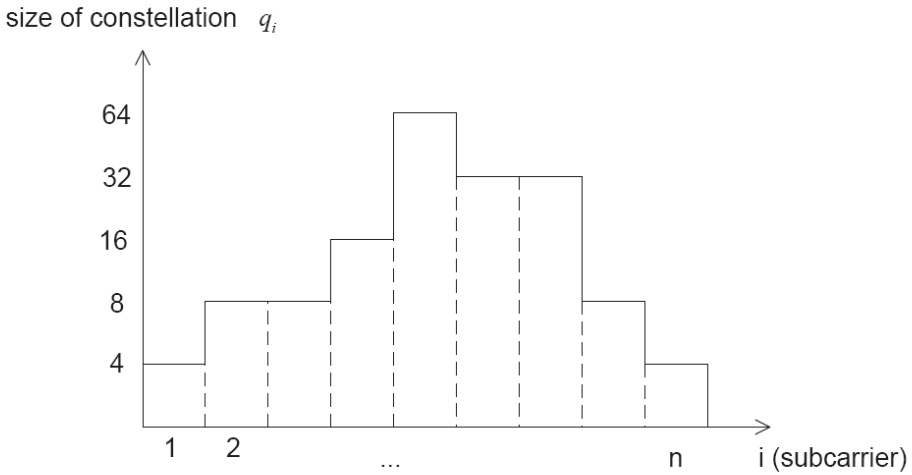
- Use Hadamard transform (HT) for intra-frame cross-frequency mixing
- For LDPC coded transmission MAP signal detection is necessary, but it is implementable for short HT (length 4)
- Gain of HT is 1.5 – 2dB



Smart link adaptation

- Example

Bitloading:

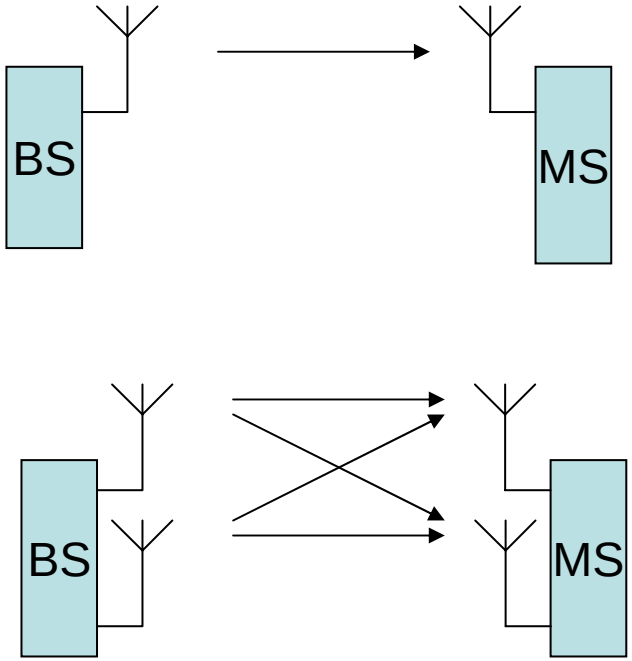


$c = (c_1, ..., c_n)$ - OFDM symbol in the frequency domain,
$c_i \in Q_i, \quad |Q_i| = q_i$.
A code with different alphabets: a *Polyalphabetic code*.

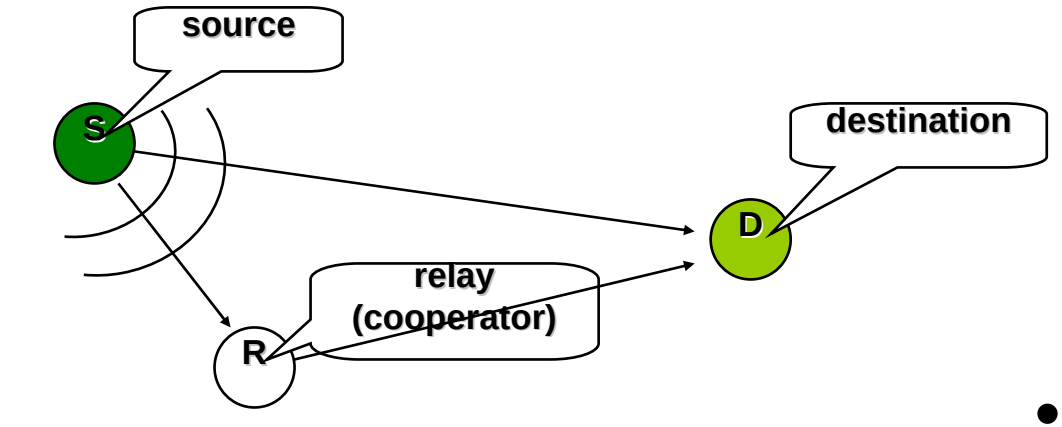
- We need a new codes to match

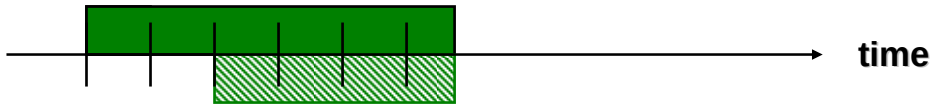
Multiple antenna transmission

- BS and MS may have more than just 1 antenna
  - Use diversity (Space-time coding, cyclic delay diversity)
  - Use multiplexing (BLAST)
  - Diversity and multiplexing: together!
  - Use adaptation (beamforming)
  - Additional handle to solve interference problem



Cooperative transmission

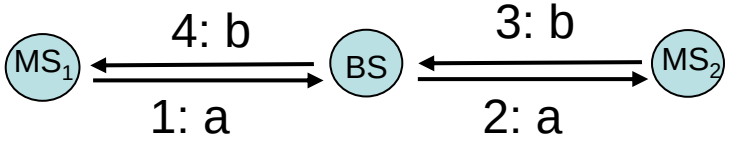




- Cooperator R can transmit:
  - the same signals
  - different signal that help D to extract message from S
- Cooperator R may use
  - the same channel
  - different channel or code division

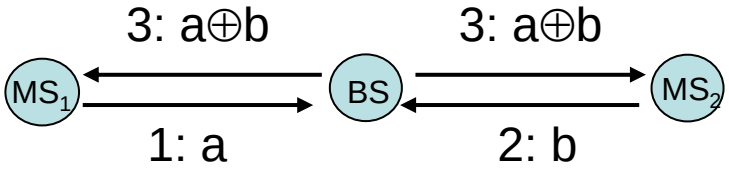
Wireless oriented routing

- MS1 and MS2 want to exchange their messages “a” and “b” with each other



Store and forward approach:

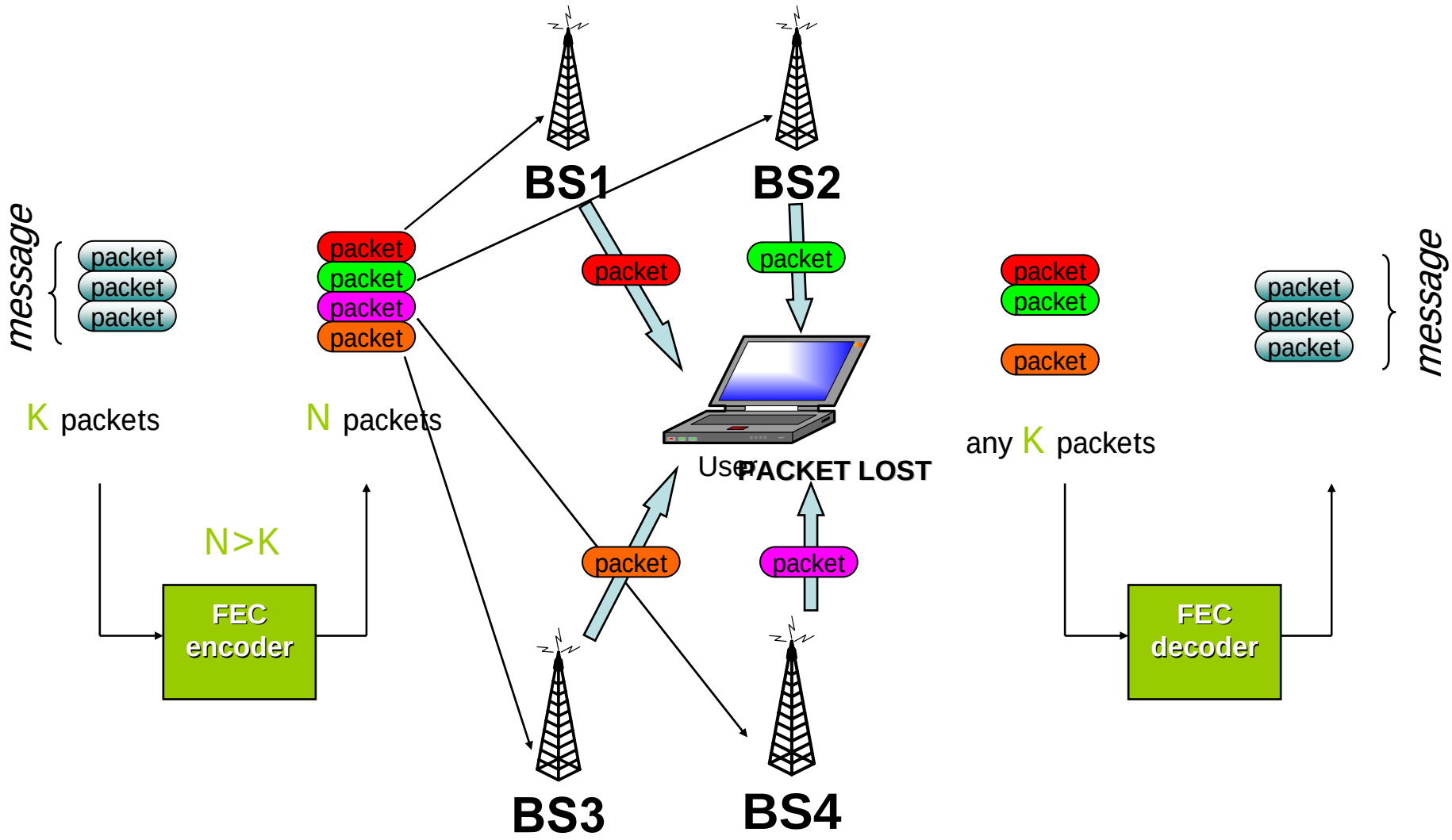
4 transmissions



Example of wireless oriented routing: 3 transmissions

- Base stations and mobile stations may have very sophisticated routing schedules taking into account their locations and message destinations

Coding on NTWK



The future is closer than you think!