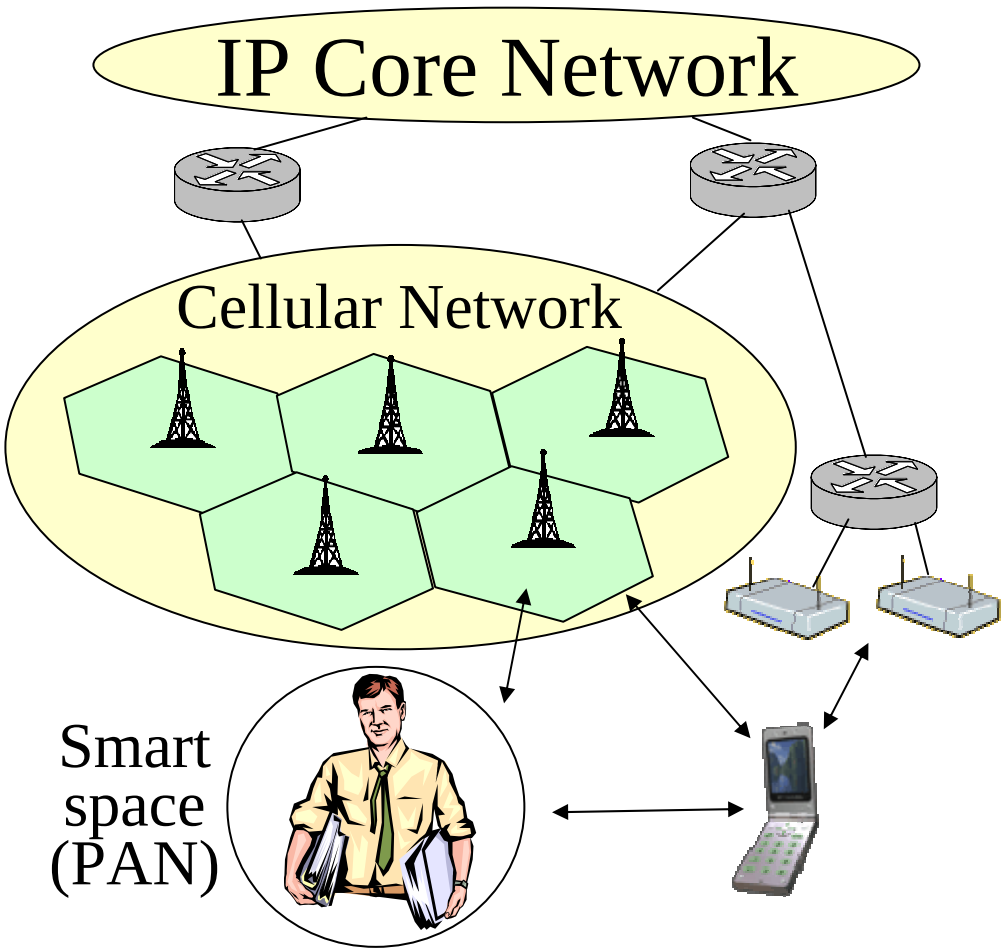
Development of OFDM/TDMA-based Broadband Wireless Access Systems --Dynamic Parameter Controlled OFDM/TDMA (DPC-OF/TDMA) System--

Seiichi Sampei
Department of Information and Communications Technology, Osaka University

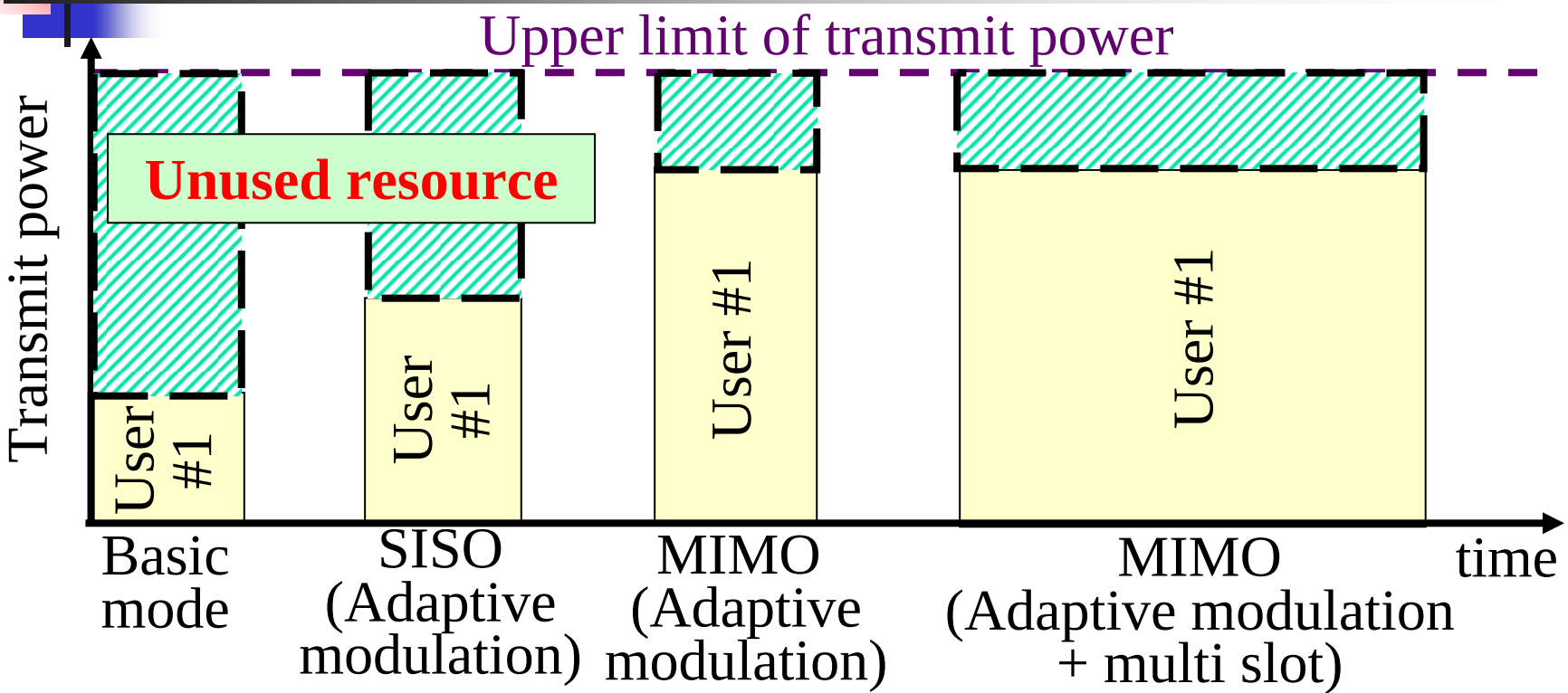
Hiroshi Harada
Wireless Access Group
National Institute of Information and Communications Technology

Requirements for Fourth Generation Wireless Access Networks



- Flexible accessibility to Ubiquitous Networks composed by cellular, hot spots, PAN and some other private networks
- Broadband services ranging from short packet to large file downloading
- High spectral efficiency (more than 10bit/s/Hz)
- Support to various terminal mobility

Basic Policy of our Radio Resource Management
-- Single slot or multi-slot ?
-- Spreading or non spreading ?



Primary policy
-TDMA
-- Dedicated slot
-- No spreading

Secondary policy
-Resource share by another users (SDMA)
if unused resource exists.

Solutions for these requirements

- Flexible available user rate
  - High peak and average user rate
- Flexible radio resource management
  - Large dynamic range of packet size)
- Flexible accessibility to various networks
  - LAN: 802.11a/b/g
  - 3G and 4G cellular
  - Others

→ - Adaptive modulation
- OFDM/TDMA
- One cell reuse

→ Segmentation of radio resource in both time and frequency domain

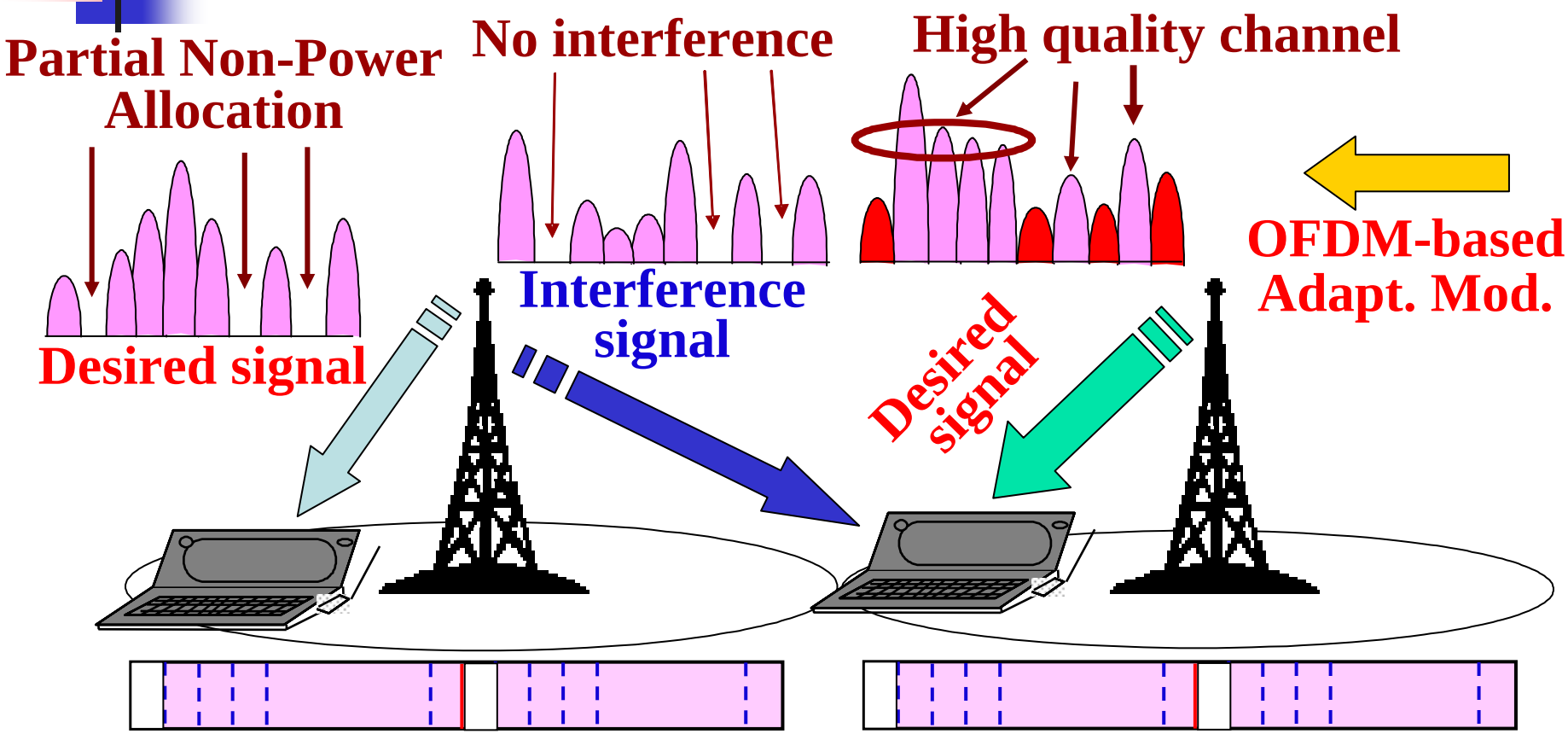
→ maximization of commonality and SDR technologies

↓

Dynamic Parameter Controlled OFDM/TDMA (DPC-OF/TDMA)

Key Technologies for DPC-OF/TDMA (1)

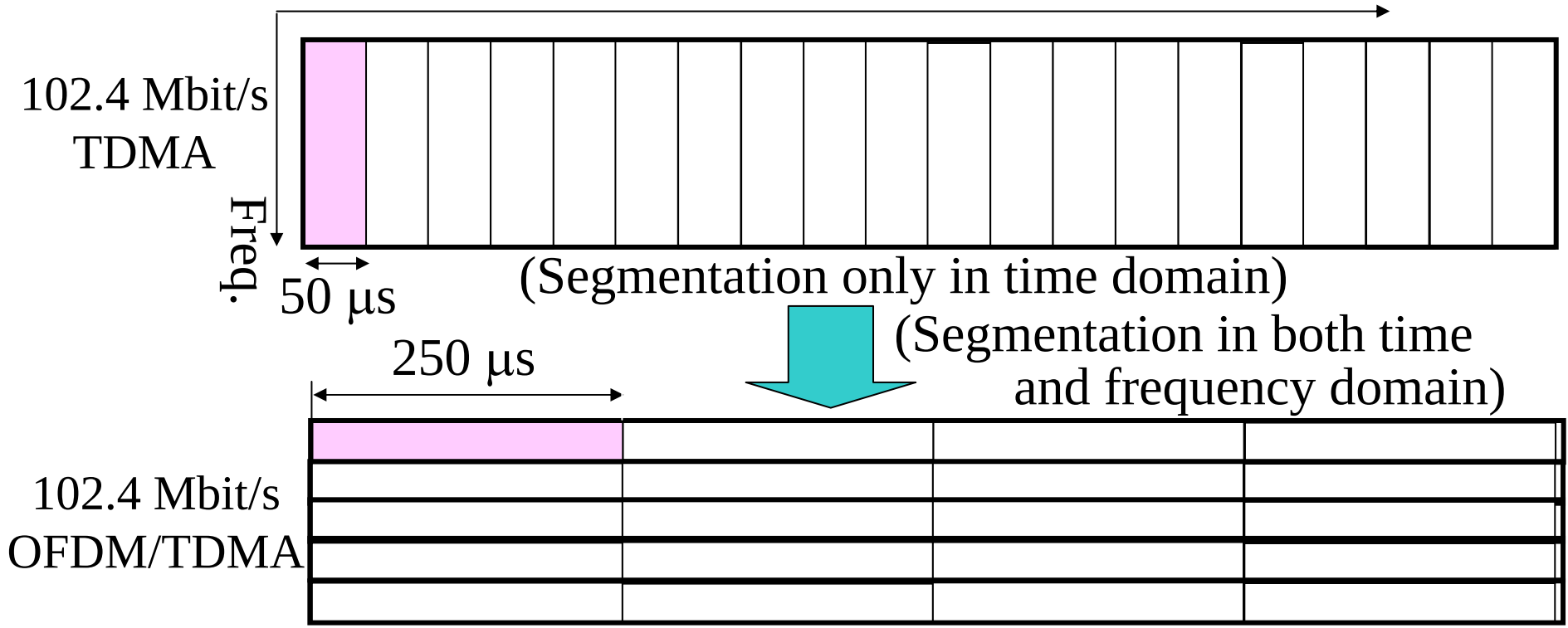
-- One Cell Reuse Scheme using OFDM-based Adaptive Modulation --



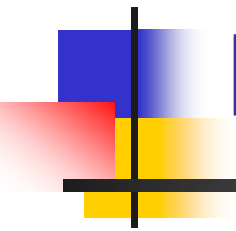
No negotiations for slot assignment between adjacent cells can simplify slot assignment process

Key Technologies for DPC-OF/TDMA (2)
-- Segmentation of radio resource in both time and frequency domain --

256 bytes transmission using r = 1/2 channel encoder

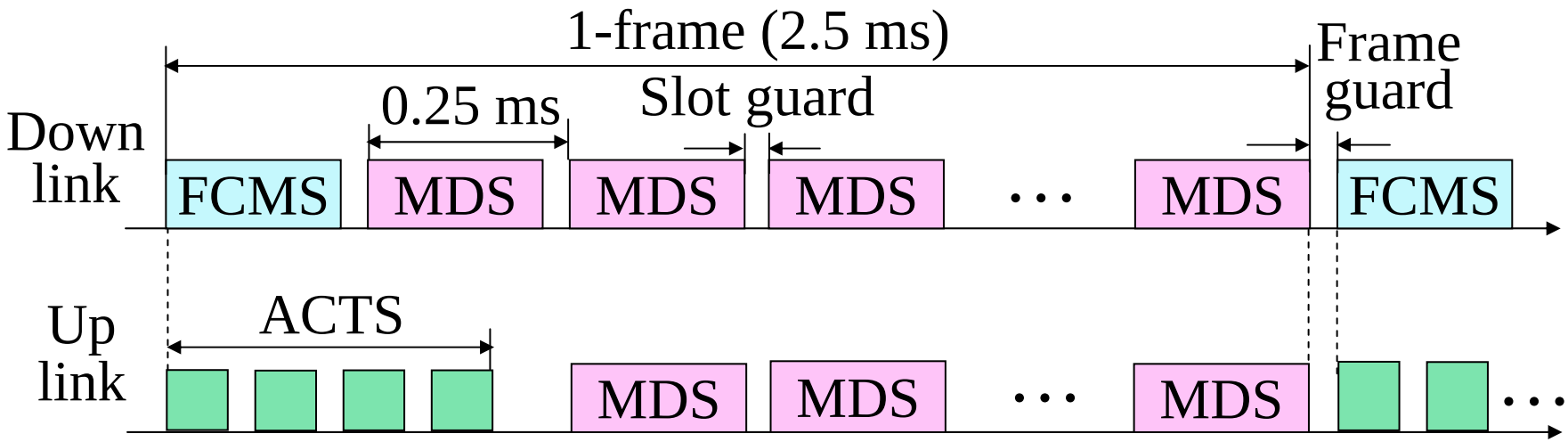


Preferable minimum slot length is 100 μs or more



MAC Layer for DPC-OF/TDMA

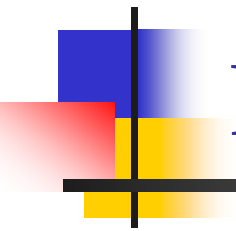
MAC frame Configuration



FCMS (Downlink): Frame Control Message Slot
Control signal, broadcast message, MDS usage

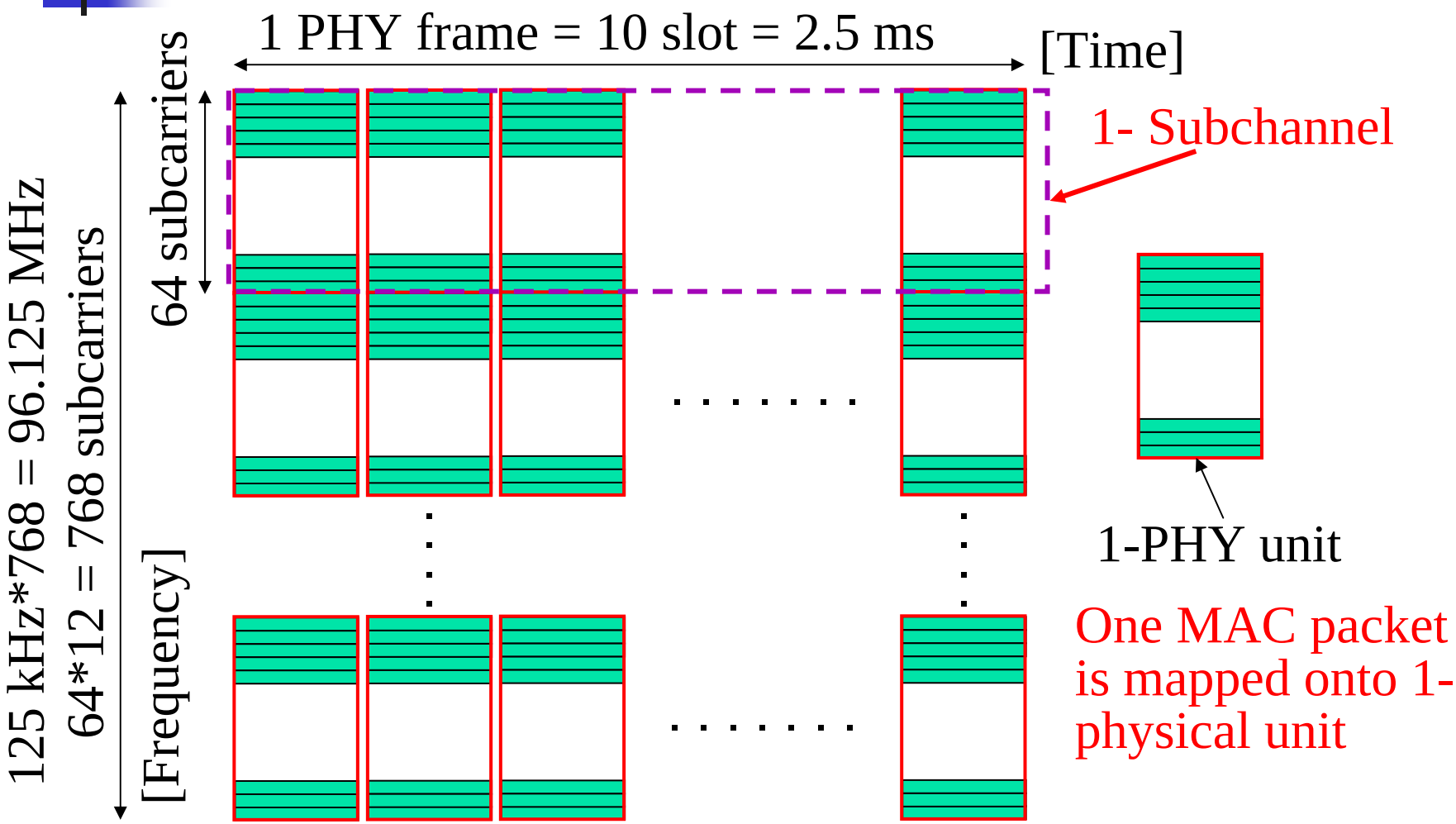
ACTS (Uplink): Activation Slot
Association request

MDS (Down/Up): Message Data Slot
Traffic Channel Data



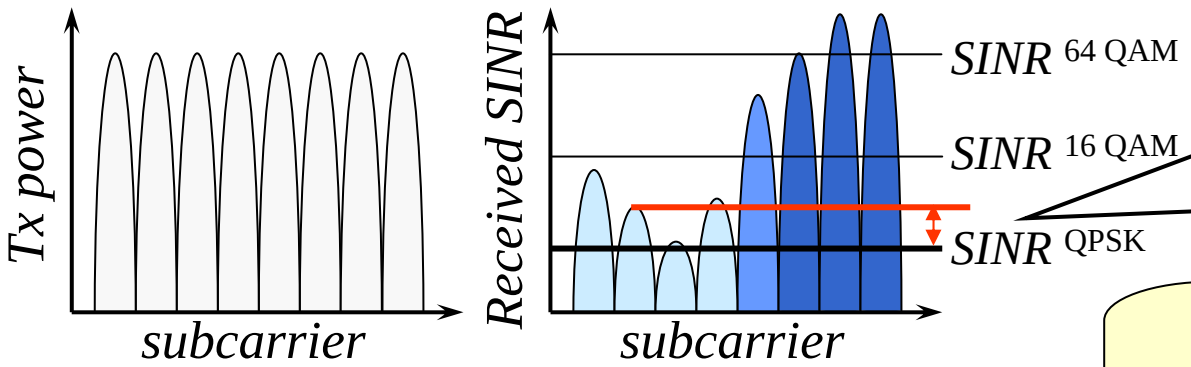
Physical Layer for DPC-OF/TDMA

Slot Format for Physical Layer



Development of OFDM Adaptive Modulation (1)
-- Simple AMS and AMS with MTPC --

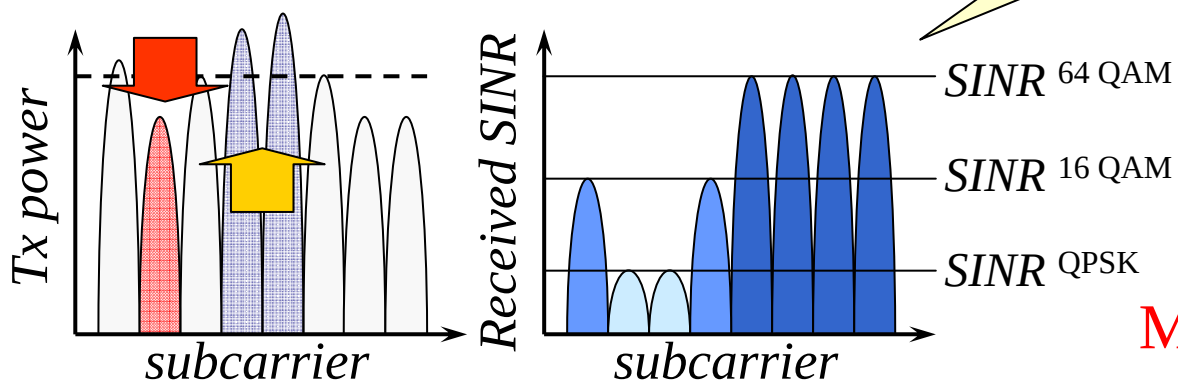
Simple OFDM adaptive modulation scheme (AMS)



This surplus power does not improve data rate

OFDM AMS with multilevel transmit power control (MTPC)

Joint allocation of modulation level and transmit power

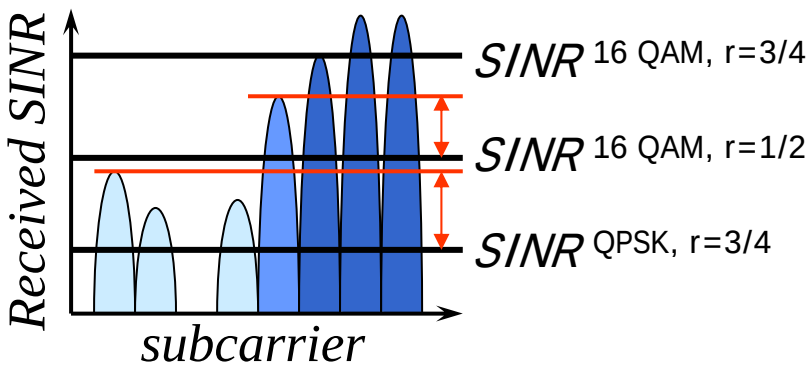


Maximizing data rate

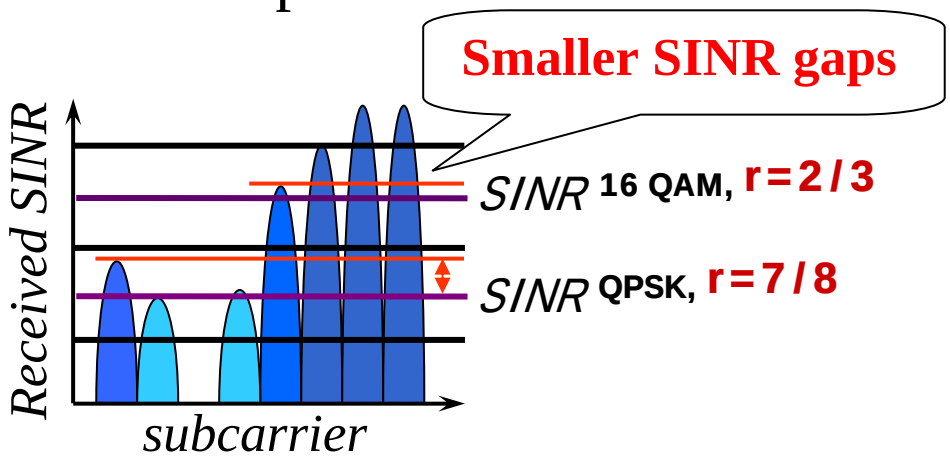
More feedback necessary!!

Development of OFDM Adaptive Modulation (2)
-- Variable Coding Rate OFDM AMS --

Simple OFDM
Adaptive Modulation



Variable Coding Rate (VCR)
OFDM Adaptive Modulation



Increase of MCS by introduction of variable coding rate can reduce surplus power and can enhance throughput

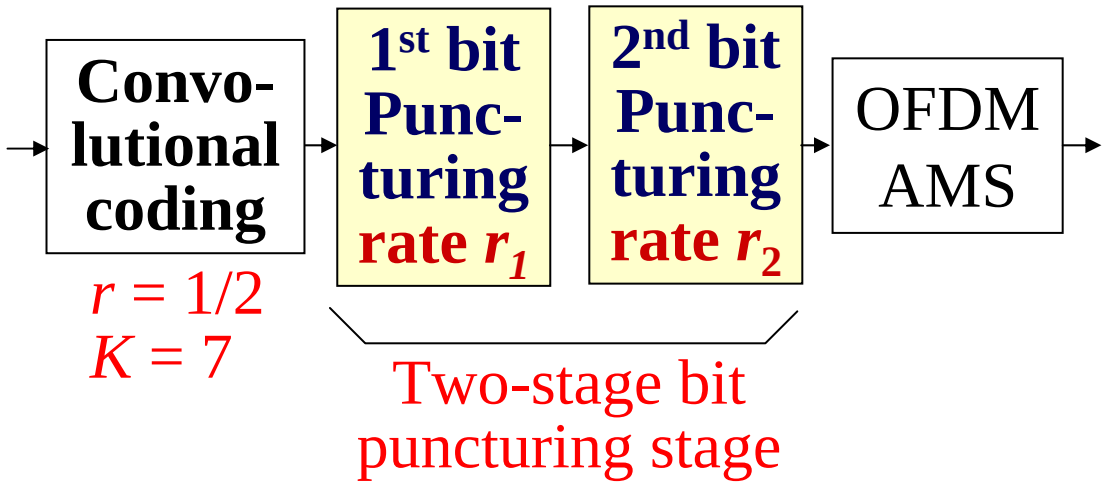
However,

Conventional punctured code
- coding rate is NOT flexible

Two stage punctured coding
-Conventional punctured code
- regular bit deletion

Modulation and Coding Scheme for VCR AMS

Mod.	r_1	r_2
64QAM	3/4	1
	2/3	60/59
	1/2	6/5
16QAM	5/6	140/139
	3/4	1
	2/3	1
	1/2	11/10
QPSK	7/8	100/99
	3/4	36/35
	2/3	1
	1/2	1
BPSK	1/2	5/4
	1/2	1
1/2 BPSK	1/2	5/4
	1/2	1



[2nd bit puncturing]
One bit is deleted every i bits

$r_2 = i/(i-1)$

MAC packet mapping onto PHY slot -- MDS mode selection --

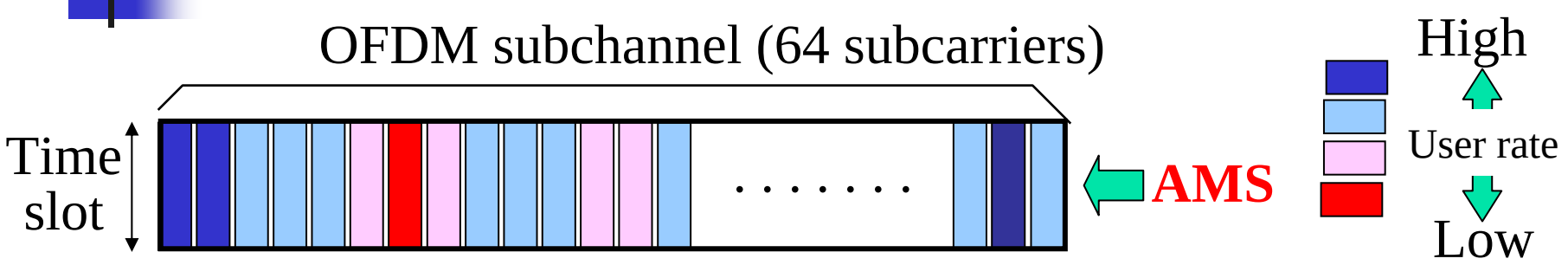
- Basic Mode
  - 128 bytes is mapped onto one PHY unit (410 kbit/s – 3.7 Mbit/s; 1 subchannel)
    (44 Mbit/s for mode 3; 12 subchannels)
- Extended Mode for MDS Transmission
  - Multiple of 128 bytes is mapped onto one PHY unit in GOOD channel conditions
  - Fraction of 128 bytes is mapped onto one PHY unit in BAD channel conditions

MDS mode (l)	Payload size $D(l)$ [bytes]
0	0
1	32
2	64
3	128
4	256
5	384
6	512

While keeping MAC protocol as simple as possible, advantage of adaptive modulation in PHY is maximized

Mode could be extended by MIMO introduction

Calculation for available MDS mode



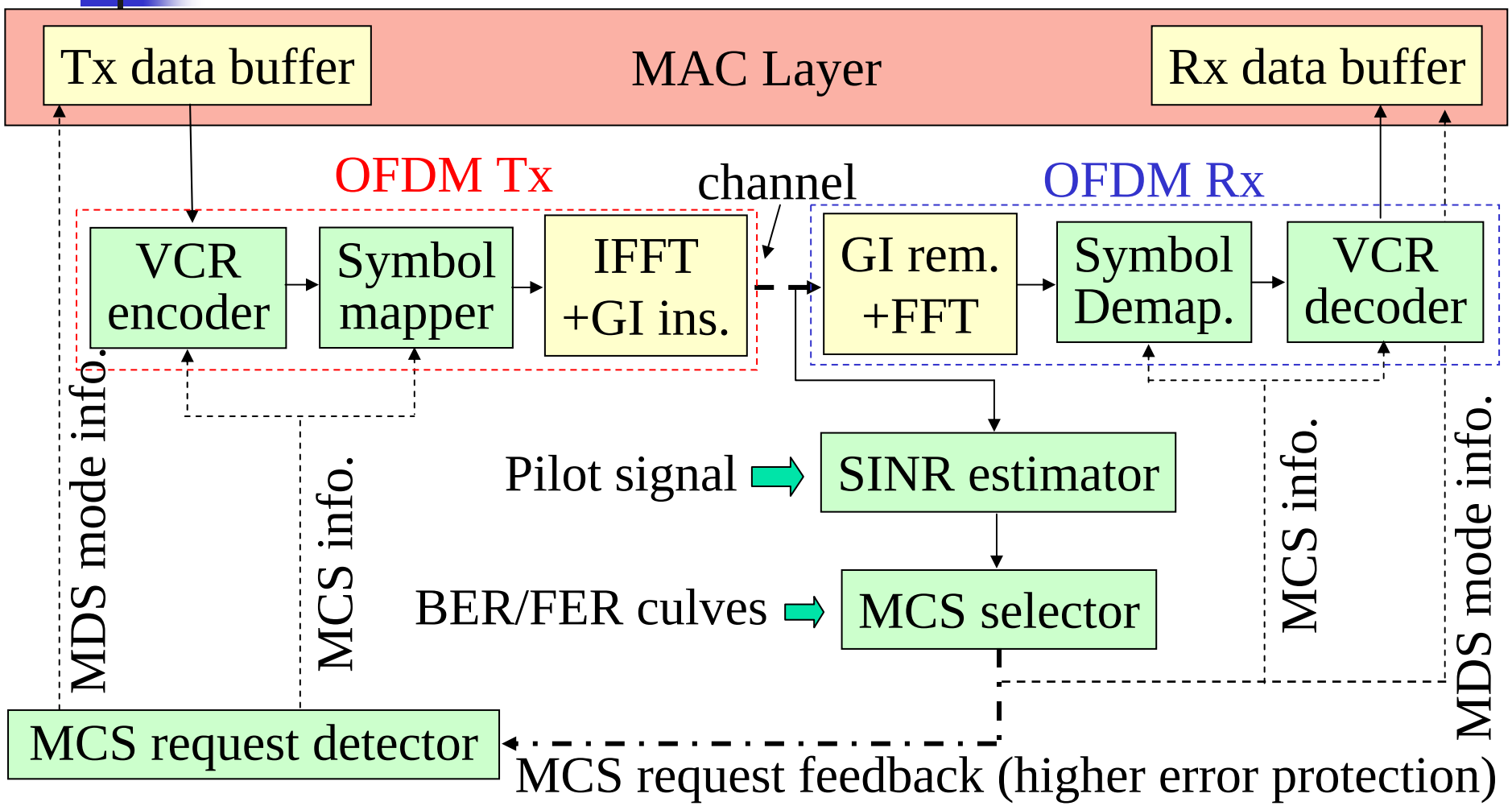
Calculate maximally allocatable number of MDS bits in all the subcarriers (N_{total}) in an OFDM AMS/TDMA subchannel

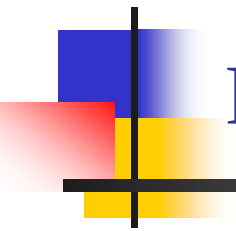
$$D(l) \le N_{total} < D(l+1)$$

Mode l will be selected

MDS mode (l)	Payload size $D(l)$ [bytes]
0	0
1	32
2	64
3	128
4	256
5	384
6	512

PHY Configuration



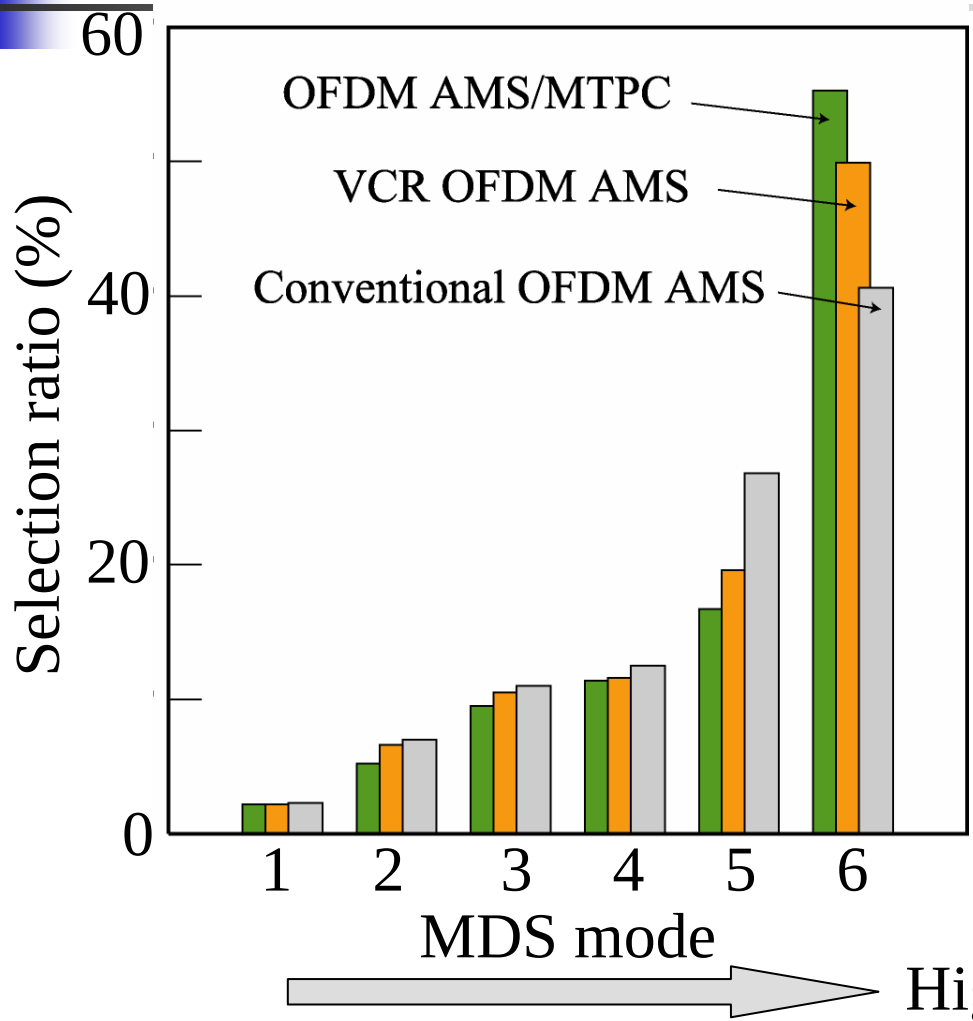


Performance Evaluation of DPC-OF/TDMA

Simulation Conditions

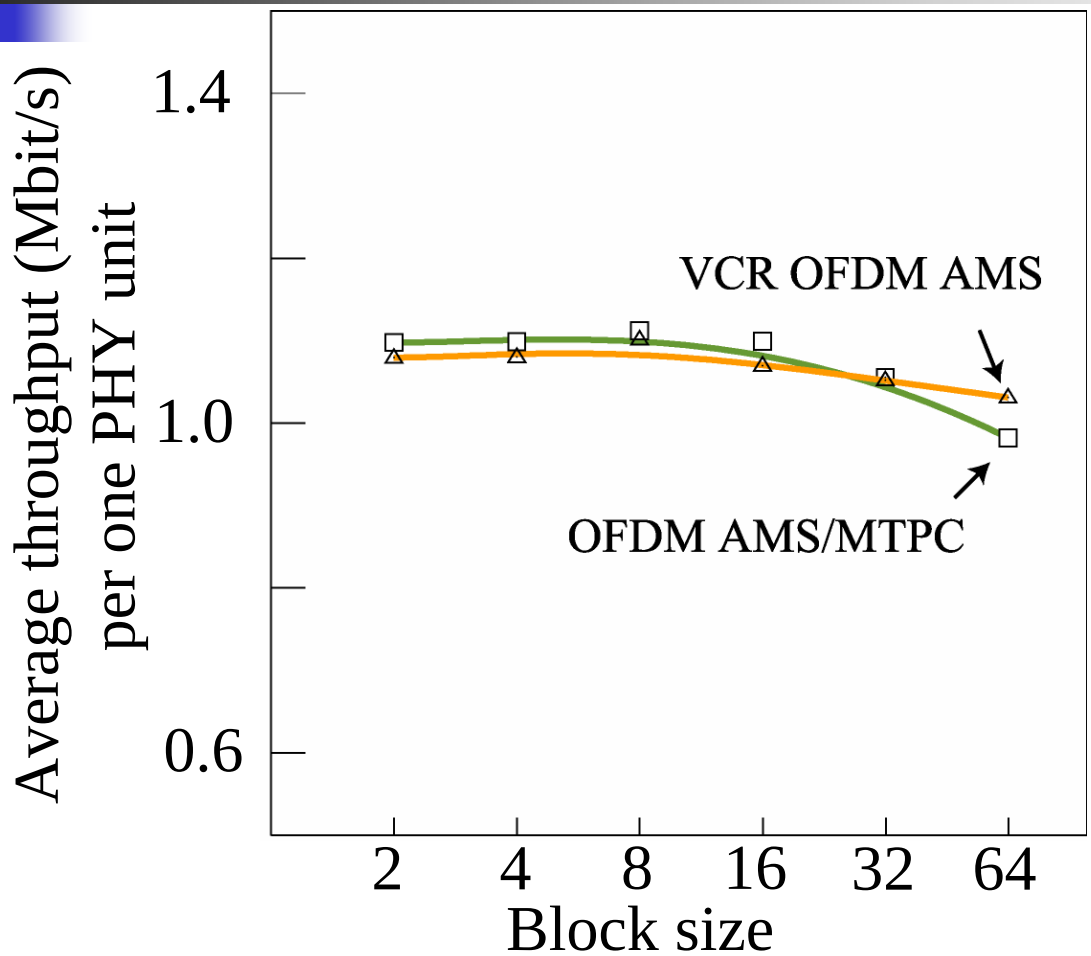
Symbol rate	**100 ksymbols/s**
Num. of subcarriers and time slots	**64 subcarriers 1 slot/frame**
FEC	**Convolutional coding (r = 1/2, K = 7)**
Max.Tx Power	**30 dBm**
Antenna gain	**AP: 15 dBi, TE: 3 dBi**
Cell radius	**100 m**
Cell model	**3-sector, 7 cell wrapping**
Path loss model	**ITU-R outdoor to indoor & pedestrian**
Shadowing	**Log-normal (σ = 8 dB)**
Channel model	**Exponential decaying 12-spike Rayleigh (rms delay spread = 200 ns)**
f_D	**50 Hz**

Selection Ratio for MDS



MDS mode (l)	Payload size $D(l)$ [bytes]
0	0
1	32
2	64
3	128
4	256
5	384
6	512

Average throughput performances



Average total throughput

100 times more

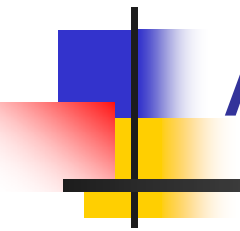
||

> 100 Mbit/s

(for averaging interference and noise level measurement)

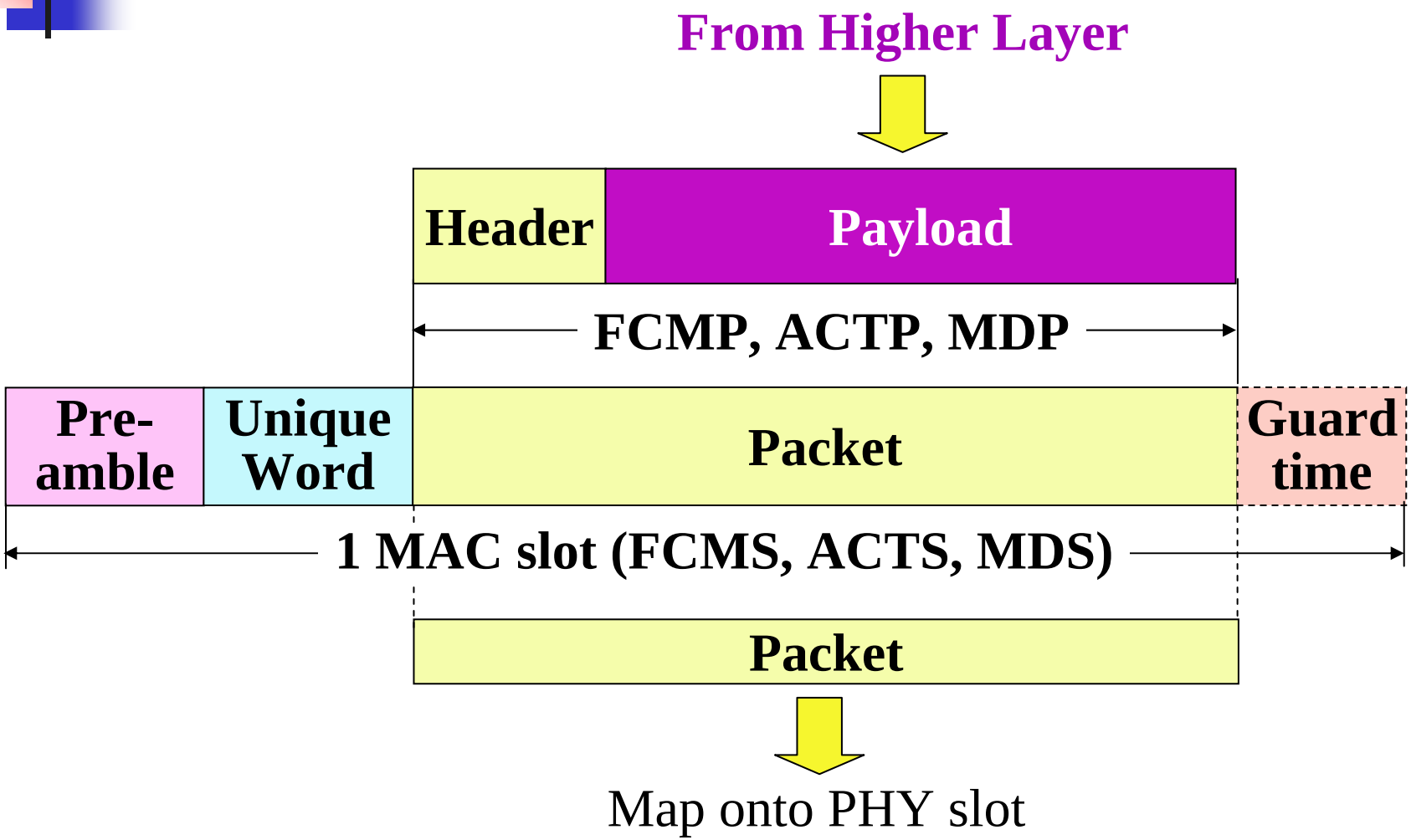
Conclusions

- Development of DPC-OF/TDMA
  - One cell reuse TDMA
  - OFDM-based adaptive modulation
- Simple MAC and flexible PHY
- Large dynamic range of supportable
- System throughput of more than 100 Mbit/s achievable



Appendix

Slot Format for MAC Sub-Layer

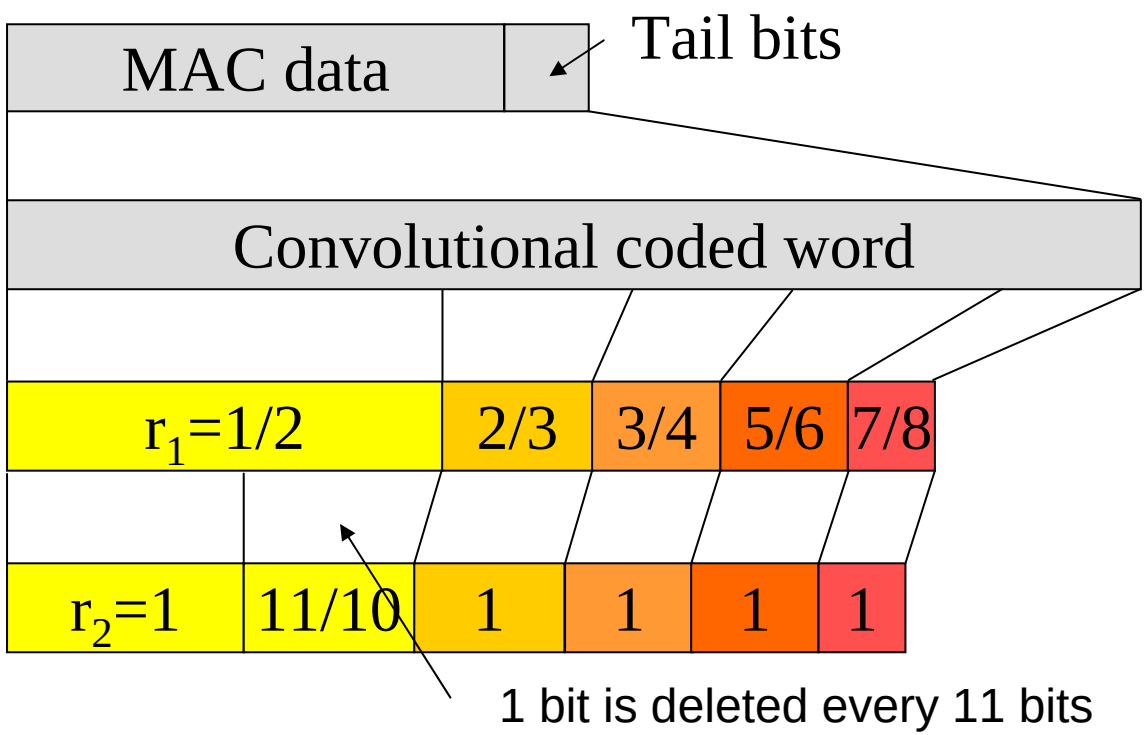


Types of MAC Packet Format

- FCMS (Frame Control Message Slot)
  - Downlink only
  - FCMP (Frame Control Message Packet) is transmitted
  - Control signal, broadcast message, MDS usage
- ACTS (ACTivation Slot)
  - Uplink only
  - ACTP (ACTivation Packet) is transmitted
  - Association request
- MDS (Message Data Slot)
  - Both Downlink and Uplink
  - MDP (Message Data Packet) is transmitted
  - Traffic data

Encoding Process

-- Convolutional Encoding with Two Stage Bit Puncturing --



r = 1/2 convolutional coding

1st bit puncturing

2nd bit puncturing

Mapping to subcarriers

Modulation, IFFT