The Next Generation Broadband Wireless Communication Network 3GPP-LTE - (Advanced)

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Roadmap

- What is 4G?
- Goals of 4G
- Mobile Communication Roadmap
    - Evaluation from 1G to 4G
- Introduction to 3G
- Introduction to 4G
    - ITU Requirements
    - Technical Specifications
    - Some Design Aspects
    - LTE-A and WiMAX Comparison
    - Introduction to Femtocell

What is 4G?

4G stands for Fourth Generation Mobile Communication which provides ‘*anytime*’, ‘*anywhere*’ wireless broadband services. Along with high quality voice, high data rates 4G supports HD videos even in very high speed.

Goals of 4G

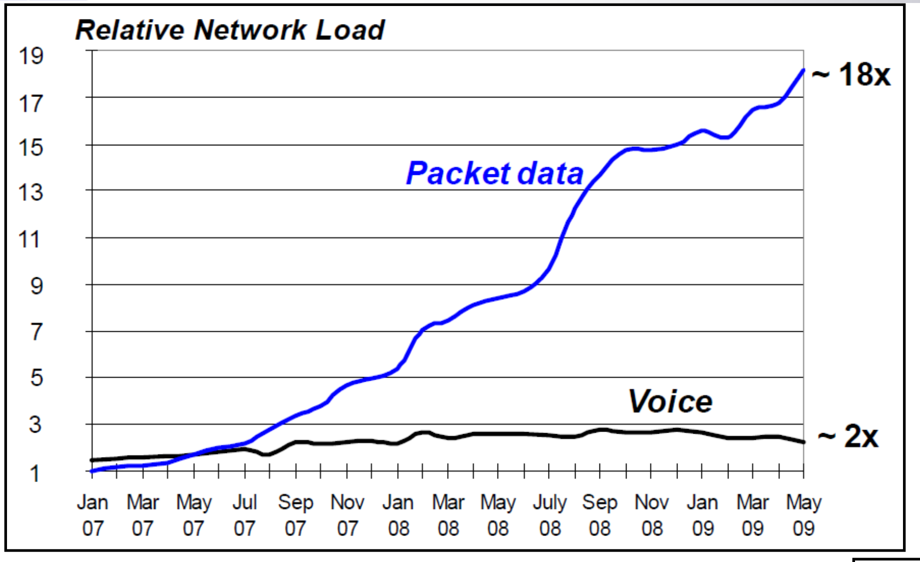
Radio Side

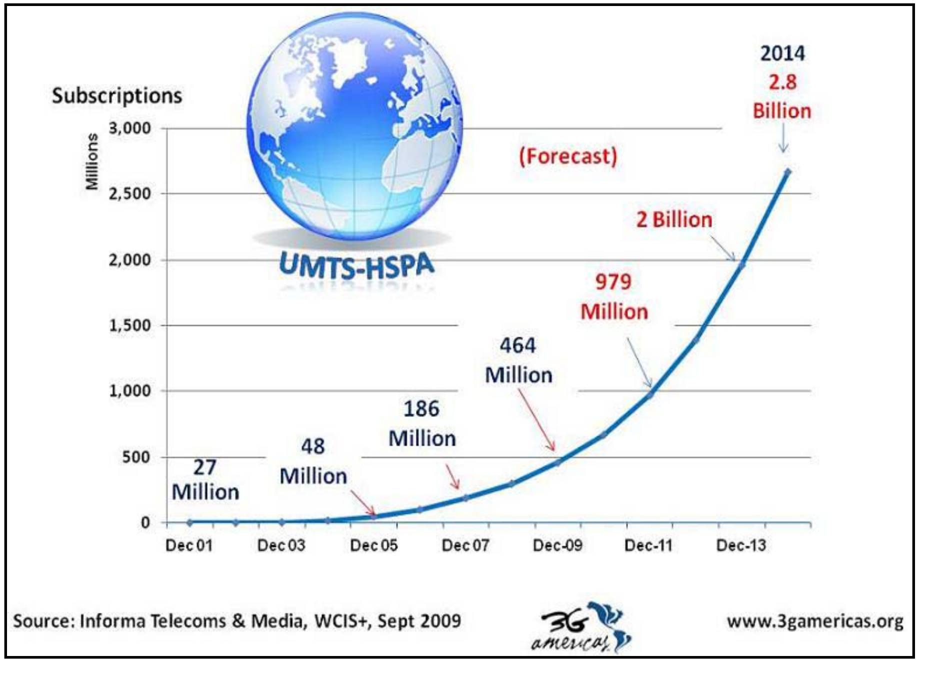
- Improvement of ***Spectral Efficiency***.
- Different **Traffic** Support e.g. **Real-Time & Non-Real-Time** application.
- Efficient *Always-ON* operation with instantaneous access to network resources.
- Re-use of existing cell site infrastructure.
- **Flexible spectrum allocation.**
- Lower ***cost per bit***
- Improved ***Quality of Service (QoS)***
- Increasing ***Coverage***

Network Side

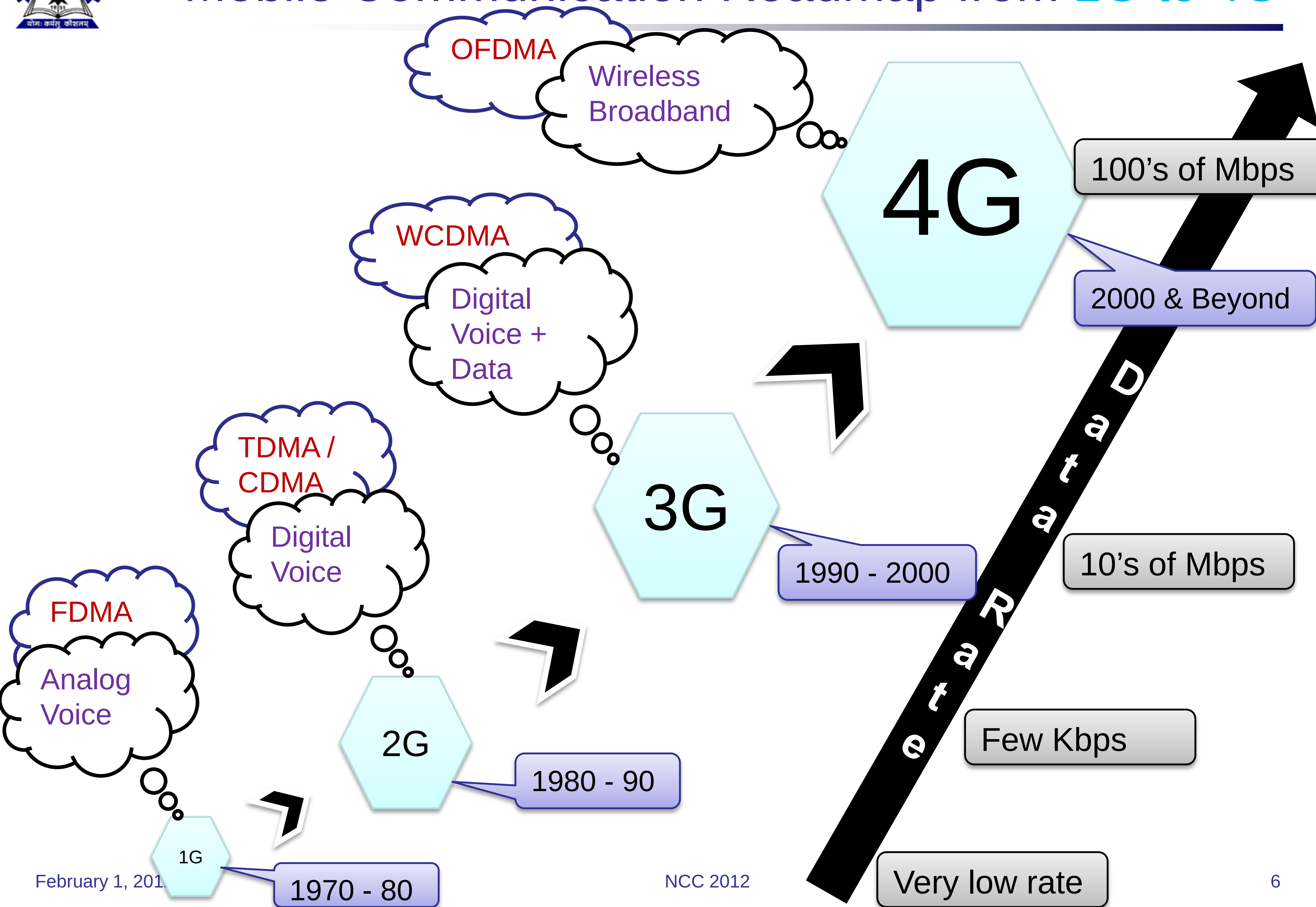
- Improvement in ***Latency, Capacity & Throughput.***
- **Simplified** Core Network.
- **Optimized IP Traffic & Services**.

Why 4G is Needed? – *Some Statistics*





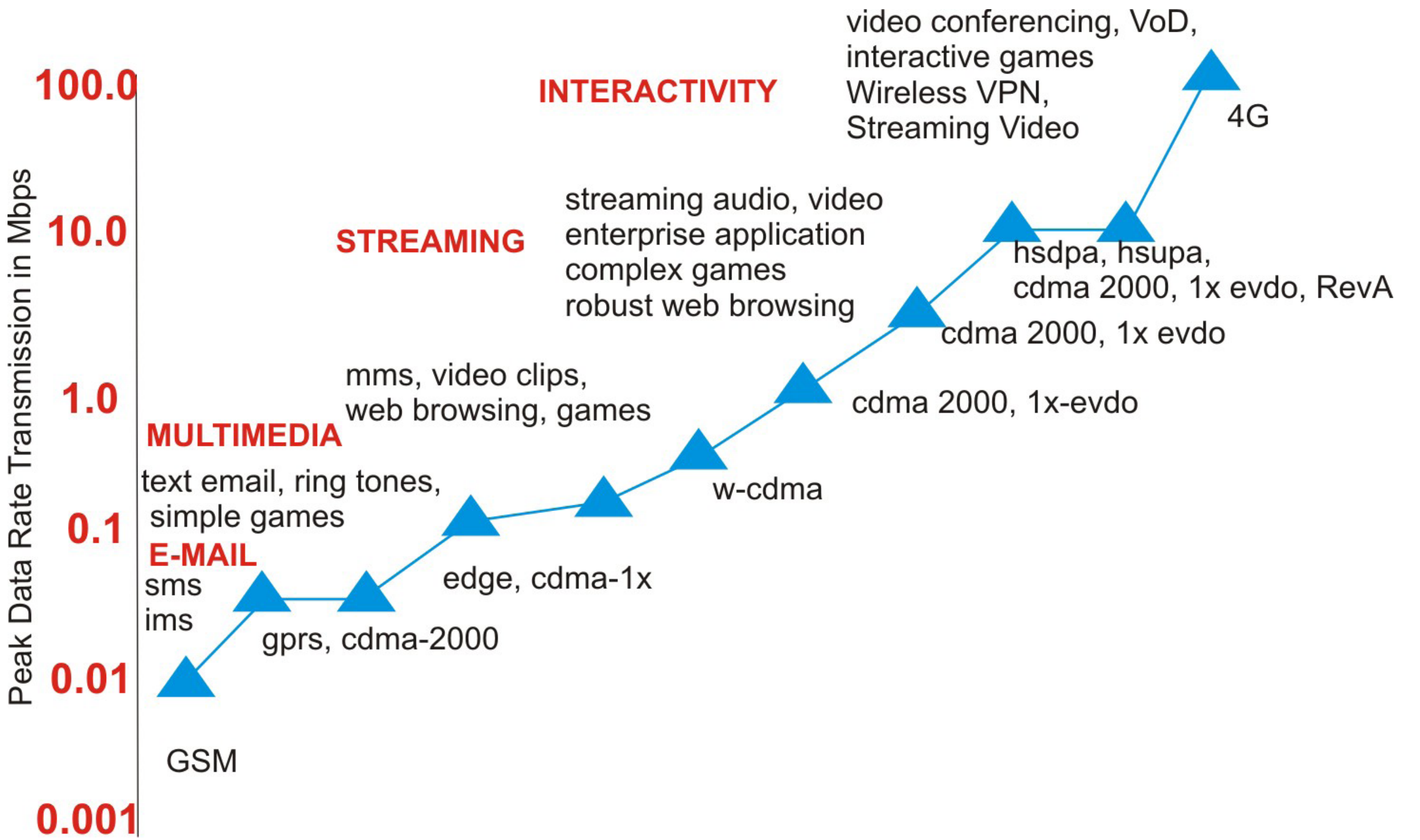
Mobile Communication Roadmap from 1G to 4G



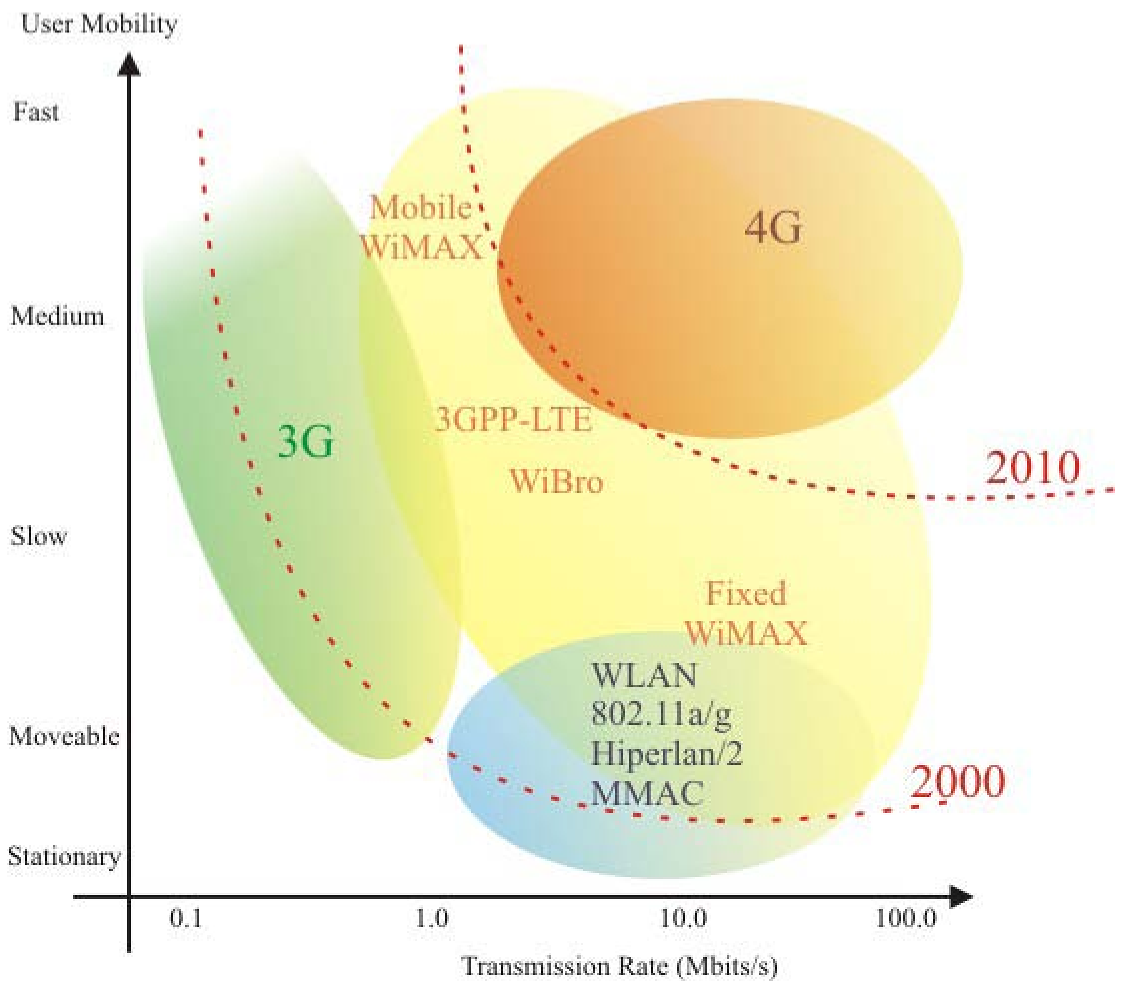
History of cellular telephony

1G	2G	2.5G	3G	Beyond 3G	4G
Analog voice	Digital voice	Voice + data	Multimedia services	Broadband multimedia	Ubiquitous networks
NMT AMPS	GSM PDC IS-95A IS-136	GPRS HSCSD EDGE IS-95B	WCDMA CDMA 2000	HSPA WiMAX UMTS-LTE CDMA 2000 1xEV	IMT-A ??
FM modulation Analog switching Cellular concept Hard handover	Digital modulation Error control Data compression Soft handover High quality voice	Voice + data Higher rate than 2G	'Any time any where' multimedia Packet based data Dynamic RRM Increased capacity	Broadband multimedia High data rate High QoS support broadband wide area	Heterogeneous networks Adaptive air interface Guaranteed QoS Real broadband at wide-area
FDMA	TDMA/CDMA	TDMA/CDMA	WCDMA	WCDMA/OFDMA	OFDMA
very low rate	9.6-28.8kbps	57-115kbps	0.144~2Mbps	~10's of Mbps	~100's of Mbps
1970s/1980s	1982/1992		1992/2001	…./2007,2012,	2017

Applications-Technologies



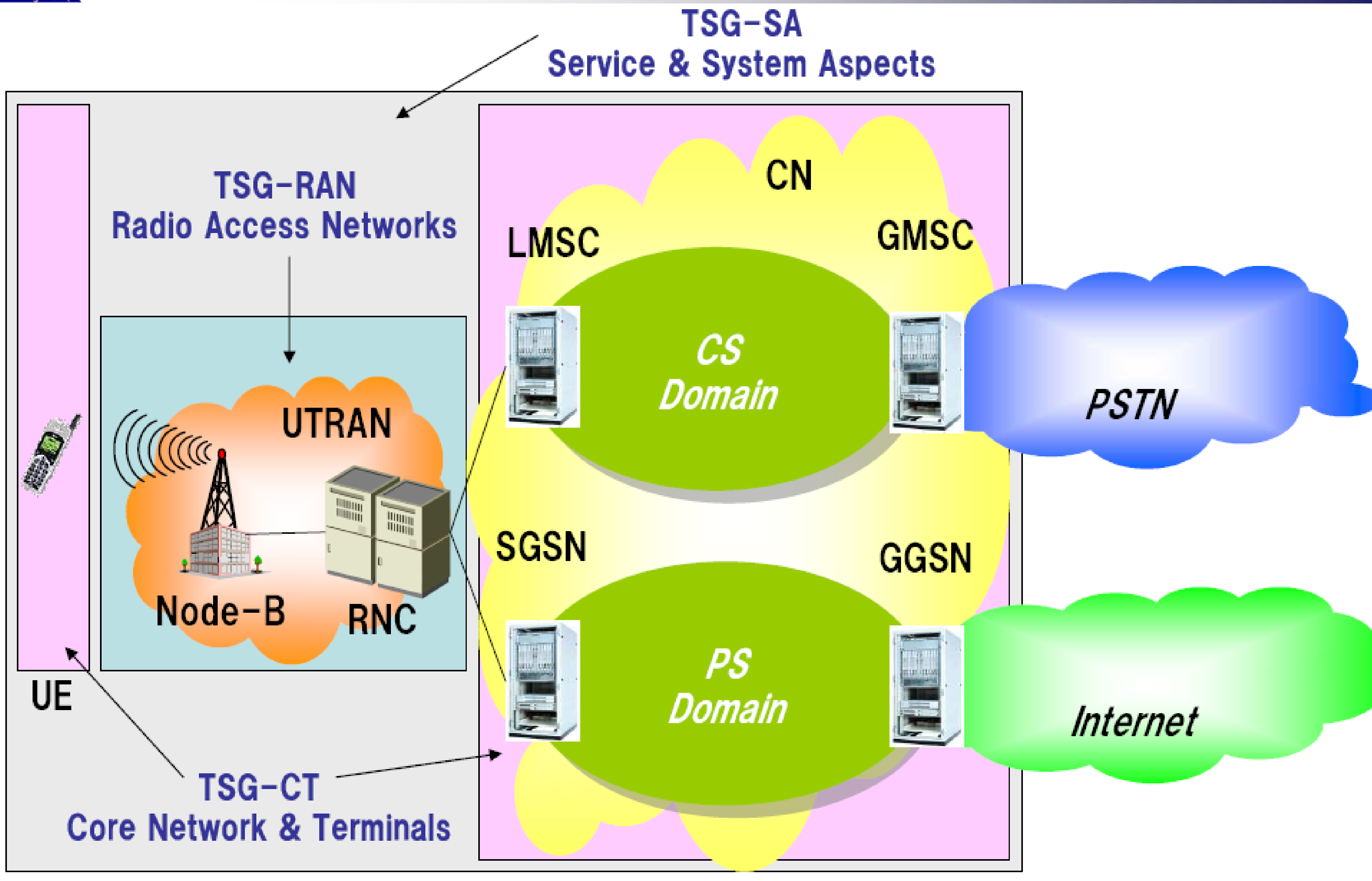
Recent and Future Wireless Communications Systems



3G++

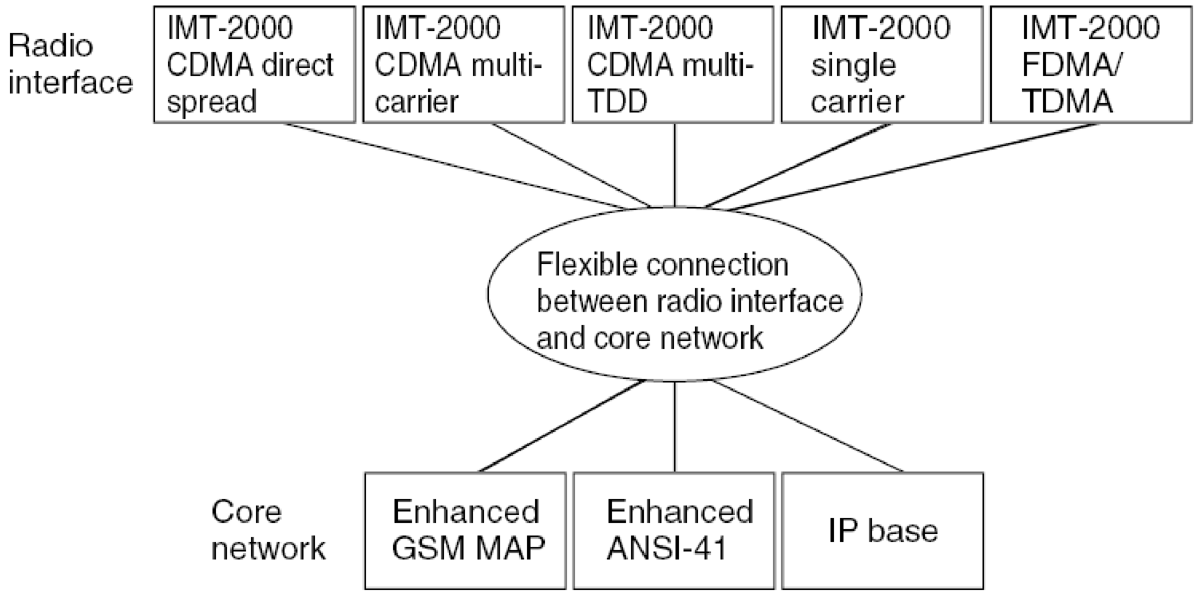
- The Third Generation Mobile Communication Systems
  - Conceived since 1992
    - Deployed 2001 onwards
      - HSPA
        - » Since 2007
  - Data Rate
    - 3G 144 kbps – 2 mbps (as per mobility condition)
    - HSPA 14.4 mbps
    - HSPA + 44 mbps
  - Bandwidth – 5MHz
  - Supports chip rate of 3.84 Mcps
  - Packet and Circuit Switched
    - Support Mobile Multi-media Services
      - Eg. Elderly health support, personal networks, Mobile TV
      - Video on Demand, Video Conferencing, Mobile Internet
- ***First attempt being made to converge high speed Internet (data) and Mobility (voice).***

3G System



Ref: NEC presentation at NSMA 08

3G Technologies



ANSI: American National Standards Institute
CDMA: Code Division Multiple Access
FDMA: Frequency Division Multiple Access
TDD: Time Division Duplex
TDMA: Time Division Multiple Access
GSM: Global System for Mobile communications
MAP: Mobile Application Part
IP: Internet Protocol

- Each of these radio technologies must be operable on the two major 3G core networks
- DS-mode is the so-called W-CDMA.

[W-CDMA Mobile Communication Systems]

PHY Layer

- Proposal from Japan W-CDMA {DS-CDMA FDD/TDD, 1.25,5,10,20 MHz}

- 3G in Europe ETSI
  - ***U**niversal **M**obile **T**elecommunications **S**ystem **(UMTS)***
    - *UMTS* Terrestrial Radio Access (UTRA),
      - W-CDMA ➔ *UTRA FDD paired bands*
      - TD-CDMA ➔ *UTRA TDD unpaired band*

- China Wireless Telecommunication Standard (CWTS)
    - TDD system, Time-Division Synchronous CDMA (TD-SCDMA),
    - Similar to UTRA TDD.

- TIA (South Korea) CDMA 2000
  - IMT-2000 Multi Carrier

Technologies Introduced in 3G++

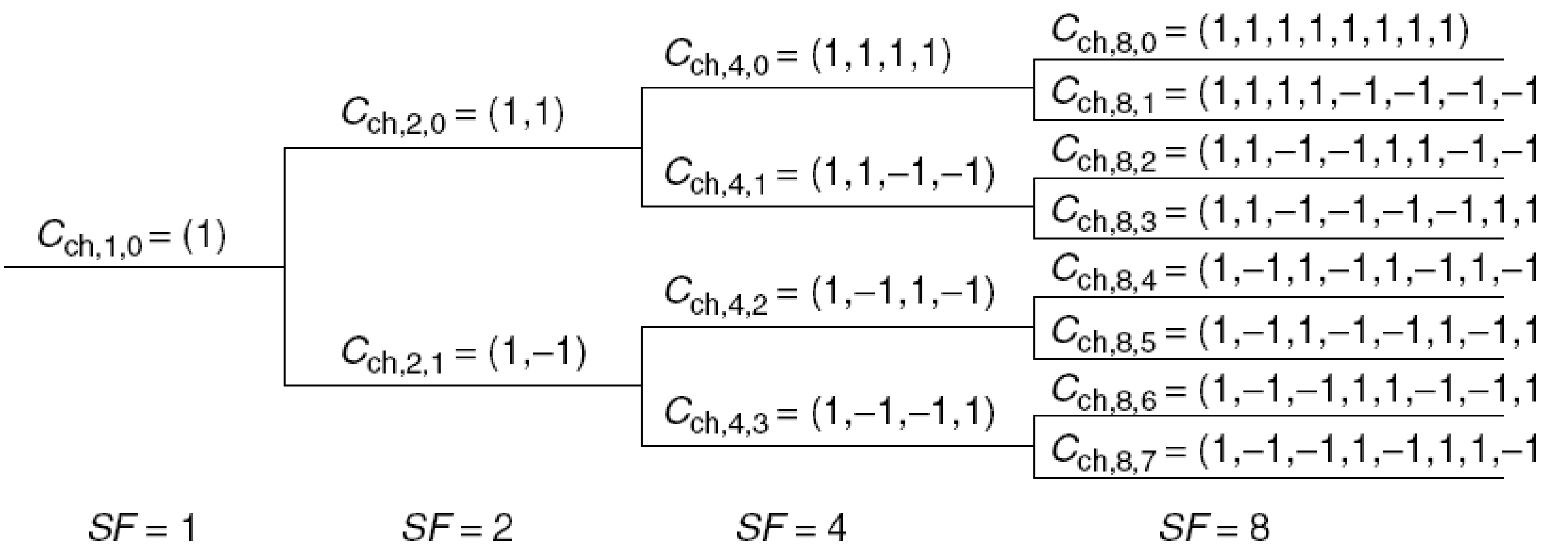
- Variable Data
  - Multiple Code Word Assignment ➔Variable Spreading Factor
  - Modulation
  - Code Rate

- Coverage / improvement
  - Turbo Code
  - Hybrid ARQ
  - Link Adaptation

- Capacity Improvement
  - Multi Antenna Transmission
  - Multi-user Scheduling

Variable Spreading Factor

- Variable Spreading Factor
  - Flexible Data Rate (speech band to high data rate)
  - Lower Peak to average power compared to multi-code transmission
  - One Sequence Rake Receiver



Difference between 3G and 4G

	3G	**4G**
Air Interface	CDMA	OFDMA, SC-FDMA
Data Rate	DL: 14 Mbps UL: 5Mbps	DL: 100 Mbps-1Gbps UL: 50Mbps-500 Mbps
Technology	Both Circiut Switched and Packet Switched	Only Packet Switched
Frequency Band	1.8 – 2.5GHz	2 – 8GHz
Forward error correction (FEC)	3G uses Turbo codes for error correction	Concatenated codes are used for error corrections in 4G
Examples	EDGE, CDMA2000, UMTS (WCDMA)	3GPP LTE-A, IEEE 802.16m WiMAX

4G Standards

- **3GPP >> LTE-Advanced**
- IEEE >> WiMAX (IEEE 802.16m)

Requirements of LTE-(Advanced)

- Work Started : 2004
- Driving Factors
  - Evolution of wire-line Capabilities
  - Need for additional Wireless Capabilities
  - Need for lower cost of data delivery

- *Standardization Process from 2005 : focused on*
  - *The Radio Access Technology*
  - *System Architecture*

3GPP-LTE

- Performance Targets
  - Spectral Efficiency 2-4 x HSPA release 6
  - Peak Data rate > 100 Mbps in DL **(upto 1Gbps)** and 50 Mbps in UL
  - Round Trip time < 10 ms
  - <u>*Optimized for packet switched network*</u>
  - High level of mobility and security
  - Optimized Terminal Power efficiency
  - Frequency Flexibility

- Core Network Side
  - Improve Network Scalability for Traffic increase and to reduce the end to end latency by reducing number of network elements

More Details on Requirements

1. **Peak spectrum efficiency (bps/Hz)**:
   - Downlink - 15 bps/Hz,
   - Uplink - 6.75 bps/Hz
2. **Cell-edge user throughput**:
   - Down link - 0.06 bps/Hz/user
   - Uplink - 0.03 bps/Hz/cell/user
3. **Latency**
   - Control Plane – Less than 50 ms
   - User Plane – Less than 5 ms
4. **User Support** – Up to 200 Active users in a cell (5 MHz)

3GPP-LTE

- State of the art
  - *New Radio Interface*
    - *OFDMA in DL , SC-FDMA in UL*
  - *Evolved System Architecture*
    - *Reduced number of Nodes*
    - *All IP network*
    - *Core Network Streamlined: User Plane and Control Plane separation*
    - *Release 8 Core Network is referred to as **E**volved **P**acket **C**ore*

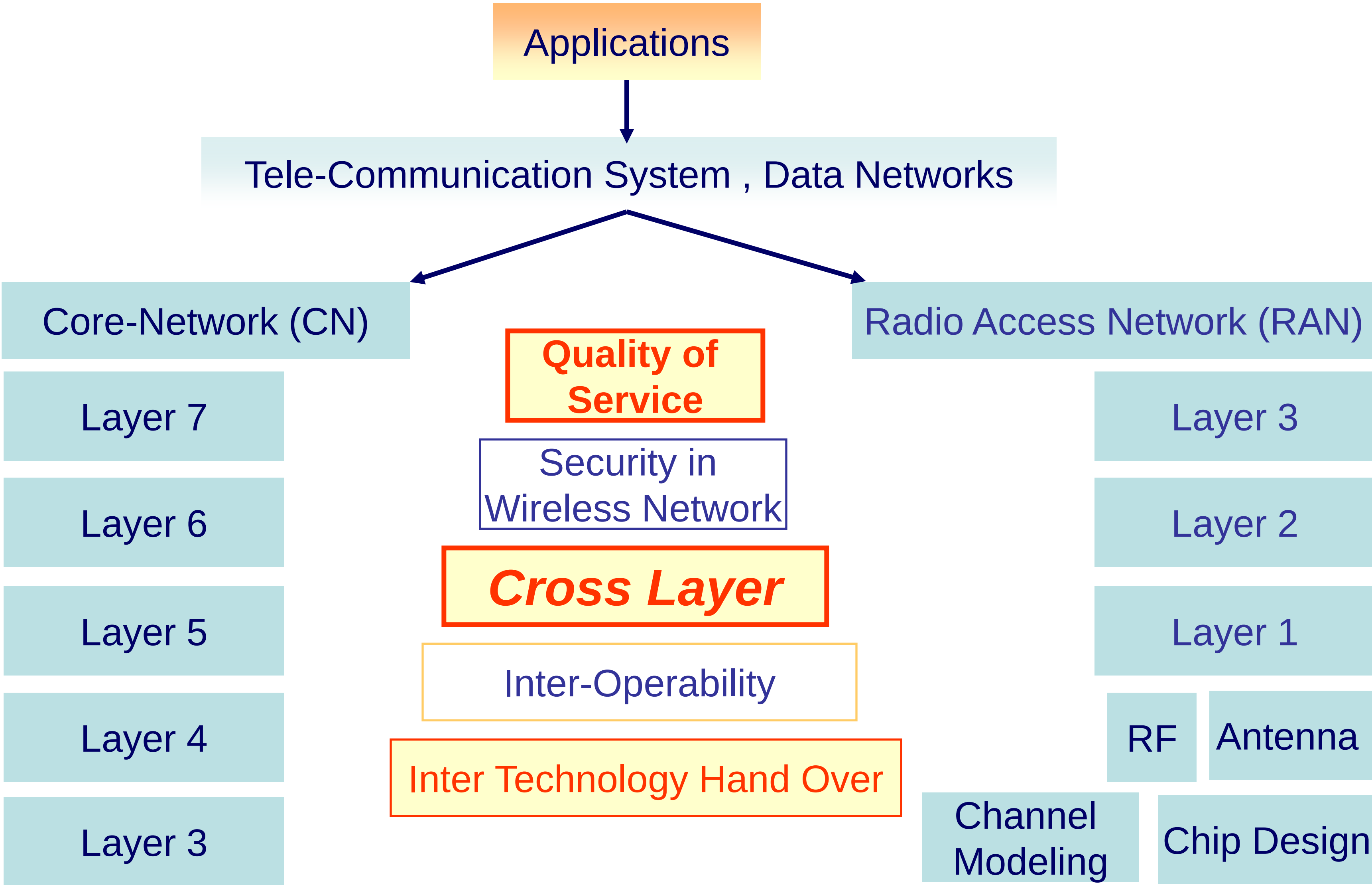
3GPP-LTE-A

- Focus Beyond Release 8
  - LTE MBMS
  - Self Optimized Networks
  - Further improvements for enhanced VOIP support
  - Requirement for Multi Bandwidth Multi Radio Base Station

- Release 9
  - LTE (release 8) correction and further optimization

- IMT-Advanced / LTE-Advanced (Release 10)
  - Support for peak data rate of up to 1Gbps in nomadic and 100 mbps in highly mobile conditions
  - Support for Large bandwidth up to 100 MHz
  - Further reduced Latencies

Telecommunication Framework



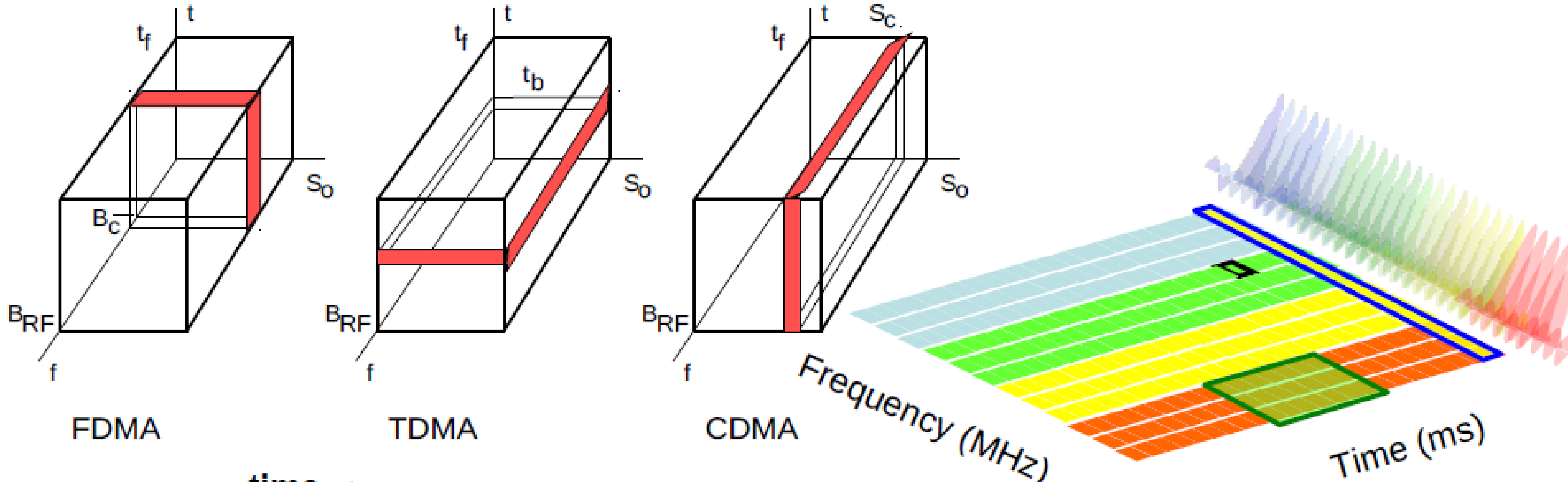
Important Design Aspects

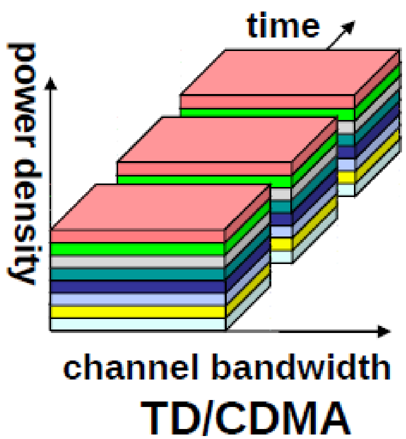
- **Multicarrier**-based radio air interface
  - **OFDMA and SC-FDMA**
- **All IP-based** flat network architecture.
- **Multi-input multi-output** (MIMO)
- **Fast Channel aware Scheduling** (Link Adaptation) and Adaptive Transmission Bandwidth (ATB)
- Active interference avoidance and coordination
- Fractional Frequency re-use (FFR)
- **Hybrid Automatic Repeat Request** (HARQ)
- Power Control
- **Carrier Aggregation**

3GPP-LTE-A

- **Important Technology advances** in the Radio Part
  - Relay Nodes : Large Coverage
  - Single User MIMO
  - Scalable System Bandwidth up to 100 MHz
  - Nomadic / Local Access
  - Flexible Spectrum Usage
  - Automatic & Autonomous Network configuration
  - Coordinated MIMO

Multiple Access Schemes





Source: Meinke/Gundlach: Taschenbuch der Hochfrequenztechnik. Vierte Auflage, Springer-Verlag, Berlin, 1986

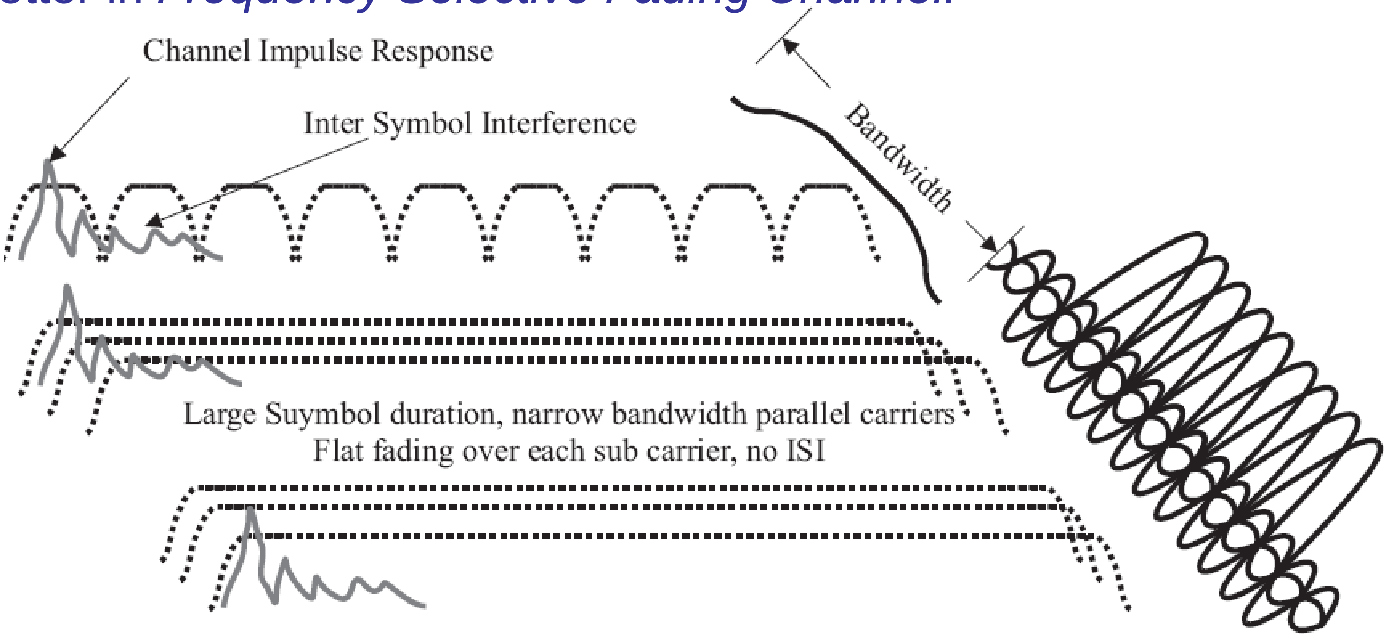
Multicarrier based Air Interface –

Orthogonal Frequency Division Multiple Access

- OFDM System breaks the available Bandwidth into narrower sub-carrier *(which are orthogonal to each other)* and transmits the data in parallel streams.

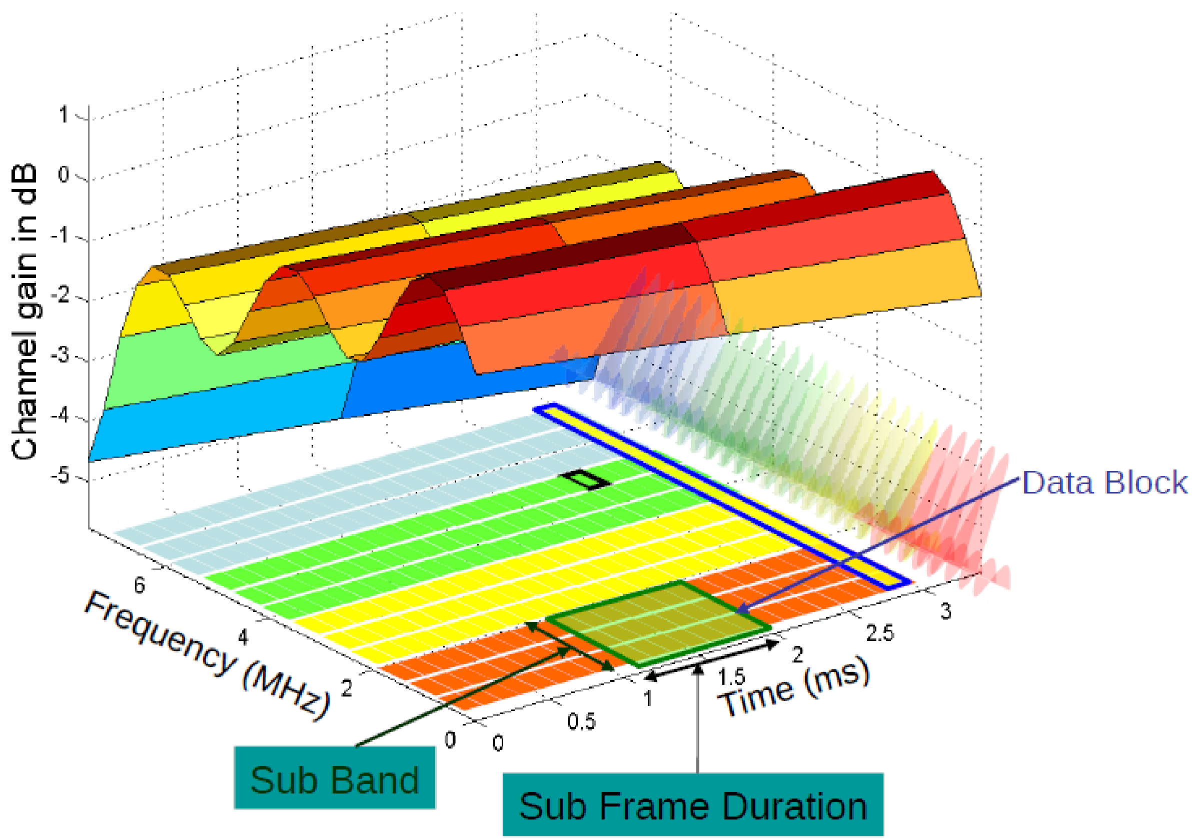
- Each sub-carrier is modulated using varying levels e.g. QPSK, QAM etc.

- Performs better in *Frequency Selective Fading Channel.*



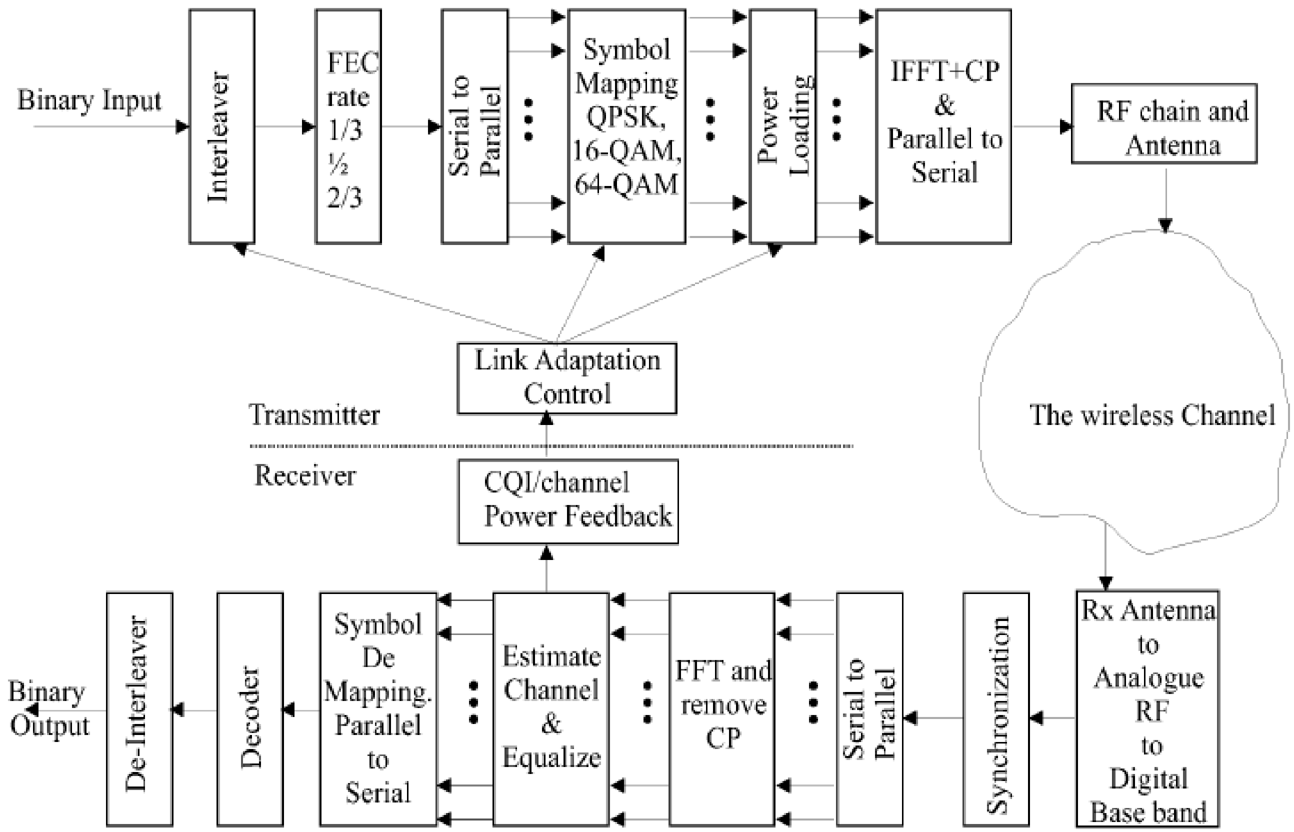
- No ISI – Single Tap Equalizer

OFDMA (Cont.)



Channel gain in dB
1
0
-1
-2
-3
-4
-5
Frequency (MHz)
6
4
2
0
Time (ms)
0
0.5
1
1.5
2
2.5
3
Data Block
Sub Band
Sub Frame Duration

OFDM Transmitter and Receiver

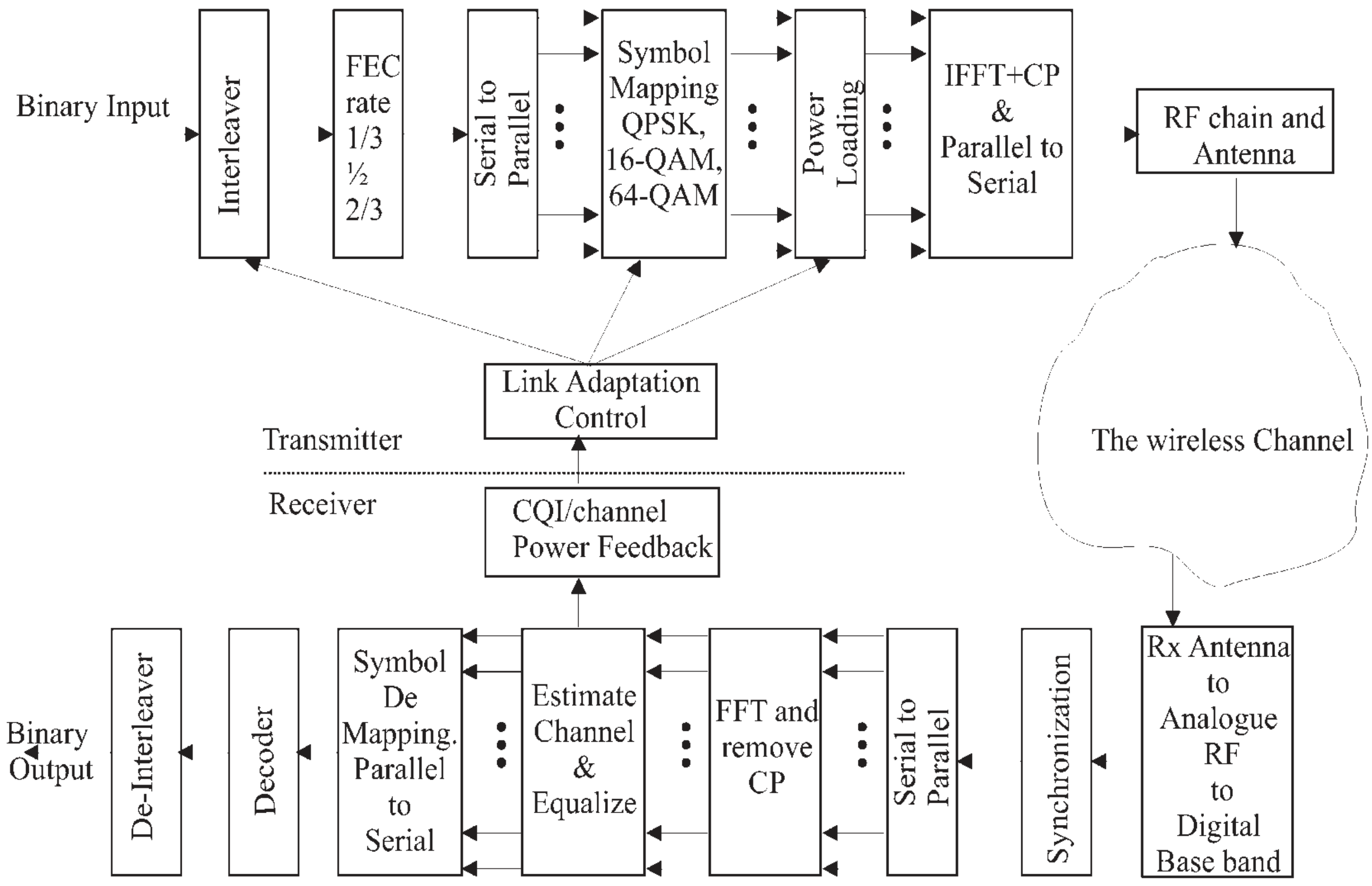


Technical Specifications (LTE)

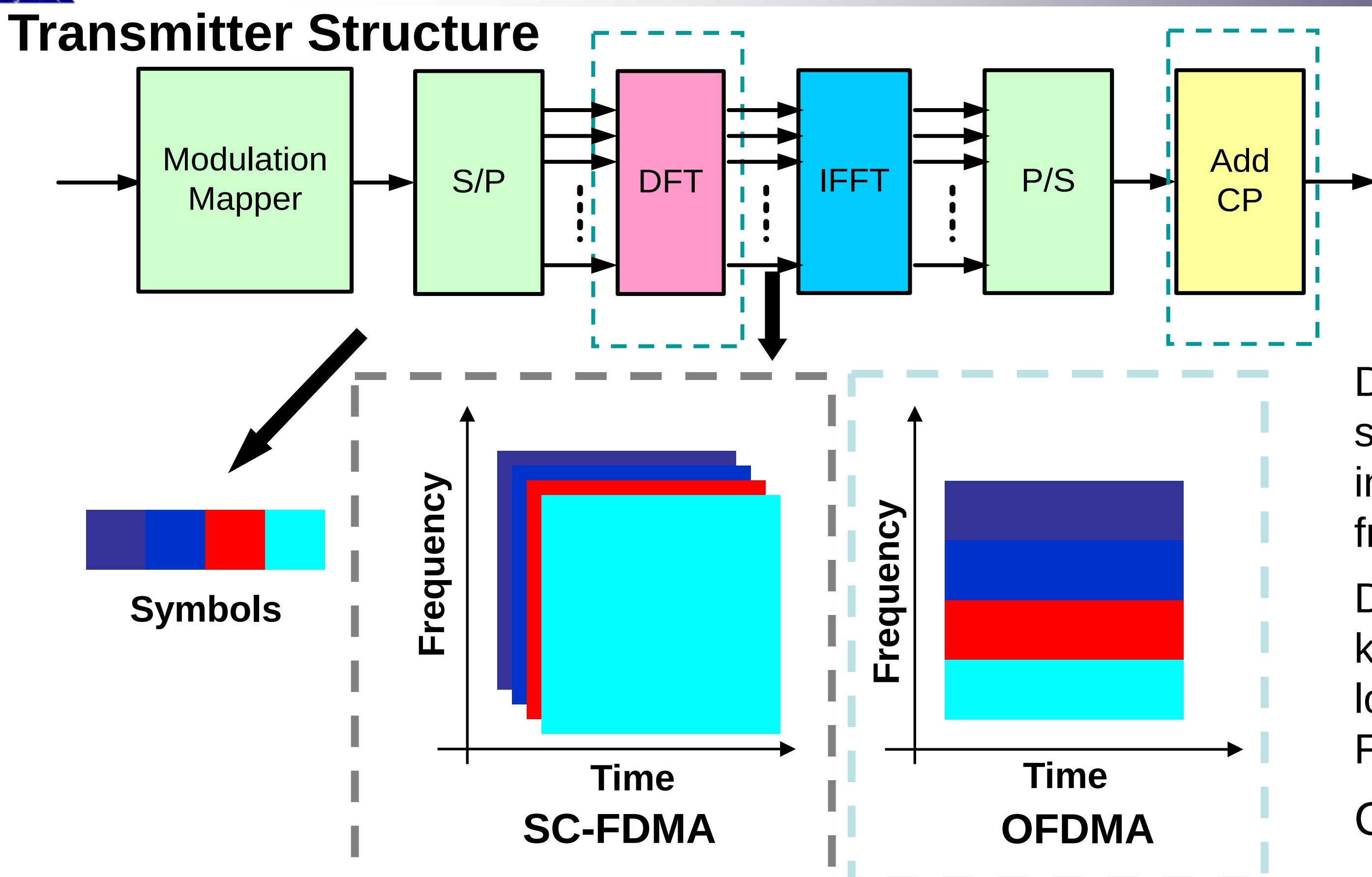
Parameters	Values
Transmission Bandwidth	1.4 ,3, 5, 10, 15 20 MHz (Scalable)
FFT Size	128,256,512,1024,1536,2048
Sub-Carrier Spacing	15 kHz
Frame Duration	1 ms(Sub frame) x 10 = 10 ms
OFDM Symbols per sub frame	14 (Normal CP) / 12 (Extended CP)
Modulation Used	QPSK,16-QAM,64-QAM
Forward Error Correction	Turbo Coding
Antenna Configuration	MIMO
Duplex Methods	FDD , TDD
Spatial Multiplexing	Single layer for UL per UE Up to 4 layer for DL per UE MU-MIMO for DL & UL

Transmission BW		1.25 MHz	2.5 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Sub-frame duration		0.5 ms					
Sub-carrier spacing		15 kHz					
Sampling frequency		1.92 MHz (1/2 × 3.84 MHz)	3.84 MHz	7.68 MHz (2 × 3.84 MHz)	15.36 MHz (4 × 3.84 MHz)	23.04 MHz (6 × 3.84 MHz)	30.72 MHz (8 × 3.84 MHz)
FFT size		128	256	512	1024	1536	2048
Number of occupied sub-carriers†, ††		76	151	301	601	901	1201
Number of OFDM symbols per sub frame (Short/Long CP)		7/6					
CP length (μs/samples)	Short	(4.69/9) × 6, (5.21/10) × 1*	(4.69/18) × 6, (5.21/20) × 1	(4.69/36) × 6, (5.21/40) × 1	(4.69/72) × 6, (5.21/80) × 1	(4.69/108) × 6, (5.21/120) × 1	(4.69/144) × 6, (5.21/160) ×1
	Long	(16.67/32)	(16.67/64)	(16.67/128)	(16.67/256)	(16.67/384)	(16.67/512)

OFDM Tx and Rx



Single Carrier FDMA (SC-FDMA)



DFT Spreading spreads M-PSK/QAM in both time and frequency.

DFT Spreading is the key component for low PAPR in SC-FDMA.

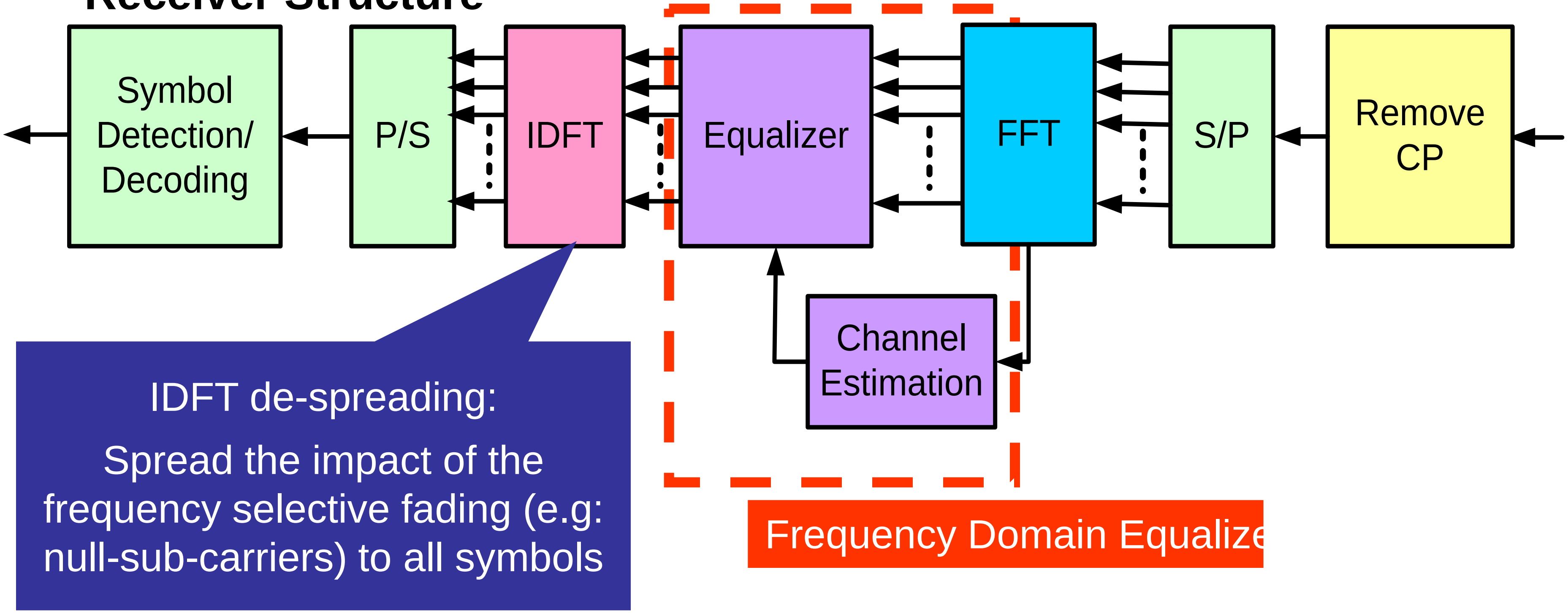
Cyclic Prefix (CP):

to mitigate ISI.

- **SC-FDMA is known as DFT-Spread OFDM.**
  - Low PAPR (better coverage and better transmit power efficiency).
  - Flexible transmission in scalable bandwidth (1.25 – 20 MHz)

Single Carrier FDMA (SC-FDMA)

Receiver Structure



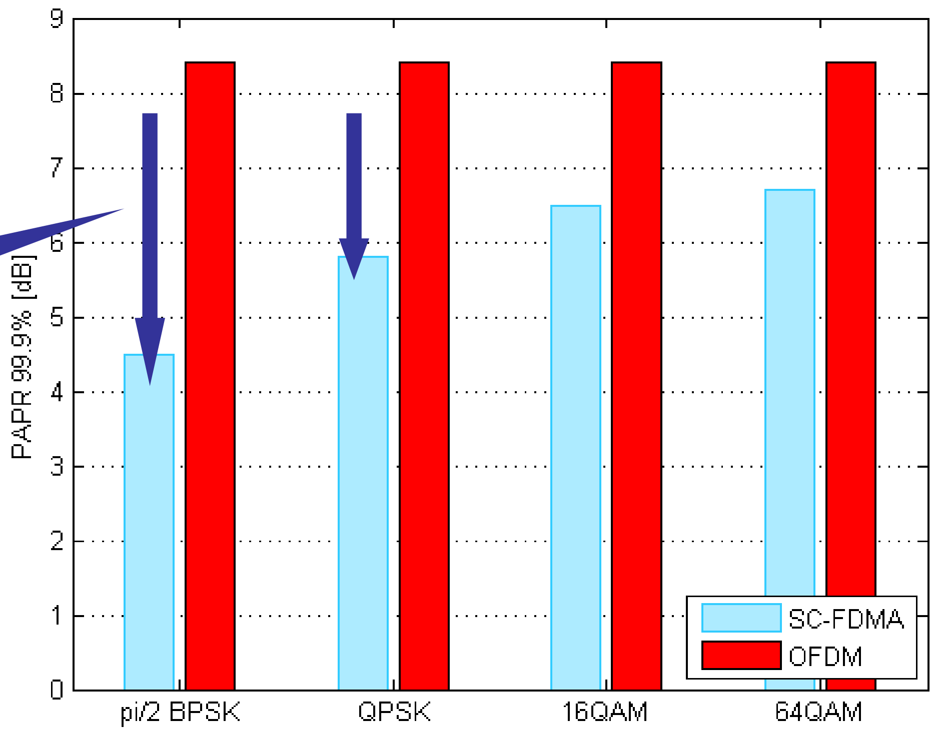
- Relatively low UE and e-node B complexity.
  - SC-FDMA uses One-tap Frequency Domain Equalizer.
  - Relatively high degree of commonality with the downlink OFDM scheme and the same parameters.

Peak-to-average Power Ratio Comparison

- High PAPR requires high back-off, means high reduction of power amplifier operating point.
- A low PAPR is desired for maximum power efficiency in the UE.

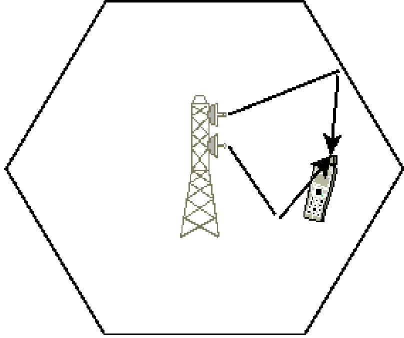
Advantage to the cell-edge UE & Better cell-coverage (~4dB)

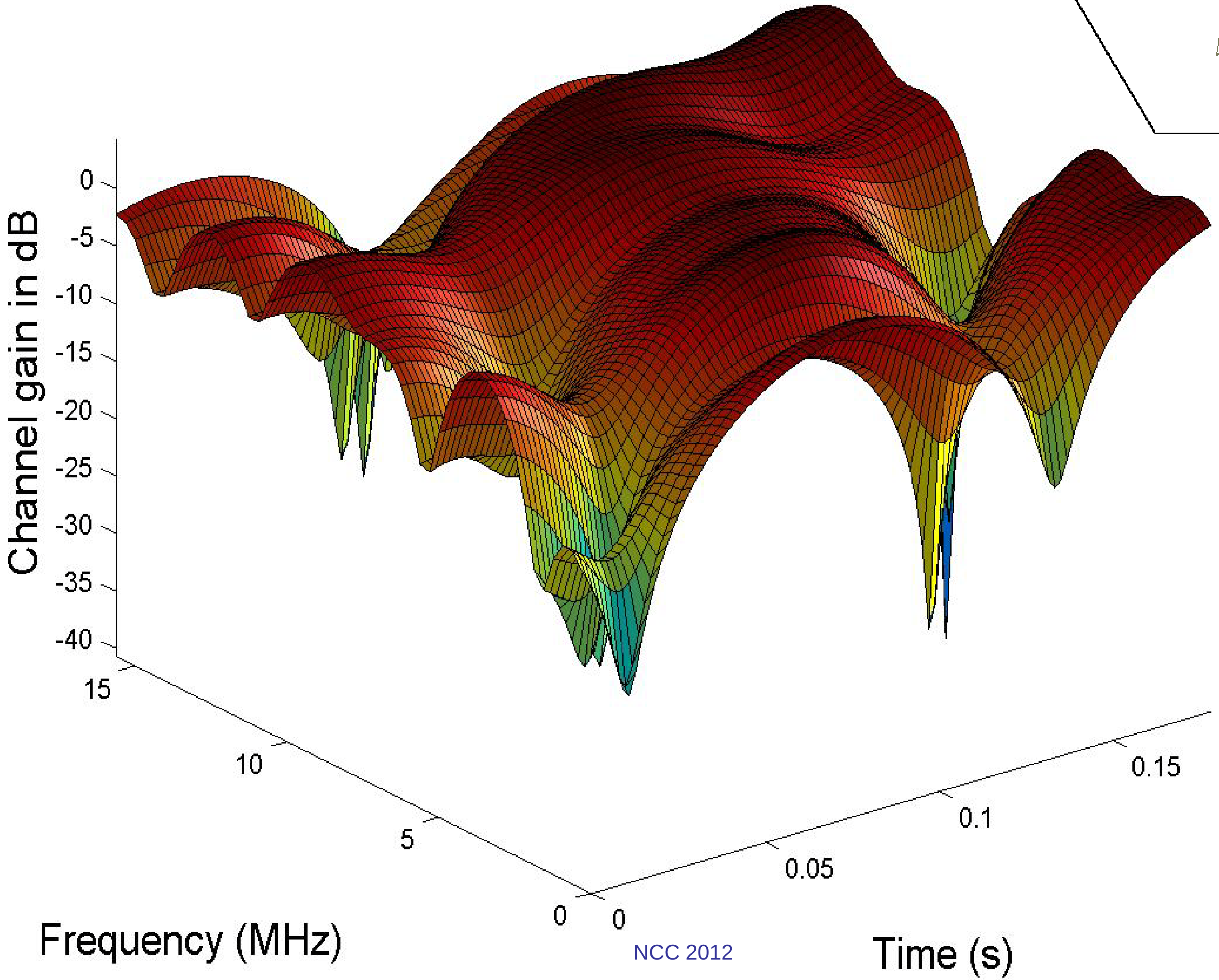
- SC-FDMA has lower PAPR than OFDM and the PAPR varies across different modulation scheme.
- Low PAPR for BPSK gives advantage for wider area coverage.



OFDMA vs. SC-FDMA PAPR Comparison for different modulation scheme.

Channel Variability in Time and Frequency





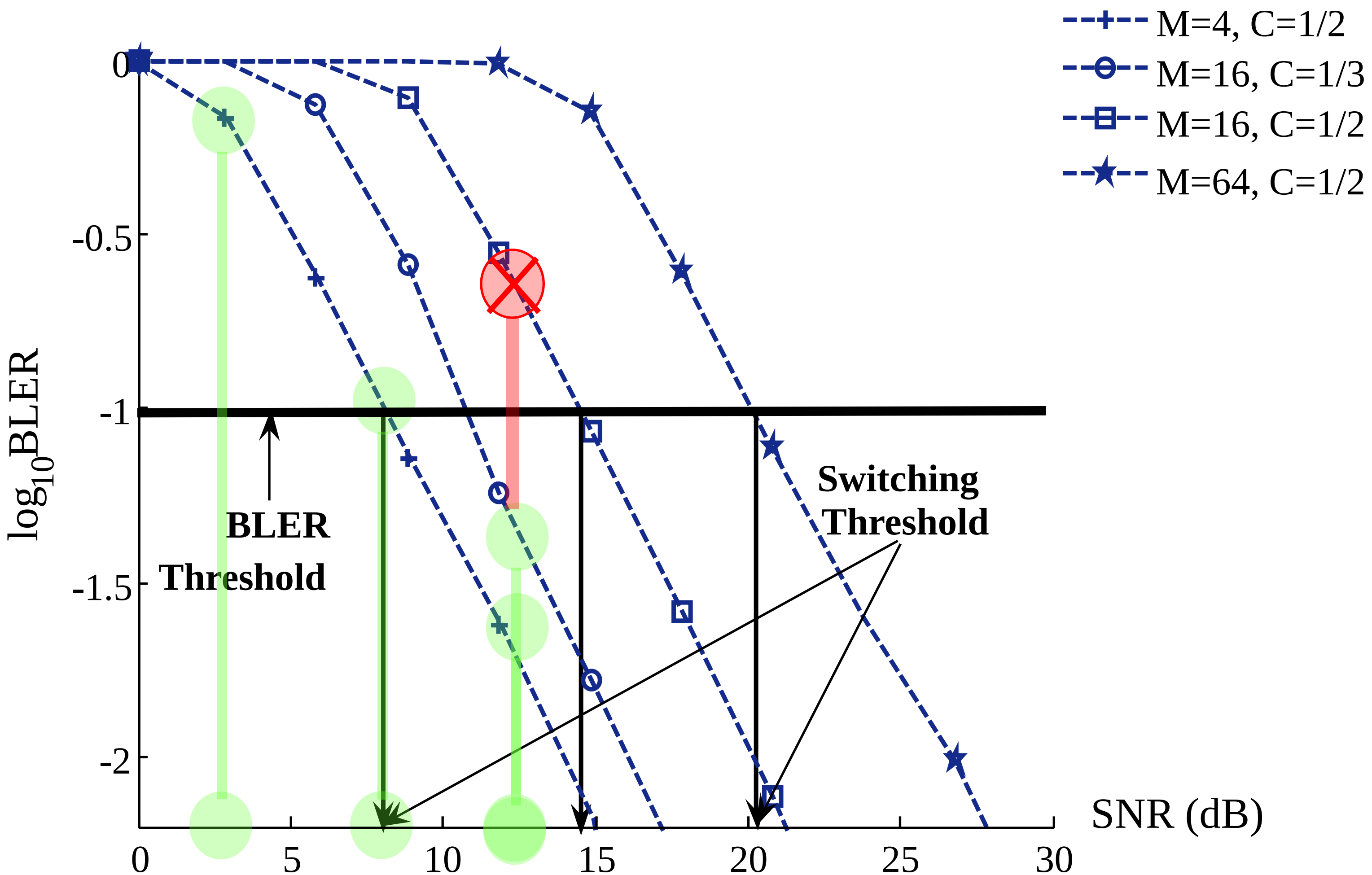
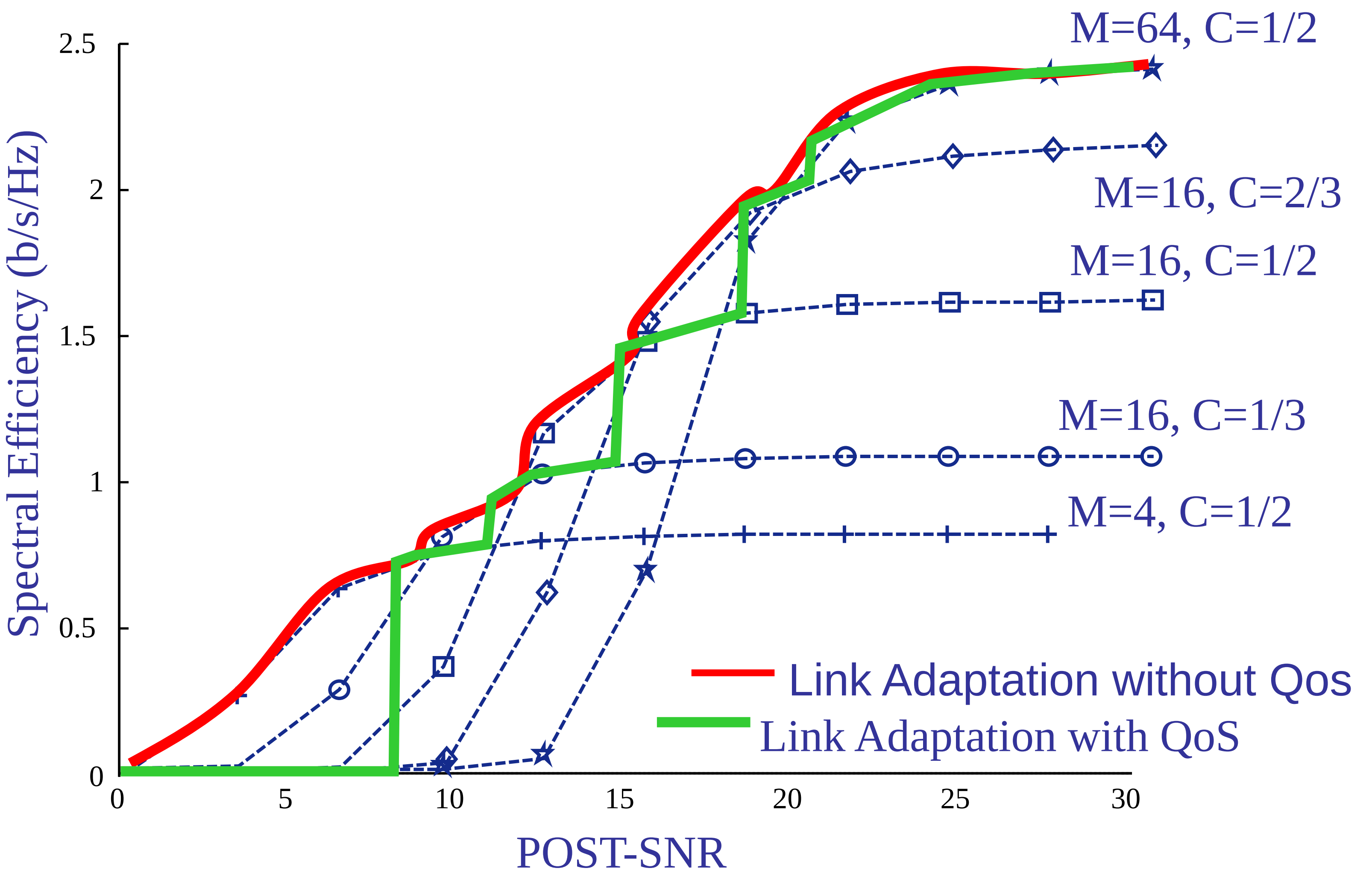


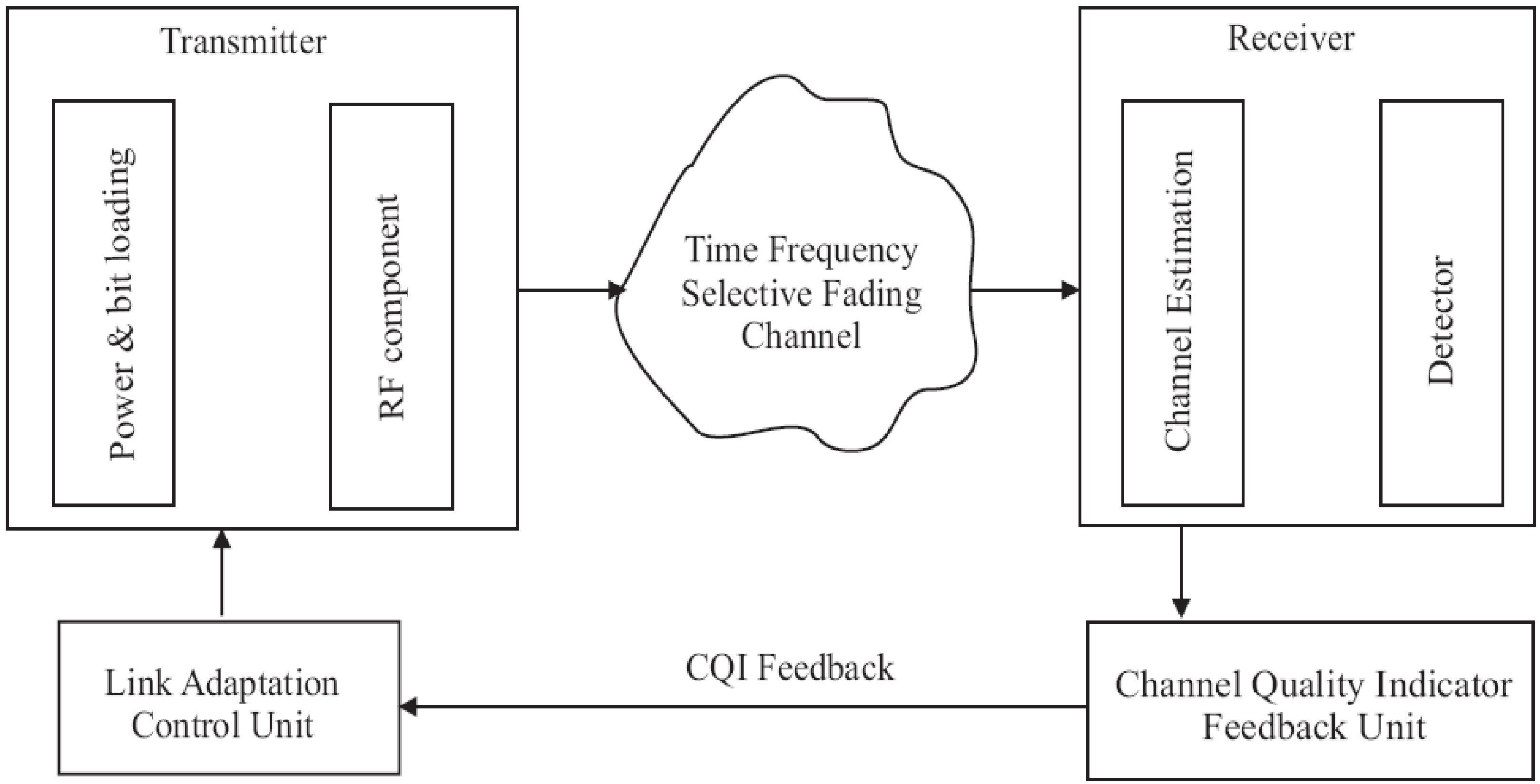
Table 2.4: Switching Threshold for Link Adaptation

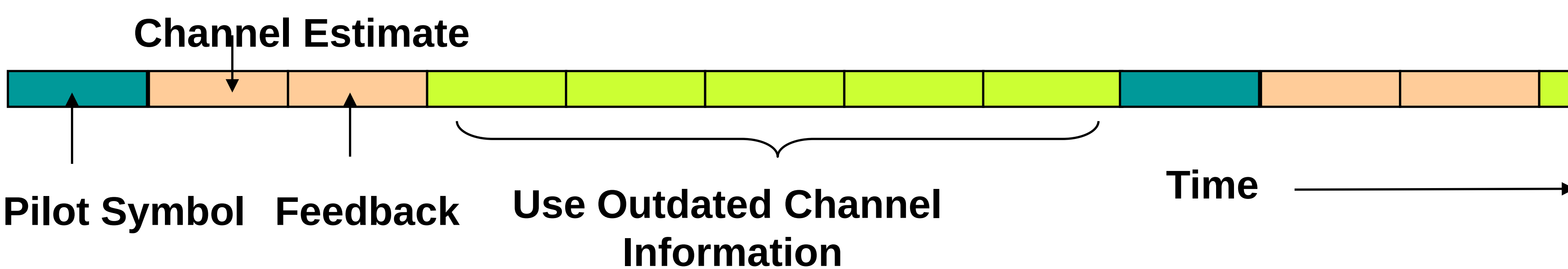
Modulation & FEC	M=0, C=0	M=4, C= $\frac{1}{2}$	M=16, C= $\frac{1}{3}$	M=16, C= $\frac{1}{2}$	M=16, C= $\frac{2}{3}$	M=64, C= $\frac{1}{2}$
SNR (dB)	0	8.2	10.9	14.7	18.4	20.4

Link Adaptation

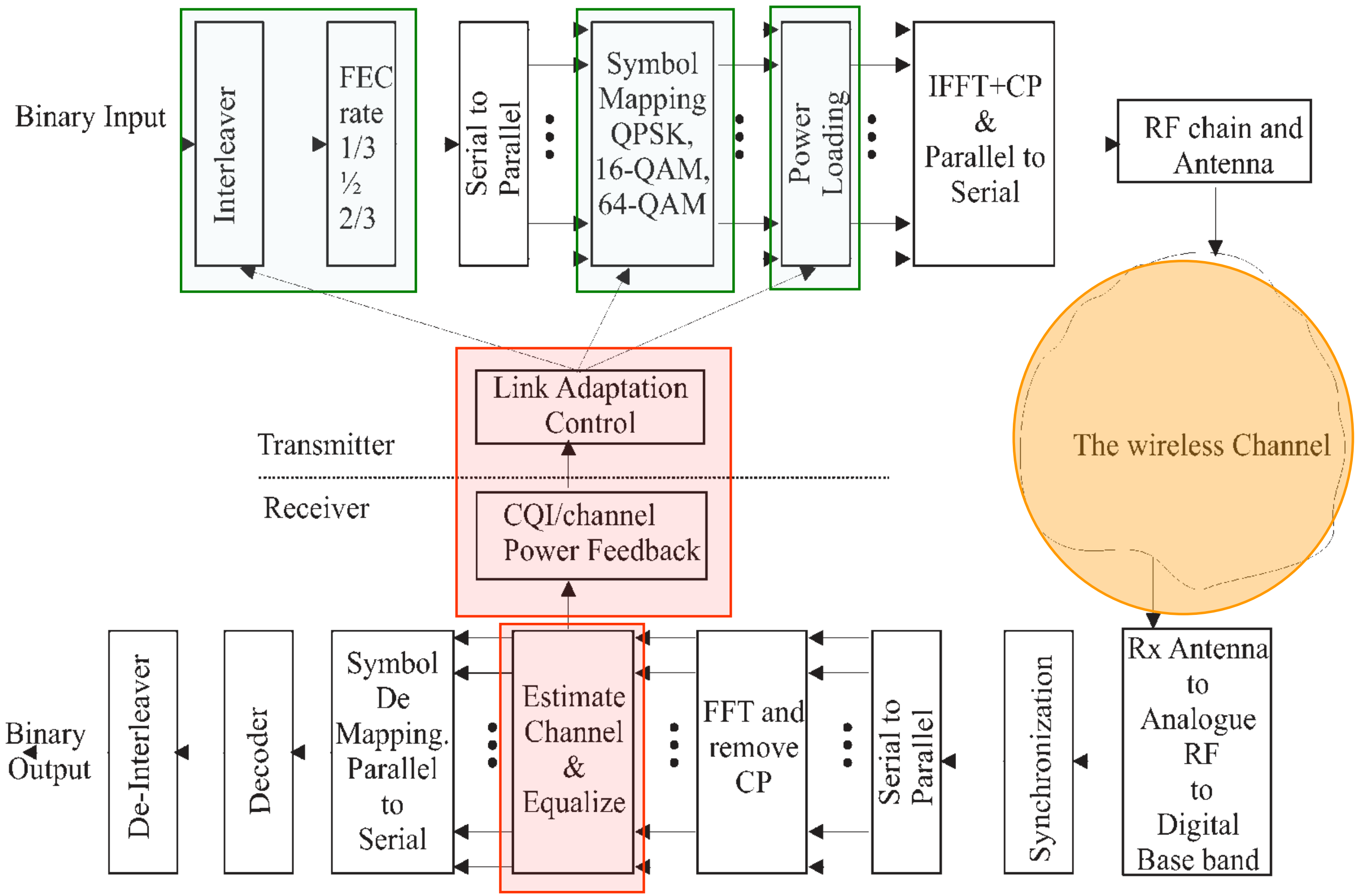


Link Adaptation





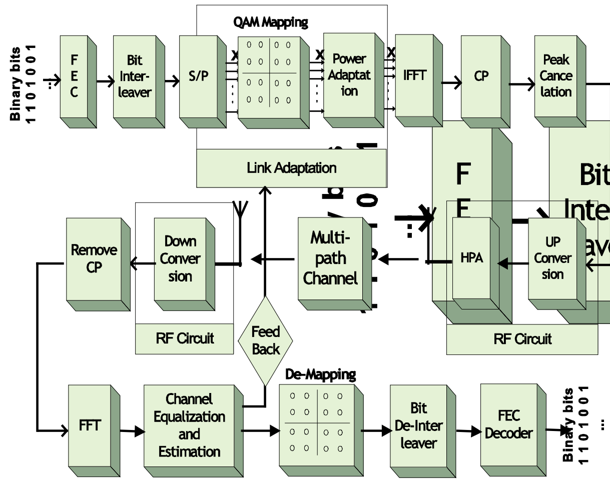
Link Adaptation

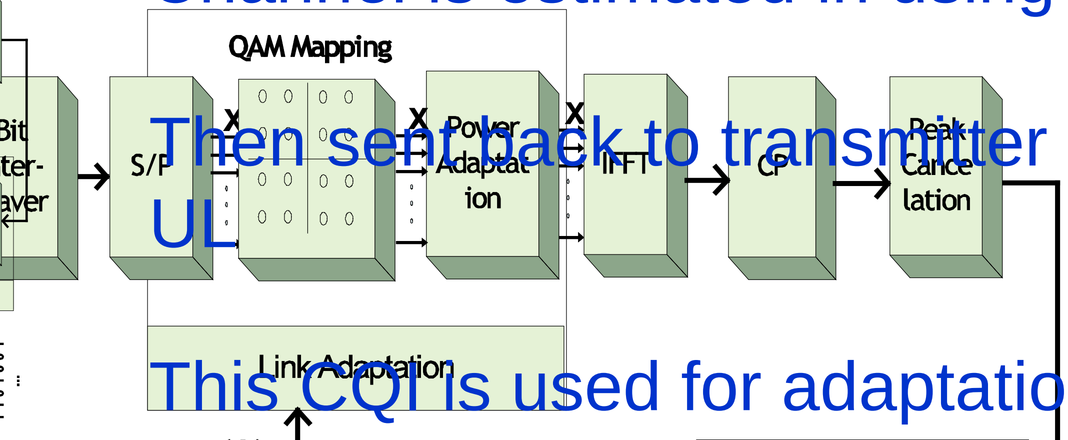


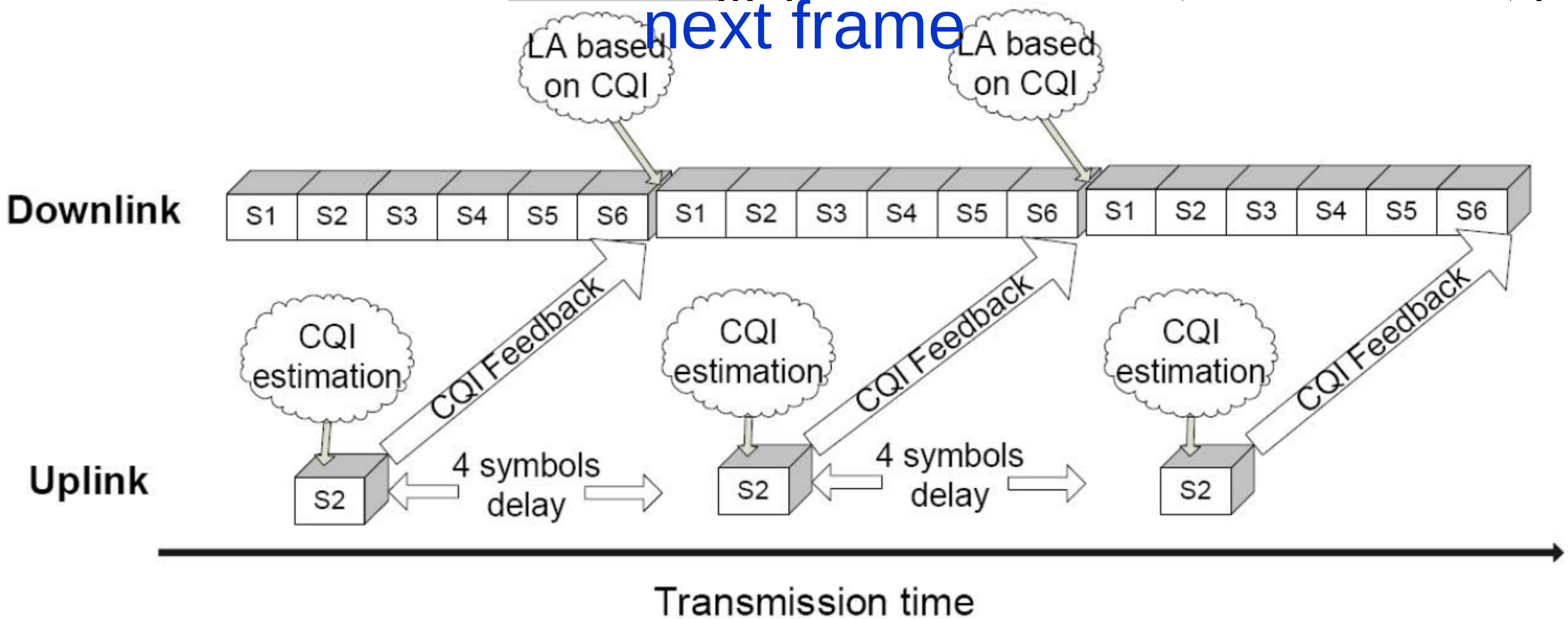
Channel is estimated in using pilots

Then sent back to transmitter using UL

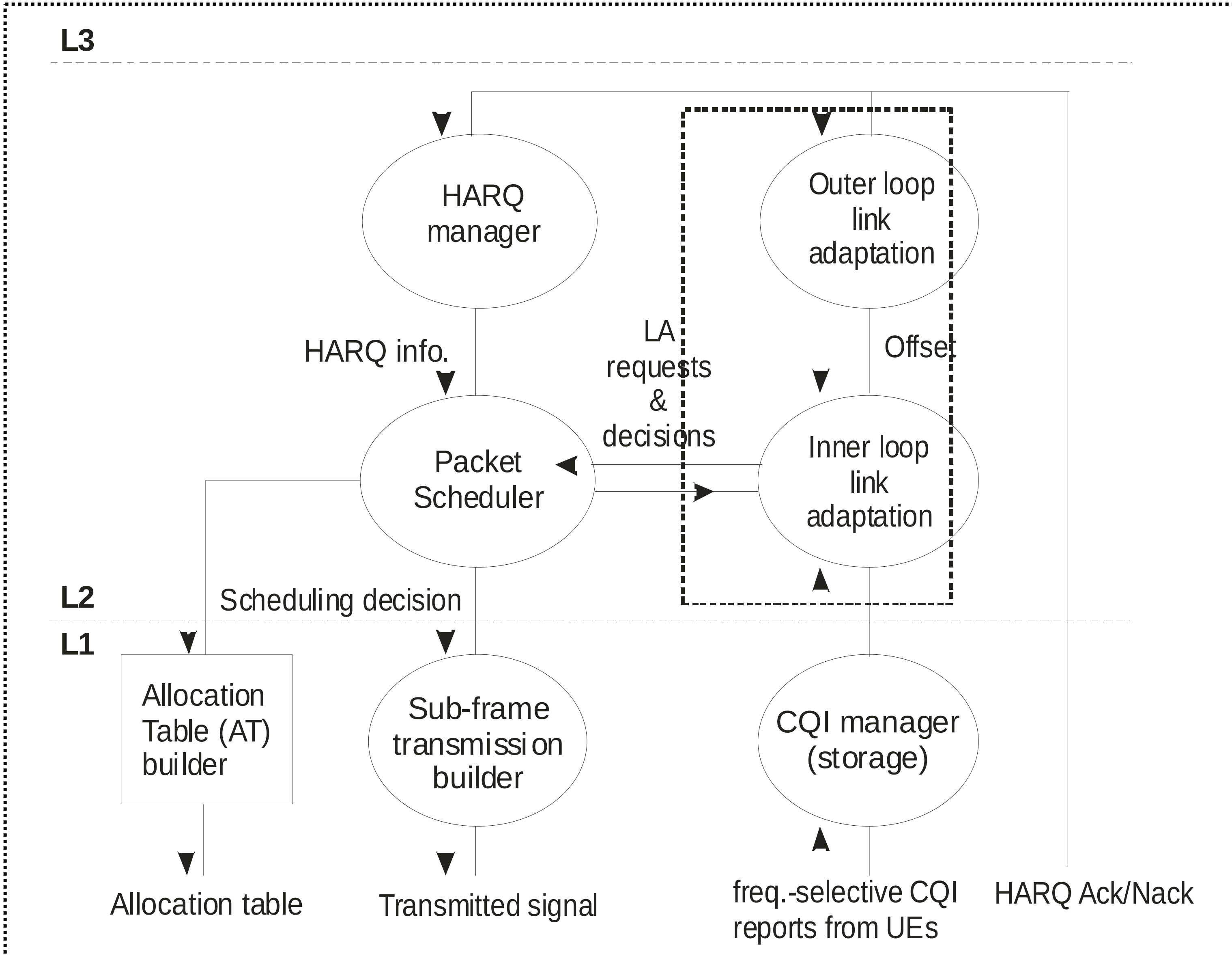
This CQI is used for adaptation in next frame



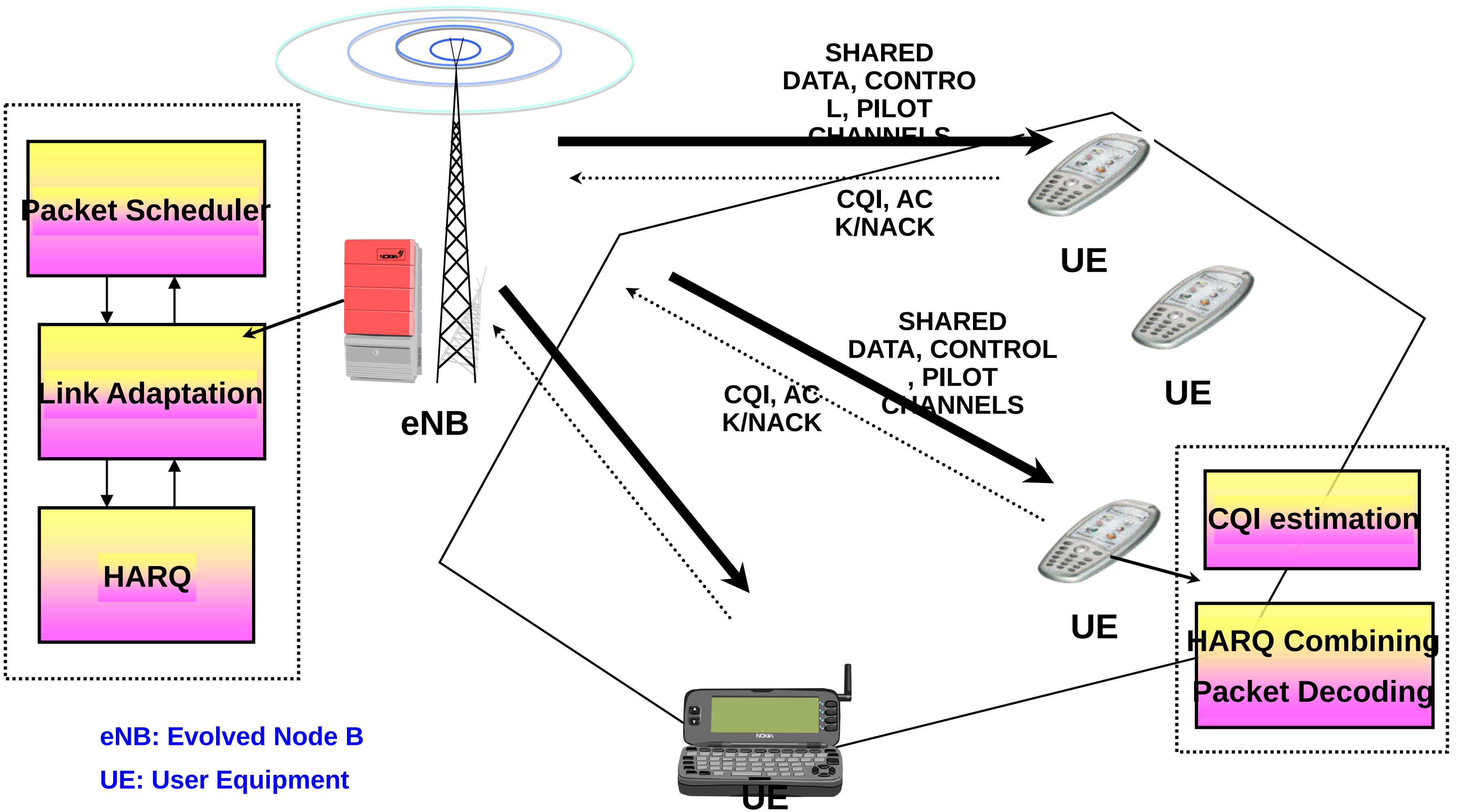




Radio Resource Management



Generalized System Model



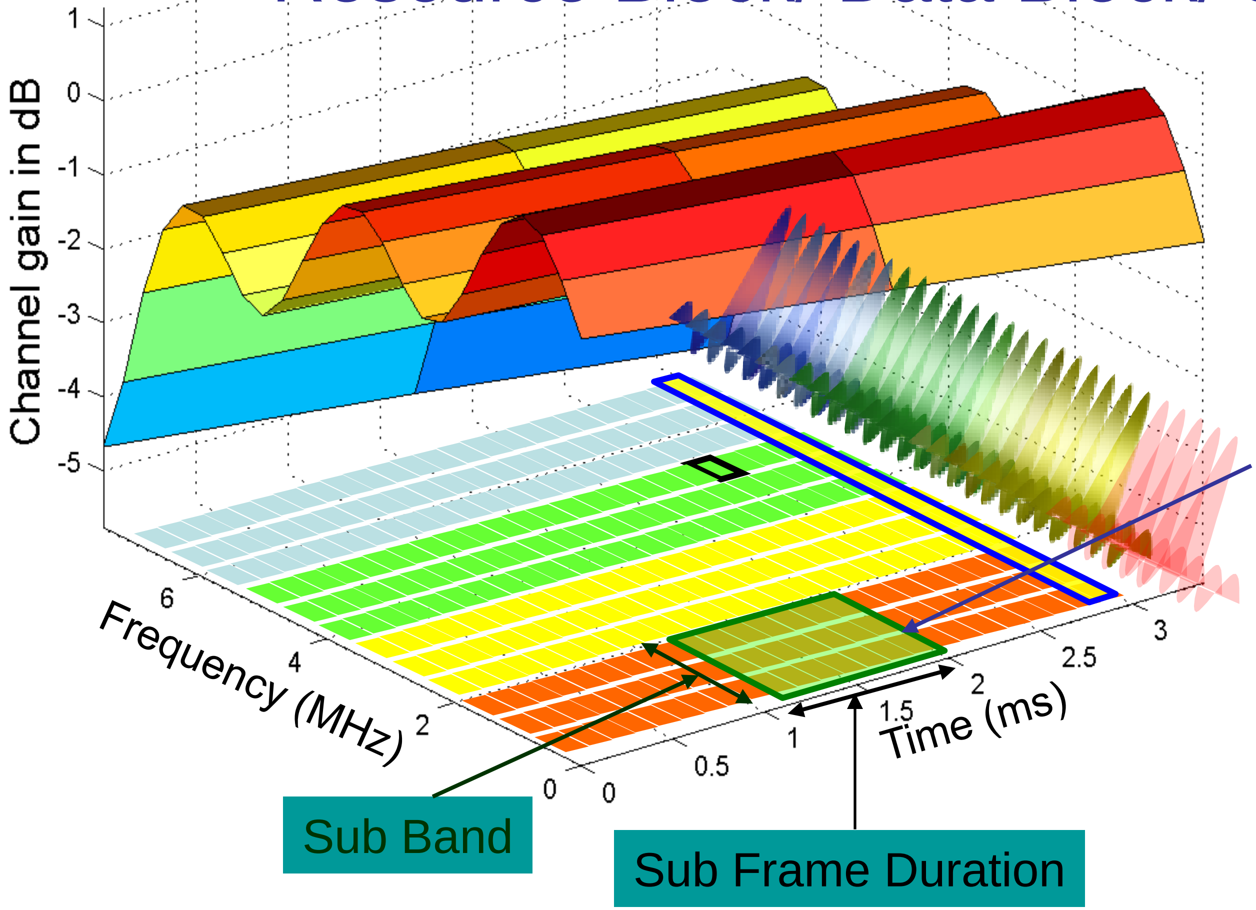
eNB: Evolved Node B

UE: User Equipment

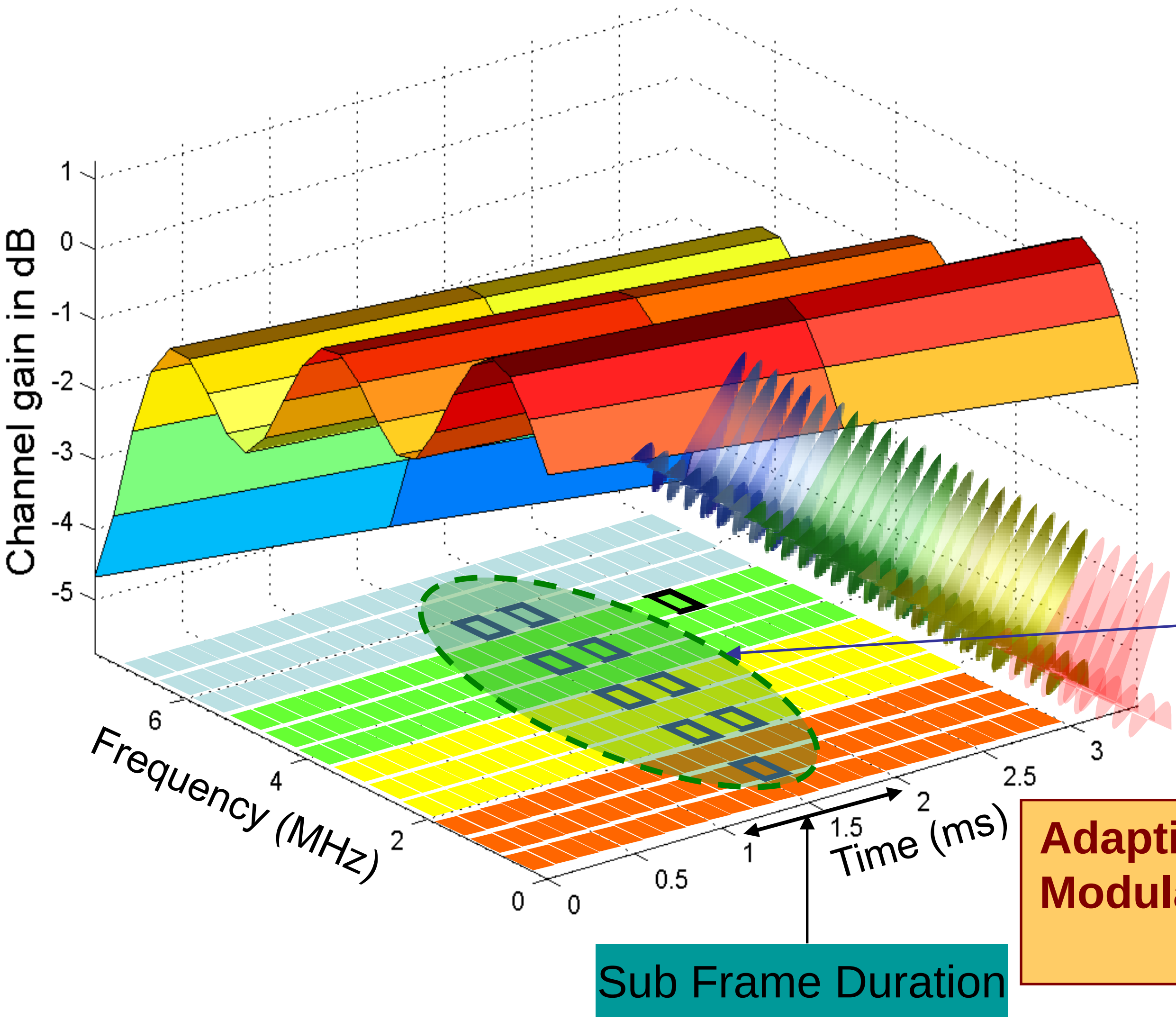
HARQ: Hybrid ARQ

Resource Block/ Data Block/ Sub-C

Adaptive Modulation Coding Power



Link Adaptation: Interleaved Sub-Channel

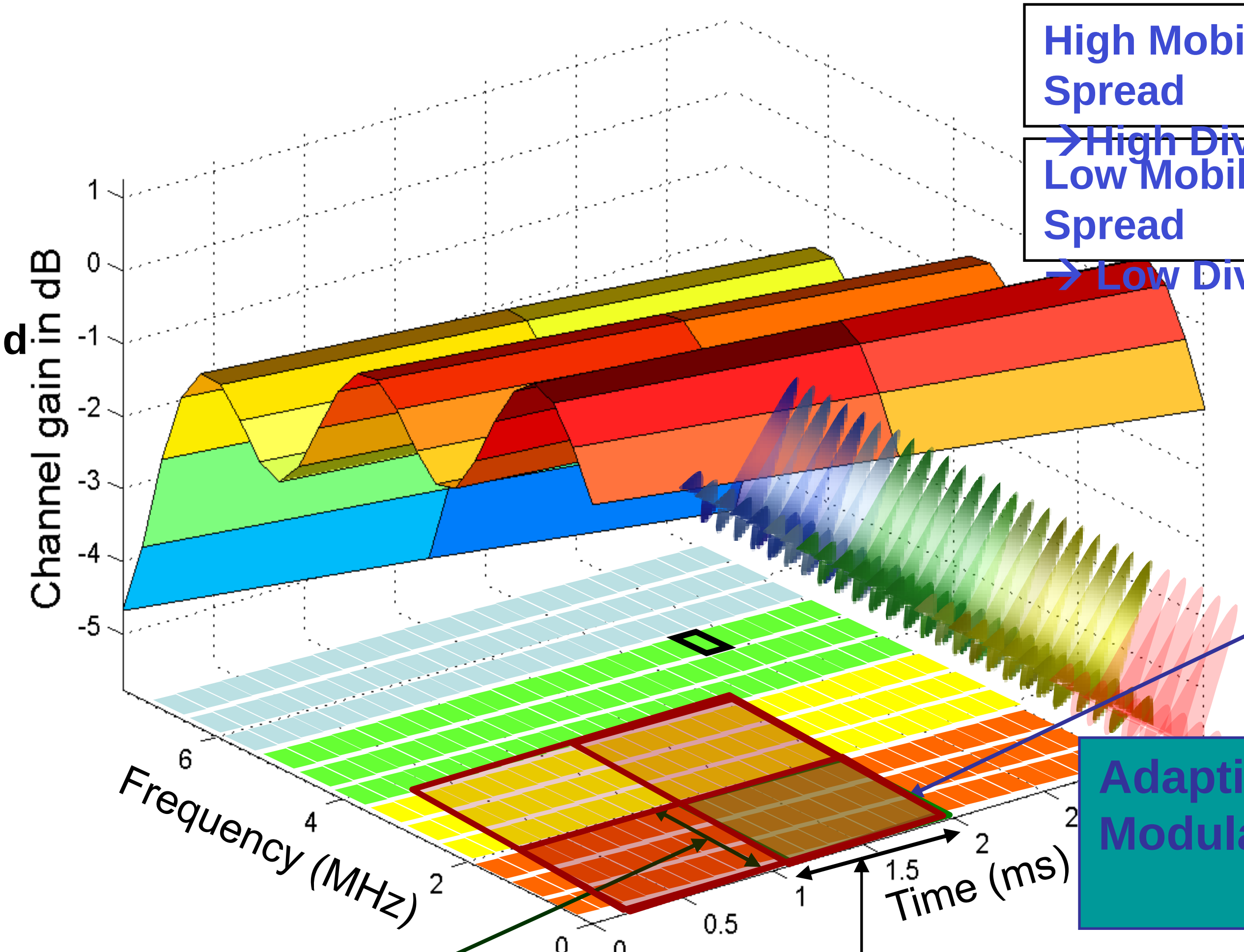


Adaptive
Modulation
Coding
Power

High Mobility, Delay Spread
→High Diversity

Low Mobility, Delay Spread
→ Low Diversity

Maximizing Spectral Efficiency
Reduced resolution and rate of adaptation

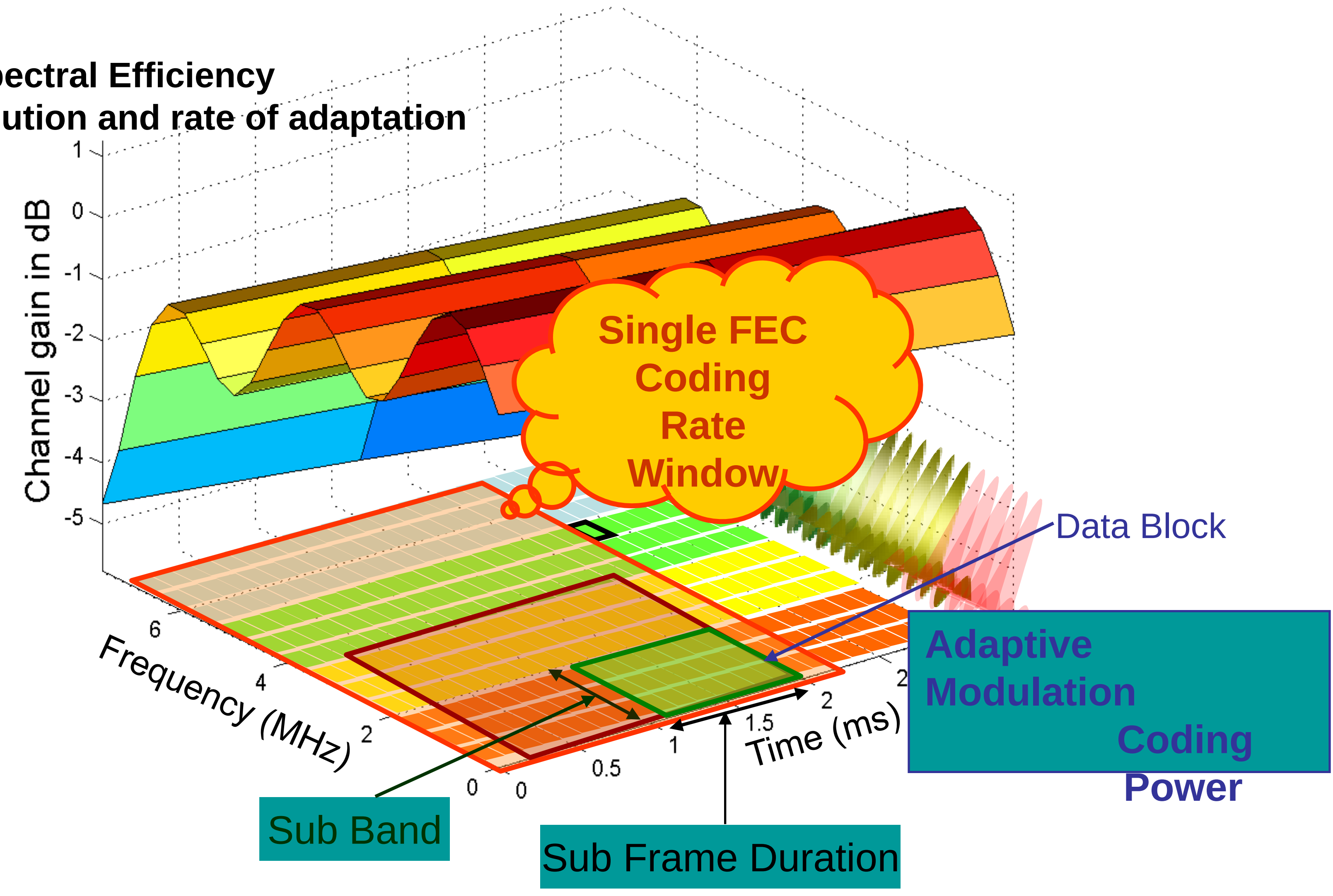


Adaptive Modulation
Coding
Power

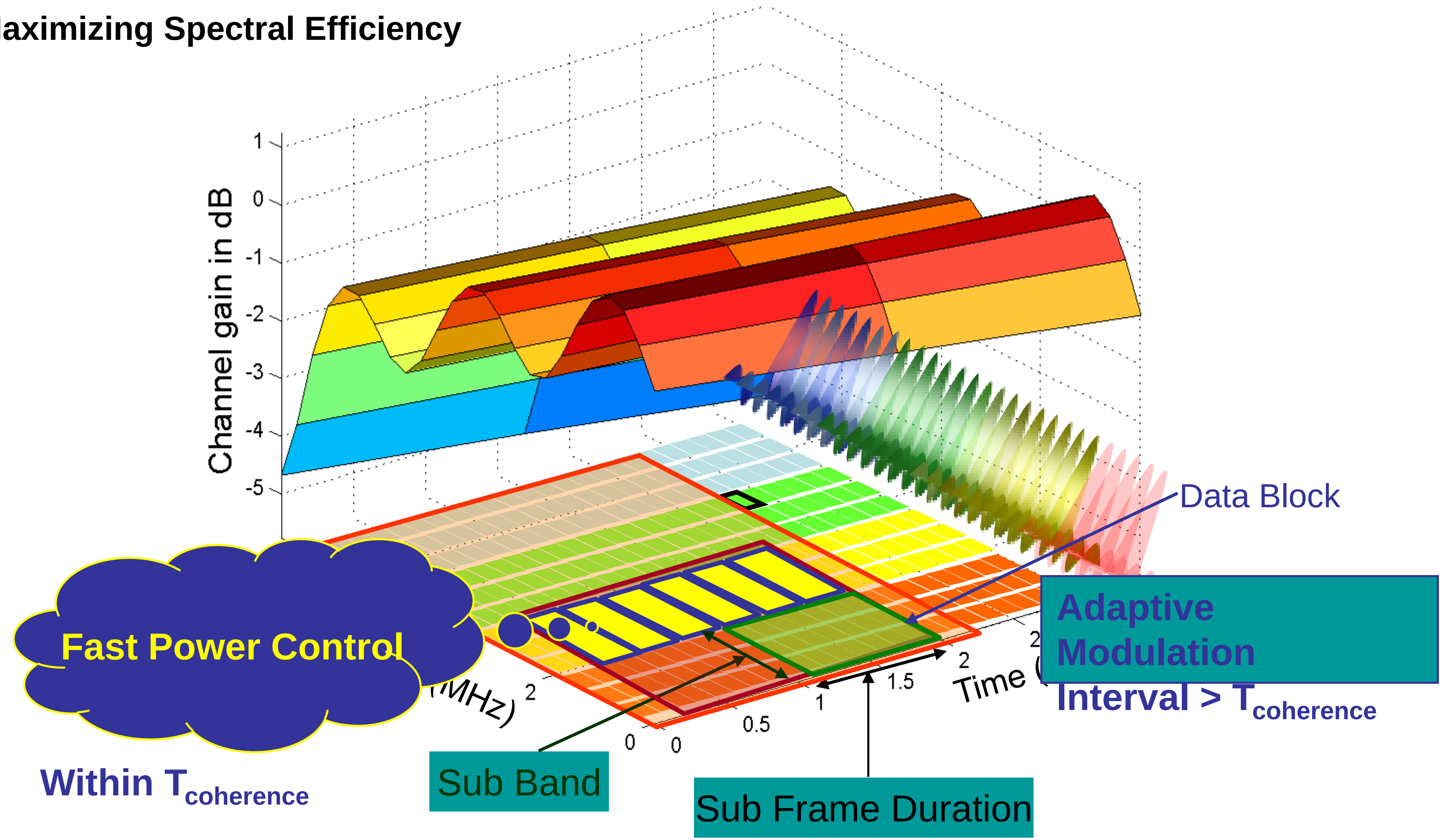
Sub Band

Sub Frame Duration

Maximizing Spectral Efficiency
Reduced resolution and rate of adaptation



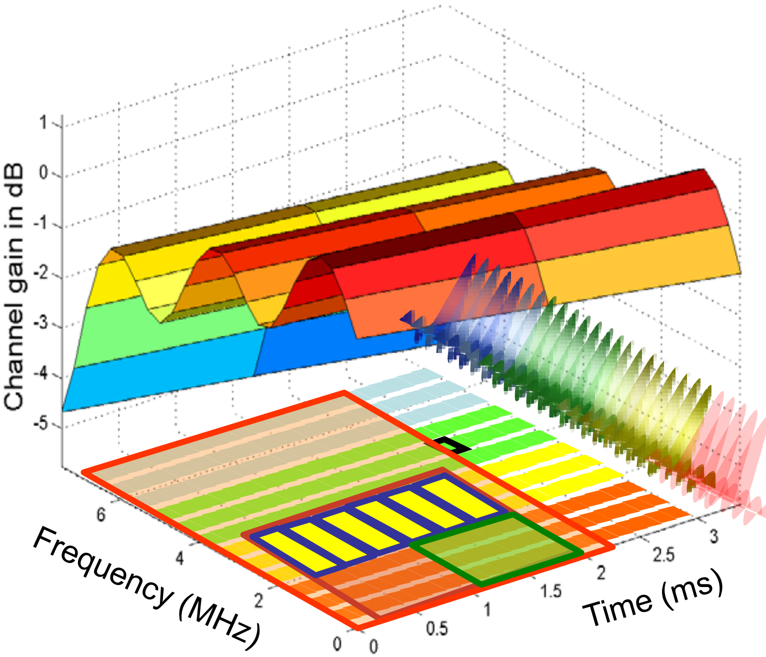
Maximizing Spectral Efficiency



Q. Exploit all degrees of freedom simultaneously ?

Objective: Optimal adaptation rates / combination of Variable Parameters

To maximize Spectral Efficiency and Meet QoS, Reduces Rate of Adaptation



Analysis Framework: Like WiMAX / 3GPP LTE Single User Link Level Simulations

Modulation
QPSK, 16-QAM, 64-QAM,

Convolution code rate 1/3, 1/2, 2/3

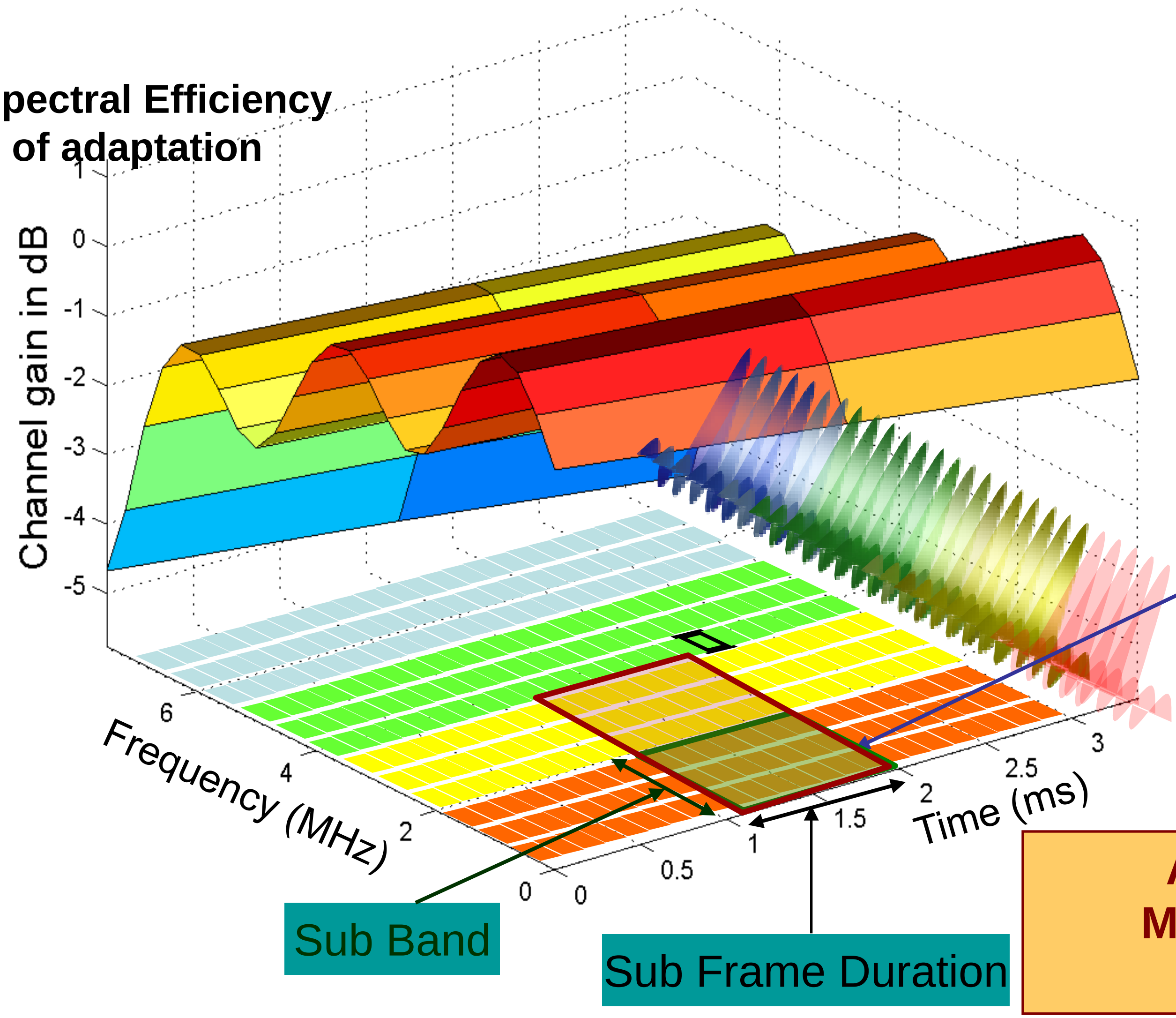
Sub carrier bandwidth
15KHz,

Minimum Sub Frame: 0.5 ms

Bandwidth 5MHz

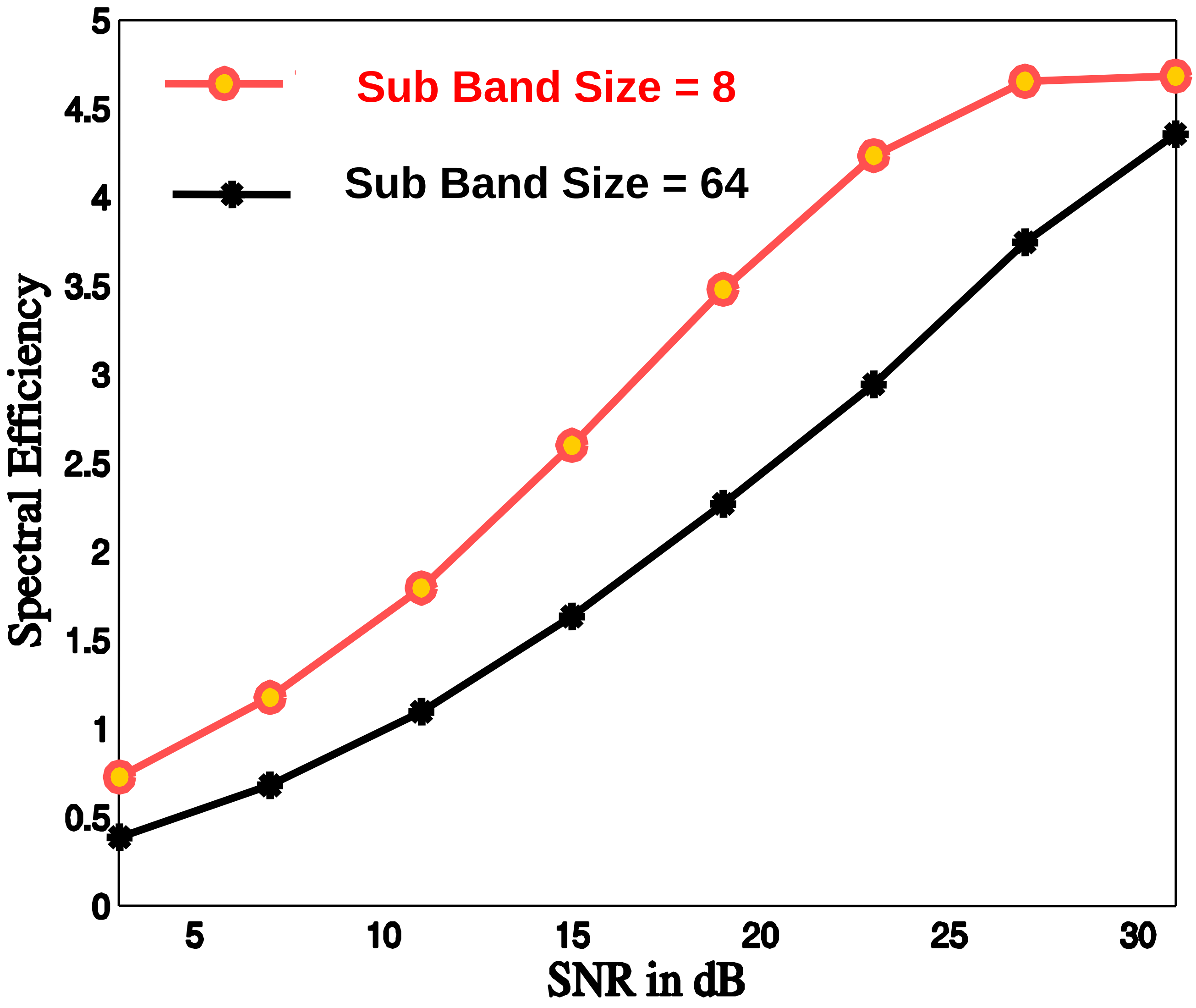
Degrees of Freedom: Sub Band, Sub Frame Length

Maximizing Spectral Efficiency
Reduced rate of adaptation



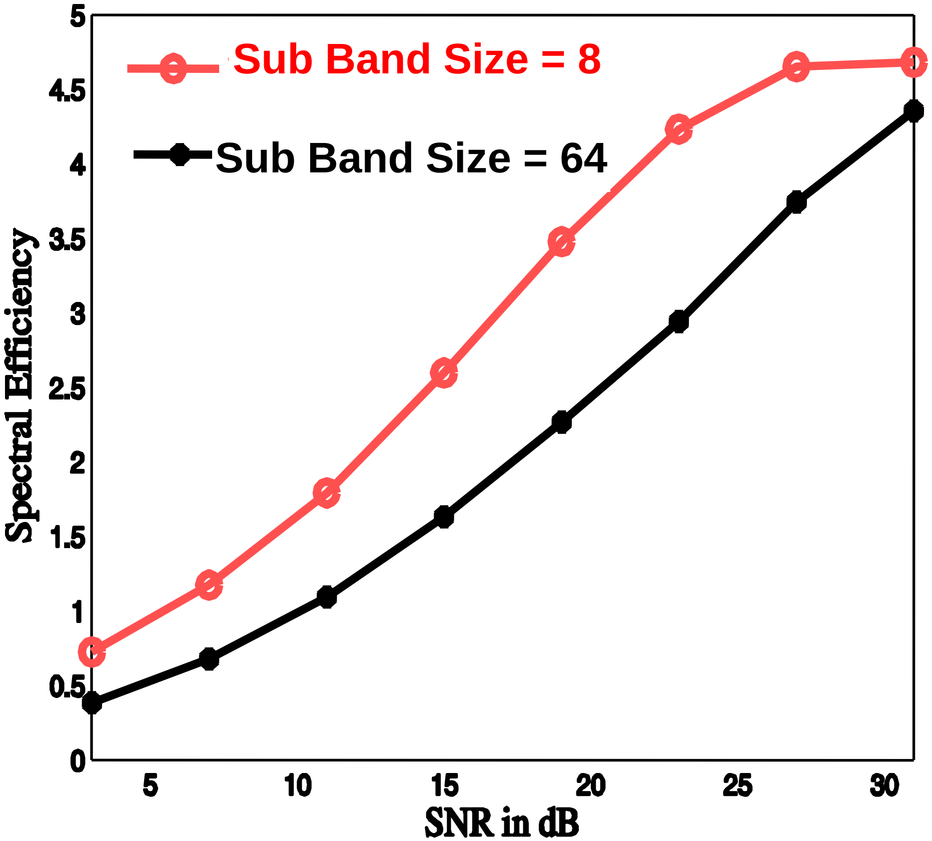
Adaptive Modulation Coding Power

Low Diversity Channel Condition: Selection of Sub band Size

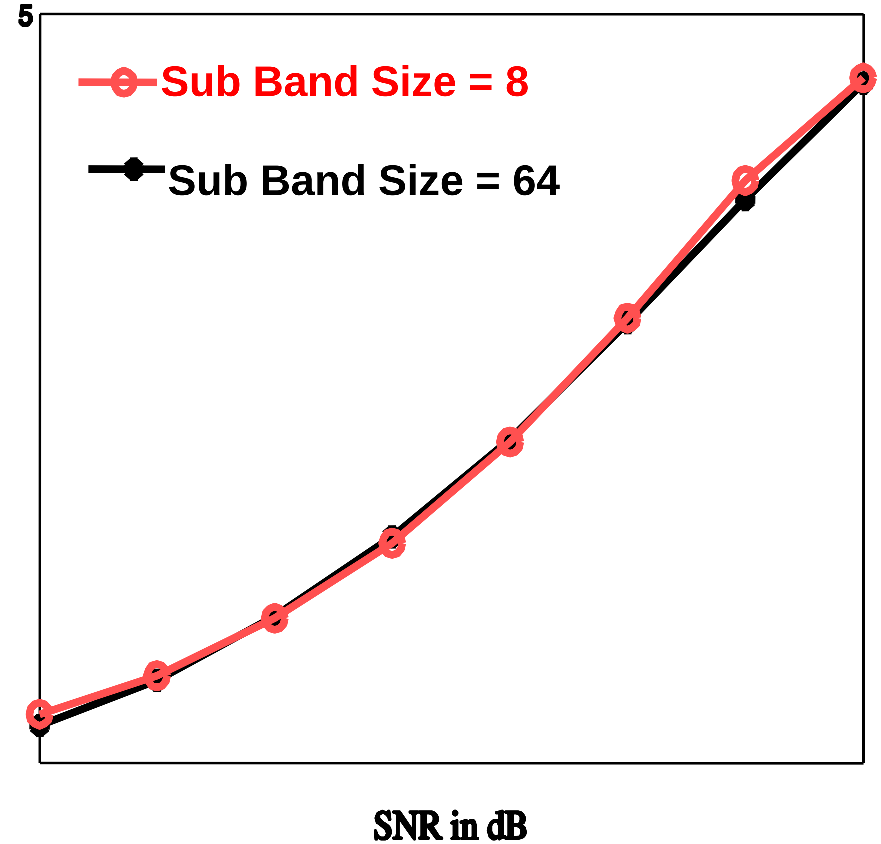


Selection Sub band Size

Low Diversity Channel Condition



High Diversity Channel Condition

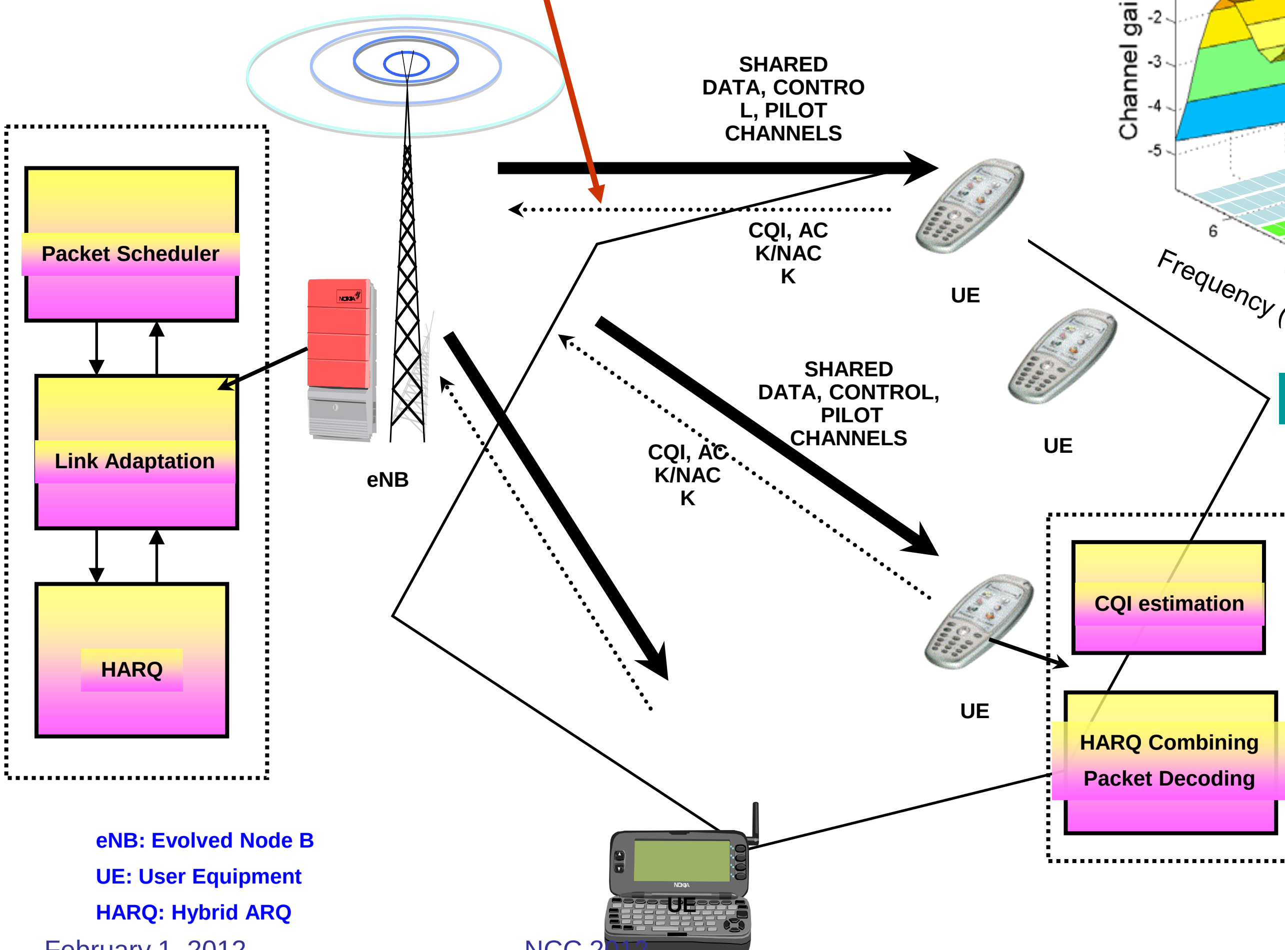


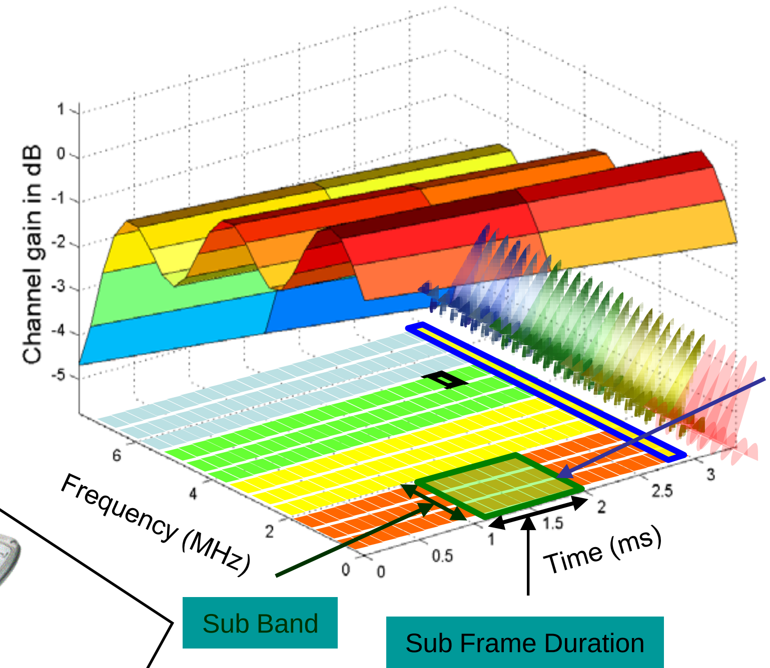
Spectral Efficiency gain > 50% @ 20dB .

Signaling overhead Modulation, Code rate and Power selection reduced 8 times or more

Generalized System Model: RRA+PS

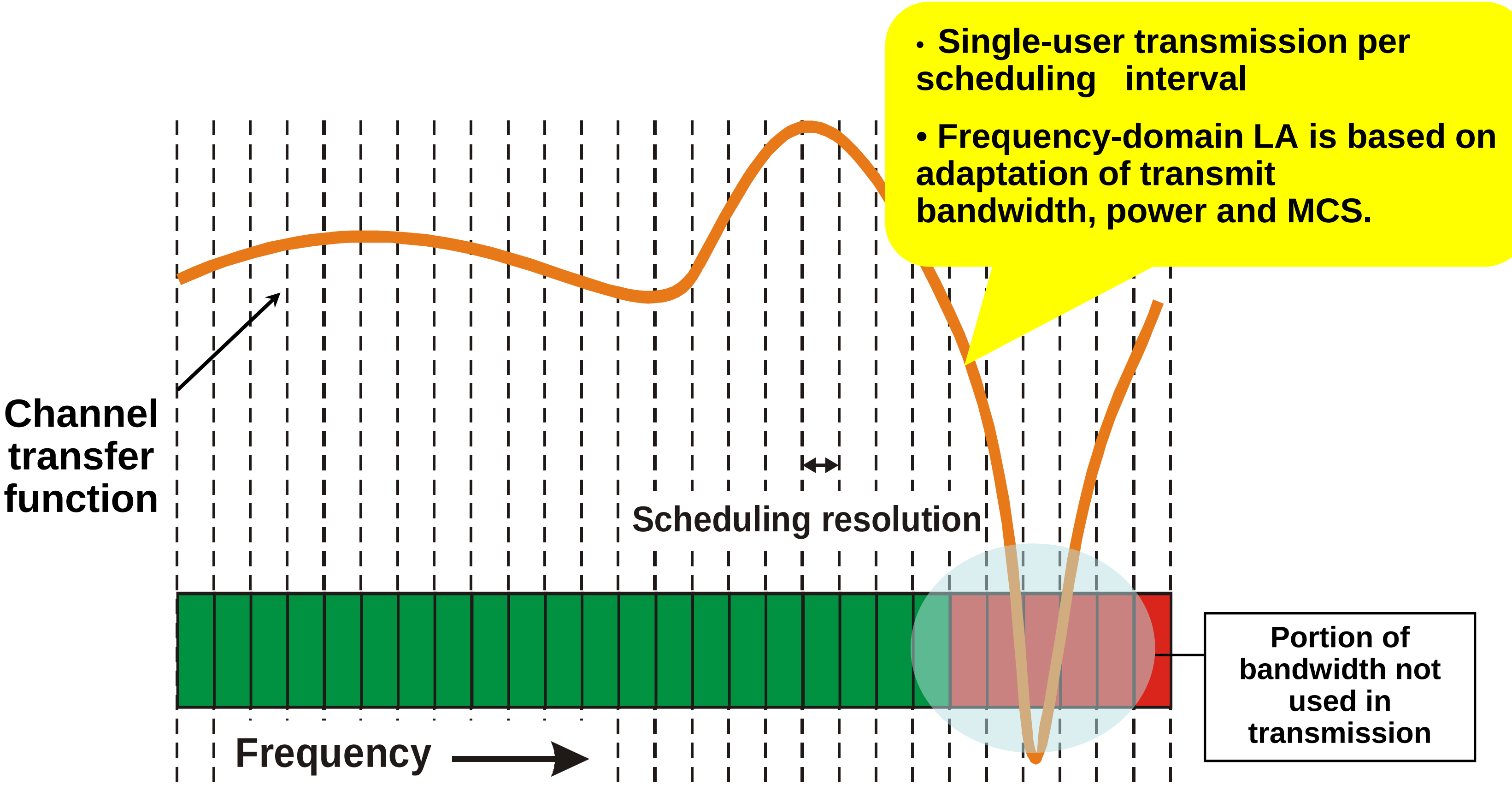
Feed Back Overhead
- Resource Allocation,
- Modulation and Coding Levels





eNB: Evolved Node B
UE: User Equipment
HARQ: Hybrid ARQ

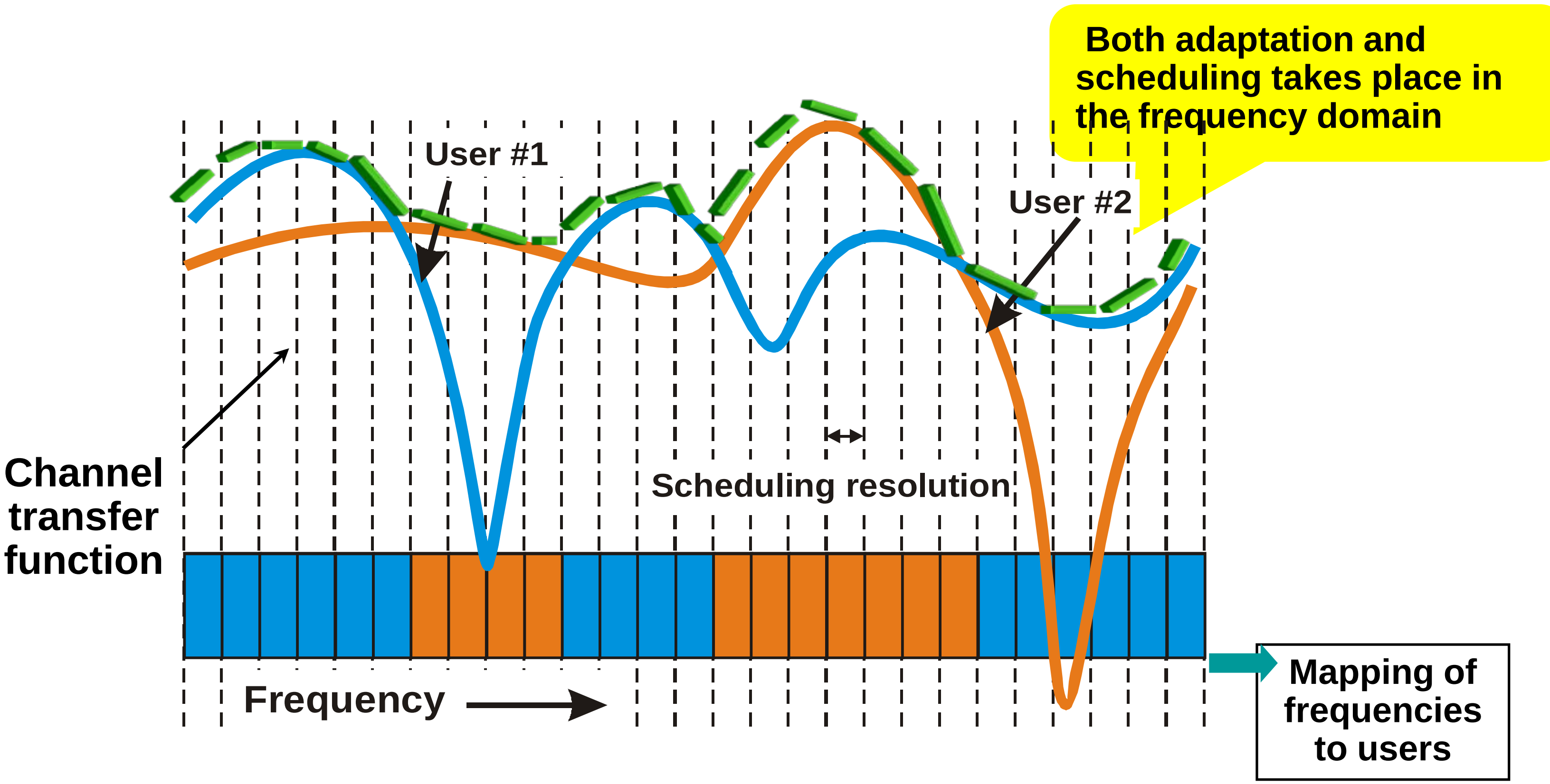
FDLA: User Multiplexing in Time Only



FDLA: Frequency-Domain Link Adaptation

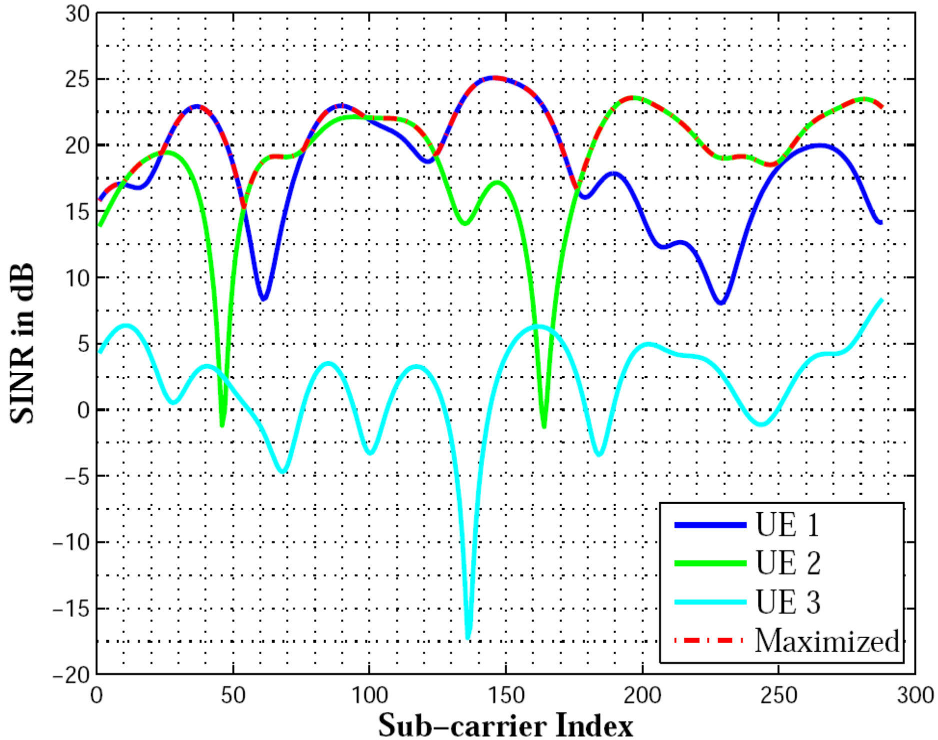
MCS: Modulation and Coding Set

FDPS: User Multiplexing in Frequency



FDPS: Frequency-Domain Packet Scheduling

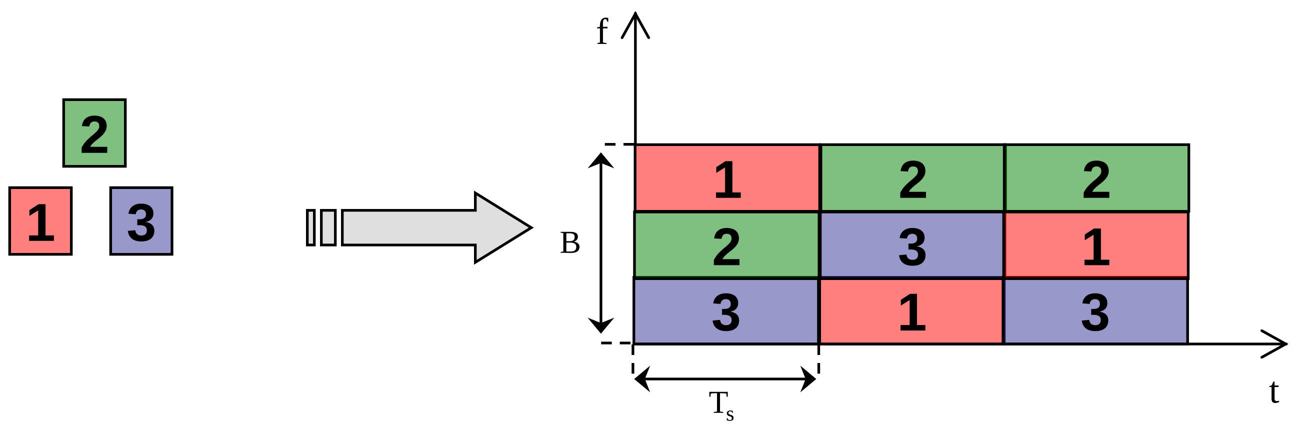
Allocate the Resources



1) By selecting the UEs with maximized SINR, performance can be improved.
2) UE 3 can never be selected because of its low SINR.

Round Robin and Max C/I in Brief

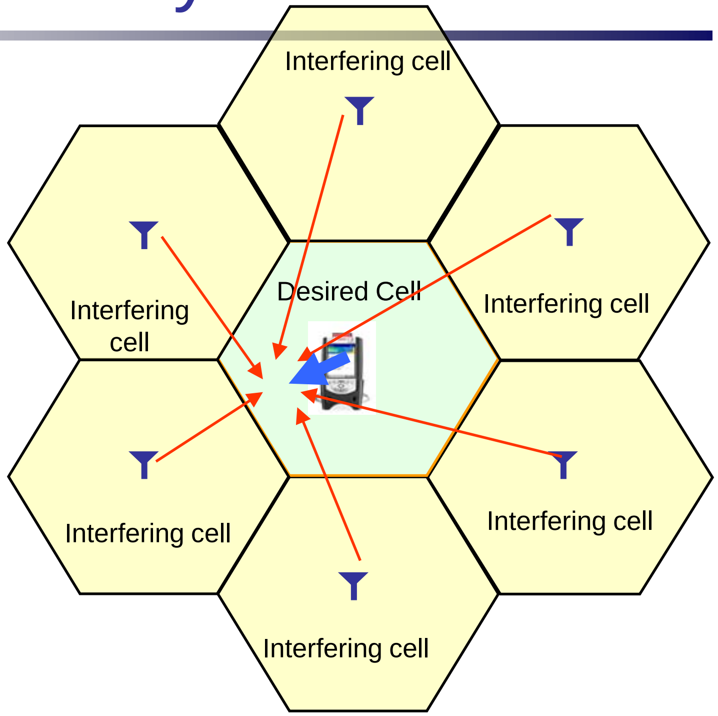
	RR	Max C/I	Mixed
User order	Random	Best Throughput	Random
Sub-channel Allocation	Random	Best Throughput	Best Throughput



Acknowledgement: Megumi Kaneko

Joint Link - System Simulator

- Multi Cell Layout: **Multiple Tiers, Multi Cell Interference**
- Channel Model
  - Path Loss, Multi Level Shadowing,
  - Multi Path Fading, Doppler
- Frequency Reuse
  - Single Frequency Network
  - Fractional Reuse: Different Types
  - MU-MIMO
- User
  - generation: Birth Death Process (File Size)
  - Mobility: random direction, full area
  - Transmit and Receive Diversity& multiplexing
  - Users can be given variable length files for transmission
- Radio Resource Management
  - **Multi User Diversity via fast Scheduling**
    - Sub channel allocation, TTI scheduling
    - Round Robin , Proportional Fair with tunable parameters
    - Qos Aware, **Different Algorithms can be tested**
  - **Link Adaptation**
    - Modulation, Coding, Power, **Hybrid ARQ**
- Traffic: FTP, HTTP, Real Time Voice / Video

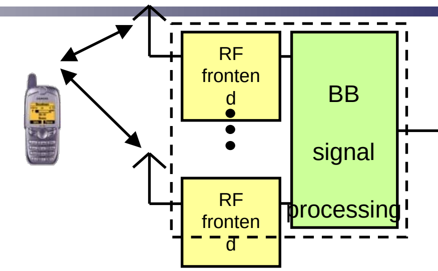


Measurement:

Detailed finger print of performance
Online measurement,
partial online and offline processing

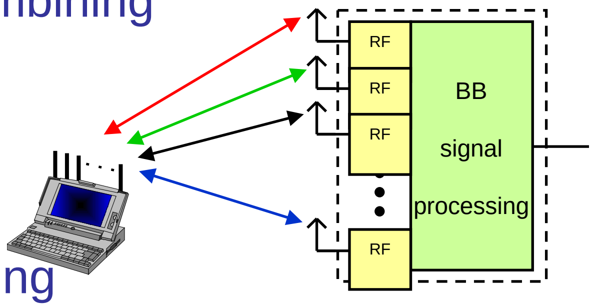
Investigation into Different Types of measurements possible to reduce simulation time

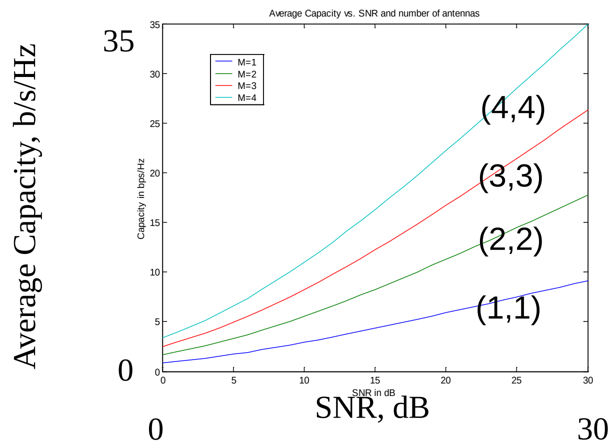
Benefits from Multiple Antenna

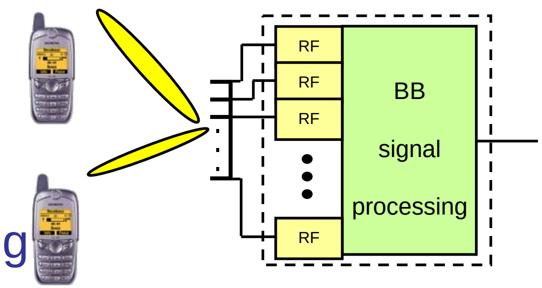


diversity concepts

- Gain from Spatial Diversity
  - Over come
    - Small Scale Fading Effect
      - Diversity combining
    - Path loss
      - Array Gain
  - Increase Capacity
    - Spatial Multiplexing
      - Parallel Stream Transmission
      - SDMA

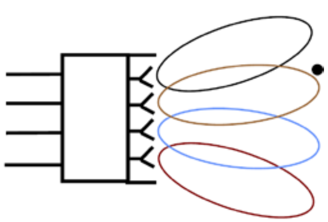




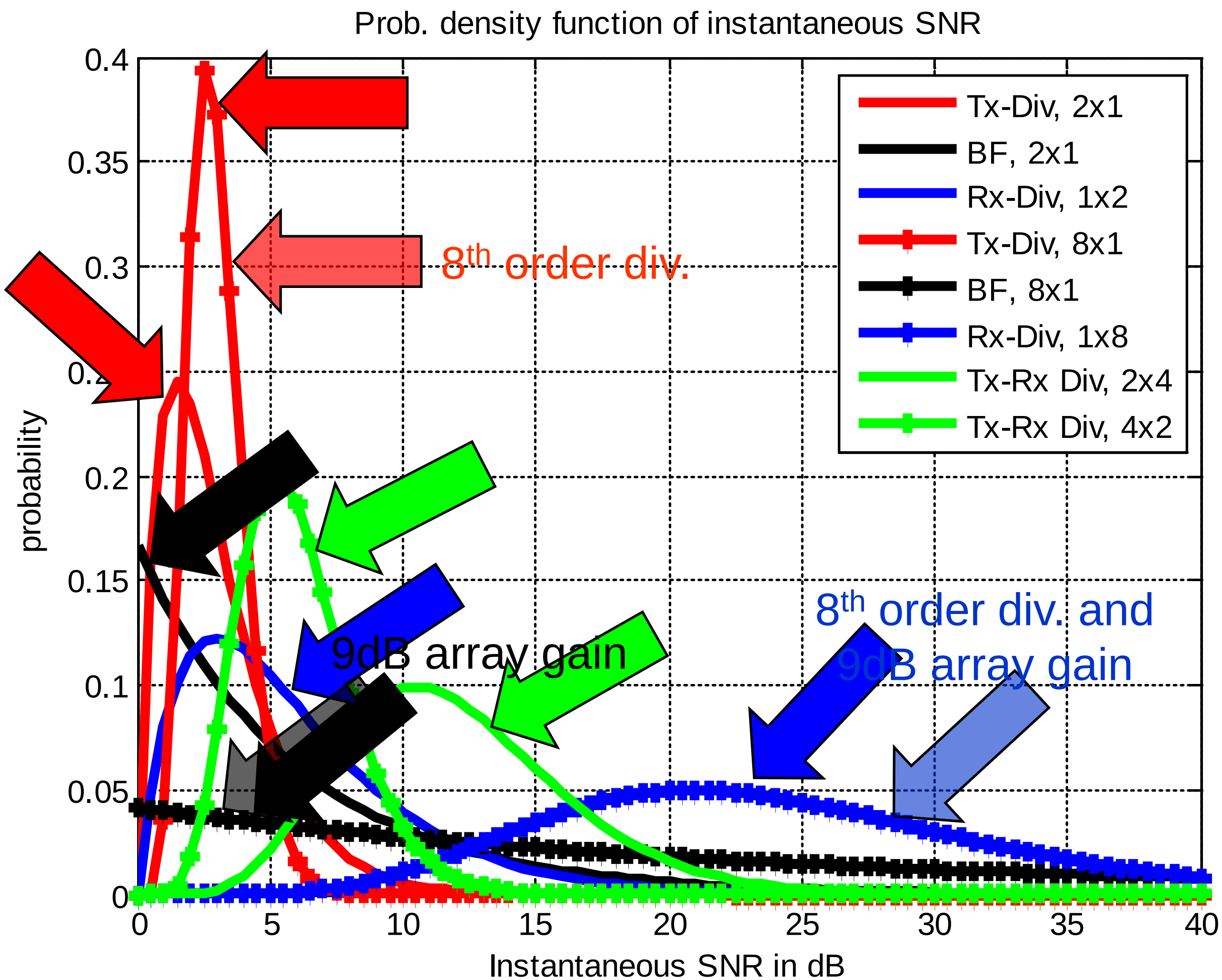


  - Beam Forming
    - Spatial Multiplexing

    - Interference Reduction



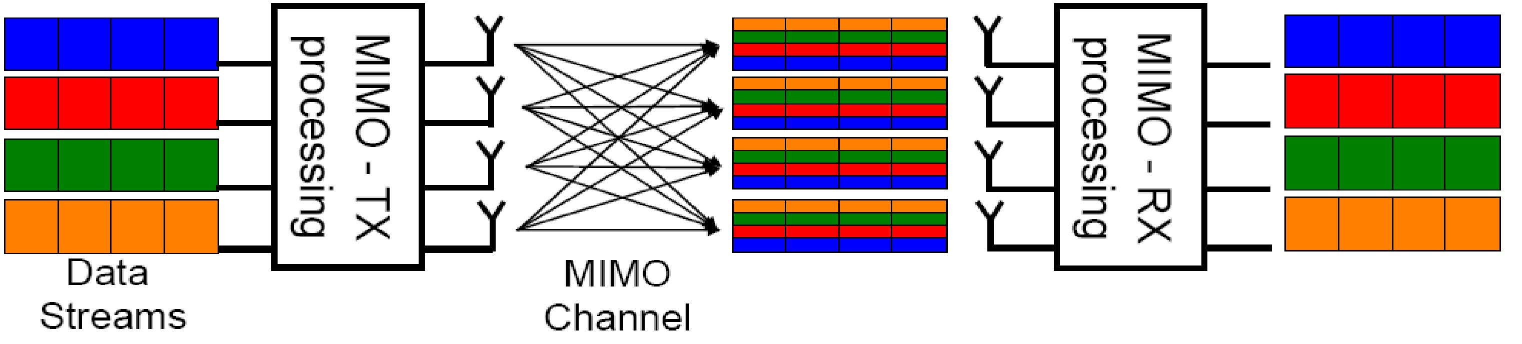
SINR Statistics: Diversity and Beamforming



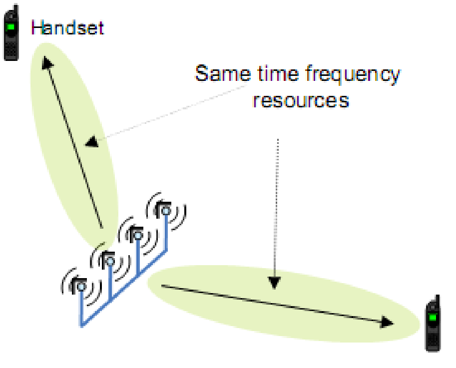
- Transmit diversity: diversity gain
- Beamforming: array gain
- Receive diversity: diversity and array gain
- Transmit – receive diversity: diversity gain at both ends and array gain at receiver

Multi Input Multi Output (MIMO)

- Multiple Antennas at eNB – 1,2,**4,8**
- Multiple Antenna at UE – 2,4
- Spatial Multiplexing

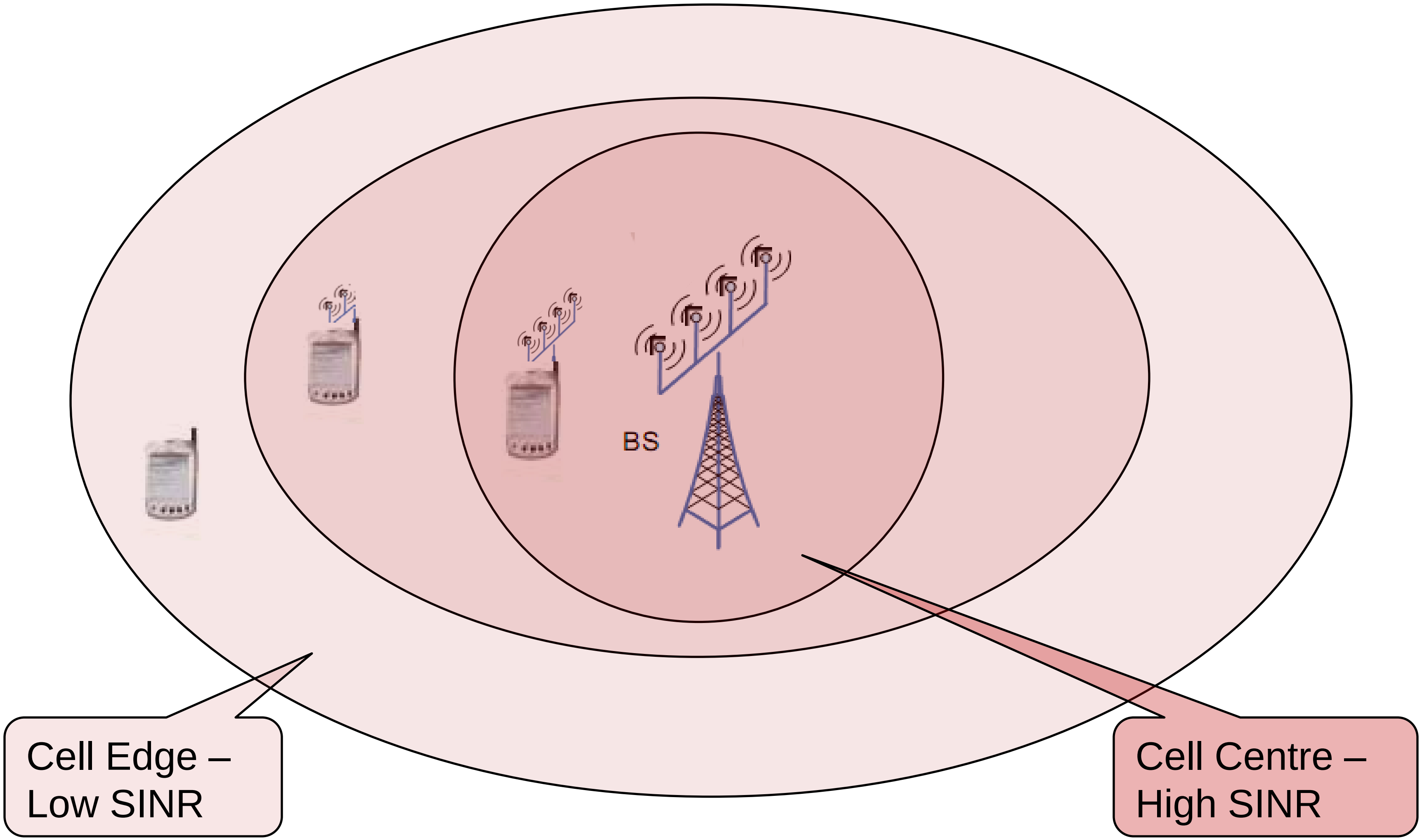


- Diversity
- Beam Forming - Improves performance at Cell Edge.



MIMO (Cont.)

- Rank Indication – Adapts Number of streams to SINR and spatial scattering



MIMO Challenges

- Space Complexity
- Separation between antenna elements
- Minimizing the interference

Multi (Carrier, Antenna, User, Cells)

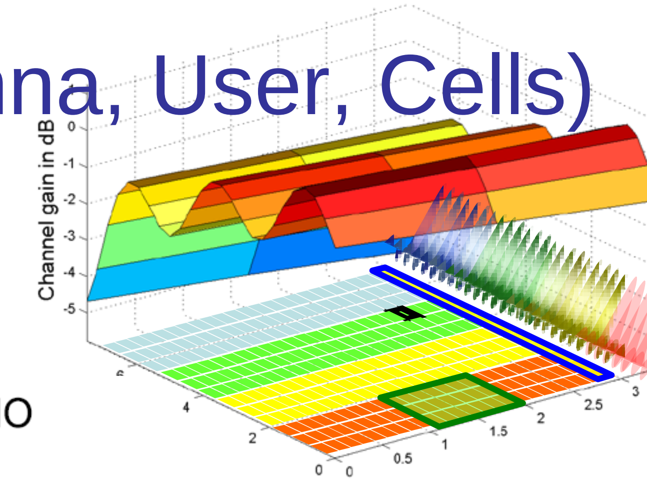
Dimensions:

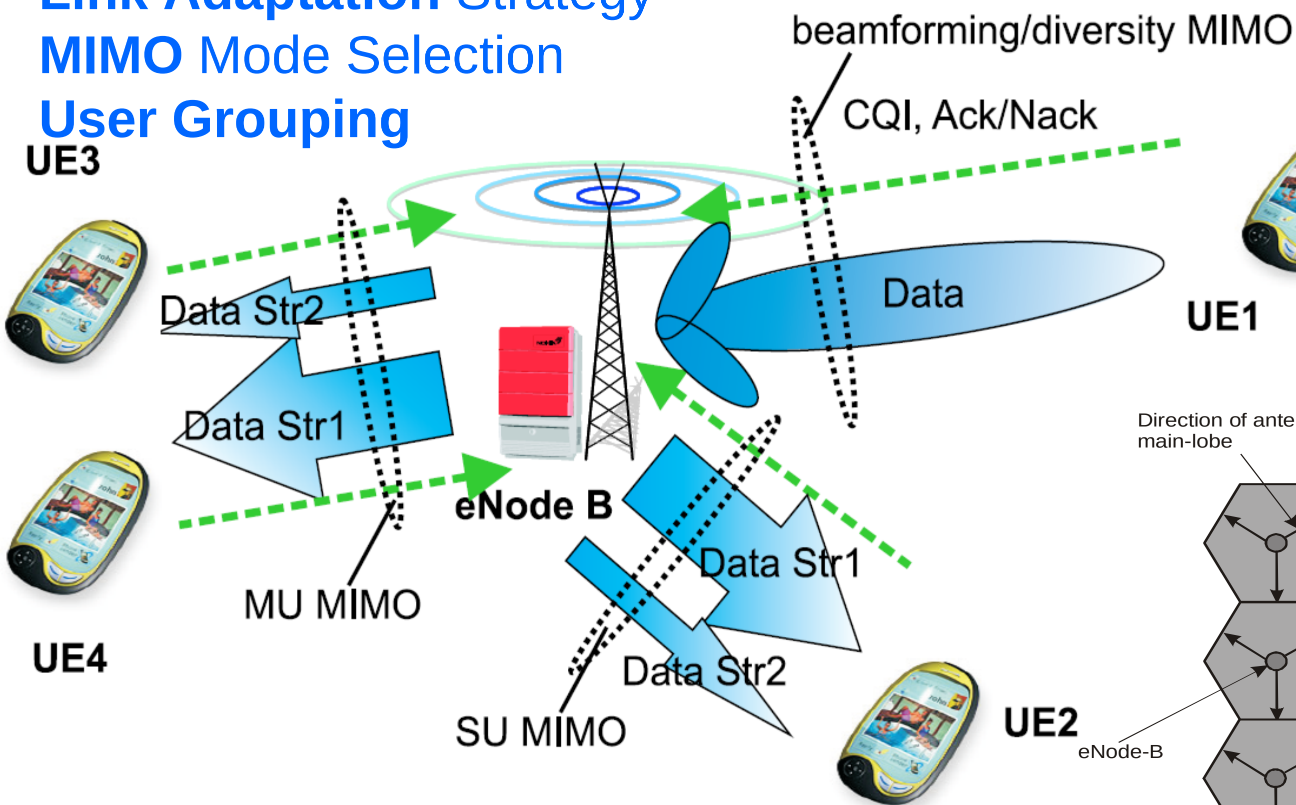
Multi User Resource Allocation / Packet Scheduling,

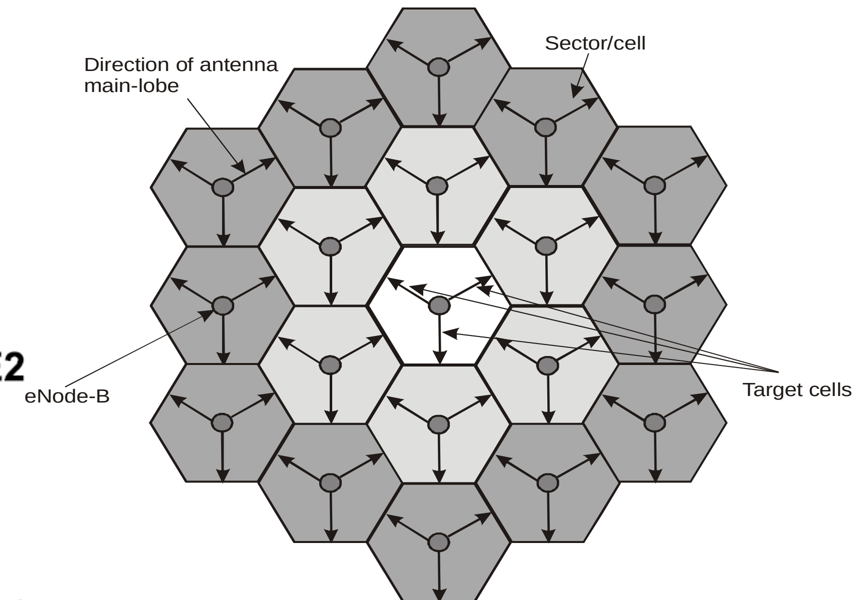
Link Adaptation Strategy

MIMO Mode Selection

User Grouping



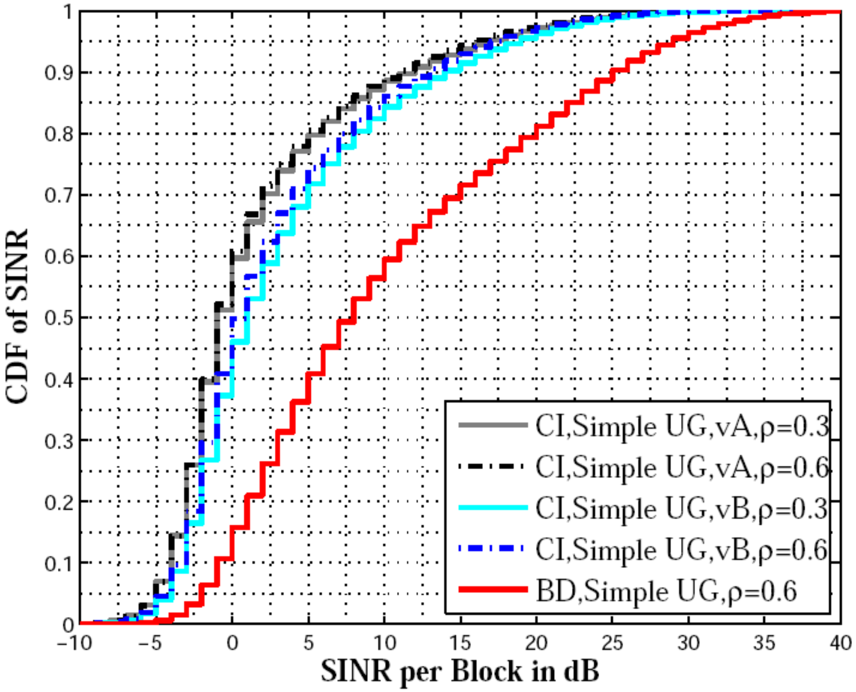


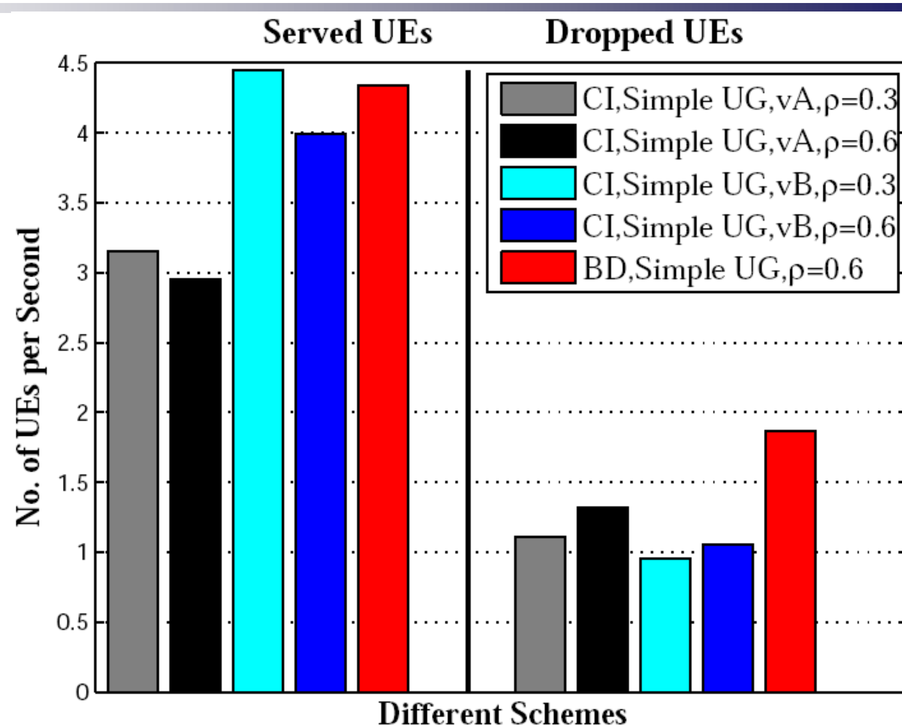


Challenges:

Maximize Overall throughput

OFDMA & SDMA with 2rx antennas





1) **SINR:** BD > CI vB > CI vA
2) **Capacity:** BD ≈ CI vB > CI vA
3) **Outage Event:** BD > CI vA > CI vB

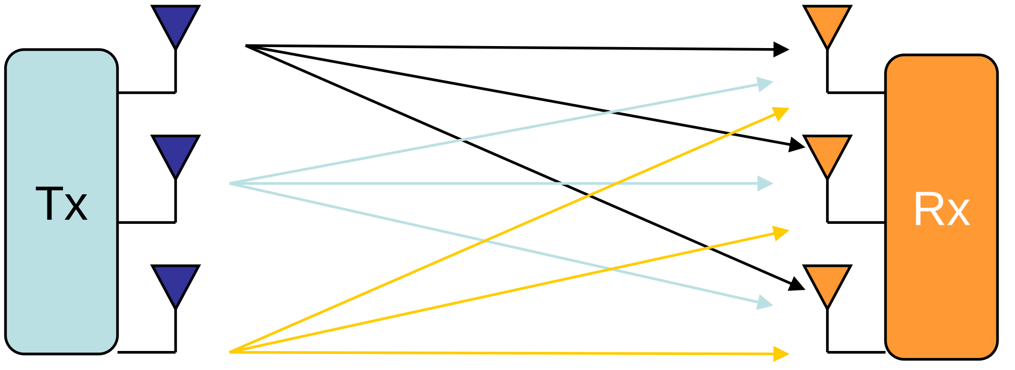
CI with receiver AS can approach (or even overcome) the performance of BD.

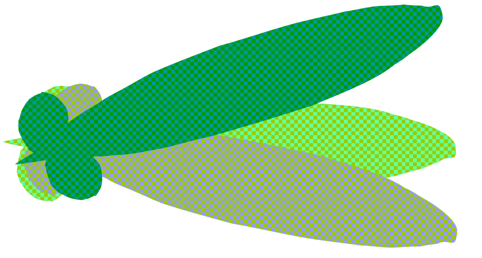
Research Directions

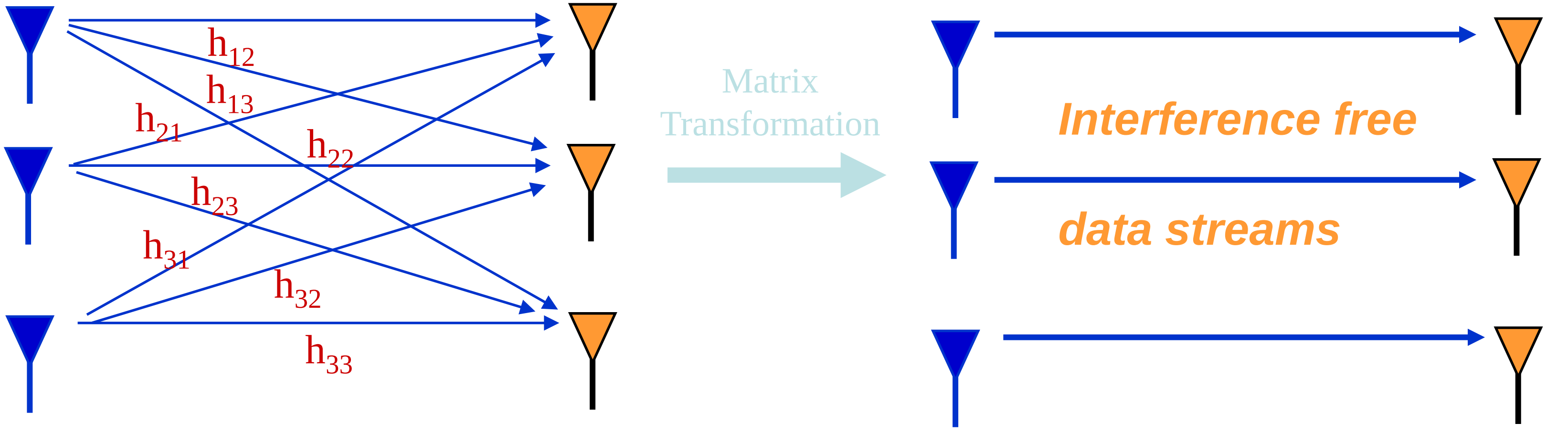
- **Base Station Cooperation**
  - **Joint Signal Transmission**
  - **Coordinated / cooperative**
    - **Pre-coding, Beam-forming**
    - **Scheduling, Radio Resource Allocation**
- **Interference mitigating Radio Access Technology**

Joint Transmission: COMP

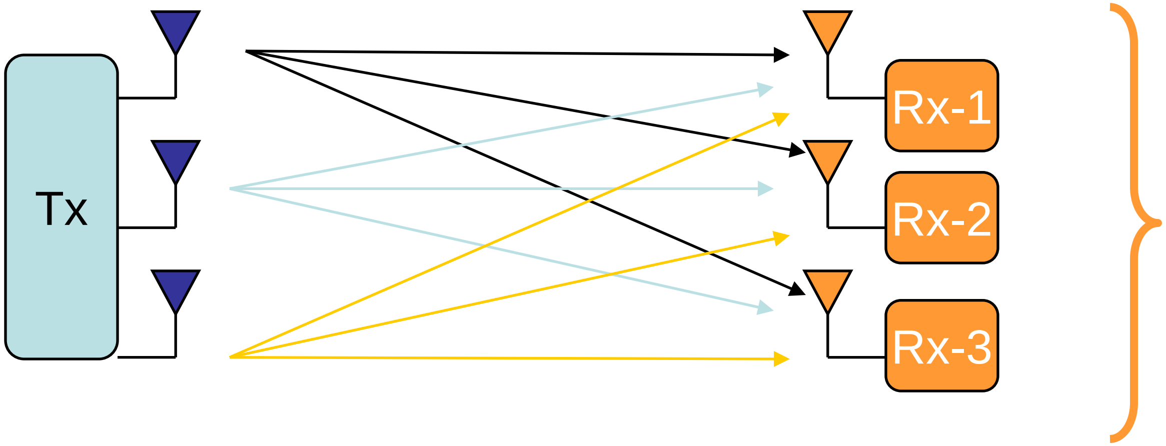
- MIMO



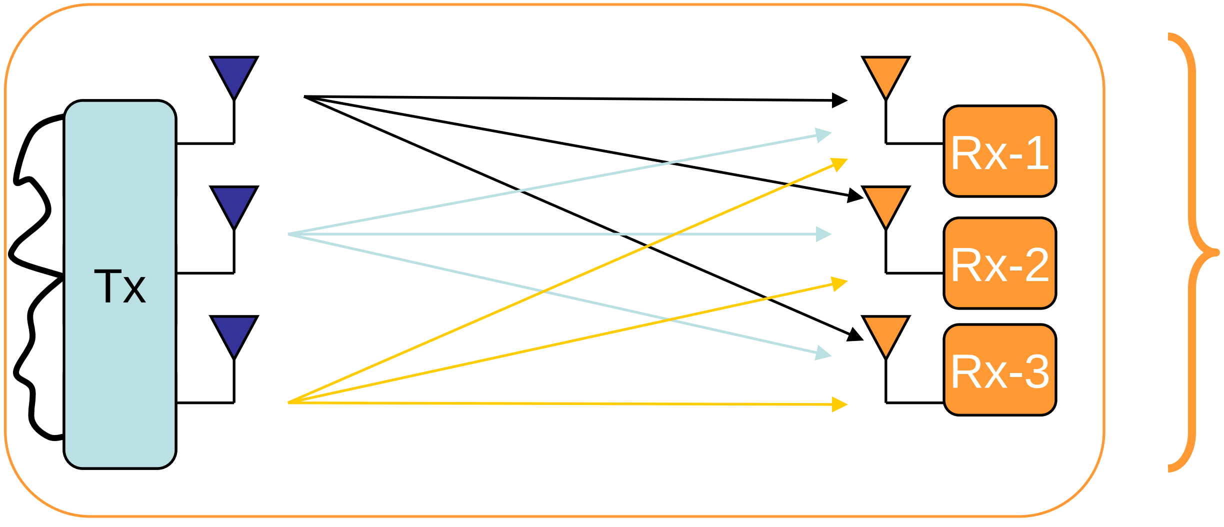




- MIMO

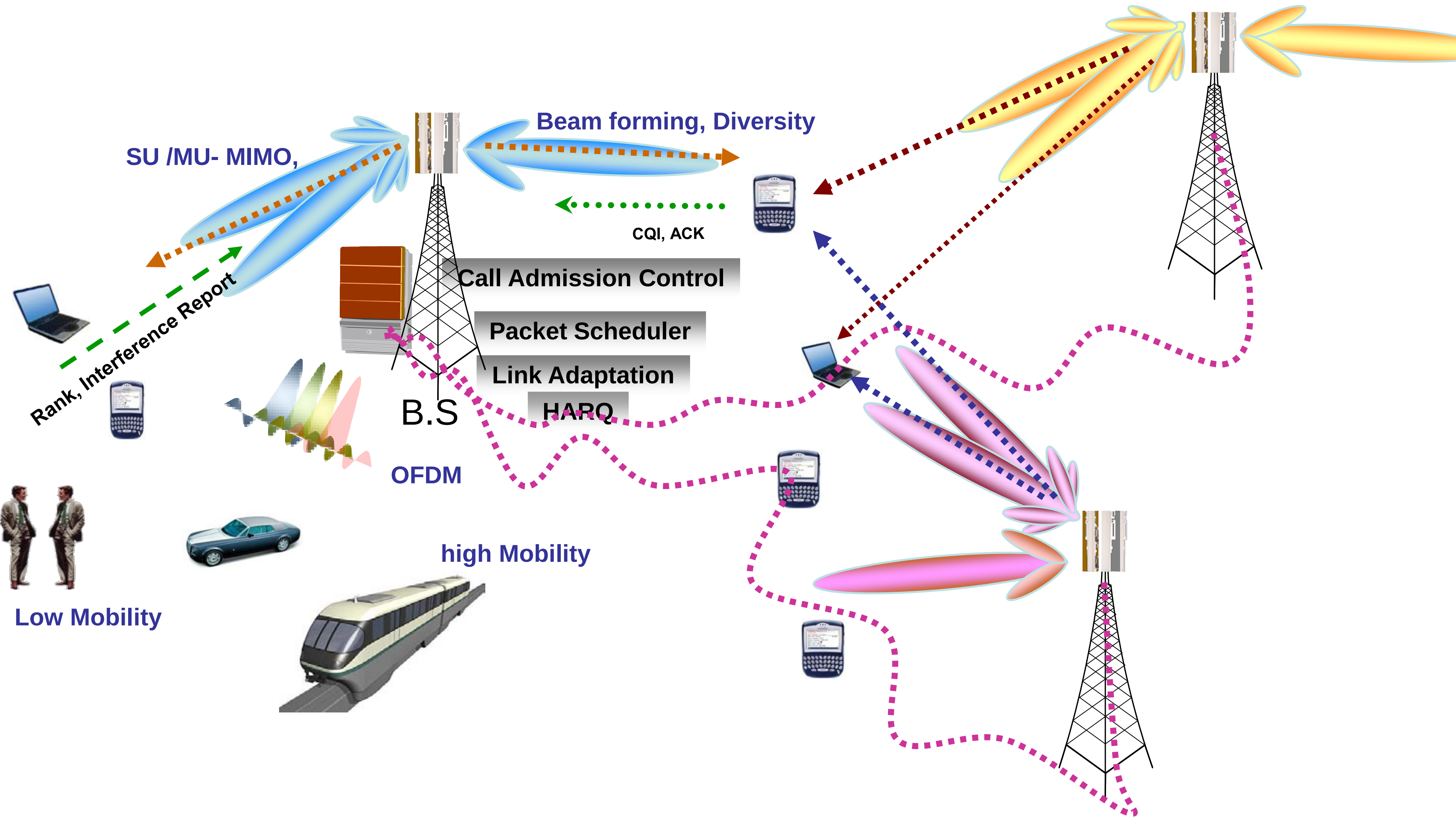


Multi-User MIMO



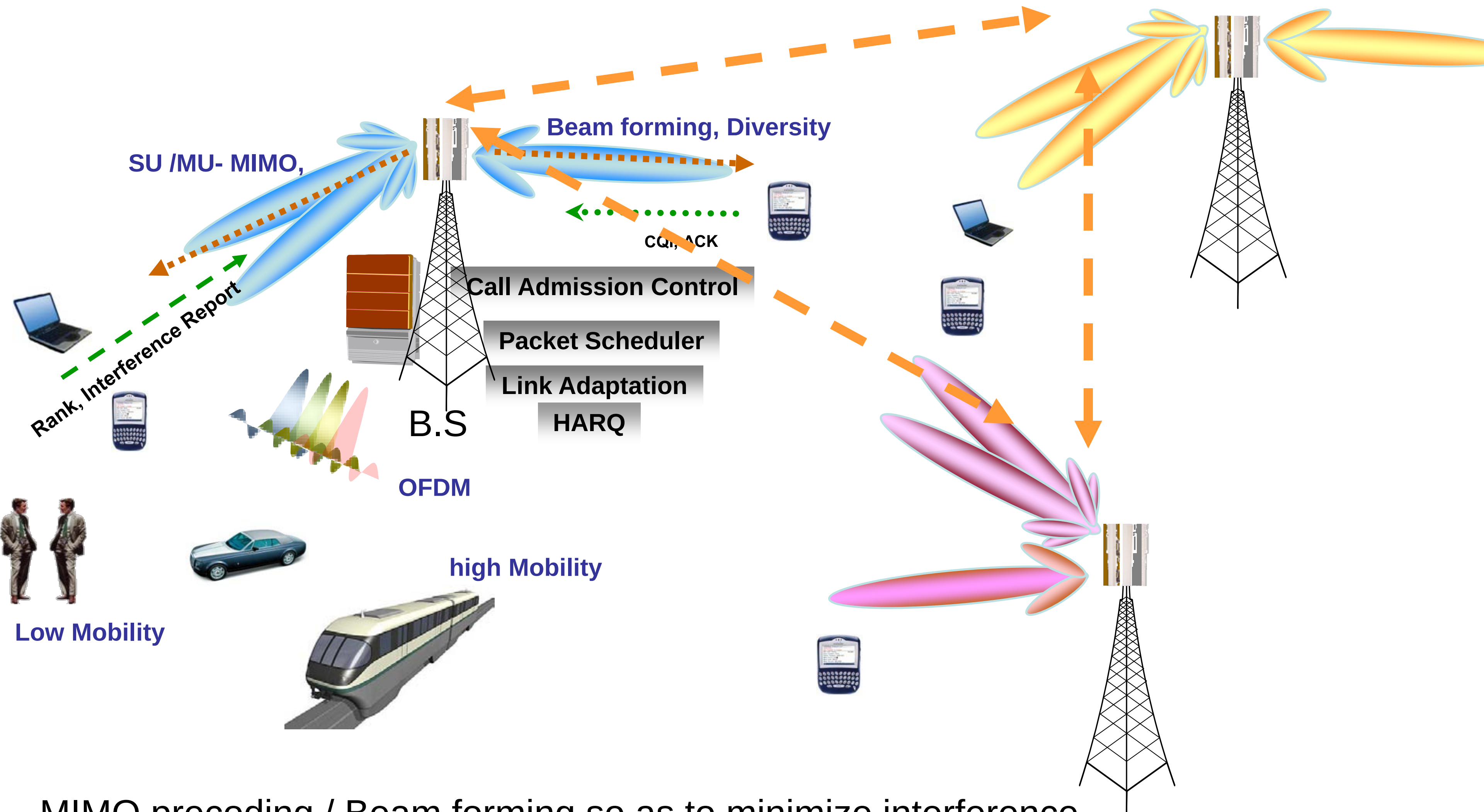
Multi-Point Transmission to Multiple Users

Joint Signal Transmission: COMP



COMP: Coordinated Multi-Point Transmission

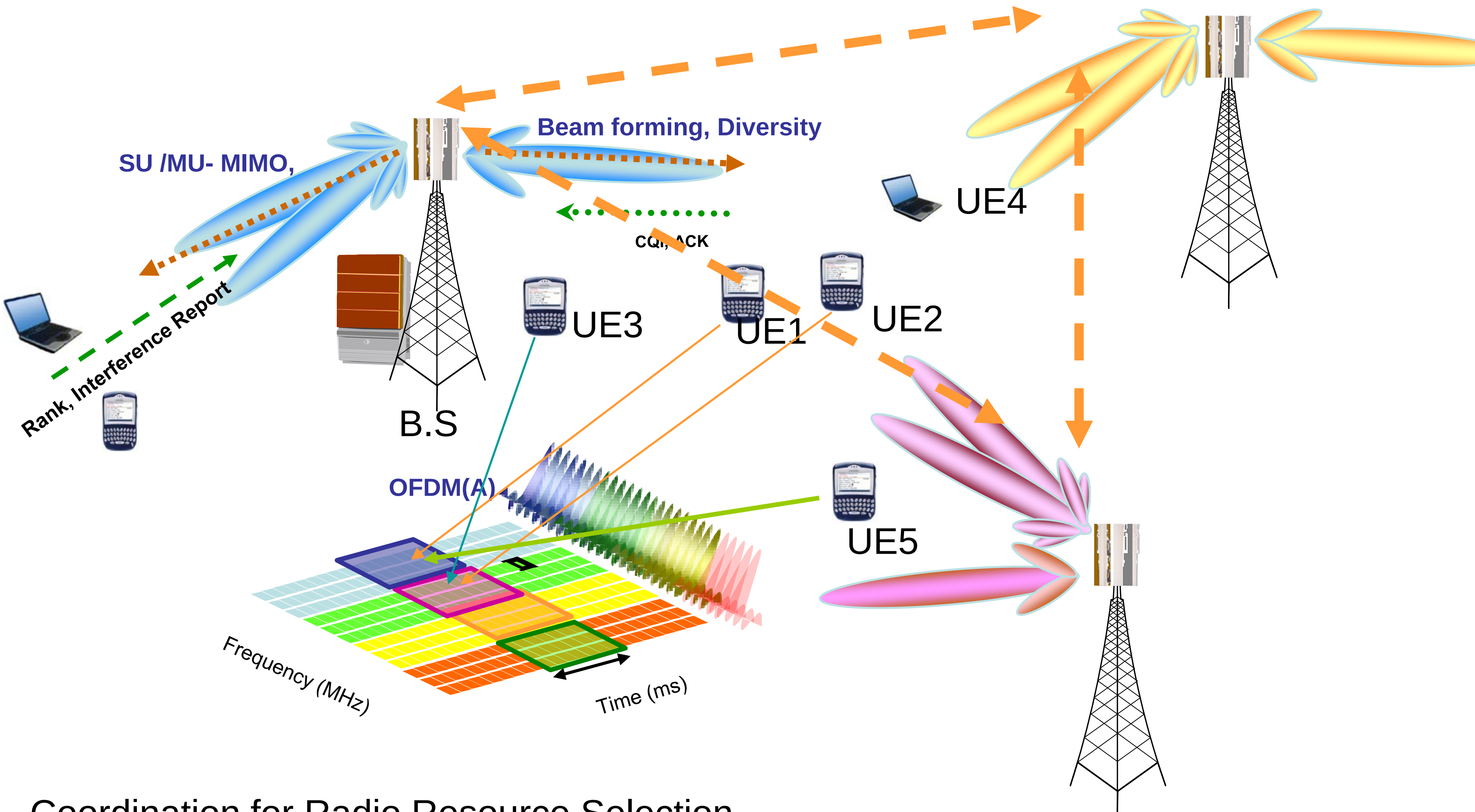
Coordinated Pre-Coding, Beam forming



MIMO precoding / Beam forming so as to minimize interference

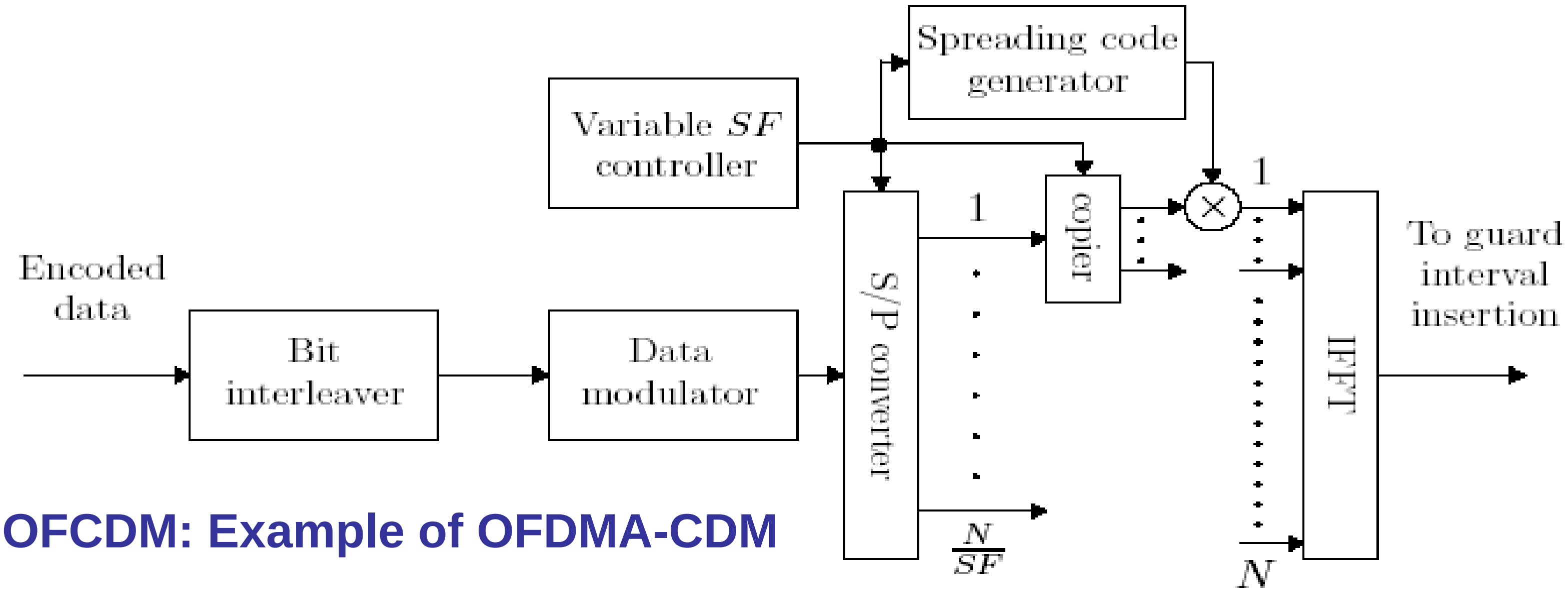
Combination of MIMO schemes / precoders for minimum interference

Coordinated Scheduling & RRA



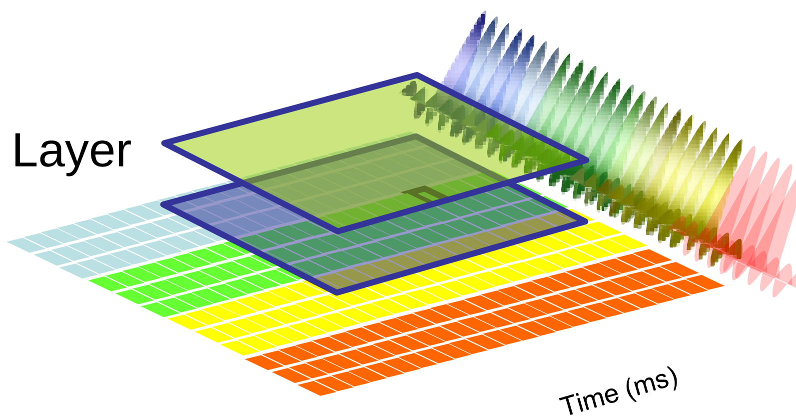
Coordination for Radio Resource Selection

Radio Access Technology: CDM-OFDMA



VSF-OFCDM: Example of OFDMA-CDM

Superimpose a Code Layer



Acknowledgement: Søren S. Christensen

River Publishers

The River Publishers' Series in Communications

Single- and Multi-Carrier MIMO Transmission for Broadband Wireless Systems

Ramjee Prasad, Muhammad Imadur Rahman, Suvra Sekhar Das and Nicola Marchetti, CtiF (Aalborg University), Ericsson, IIT Kharagpur, CtiF (Aalborg University)

ISBN: 978-87-92329-06-6

Description

The main focus of "**Single- and Multi-Carrier MIMO Transmission for Broadband Wireless Systems**" is to provide the basic understanding of the underlying techniques related to PHY-MAC design of future wireless systems. It includes basic concepts related to single- and multi-carrier transmissions together with MIMO techniques. Discussions related to different recent standards that use single- and multi-carrier transmissions are also explained.

"**Single- and Multi-Carrier MIMO Transmission for Broadband Wireless Systems**" provides a comprehensive and holistic approach to the variety of technical solutions. Future system design would require these different technologies to work together, and not independently. Therefore, it is very important to analyze the effects and gains when they are put together in a unified platform.

4G Standards

- *3GPP >> LTE-Advanced*
- **IEEE >> WiMAX (IEEE 802.16m)**

Technical Specifications (LTE)

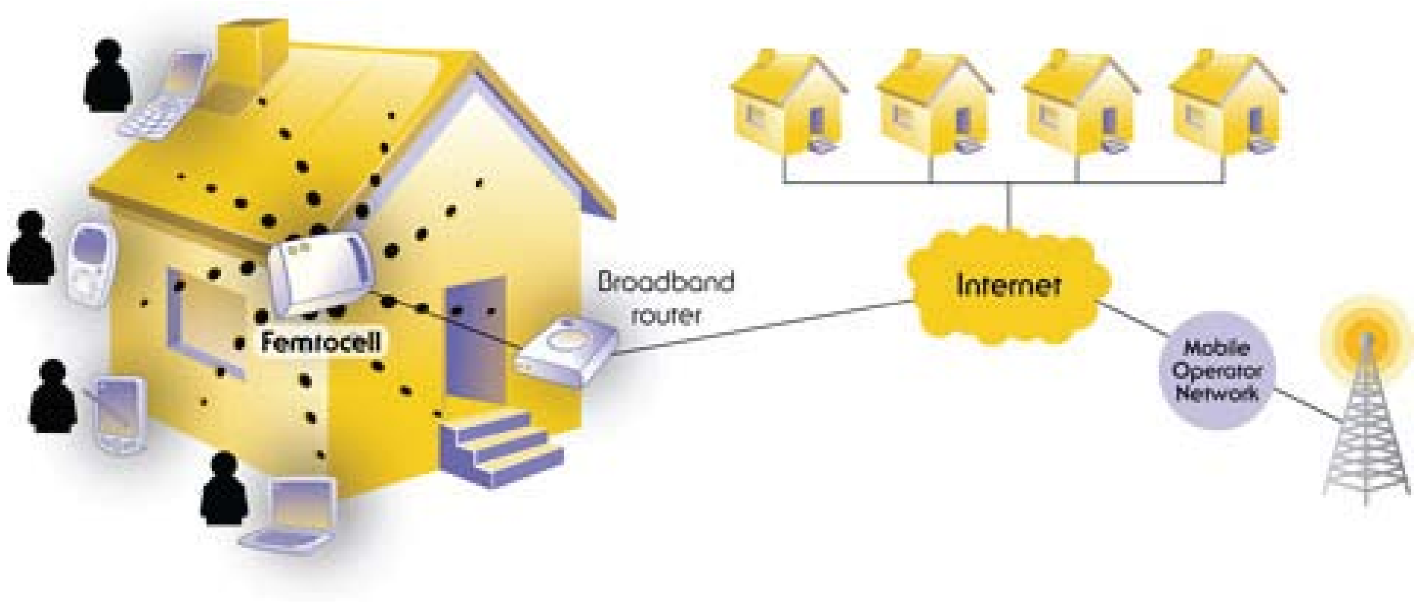
Parameters	WiMAX (802.16e)	LTE
Transmission Bandwidth	1.25, 3.5, 5, 7, 8.75, 10, 20 MHz	1.4 ,3, 5, 10, 15 20 MHz (Scalable)
FFT Size	128, 256, 512, 1024, 2048	128, 256, 512, 1024, 2048
Sub-carrier Spacing	7.81, 9.77, 10.94 kHz	15 kHz
Modulation Used	QPSK,16-QAM,64-QAM	QPSK,16-QAM,64-QAM
Multiplexing Used	OFDMA (DL)/ OFDMA(UL)	OFDMA (DL)/ SC-FDMA(UL)
Coding Techniques	Turbo, Convolutional, Bit Repetition	Turbo Coding
Antenna Configuration	Beamforming, MIMO	MIMO
Duplex Methods	TDD/FDD	TDD/FDD

Important Features of WiMAX

- OFDMA chosen as Multiplexing technique for both UL and DL
  - With support of TDD and FDD operation
  - Support of various bandwidth from 1.25 MHz to 20 MHz
  - **Distributed Subcarrier Allocation Rules**
- Adaptive Modulation and Coding
  - QPSK, 16-QAM and 64-QAM
  - Coding Techniques
    - Turbo Code
    - **Convolutional Coding**
    - **Bit Repetation**
    - Various Code Rates (1/2, 2/3,3/4, 5/6)
- Support for Multiple Antenna Techniques
  - TX-RX diversity
  - **Beamforming**
  - MIMO

Femtocells

Femtocells are the low power base stations installed in home or office connected to service provider's core network via DSL or fiber cable.



Source : www.femtoforum.org

Why Femtocells?

- In conventional cellular networks due to high penetration loss of radio signals, the indoor users experiencing low Signal to Interference plus Noise Ratio (SINR), leading to low throughput.

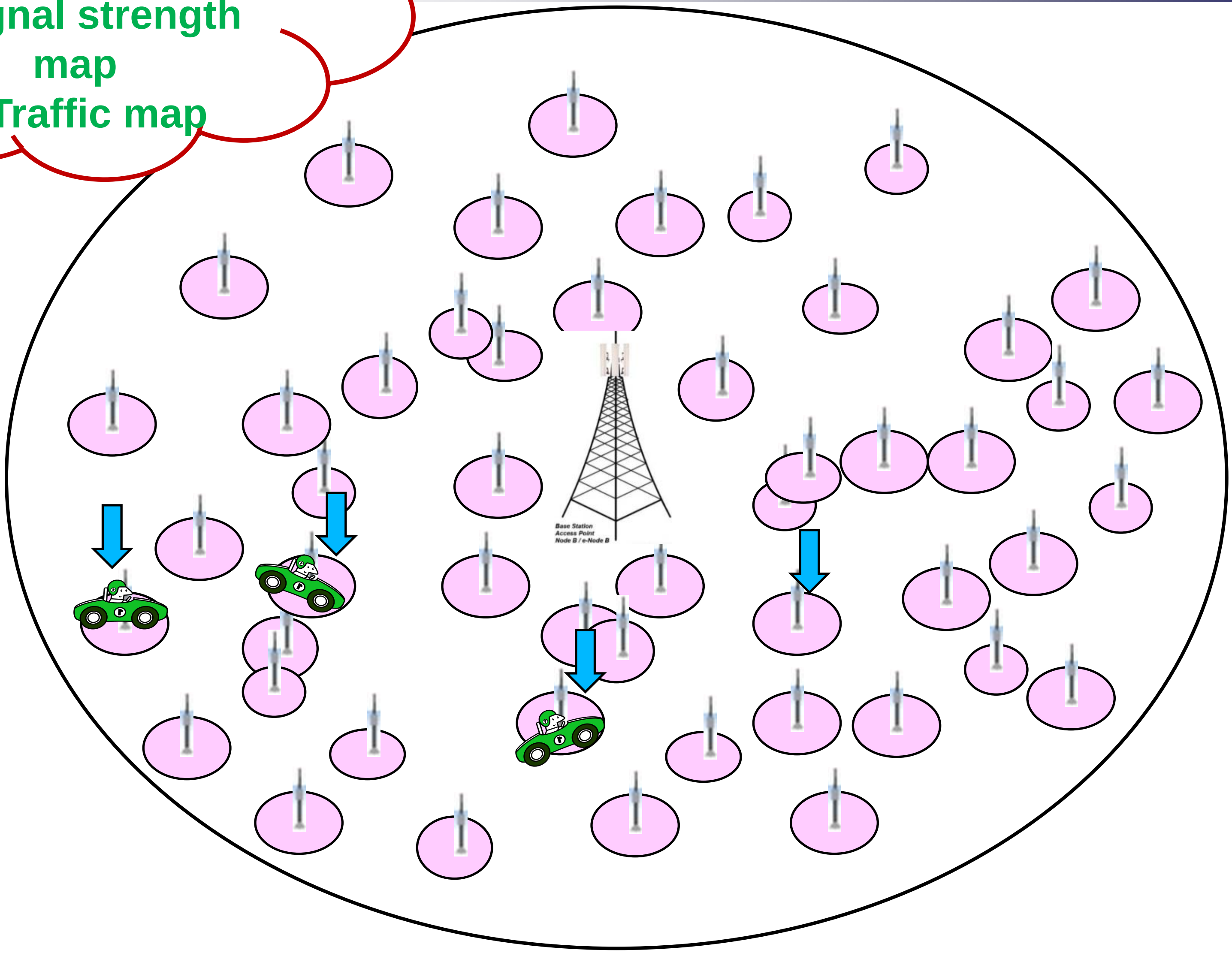
- Further, throughput experienced by users at cell edge is poor due to high pathloss and heavy co-channel interference from neighboring base stations.

- To improve the situation desired link budget needs to be improved.

- The concept of femtocell implies, very low power base station to be used to provide access to a cell of few meter radius.

Expected inputs from Vodafone

1. Signal strength map
2. Traffic map



Femtocells

Benefits for users:

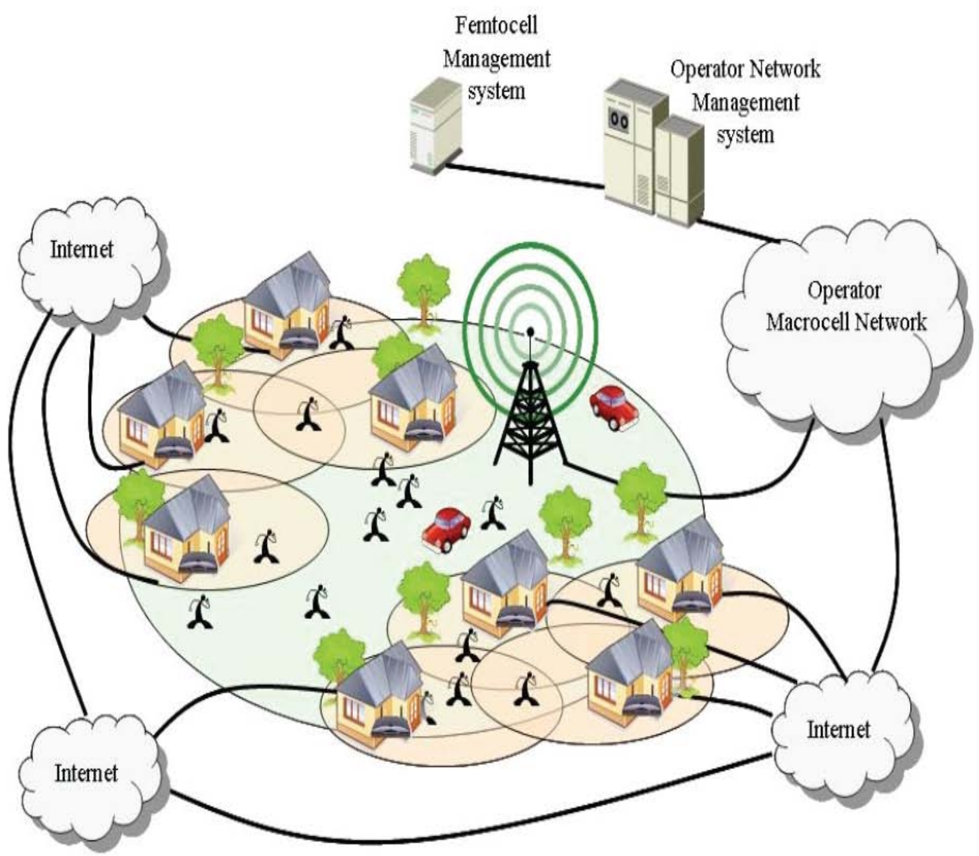
- Provides better coverage
- Provides high data rate

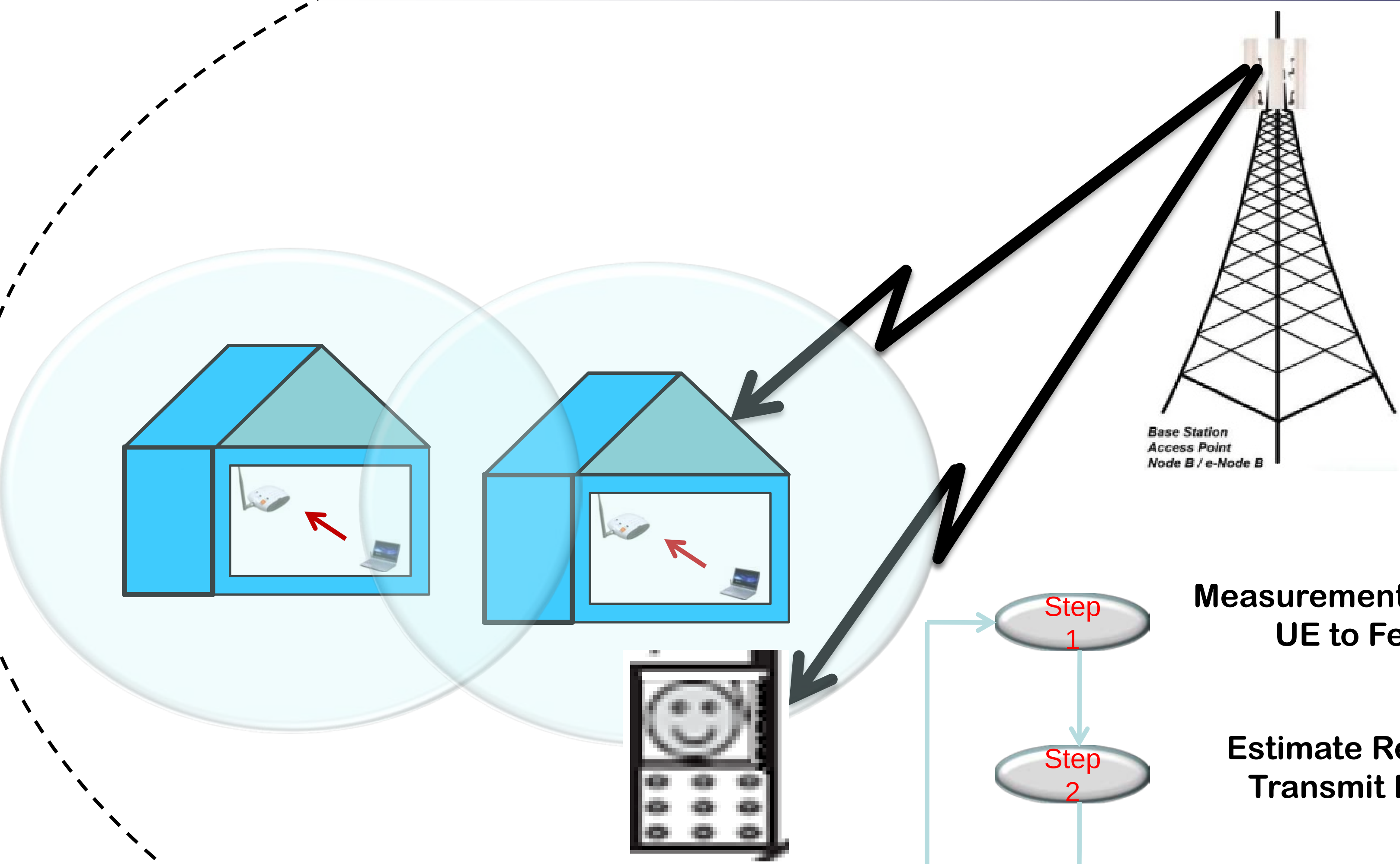
Benefits for operators:

- Increased network capacity
- Reduced traffic in macro cell
- Lower CAPEX & OPEX

Technical issues:

- Co-Channel Interference (CCI)
  (between macro and femto layer)
- Access control
  (Open and closed access issues)
- Frequent hand over





Measurement Report from UE to Femtocell

Estimate Required Transmit Power

Reduce Transmit Power

Downlink power control:

HeNB transmit power:

$$P_{ft} = min(P_{f-tmax}, max(\gamma_{target} + P_I + P_n - G_f))$$

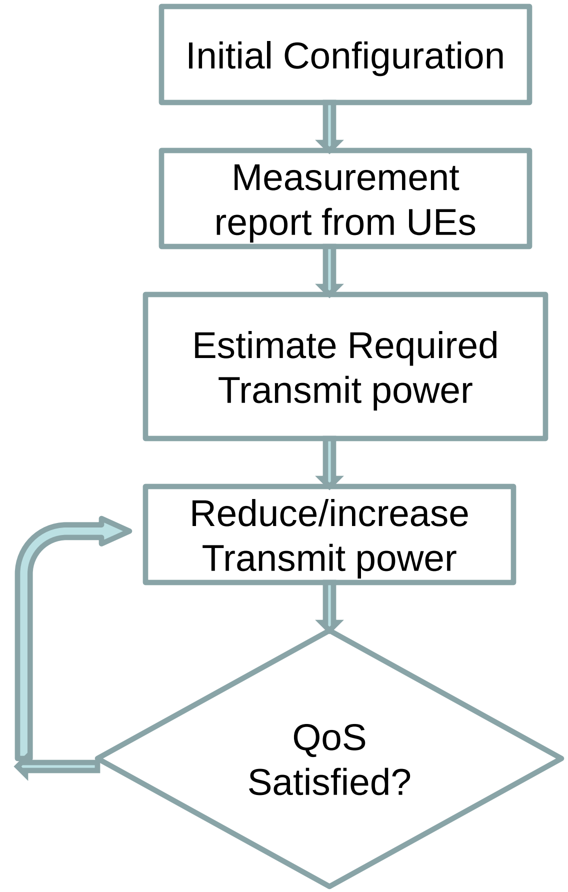
$P_{f\text{-}max}$ -> maximum transmit power (20 dBm)
P_I -> Total Interference power (dBm)
P_n -> noise power (dBm)
γ_{target}> Gain between HeNB and HUE
-> target SINR = 5dB

$$P_d = P_T{}^D P_G{}^D |(h_1{}^D h_1{}^{D*}) + (h_2{}^D h_2{}^{D*})|^2$$

$$P_{i,m} = \sum_{m=1}^{N_p} P_T{}^{M_p} P_G{}^{M_p} |(h_1{}^{M_p} h_1{}^{D*}) + (h_2{}^{M_p} h_2{}^{D*})|^2$$

$$P_{i,f} = \sum_{q=1}^{N_f} P_T{}^{F_q} P_G{}^{F_q} |(h_1{}^{F_q} h_1{}^{D*}) + (h_2{}^{F_q} h_2{}^{D*})|^2$$

$$\gamma = \frac{P_d}{P_{i,m} + P_{i,f} + BFN_0}$$



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Simulation Parameters:

Parameter	Value
Cell Layout	19 Cells, 3 Sectors , Wrap Around
Scenario	Urban Micro (UMi)
Inter site Distance	200 m
Bandwidth	10 MHz
Carrier Frequency	2.5 GHz
MeNB transmit power	41 dBm
Maximum HeNB transmit power	20 dBm
Macro base station antenna height	20 m
Number of Tx and Rx antennas	1×2 (macro and femto)
MeNB antenna gain (boresight)	17 dB
HeNB antenna gain	0 dB
Thermal noise level	-174 dBm/Hz
Receiver noise figure	7 dB
UE speed of interest	3 kmph for Outdoor users 30 kmph for outdoor users
Minimum sepeartion	Between MeNB and macro UE : 20 m Between MeNB and HeNB : 20 m Between HeNB and femto UE : 1 m Between HeNBs : 20 m
Shadow fading std (dB)	4 for outdoor users 7 for indoor users
Shadowing correlation between sectors	.5

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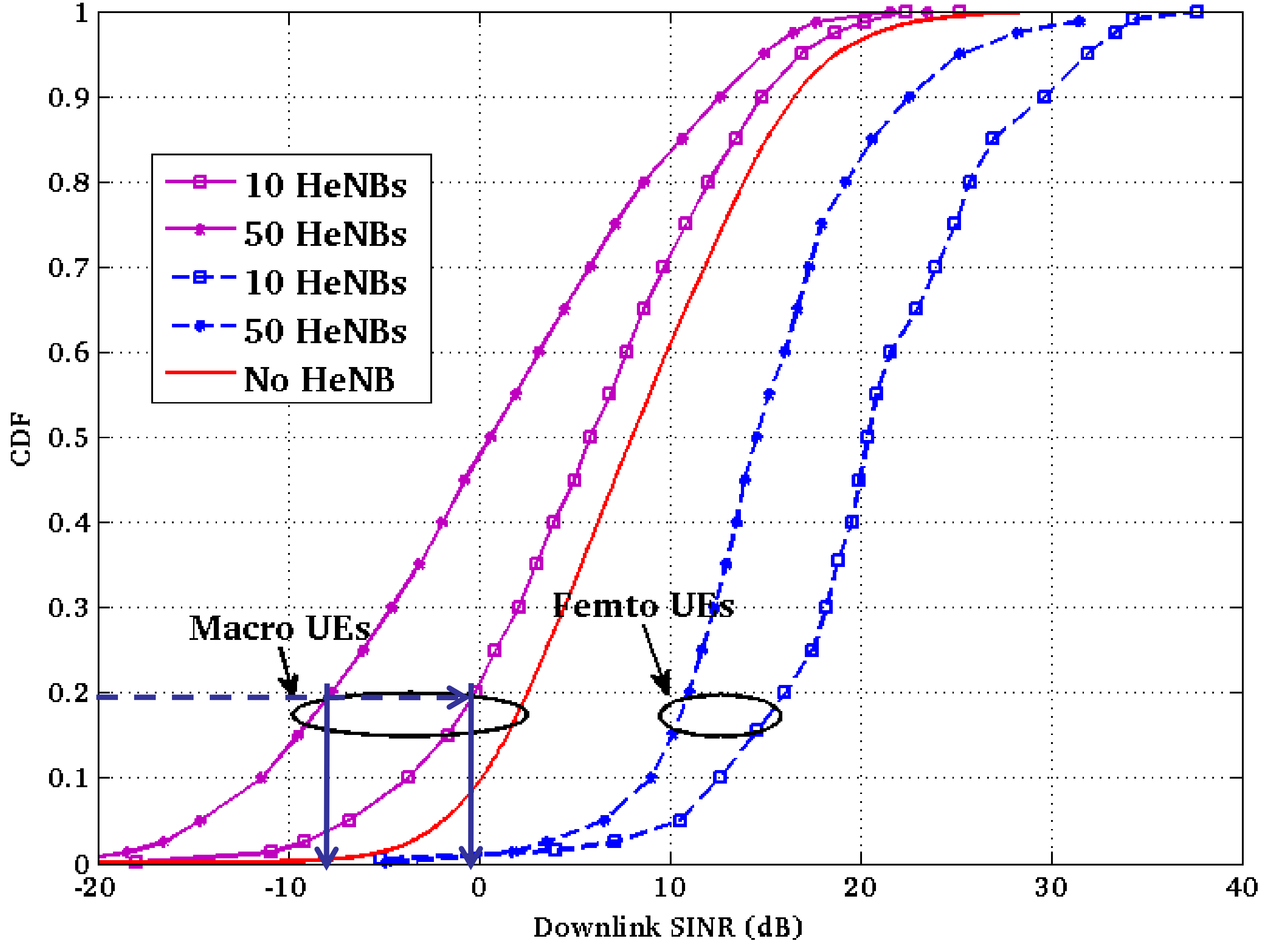
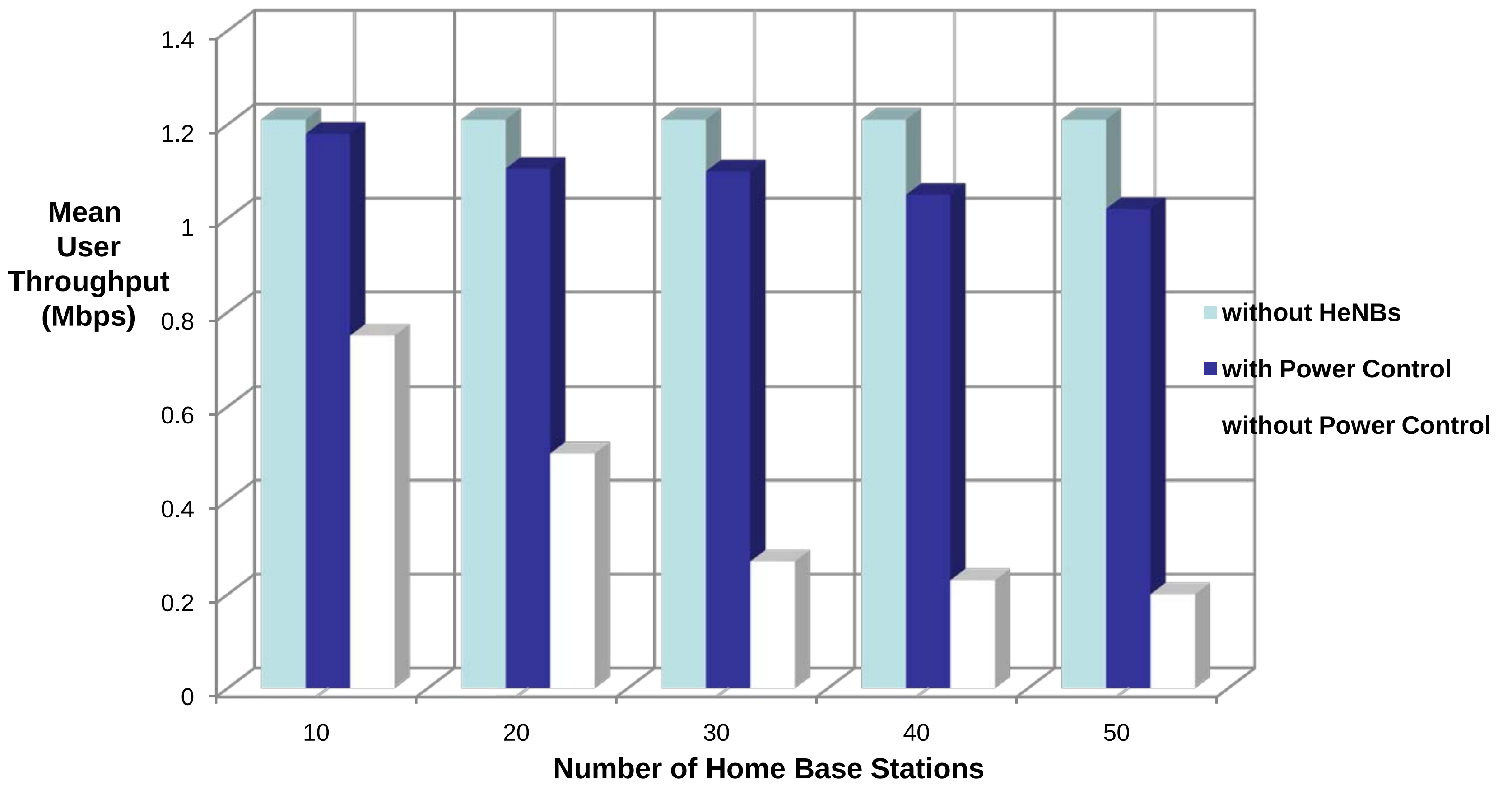
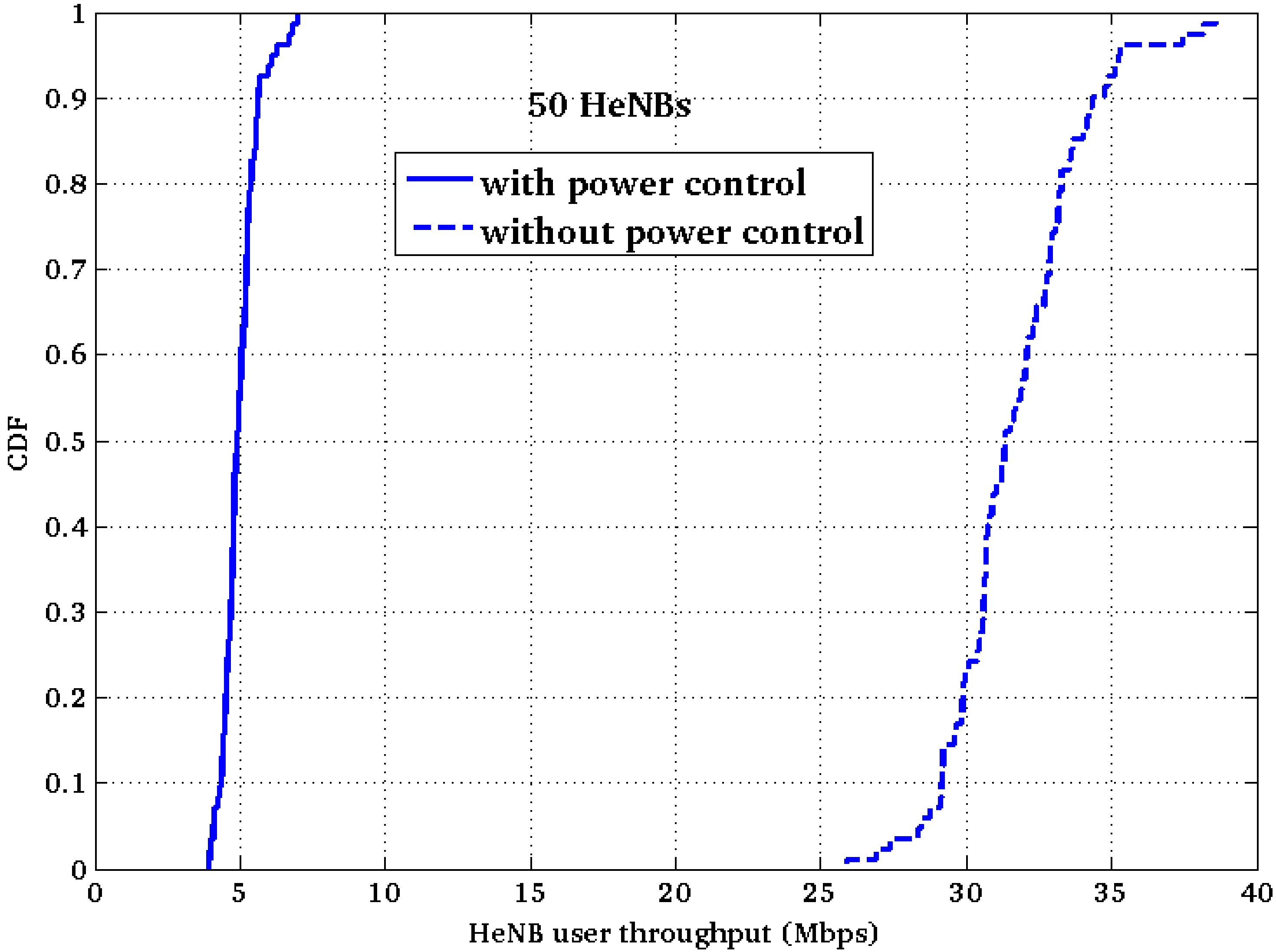
Downlink SINR without power control: (for varying femtocell Density)



User Throughput Performance with Power Control



User throughput with power control:



Discrete power levels:

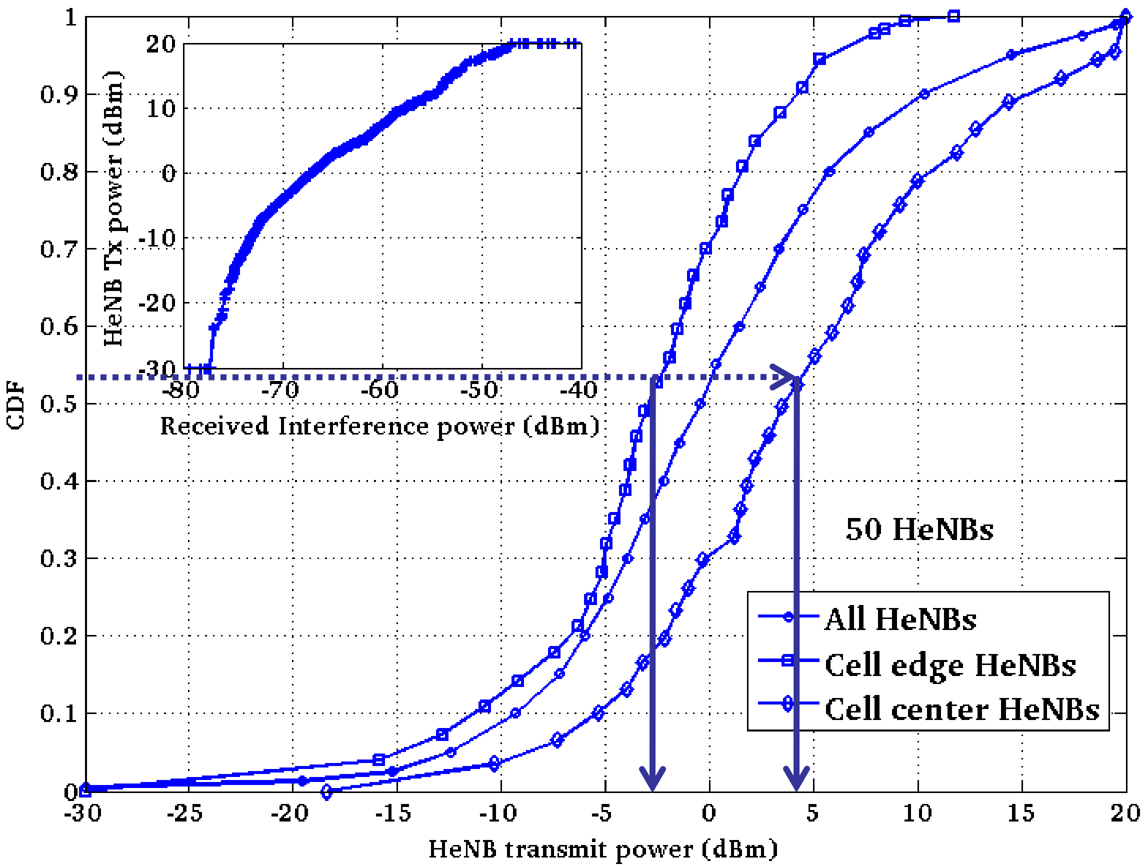
<u>Observations from continuous power levels:</u>

- Mean transmit power of cell edge HeNBs => 0 dBm
  - Standard deviation 7 dBm
- Mean transmit power of cell edge HeNBs => 5 dBm
  - Standard deviation 10 dBm

<u>Performance with discrete power levels:</u>

- Performance of the macro users with 2 power levels (0 dBm and 5 dBm) is similar to the performance with 5 power levels (0,5,10,15,20) dBm.
- Outage performance HeNB users decreases with two power levels when compared to 5 power levels.

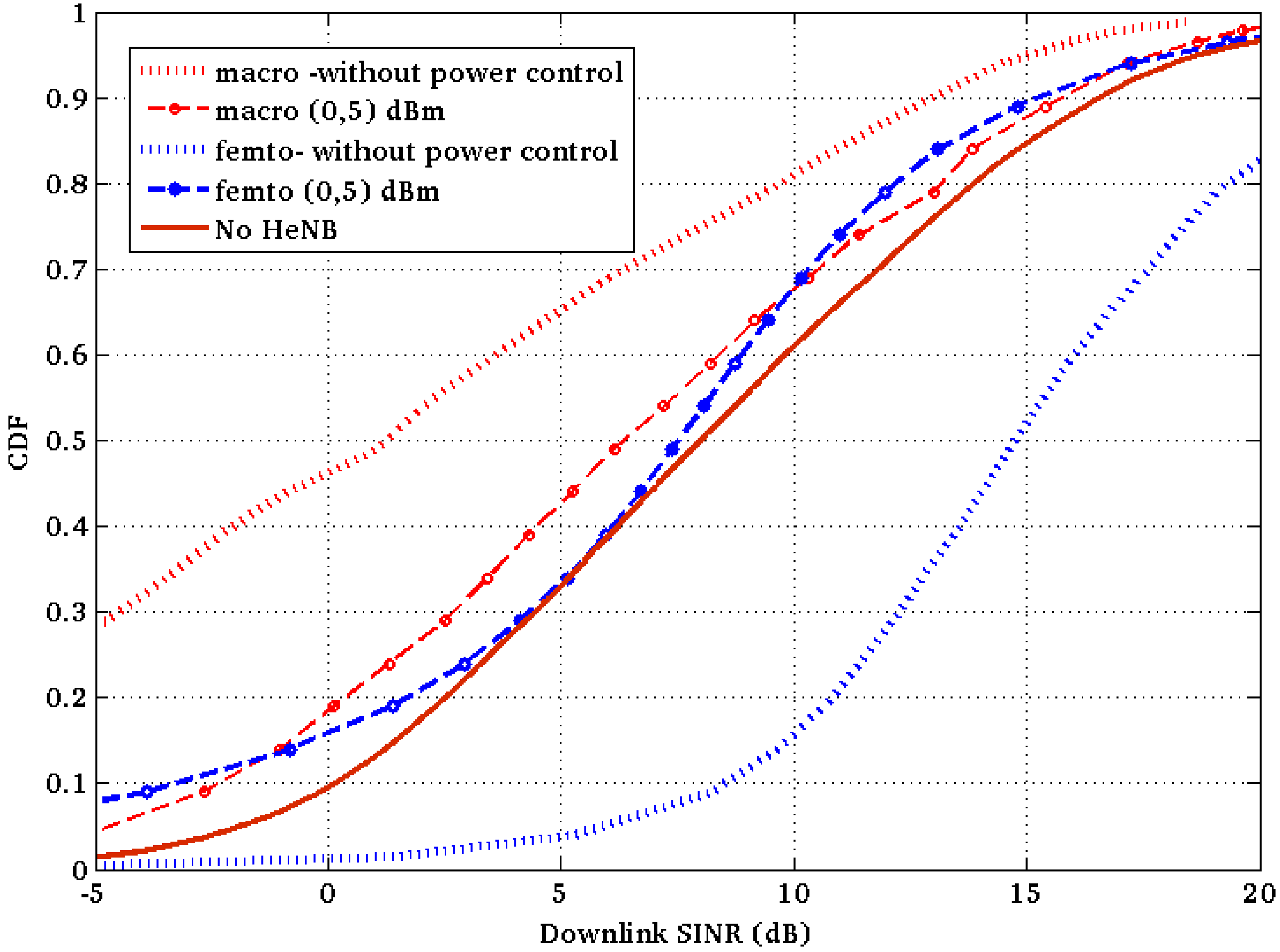
HeNB transmit power with power control:



The mean transmit power => 4.5 dBm for cell center HeNBs

0 dBm for cell edge HeNBs

Performance of HeNB transmit power control:



Conclusions & Future Work:

- ***SINR and Capacity for Femto Deployment*** - presented in last review
- ***Adaptive power control for self configuration –*** work done in this quarter
  - ***Throughput Improvement*** by **70%**
  - Extended to simple two discrete power levels
    - Reduces frequent measurement report
    - Fast adaptation
- ***Opportunistic spectrum access***
  - Using Frame format decoding -**Possible IPR and Standard contribution**
- ***Using existing Radio Access Techniques with minor modifications -*** **Towards Standard contribution**

Thank You

Thank You