3GPP Self-evaluation Methodology and Results

"Assumptions"

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3GPP Self-evaluation for LTE-Advanced Introduction

- Self-evaluation for LTE-Advanced FDD Radio Interfance Technology (RIT) and TDD RIT was conducted in 3GPP
- The radio system capabilities evaluated here span the radio capabilities from LTE Rel-8 and extend through Rel-10 and beyond (LTE-A).

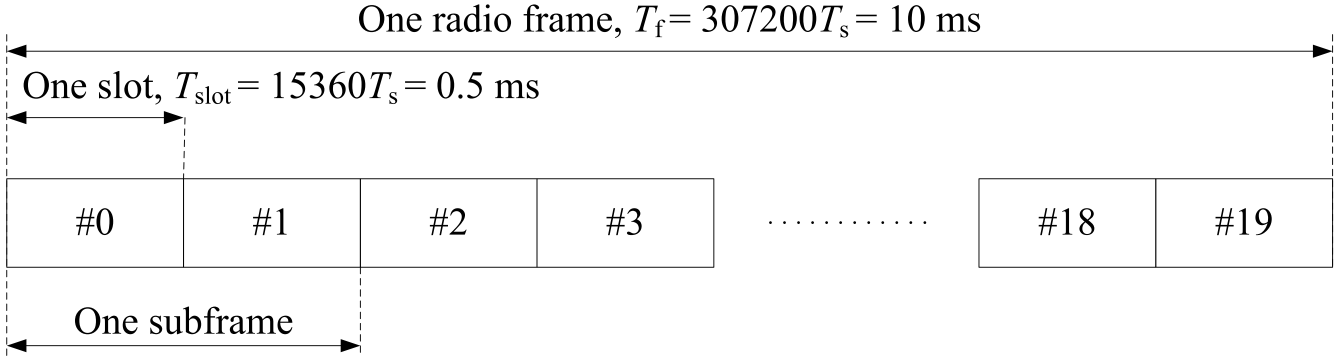
  As such the capabilities represent a range of possible functionalities and solutions that might be adopted by 3GPP in the work on the further specifications
- The ITU-R report, M.2133, M.2134, M.2135 and IMT-ADV/3 were utilized in the preparation of the evaluation
- Following 18 corporate entities participated to the performance evaluation campaign:

  Alcatel-Lucent/Alcatel-Lucent Shanghai Bell, CATT, CMCC, Ericsson/ST-Ericsson, Fujitsu, Hitachi, Huawei, LGE, Motorola, NEC, Nokia/Nokia Siemens Networks, NTT DOCOMO, Panasonic, Qualcomm, RITT, Samsung, Texas Instruments, ZTE

Outline

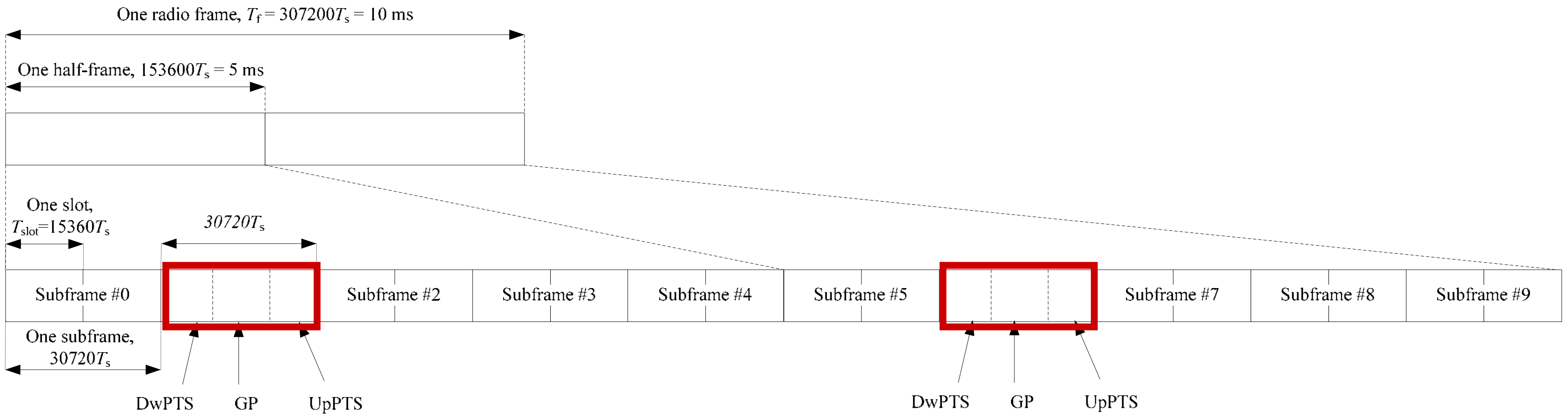
Outline

1.1 Frame structure: FDD



- 1 radio frame (10 msec) has 10 subframes
- 1 subframe = 1 msec
- Data packet scheduling unit: One-subframe

1.2 Frame structure: TDD



- GP = Guard period
- UpPTS (Uplink Pilot Timeslot) is reserved for uplink transmission
- DwPTS (Downlink Pilot Timeslot) is reserved for downlink transmission

1.3 Frame structure: TDD
UL & DL Ratio

1 frame (10msec)

UL-DL configuration	DL-UL Switch-point periodicity	Subframe number									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

(Sect. 4.2、36211)

D **: Downlink** U **: Uplink** S **: DL+GP+UL**

Baseline configuration

- 5 msec periodicity
- 4 full DL subframes
- 2 Special subframe: DwPTS 11symbol, GP 1 symbol, UpPTS 2 symbol,
- 4 full UL subframes

Outline

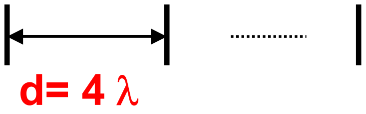
2.1. Scenario / Channel model

Evaluation scenario from M. 2135 (ITU-R guideline)

Simulation Scenario / Channel model	CF (GHz)	ISD (meters)	BW (MHz)	Speed (km/h)	Additional Simulation Parameters
Indoor / Indoor hotspot (InH)	3.4	60	FDD:20+20 TDD: 40	3	M.2135
Microcellular / Urban micro-cell (UMi)	2.5	200	FDD:10+10 TDD: 20	3	M.2135
Base coverage urban / Urban macro-cell (UMa)	2.0	500	FDD:10+10 TDD: 20	30	M.2135
High speed / Rural macro-cell (RMa)	0.8	1732	FDD:10+10 TDD: 20	120	M.2135

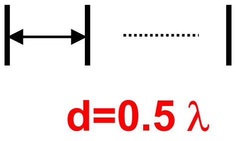
2.2 Antenna model at eNB: Configuration

Antenna configuration (A)



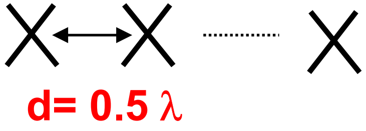
Co-polarized antennas
separated 4 wavelengths

Antenna configuration (C)



Co-polarized antennas
separated 0.5 wavelength

Antenna configuration (E)



Cross-polarized +/- 45 (deg)
antennas columns separated 0.5
wavelength

Various antenna configurations have been evaluated

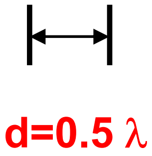
2.2 Antenna model at eNB: Tilting

$$A_e(\phi) = -\min\left[12\left(\frac{\phi-\phi_{\text{tilt}}}{\phi_{3\text{dB}}}\right)^2, A_m\right]$$

Channel model	Tilt angle ϕ_{tilt} (degrees)
Indoor / Indoor hotspot (InH)	N/A
Microcellular / Urban micro-cell (UMi)	12
Base coverage urban / Urban macro-cell (UMa)	12
High speed / Rural macro-cell (RMa)	6

2.3 Antenna model at UE

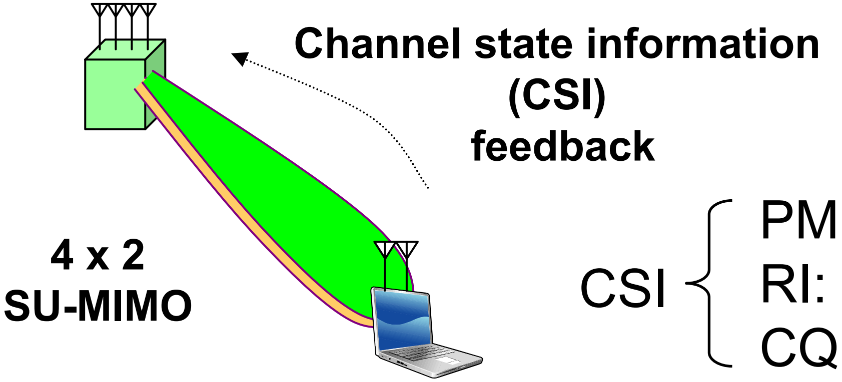
Vertically polarized antennas
(Baseline)



Cross polarized antennas
(Alternative)

Outline

3.1 DL transmission: LTE Rel-8 SU-MIMO



CSI
- PMI: Precoding matrix indicator
- RI: Rank indicator
- CQI: Channel quality indicator

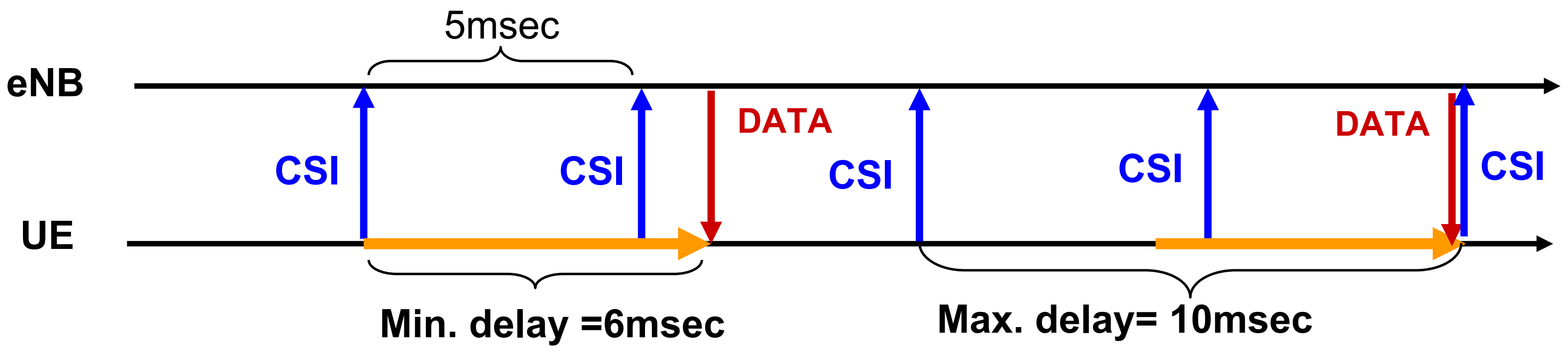
- Demodulation based on common reference signal (CRS)
- Codebook based precoding

3.1 DL transmission: Rel-8 SU-MIMO

CSI feedback and precoding

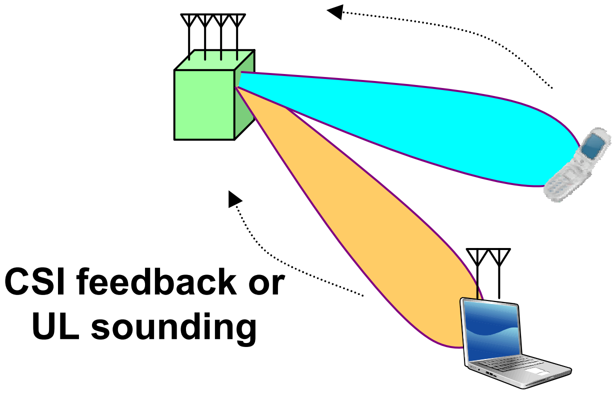
CSI at eNB (via Feedback or UL sounding)	• Wide-band PMI feedback • RI • Subband CQI (subband size = 6 Physical Resource Block (PRB) for 10MHz) with Measurement error: N(0,1) per PRB • PMI/CQI feedback periodicity: e.g., 5 msec • PMI/CQI feedback delay: e.g., 6 msec
Precoder	Codebook based precoding with 4-bit House holder codebook (TS.36211 Sect. 6.3.4.2.3)

Feedback time line example (5 msec period, 6msec delay)



3.2 DL transmission for LTE-A: MU-MIMO

Multi-user (MU) MIMO

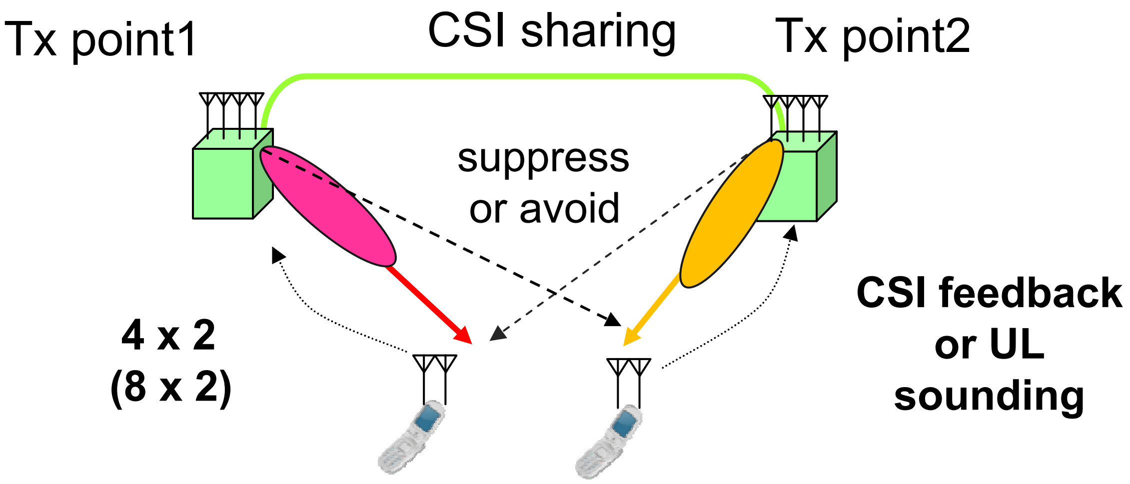


**4 x 2 (8 x 2)
MU-MIMO**

- Demodulation based on UE specific RS
  → Various precoding strategies are possible
- Precoding-based on CSI feedback and/or UL sounding

3.2 DL transmission for LTE-A: CS/CB-CoMP

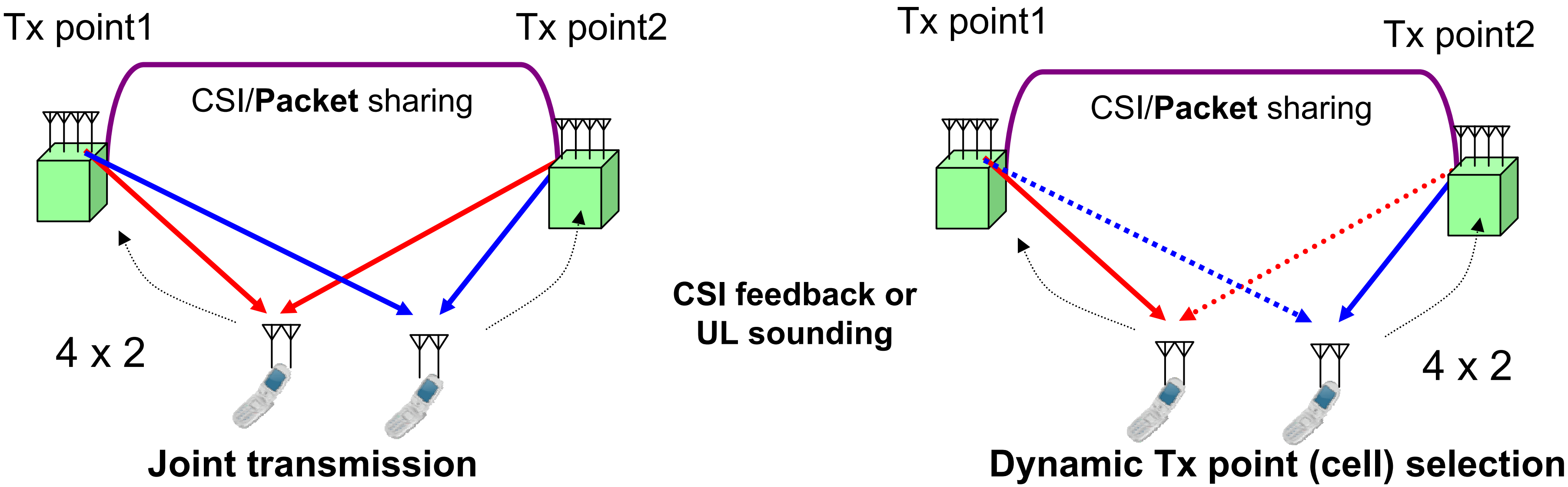
Coordinated beamforming and scheduling (CS/CB)-CoMP



- Coordination between multiple Tx points via CSI sharing
  - ✓ Inter-site CoMP
    - → Require X2 or fiber connection between points
  - ✓ Intra-site CoMP
    - → Easier CSI sharing
- Use of inter-cell CSI for coordination
- Demodulation based on UE-specific RS

3.2 DL transmission for LTE-A: JP-CoMP

Joint processing (JP) CoMP



- Coordination between multiple Tx points via CSI and data sharing
  - ✓ Inter-site CoMP
    - → Require X2 or fiber connection between points
  - ✓ Intra-site CoMP
    - → Easier CSI and data sharing
- Use of inter-cell CSI for coordination
- Demodulation based on UE-specific RS
  - → Various precoding strategies are possible

3.2 DL transmission for LTE-A: MU-MIMO and CoMP

CSI feedback and precoding

CSI at eNB (via feedback or UL sounding)	• Long-term CSI, e.g., ✓ Wideband transmit covariance matrix or its eigen vector (with or w/o quantization) • Short-term CSI, e.g., ✓ Rel-8 compatible (Wideband PMI) ✓ Narrow-band channel covariance matrix or its eigen vector ✓ Channel transfer function • Subband CQI (for scheduling and MCS selection) • Feedback delay: e.g., 3 – 6 msec • Feedback period: e.g., 2 – 5 msec
Precoder examples	• (Regularized) Zero-forcing (ZF) • Maximum Signal-to-leakage ratio (SLR) • Block-diagonalization (BD) • Eigen-beamforming

Long-term or short-term CSI was assumed for precoder design

3.3 DL Receiver (at UE)

- MMSE

  Suppress intra-cell interference

- MMSE with interference rejection combining (IRC)

  Typically, received covariance matrix of inter-cell interference is used in computing MMSE filter

Real channel estimation is assumed

Outline

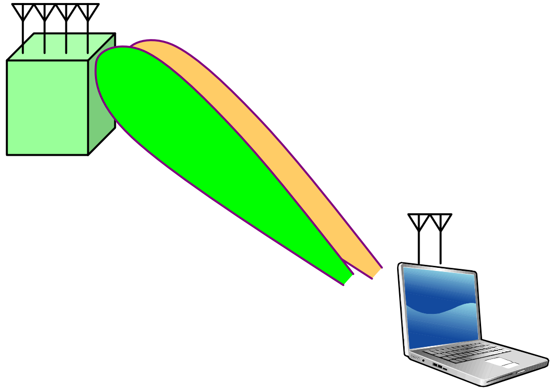
3.4 UL transmission: Rel-8 SIMO / MU-MIMO

1 x 4 SIMO

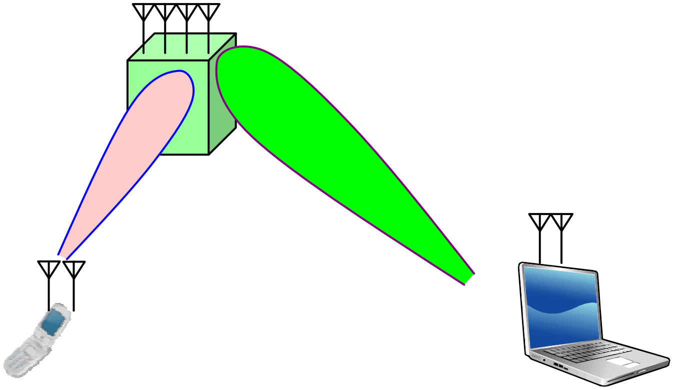
1 x 4 MU-MIMO

- Multiple antenna reception at eNB
- MU-MIMO extension
- Fractional power control

3.5 UL transmission: LTE-A (SU/MU-MIMO)



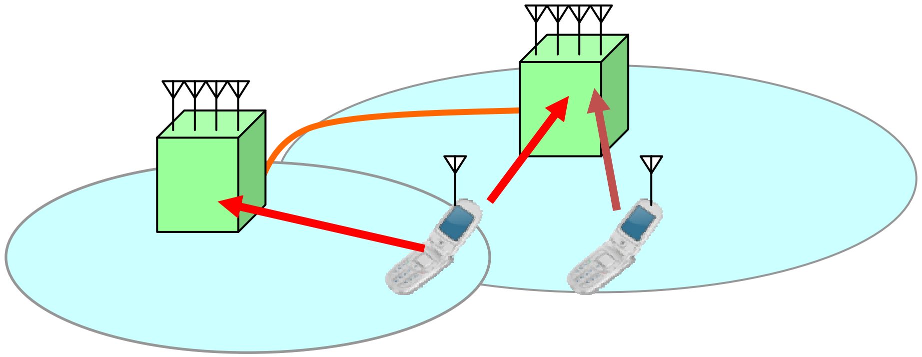
2 x 4 SU-MIMO



2 x 4 MU-MIMO

- Dual-stream transmission by precoding and rank adaptation

3.5 UL transmission: LTE-A (CoMP)



1 x 4 CoMP
(2 x 4 CoMP)

- Packet combining from multiple points
- Coordinated scheduling among multiple point

3.6 UL Receiver (at eNB)

- MMSE

  Suppress intra-cell interference

- MMSE with interference rejection capability (IRC)

  Typically, received covariance matrix of inter-cell interference is used in computing MMSE filter

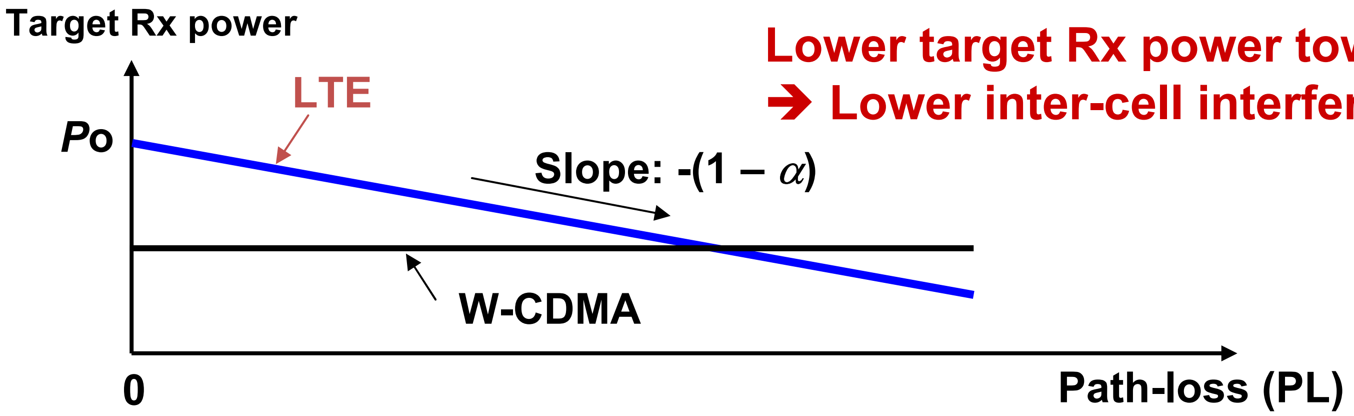
- MMSE-SIC

  Cancel the interference replica (MU-MIMO)

Real channel estimation is assumed

3.7 UL power control (PC): Fractional PC

Fractional PC: **Lower target Rx power / SIR when path-loss becomes larger**



Lower target Rx power towards cell edge
➔ Lower inter-cell interference

Physical uplink shared channel (PUSCH) power calculation at UE

$$P(i) = \min\{P_{\mathrm{MAX}}, \underset{\text{Open-loop}}{\boxed{P_0 + \alpha \cdot PL + X}} + \underset{\text{Closed-loop}}{\boxed{f(i)}}\} \qquad X = 10\log_{10}(M_{\mathrm{PUSCH}}(i)) + \Delta_{\mathrm{TF}}(i)$$

P0 : Target receive power (per PRB)
α : Offset for Po
f(i) : PC command
→ Fill the gap between target and actual received power

3.7 UL power control: PC Parameters

P0 and α $(0 \le \alpha \le 1.0)$ are fitted to each environment

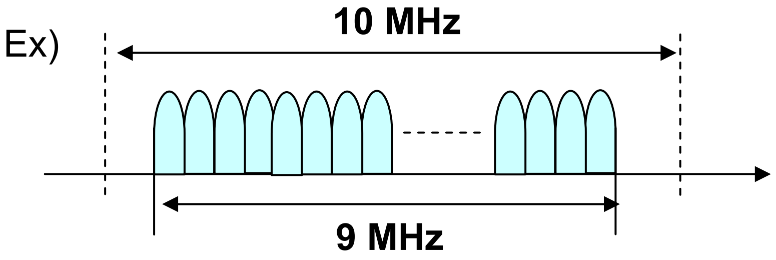
Example:

α = 0.8
Indoor hotspot: P0 = -80 dBm
Urban micro-cell: P0 = -85 dBm
Urban macro-cell: P0 = -83 dBm
Rural macro-cell: P0 = -84 dBm

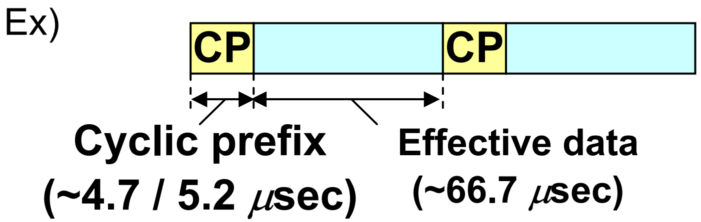
Outline

4.1 DL overhead: Guard

- Guard-band = 10 % (1 MHz / 10MHz)

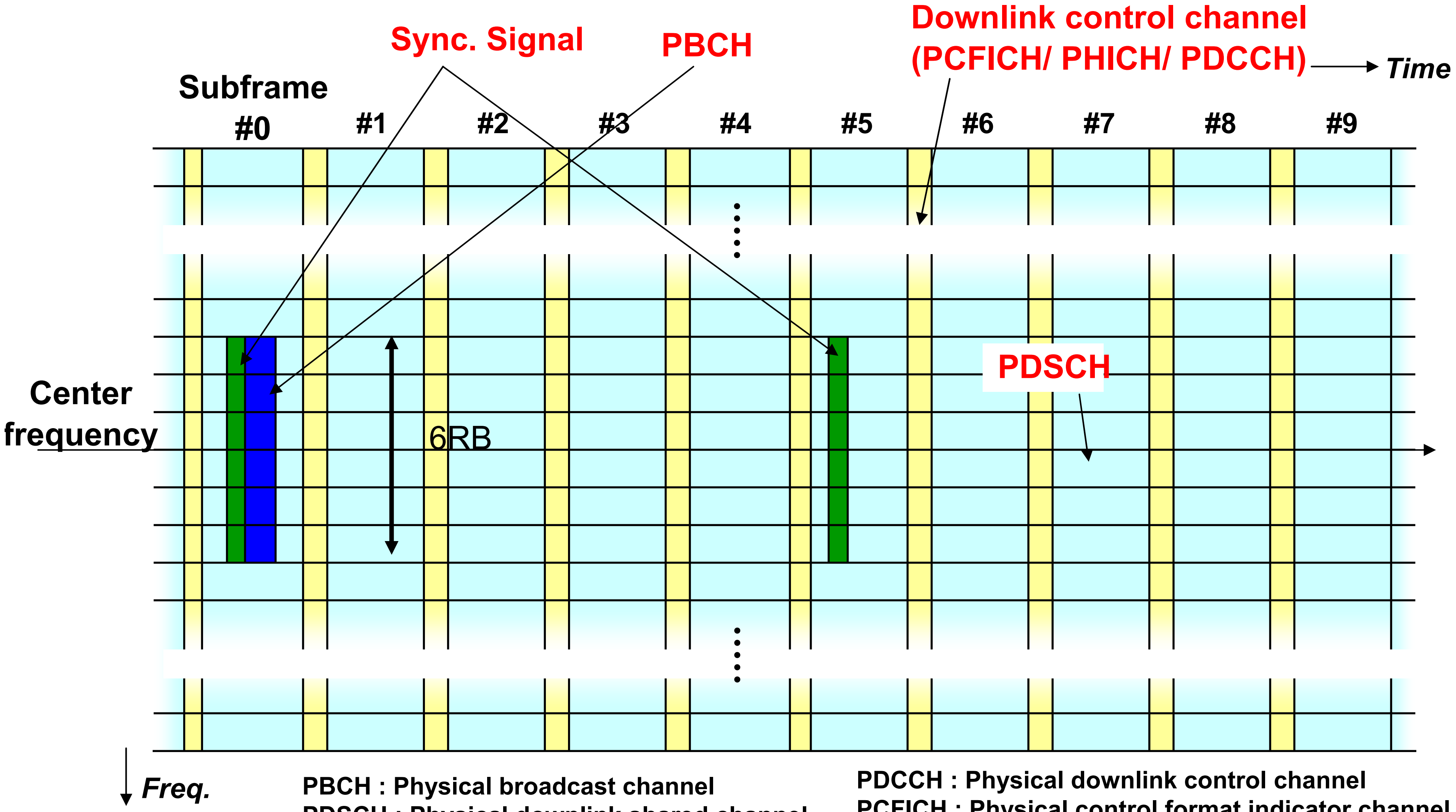


- Guard-interval = 6.67 % (Normal CP)



4.1 DL overhead: PBCH and Sync. Signal

- BCH resource: = 4 OFDM symbols x 6 RB (RS excluded)
- Synchronization Signal resource= 4 OFDM symbols x 6 RB

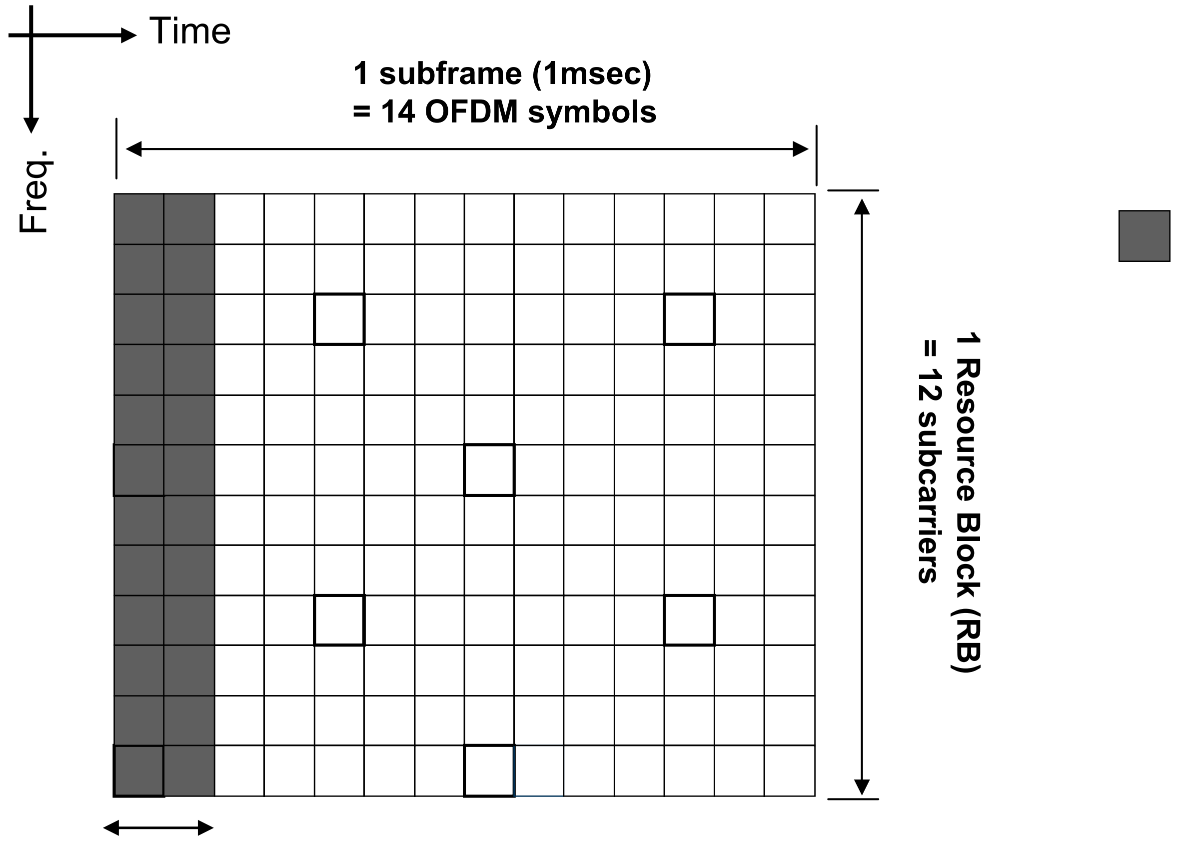


PBCH : Physical broadcast channel
PDSCH : Physical downlink shared channel

PDCCH : Physical downlink control channel
PCFICH : Physical control format indicator channel
PHICH : Physical HARQ indicator channel

4.1 DL overhead: L1/L2 control channel

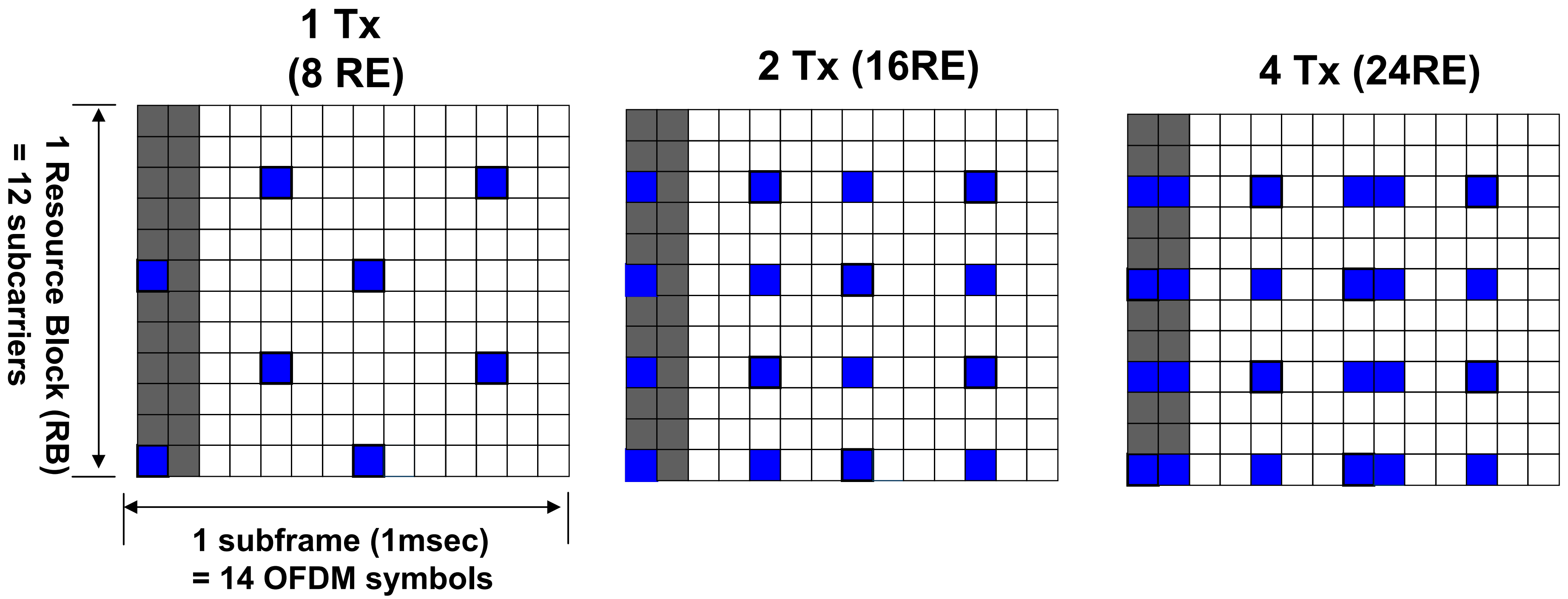
Example



L=2 symbols

L= 1, 2, 3 (if system bandwidth > 10 RB)

4.1 DL overhead: + Common RS (CRS)



(RS Ratio: ~4.8 %)

(RS Ratio: ~9.5 %)

(RS Ratio: ~14.3 %)

🟦 CRS

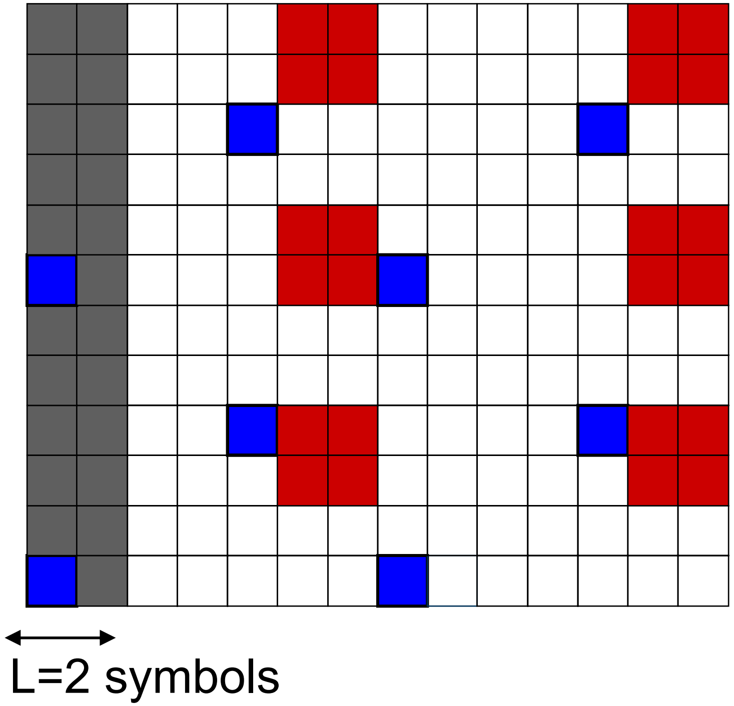
⬛ Control

RE=Resource element

4.1 DL overhead: + Demodulation RS (DM-RS) LTE-Advanced

LTE-A assume demodulation RS (DM-RS)

Example



🟦 CRS (1Tx)

🟥 DM-RS (rank > 2)

⬛ Control

DM-RS density

- **12 RE for rank 1 – 2**
- **24 RE for rank > 3**

4.1 DL overhead: + CSI-RS LTE-Advanced

- LTE-A supports CSI-RS for CSI measurements.
- CSI-RS is sparse in time and frequency

Example: 0.12% per port per radio frame (10msec)

→ About 400 RE for 4 Tx

(Ref: RP-090745, Sect. 4.2.3.2.4.2)

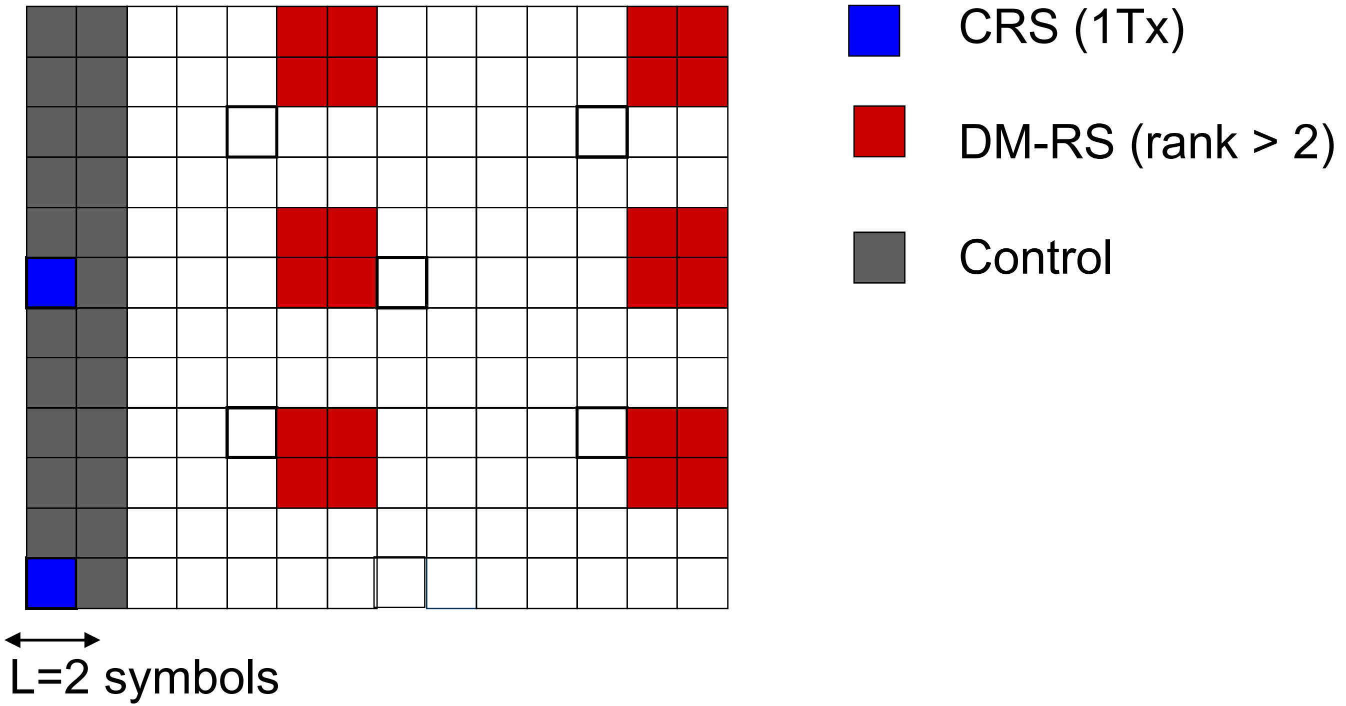
4.1 DL overhead: MBSFN subframe LTE-Advanced

LTE-A can configure MBSFN subframes to schedule non-MBSFN data (PDSCH)

Example

Data region of MBSFN subframe is not Rel-8 compatible → No CRS needed.

Example



4.1 DL overhead: Summary

	Rel-8 SU-MIMO	LTE-A MU-MIMO / CoMP
Guard	**Y**	**Y**
PBCH and SS	**Y**	**Y**
DL control	**Y**	**Y**
Common RS (CRS)	**Y**	**Y**
Demodulation RS (DM-RS)	**N**	**Y**
CSI-RS	**N**	**Y**
Use of MBSFN subframes	**N**	**Y**

4.2 DL RS and control overhead details: FDD, Rel-8

Rel-8 DL SU-MIMO

Total REs		50 RBs * 12 subcarriers * 10 frames * 14 OFDM symbols = 84000
	DL control	50 * 12 * 10 * L = 6000 (L = 1), 12000 (L = 2), 18000(L = 3)
	CRS	・50 * 20* 10 = 10000 (L=1) (4 antenna ports, first 1 symbol included in DL control) ・50 * 16 * 10 = 8000 (L=2, 3) (4 antenna ports, first 2 symbols included in DL control)
	DM-RS	n/a
	SS + PBCH	288 + 240
	CSI RS	n/a
Total control and RS overhead		**19.68% (L=1), 24.44% (L = 2), 31.58% (L = 3)**

4.2 DL RS and control overhead details: FDD, LTE-A

LTE-A (MU-MIMO/CoMP): With 6 MBSFN subframes per 10ms, 1CRS port

Total REs		50 RBs * 12 subcarriers * 10 frames * 14 OFDM symbols = 84000
Normal subframes: 4 out of 10 subframes (= 33600 REs)		
	DL control	50 * 12 * 4 * L = 2400 (L=1), 4800 (L = 2), 7200 (L = 3)
	CRS	50 * 6 * 4 = 1200 (1 antenna port, 1 symbol included in DL control)
	DM-RS	50 * X * 4 = 2400, X = 12 (for up to 2 layers), X = 24 (for more than 2 layers)
	SS + PBCH	288 + 276
	CSI-RS	Y (Y depends on number of antenna ports and reporting period)
MBSFN subframes: 6 out of 10 subframes (=50400 REs)		
	DL control	50 * 12 * 6 * L = 3600 (L=1), 7200 (L = 2), 10800 (L = 3)
	CRS	0 (included in DL CCH)
	DMRS	50 * X * 6 = 3600, X = 12 (for up to 2 layers), X = 24 (for more than 2 layers)
	SS + PBCH	0
	CSI-RS	0
Total control and RS overhead		**16.86% (L = 1, X = 12, Y = 400)**, **24.00% (L = 2, X = 12, Y = 400)** **31.15% (L = 3, X = 12, Y = 400)**

4.2 DL RS and control overhead details: TDD, Rel-8

LTE Rel-8 DL SU-MIMO

Total REs		100 RBs * 12 subcarriers * (4 normal frames * 14 symbols + 2 special frames *11 symbols) = 93600
	DL control	・100 *12* (2 * 1+ 2 * 1) = 7200 (L = 1) ・100 * 12 * (4* L+2*2) = 14400 (L = 2), 19200(L = 3)
	CRS	・100*(4*20+2*16) = 11200 (L=1) (4 antenna ports, first 1 symbol included in DL control, DwPTS of 11 sym is counted) ・100*(4*16+2*12) = 8800 (L=2, 3: 4 antenna ports, first 2 symbols included in DL control, DwPTS of 11 sym is counted)
	DM-RS	n/a
	SS + PBCH	288 + 240
Total control and RS overhead		**20.22％(L = 1), 25.35% (L = 2), 30.48% (L = 3)**

4.2 DL RS and control overhead details: TDD, LTE-A

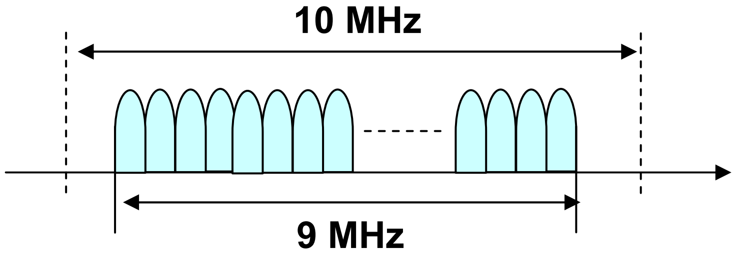
LTE-A (MU-MIMO/CoMP) With 2 MBSFN subframes per 10ms, 1CRS port

Total REs		100 RBs * 12 subcarriers * (2*normal frame*14 + 2 MBFSN subframe*14 + 2*special frame * 11)=93600
Normal subframes + Special subframe: 2 + 2 out of 6 subframes		
	DL control	・100 *12* (2 * 1+ 2 * 1) = 4800 (L = 1) ・100 *12* (2 * L + 2 * 2) = 9600 (L = 2), 12000 (L = 3 for normal subframe, L=2 for DwPTS)
	CRS	100 * (2* 6 + 2*4) = 2000 (1 antenna ports, 1 symbol included in DL CCH)
	DM-RS	100 * (2*X1+ 2*X2) = 4200, (X1,X2) = (12, 9) for up to 2 layers. For more than t 2 layers (X1,X2) = (24 18).
	SS + PBCH	288 + 276
	CSI-RS	n/a
MBSFN subframes: 2 out of 6 subframes		
	DL control	100 * 12 * 2 * L = 2400 (L = 1), 4800 (L = 2), 7200 (L = 3)
	CRS	0 (included in DL CCH)
	DM-RS	100 * 2 * X = 2400, X = 12 (for up to 2 layers). For more than 2 layers, X = 24
	SS + PBCH	0
	CSI-RS	0
Total control and RS overhead		**17.48 % (L = 1, X1 = 12, X2 = 9), 25.18 % (L = 2, X1 = 12, X2 = 9) 30.30 % (L = 3, X1 = 12, X2 = 9)**

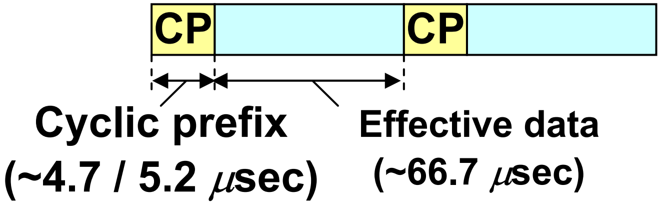
Outline

4.3 UL overhead: Guard

- Guard-band = 10 % (1 MHz / 10MHz)



- Guard-interval = 6.67 % (Normal CP)



4.3 UL overhead

- CQI / ACK/NCK on PUCCH: e.g., 4 PRB / 10 MHz
- DM-RS: 2 symbols per subframe (~14.3%)
- SRS: e.g., full-bandwidh, 10 msec period (~0.7%)
- PRACH: e.g., 6RB bandwidh and 10msec period (1.2 %)

PUCCH: Physical uplink control channel
SRS: Sounding reference signal
PRACH: Physial random access channel

Outline

5. VoIP evaluation assumption

PDCCH limitation	**Included, e.g.,** **• 3 (2 for DwPTS) OFDM symbols** **• Max. 8 (4) PDCCH for UL (4) PDCCH for UL (DL)** **• Max. 10 Control channel element (CCE) for UL and DL (FDD)** **• Max. 38 CCE for normal UL and DL, 26CCE for special UL and DL (TDD)**
Antenna configuration	**UL 1 x 4** **DL 1 x 2, or 4 x 2**
TDD configuration	**DL:UL = 3:2, DwPTS=12, GP=1, UpPTS =1**
VoIP scheduler	**Semi-persistent, Dynamic**

6. Other simulation parameters

Network synchronization	**Synchronized**
Handover margin	**1.0 dB**
Downlink scheduler	**Proportional fairness / Channel dependent**
Downlink HARQ	**Incremental redundancy / Chase combining**
UL scheduler	**Proportional Fairness / Channel dependent**
UL HARQ	**Incremental redundancy / Chase combining**
Scheduling bandwidth for mobility evaluation	**4 – 5 RB**

Thank you !

Outline

Annex Table of parameters (1)

Parameter	Values used for evaluation
Deployment scenario / channel model	Indoor (InH) , Microcellular (UMi), Base Coverage Urban (UMa), High Speed (RMa)
Duplex method and bandwidths	FDD: 10+10 MHz except 20+20 MHz for indoor TDD: 20 MHz also 40 MHz for indoor Baseline asymmetry during 5 subframes period: - 2 full DL subframes, - Special subframe: DwPTS 11sym, GP 1 sym, UpPTS 2 sym, - 2 full UL subframes
Antenna configuration eNB	A) Co-polarized, separated 4 wavelengths C) Co-polarized, separated 0.5 wavelength E) Cross-polarized (+-45deg), separated 0.5 wavelength
Antenna tilt at eNB	InH=N.A, UMi=12, UMa=12, RMa=6 (degrees)
Antenna configuration UE	• Vertically polarized, 0.5 wavelength separation (baseline) • Cross polarized orthogonal antennas (alternative)
Network synchronization	Synchronized
Handover margin	1.0 dB

Annex Table of parameters (2)

Parameter	Values used for evaluation
DL transmission scheme	**LTE Rel-8** • SU-MIMO with closed loop precoded spatial multiplexing (transmission mode 4 in TS36211) • Single stream beamforming (transmission mode 7 in TS36211) Baseline: 4 x 2 SU-MIMO **LTE-A** • MU-MIMO • Coordinated scheduling / Beamforming (CS/CB)-CoMP • Joint processing (JP)-CoMP
DL scheduler	Propotional fair / Channel dependent
DL link adaptation	Baseline (LTE Rel-8): A) Non-frequency selective PMI and frequency selective CQI report with 5ms periodicity, subband CQI with measurement error: N(0,1) per PRB B) Sounding-based precoding, frequency selective CQI report with 5ms periodicity, subband CQI with measurement error: N(0,1) per PRB
DL HARQ scheme	Incremental redundancy / Chase combining
DL channel estimation	Real
DL receiver type	MMSE (with / without IRC)

Annex Table of parameters (3)

Parameter	**Values used for evaluation**
UL transmission scheme	**LTE Rel-8** •Rel-8 SIMO with and without MU-MIMO Baseline: 1 x 4 SIMO **LTE-A** • SU-MIMO / MU-MIMO • UL CoMP
UL scheduler	Proportional fair / channel dependent
UL power control	**Baseline**: Fractional power control **Alternative**: Other Rel-8 specified Power control parameters (P0 and α) are chosen according to the deployment scenario (IoT reported with simulation results)
UL link adaptation	Non-ideal based on delayed SRS-based measurements: MCS based on LTE transport formats and SRS period and bandwidths according to TS36211
UL HARQ scheme	Incremental redundancy / Chase combining
UL channel estimation	Real
UL receiver type	MMSE / MMSE-SIC (MU-MIMO)

Annex Table of parameters (4)

Parameter	Values used for evaluation
Rel-8 overhead	• Guard band (10%), Guard interval (6.67%), (DL and UL) Downlink • PBCH and Sync. signal • DL control channel L OFDM symbols (=1,2,3) • CRS (4 ports for SU-MIMO, 1 port for single layer BF) • DM-RS (for single layer BF) Uplink • UL CCH according to CQI/PMI reporting mode • SRS • RACH
LTE-A overhead	•Guard band (10%), Guard interval (6.67%), (DL and UL) Downlink: • 6 MBSFN subframes per DL radio frame (FDD), 2 MBSFN subframes per DL radio frame (TDD) • PBCH and Sync. signal • DL control channel L OFDM symbols (=1,2,3) • CRS (1 port) • DM-RS • CSI-RS Uplink • UL CCH according to CQI/PMI reporting mode • SRS • RACH