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Multi Antenna Technologies

LTE Radio Parameters 1 [FL18A]

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Module Objectives

After completing this module, the participant should be able to describe discuss and analyze :

- Different multi antenna options in LTE
- MIMO options: Spatial Multiplex and Tx Diversity

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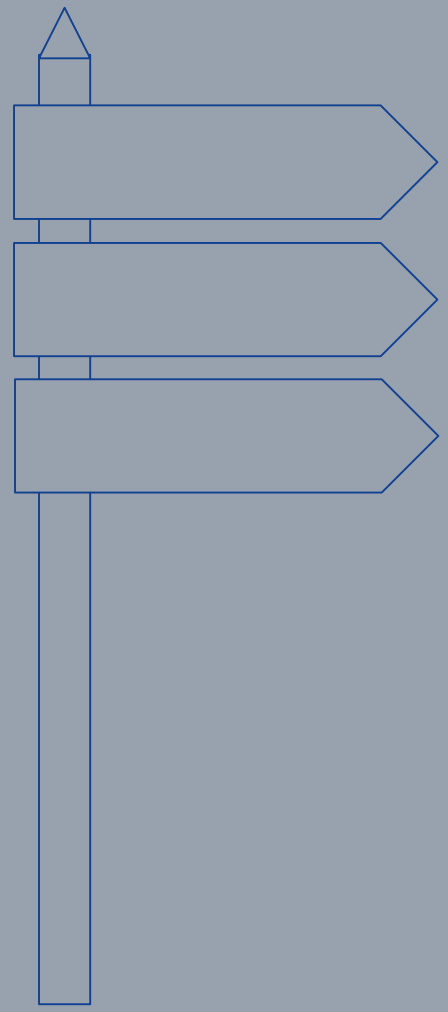
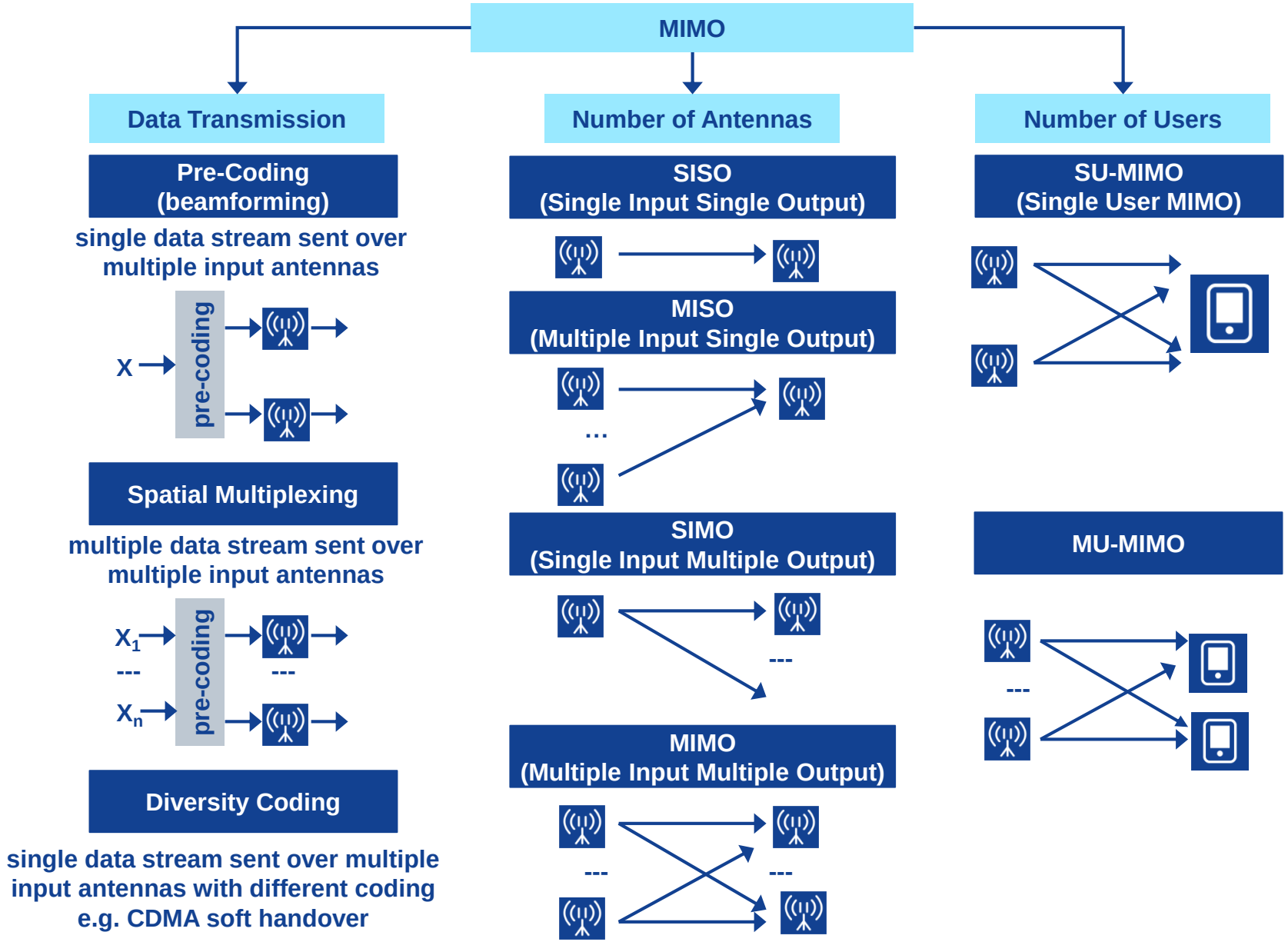
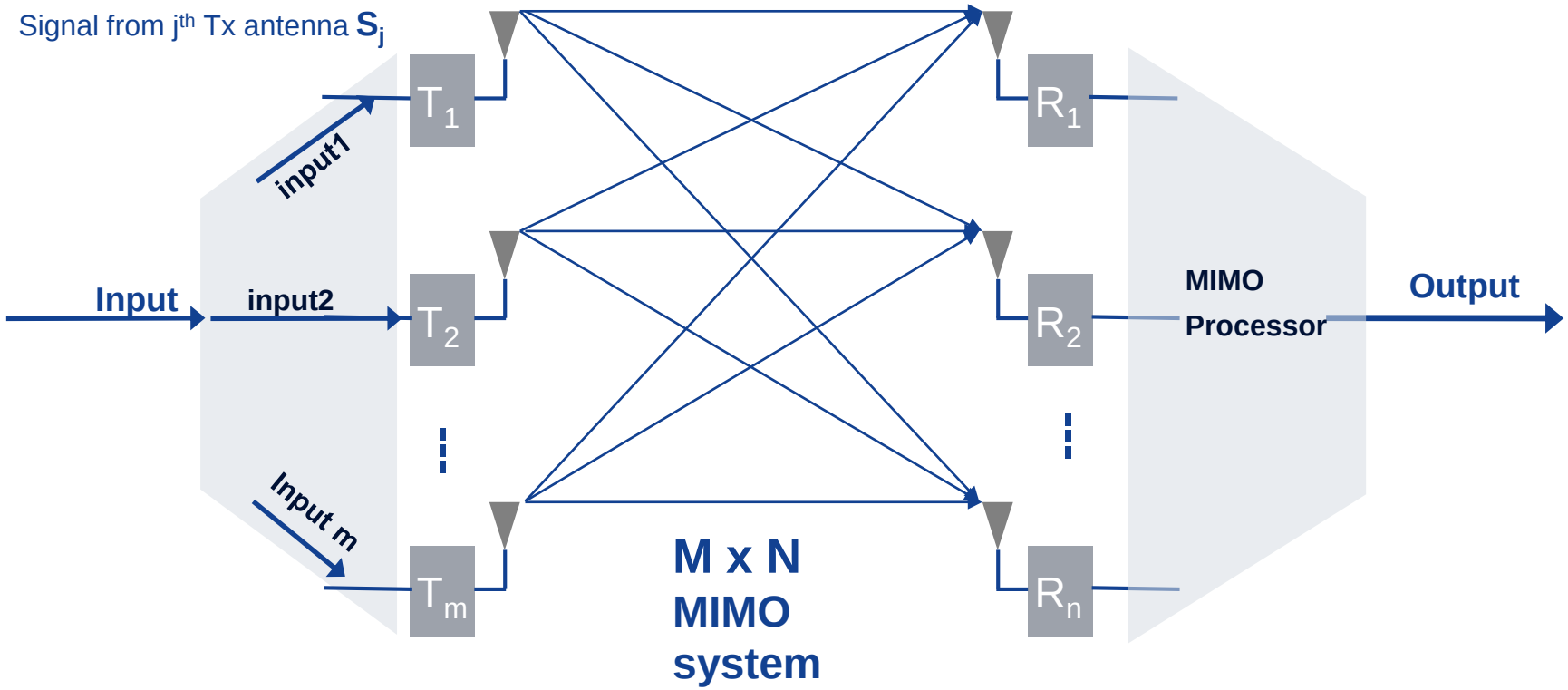


- **Overview**
- Single antenna port transmission
- Transmit diversity
- Open loop spatial multiplexing
- Closed loop spatial multiplexing
- Dynamic open loop spatial multiplexing
- Adaptive closed loop spatial multiplexing
- DL Single User MIMO 4x4

Types of MIMO Tx



Multiple-Input Multiple-Output MIMO Principle



- MIMO: Multiple-Input Multiple Output
- M transmit antennas (eNB if DL) , N receive antennas (UE if DL) form MxN MIMO system
- huge data stream (input) distributed toward m spatial distributed antennas; m parallel bit streams (Input 1..m)
- Spatial Multiplexing generate parallel “virtual data pipes”
- using Multipath effects instead of mitigating them

3GPP Transmission Modes

LTE Transmission mode	MIMO Scheme
Mode-1	single antenna transmission
Mode-2	transmit diversity
Mode-3	open loop codebook based pre-coding
Mode-4	closed loop codebook based pre-coding
Mode-5	Multiuser MIMO version of transmission mode-4
Mode-6	single layer special case of closed loop codebook based pre-coding, based on beamforming
Mode-7	release 8 non codebook based pre-coding supporting only single layer, based on beamforming
Mode-8	release 9 non codebook based pre-coding supporting upto 2 layers, based on beamforming
Mode-9	release 10 non codebook based pre-coding supporting upto 8 layers, based on beamforming

3GPP Transmission Modes R8

Mode 1

- Single antenna port; port 0
- 1 TX antenna transmitting always on port 0.

Mode 3

- Open loop spatial multiplexing.
- Multiple antennas transmitting different signals.
- No feedback from the UE used.
- Improves user data rate.

Mode 2

- Transmit diversity.
- Multiple antennas transmit same signal.
- Improves SINR.

- Mode 4

- Closed Loop spatial multiplexing.
- Multiple antennas transmitting different signals.
- Feedback from the UE used.
- Improves user data rate.

3GPP Transmission Modes R9

Mode 5

Multi user MIMO.
Multiple antennas transmitting to different UEs in the cell.
Increase sector capacity.

Mode 7

- Single Antenna port; port 5.
- Beamforming.
- UE specific reference signals are generated for feedback.

Mode 6

- Closed-loop Rank=1 precoding.
- Beamforming.
- UE signals back the suitable precoding for the beamforming operation.

Mode 8

2 Antenna ports; port 7 and 8.
Dual Stream Beamforming.
UE specific reference signals are generated for feedback.

3GPP Transmission Modes R10

Mode 9

- Release 10 Multi user and Single user MIMO
- Non-codebook based Beamforming
- 8 antenna ports
- Max 8 CSI-RS ports 15..22
- Max 8 DM-RS ports 7..14

O&M (Nokia) to 3GPP TM mode mapping

O&M Parameter: dlMimoMode (Nokia)	Corresponding Transmission Mode (3GPP)
SingleTX (0)	TM1: Single-antenna port; port 0
TXDiv (10)	TM2: Transmit Diversity
4 way TxDiv (11)	TM2: Transmit Diversity
Dynamic Open Loop MIMO (30)	TM3: OL spatial multiplexing TM2: Transmit diversity
Closed Loop MIMO (40)	TM4: CL spatial multiplexing TM6: CL Rank=1
Closed Loop MIMO 4x2 (41)	TM4: CL spatial multiplexing TM6: CL Rank=1
Closed loop MIMO 4x4 (43)	TM4: CL spatial multiplexing Cat 5/8 TM9: CL spatial multiplexing Cat 6/7 R10+
TDD only	
Closed Loop MIMO 8x2 (42)	TM4: CL spatial multiplexing TM6: CL Rank=1
Closed Loop MIMO 8x4 (44)	TM4: CL spatial multiplexing Cat 5/8 TM9: CL spatial multiplexing Cat 6/7 R10+
Single Stream Beamforming (50)	TM7: beamforming, single antenna port 5
Dual Stream Beamforming (60)	TM8: beamforming, port 7 and/or port 8

LNCEL_FDD: dlMimoMode;

Downlink MIMO mode;

SingleTX (0), TXDiv (10), 4-way TXDiv (11), Dynamic Open Loop MIMO (30), Closed Loop Mimo (40), Closed Loop MIMO (4x2) (41), Closed Loop MIMO (4x4) (43);

Default: TXDiv (10)

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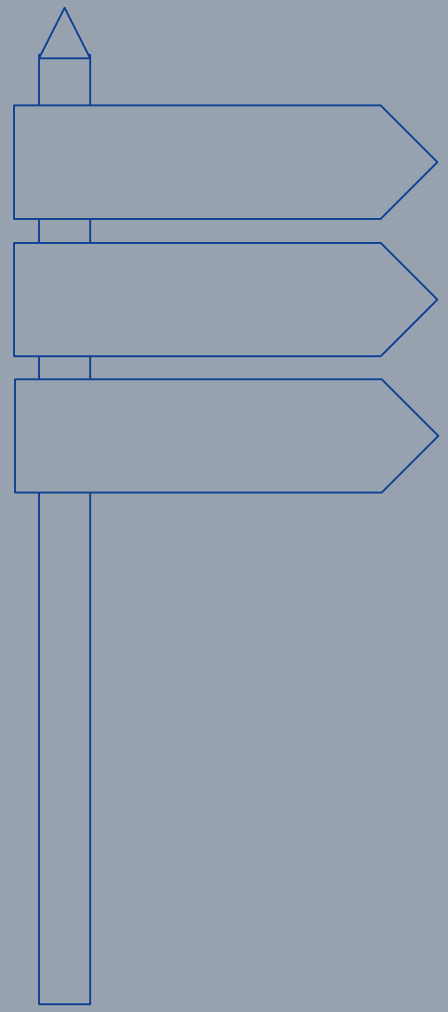

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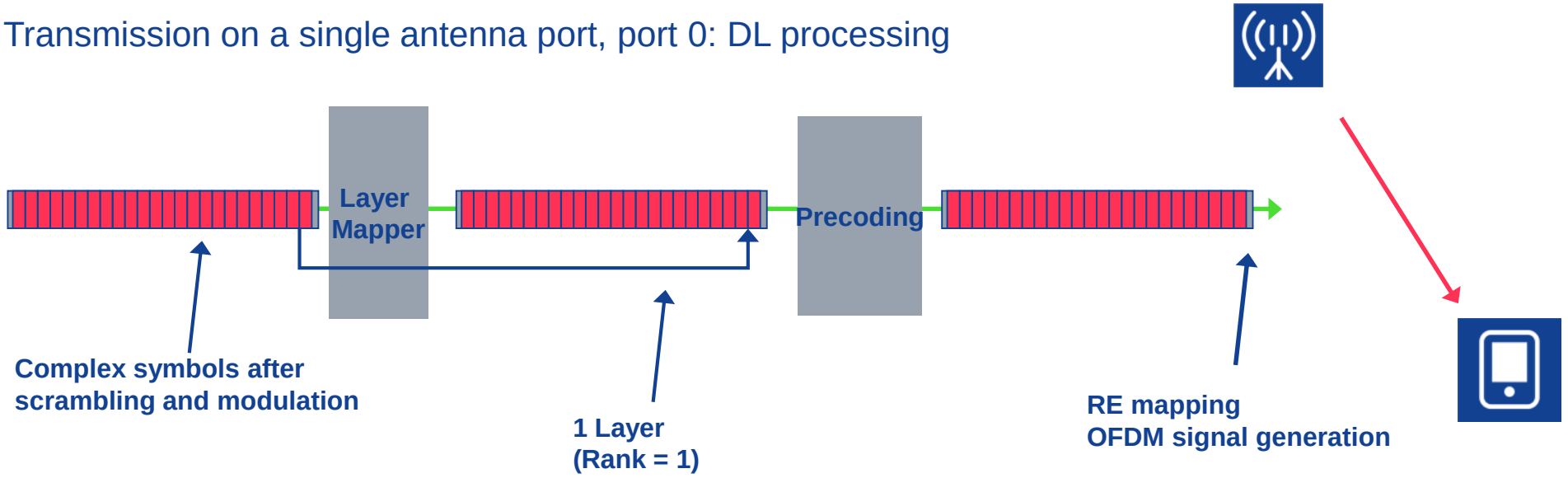
Single antenna port transmission

- 1x1 SISO or 1x2 SIMO
- Supported: DL and UL
- Flexi eNB supports 2-branch RX diversity (future: 4-branch)
  - SINR enhanced
  - Based on Maximum Ratio Combining (MRC)
  - Additional gain from MRC: up to 6 dB (10% BLER, depending on conditions)
  - Requires: uncorrelated antennas, x-polarized or d > 10 x wavelength

dlMimoMode
SingleTX (0)

Transmission on a single antenna port, port 0: DL processing



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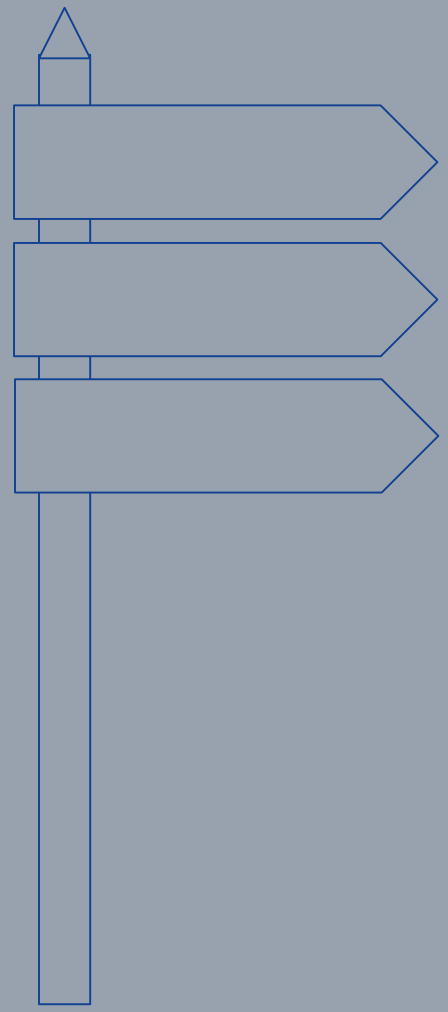

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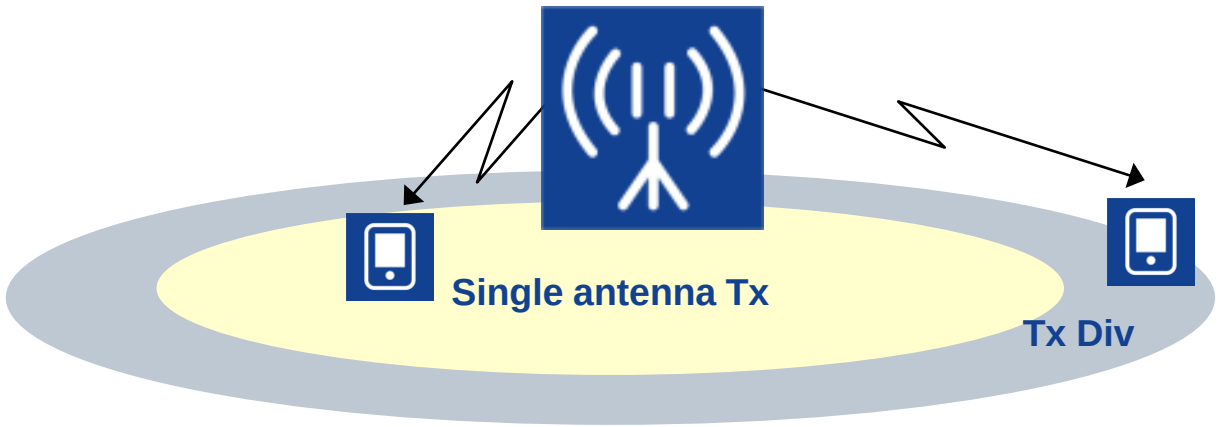
Transmit Diversity

dlMimoMode
TXDiv (10)

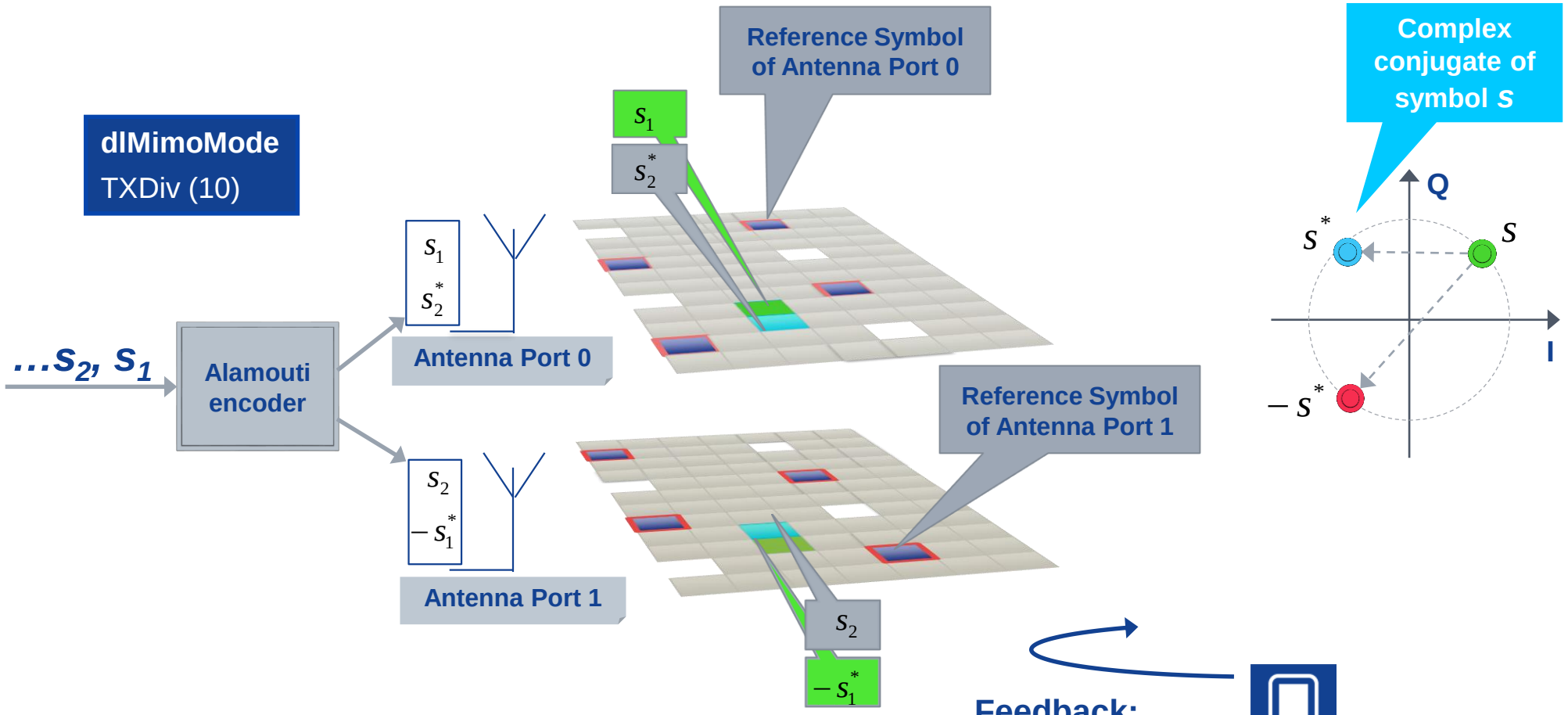
- **2x2 and 4x2 based** on **Space Frequency Block Coding (SFBC)**
- Supported on DL
- Increases robustness, enhances cell edge performance
- **Link budget gain of 3 dB** with 1x2 case (Tx power per Tx branch as in single antenna case)
- → capacity and coverage enhancements
- Rank 1 transmission, i.e. **no multiplication of data rates**
- aka Alamouti scheme

Coverage improvement example:

- **592 m → 808 m (dense urban)**
- **694 m → 948 m (urban)**
- **2024 m → 2970 m (suburban)**
- **7665 m → 11248 m (rural)**

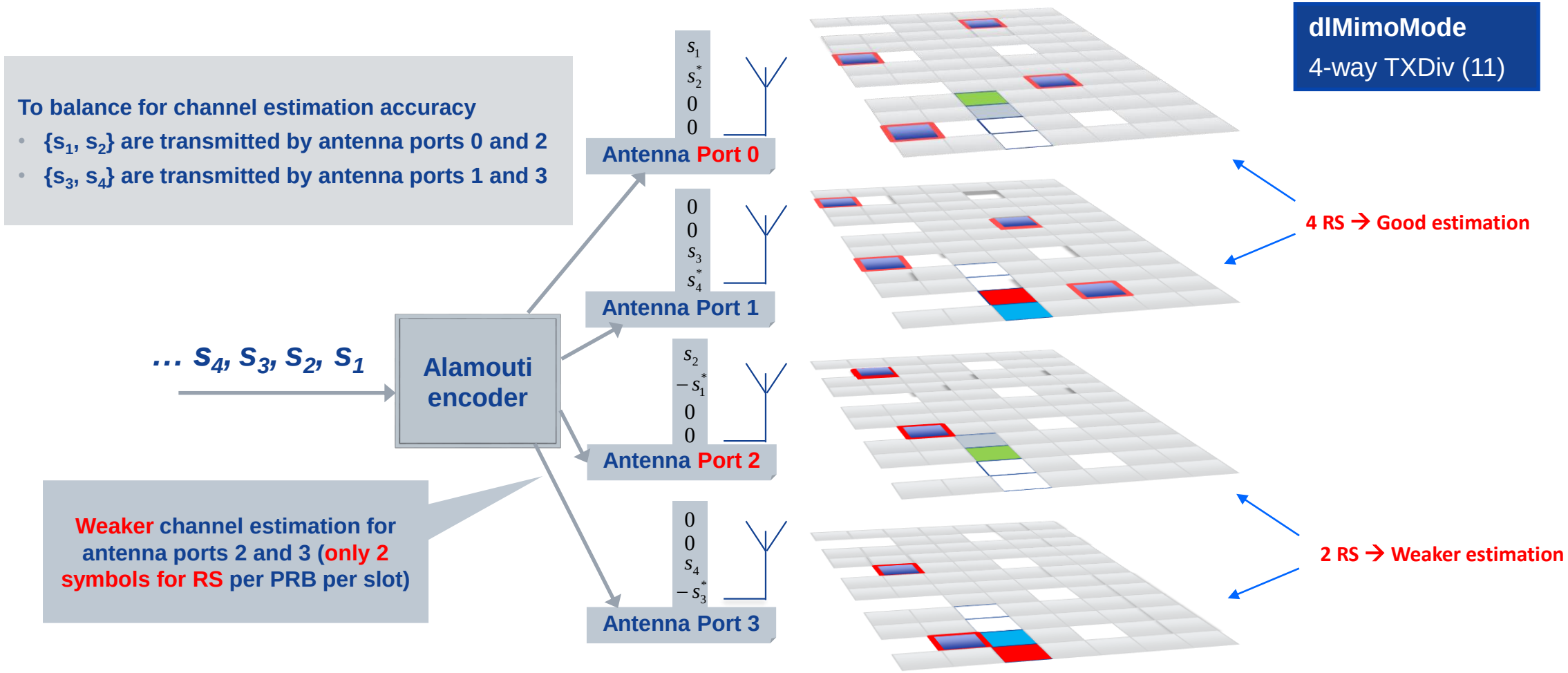


Transmit Diversity for 2 Antennas



Transmit Diversity for 4 Antennas

For 4 Tx ant, TX diversity uses combination of space frequency block coding SFBC and frequency switched transmit diversity FSTD



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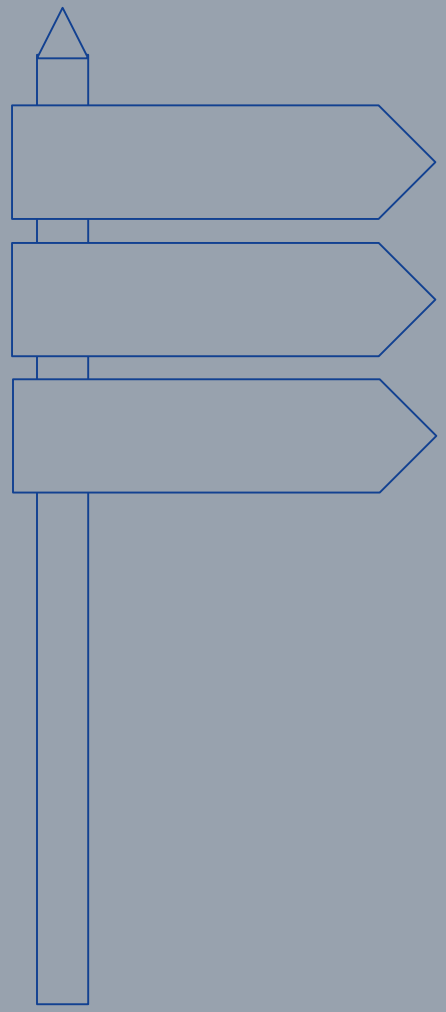

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OL Spatial Multiplexing

- **Rank 2 transmission → throughput enhancements**
- 2 code words
- Precoding based on large delay CDD: **W D U**
- code book (**no PMI feedback**, i.e. open loop):

→ default precoding matrix

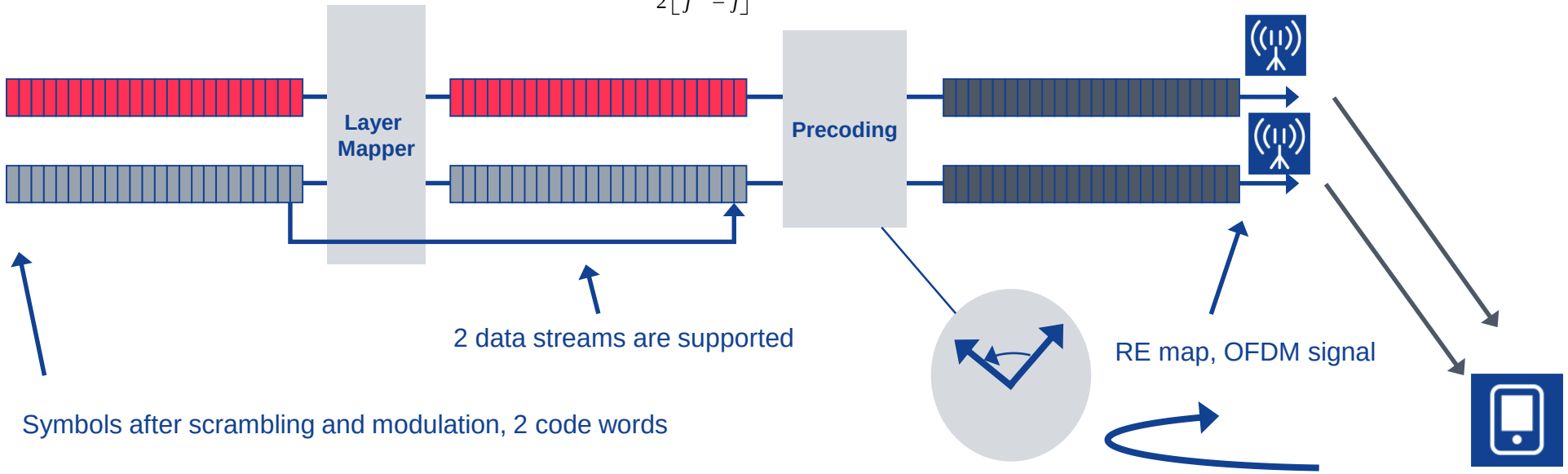
Overall precoding is given by:
W´= WxP with **P =UxD**

dlMimoMode
Dynamic Open Loop MIMO (30)

$$W: \quad \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix} \quad \frac{1}{2}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix} \quad \frac{1}{2}\begin{bmatrix}1 & 1\\ j & -j\end{bmatrix}$$

$$D: \quad \begin{bmatrix}1 & 0\\ 0 & e^{-j2\pi/2}\end{bmatrix}$$

$$U: \quad \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\ 1 & e^{-j2\pi/2}\end{bmatrix}$$



Feedback:
- **CQI**
- **RI**

*CDD = Cyclic Delay Diversity = delay of signal between antennas

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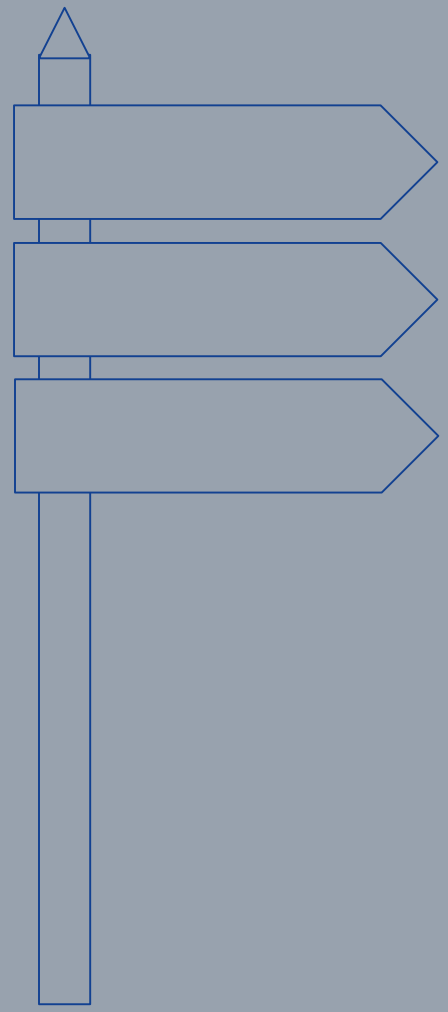

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Closed Loop Spatial Multiplexing – Single Stream

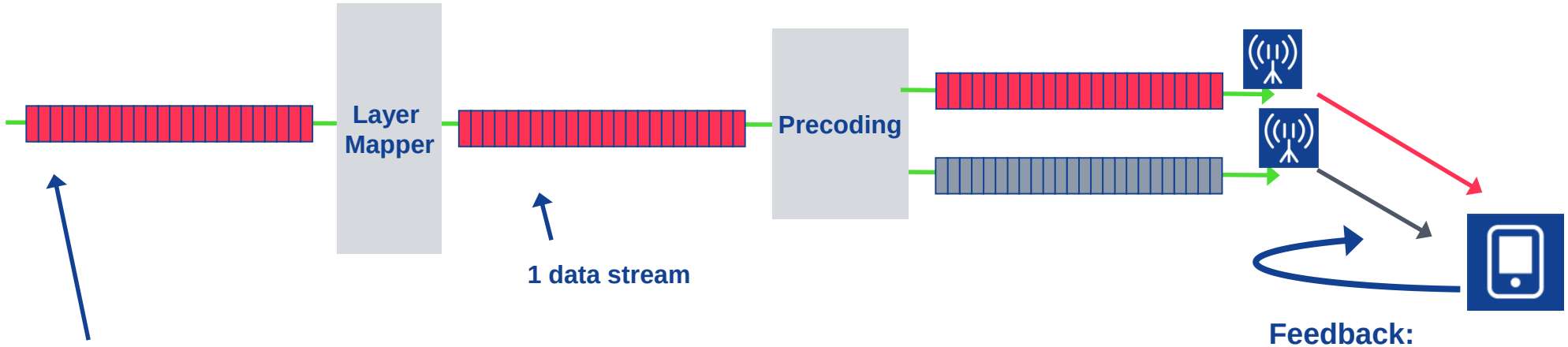
closed loop **rank 1 with precoding**

- → 1 code word
- Precoding without CDD: matrix **W**
- code book based → precoding matrix
- no code book restriction
- **UE feedback: precoding matrix indicator (PMI)**

W

$$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix} \quad \frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix} \quad \frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix} \quad \frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$$

dlMimoMode
Closed Loop Mimo (40)



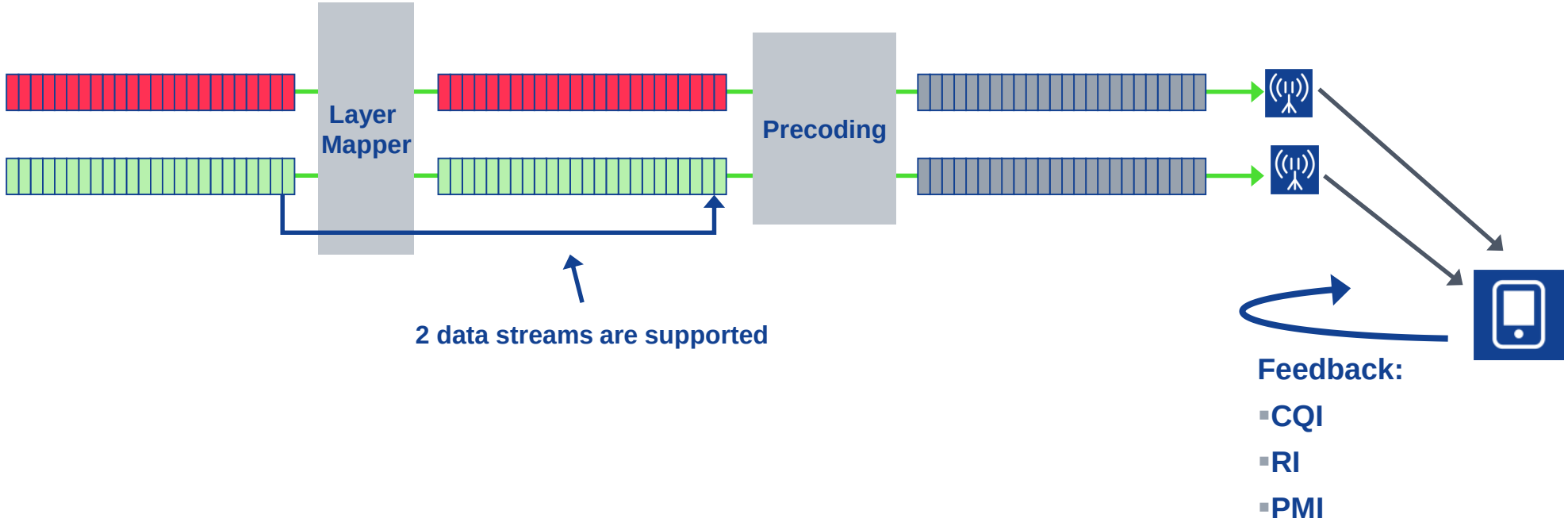
Closed Loop Spatial Multiplexing – Dual Stream

Rank 2 transmission → throughput enhancements

- 2 code words
- Precoding without CDD
- code book based → precoding matrix
- UE feedback: precoding matrix indicator (PMI)

dlMimoMode
Closed Loop Mimo (40)

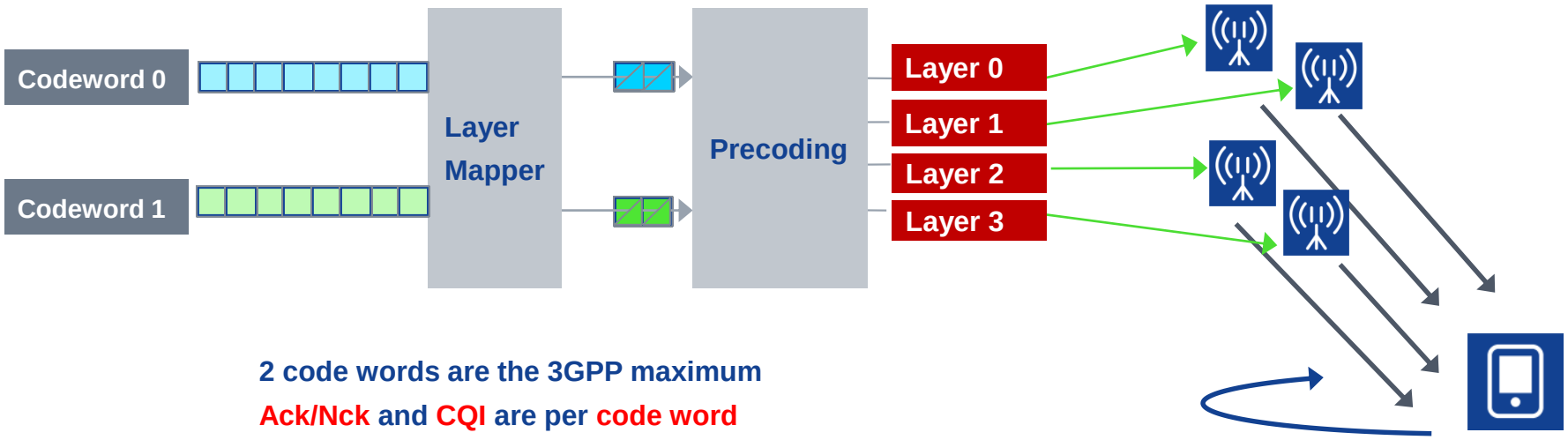
$$W \left\{ \frac{1}{2}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}, \frac{1}{2}\begin{bmatrix} 1 & 1 \\ j & -j \end{bmatrix} \right.$$



Closed Loop Spatial Multiplexing – Dual Stream 4x2

- 2 codewords only TM4
- Precoding without CDD
- Code book based **16 index** values as per 3GPP 36.211 R9, precoding matrix **W**
- **UE feedback: precoding matrix indicator (PMI)**

dlMimoMode
Closed Loop MIMO (4x2) (41)



2 code words are the 3GPP maximum
Ack/Nck and CQI are per code word
2 CW gives an optimum overhead.

Feedback:
- **CQI**
- **RI**
- **PMI**

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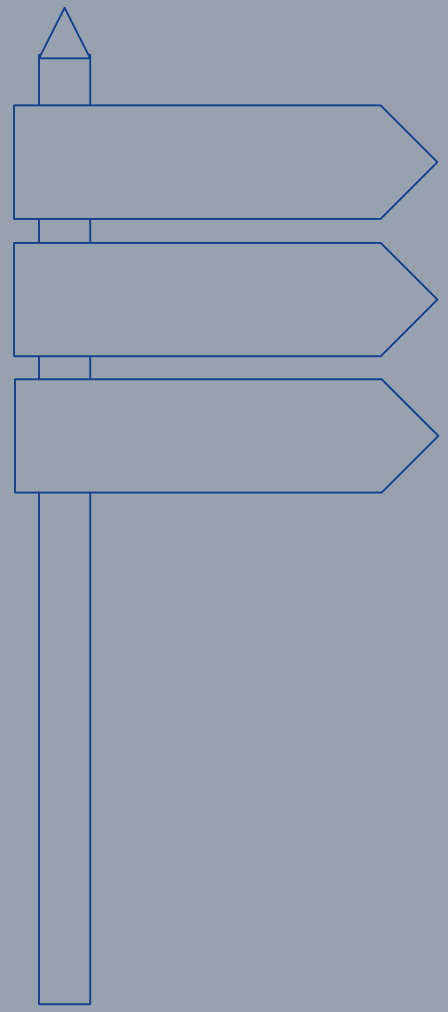

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Dynamic Open Loop Spatial Multiplexing

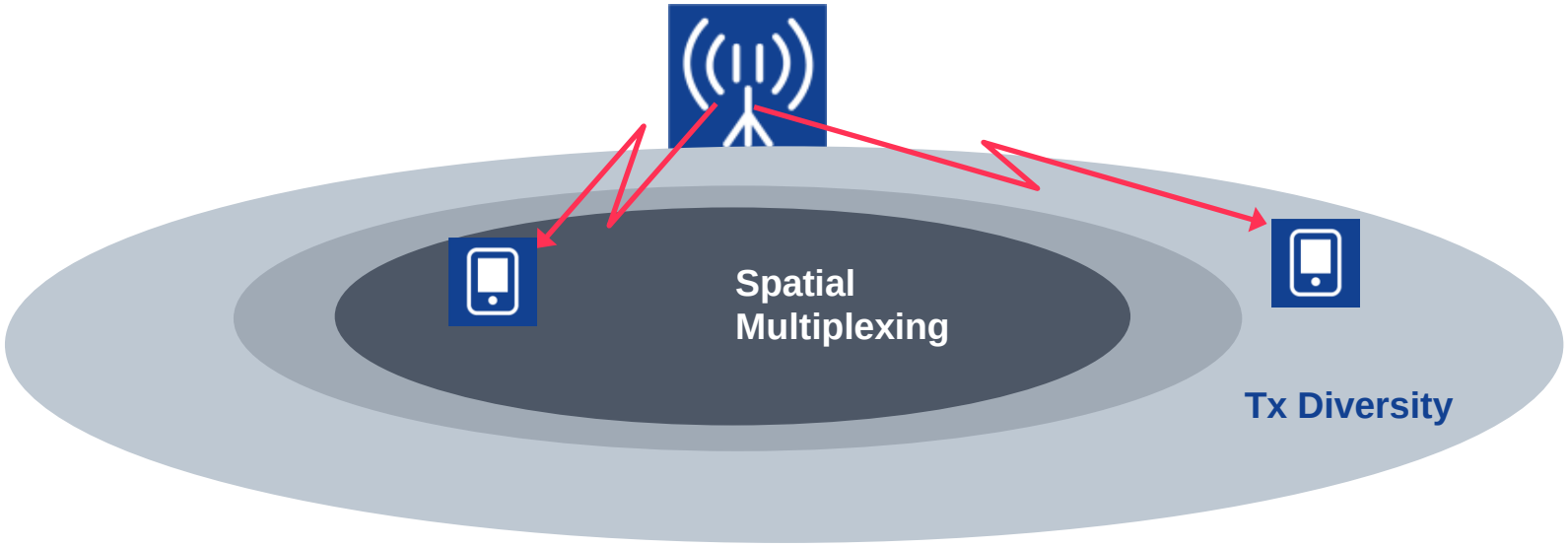
Depending on Radio Conditions:

Switch between Transmit Diversity and Spatial Multiplexing

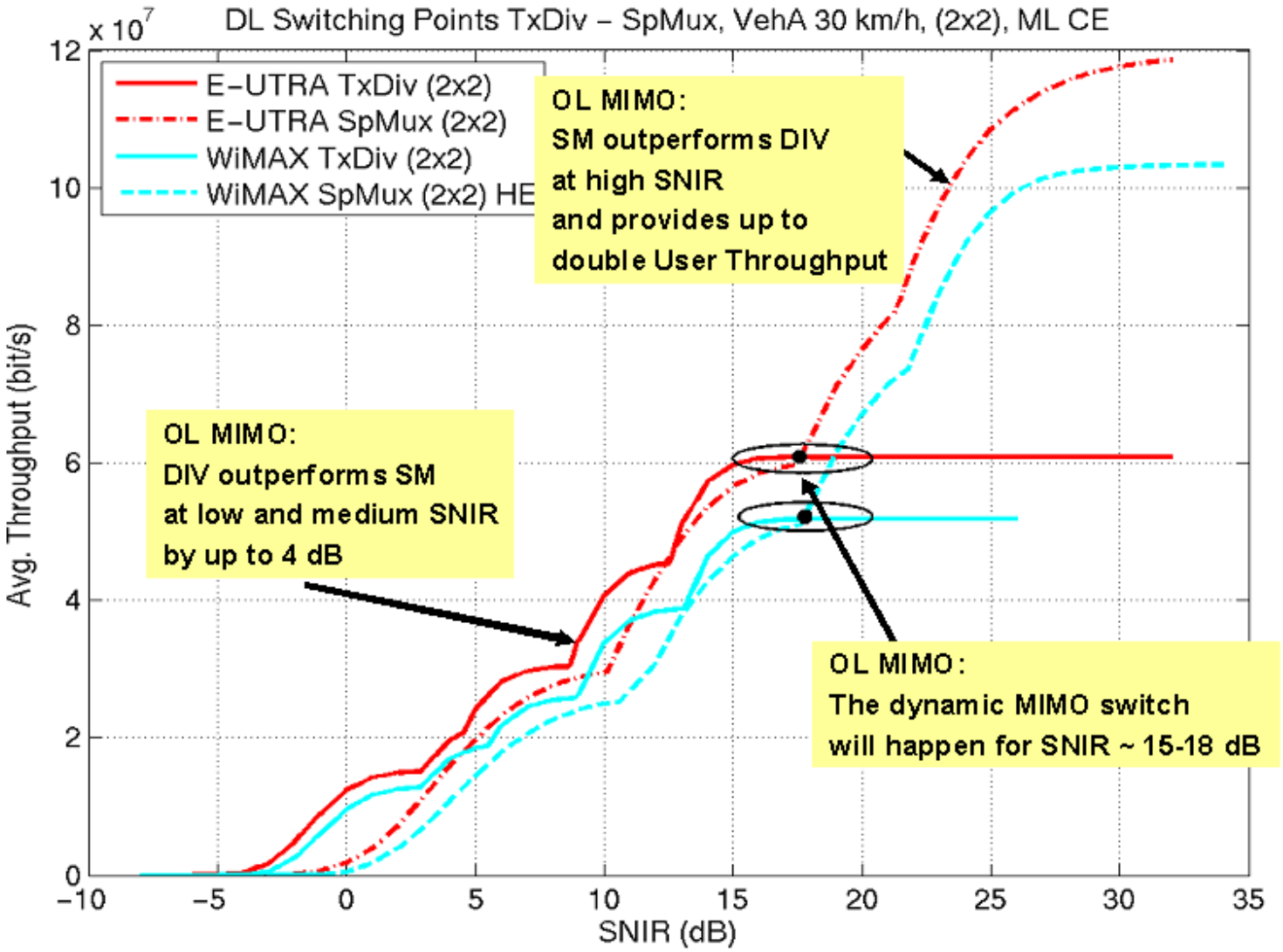
- Open loop adaptive MIMO Switch Algorithm
- Support of UE Capabilities
- Per UE basis
- CQI and Rank Information: used as switching criteria

dlMimoMode

Dynamic Open Loop MIMO (30)



Dynamic Open Loop Spatial Multiplexing



Simulation Results (Source 4GMAX)

Dynamic Open Loop Spatial Multiplexing

Various parameters support adaptive switching between 1-stream Transmit Diversity and 2-stream Spatial Multiplexing:

- **mimoOlCqiThD** - This defines the CQI Threshold for fallback to Open Loop MIMO diversity (in CQI).
- **mimoOlCqiThU** - This defines the CQI Threshold for activation of Open Loop MIMO Spatial Multiplexing (in CQI).
- **mimoOlRiThD** - This defines the Rank Threshold for fallback to Open Loop MIMO diversity.
- **mimoOlRiThU** - This defines the Rank Threshold for activation of Open Loop MIMO Spatial Multiplexing.

Downgrade Switch

If

mimoCQI <= mimoDivCqiThDownOL

OR

mimoRANK <= mimoDivRiThDownOL

Upgrade Switch

If

mimoCQI > mimoSmCqiThUpOL

AND

mimoRANK > mimoSmRiThUpOL

LNCEL/LNCEL_FDD: mimoOlCqiThD;

CQI threshold for fallback to MIMO diversity;

0...16, step 0.1;

Default: 7

LNCEL/LNCEL_FDD: mimoOlCqiThU;

CQI threshold for activation of OL MIMO SM;

0...16, step 0.1;

Default: 8

LNCEL/LNCEL_FDD: mimoOlRiThD;

Rank threshold for fallback to MIMO diversity;

1...2, step 0.05;

Default: 1.4

LNCEL/LNCEL_FDD: mimoOlRiThU;

Rank threshold for activation of OL MIMO SM;

1...2, step 0.05;

Default: 1.6

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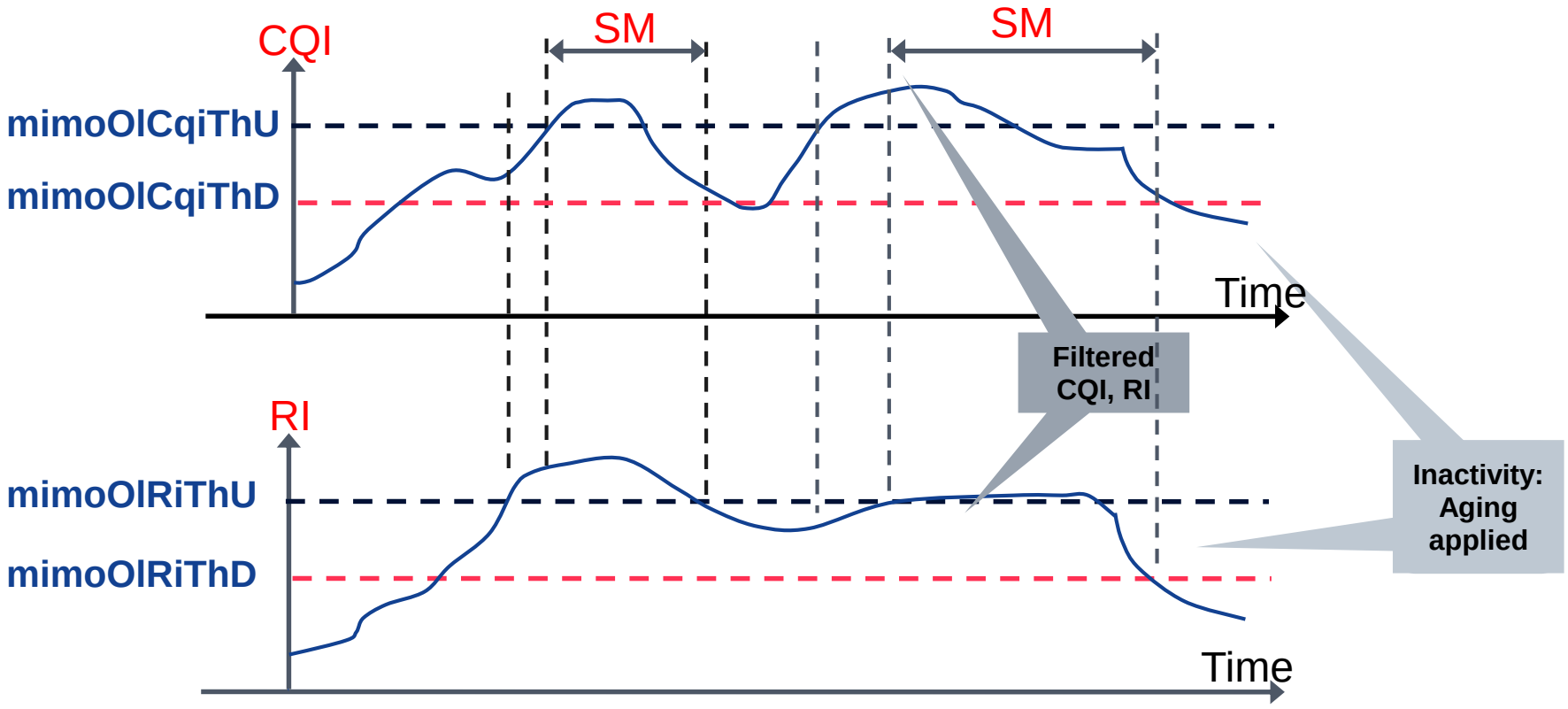
Dynamic Open Loop Spatial Multiplexing



SM = Spatial Multiplexing

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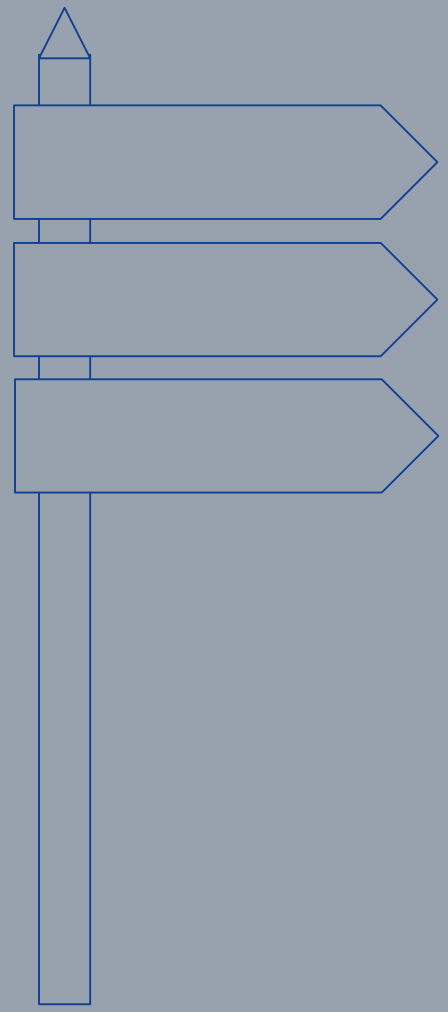

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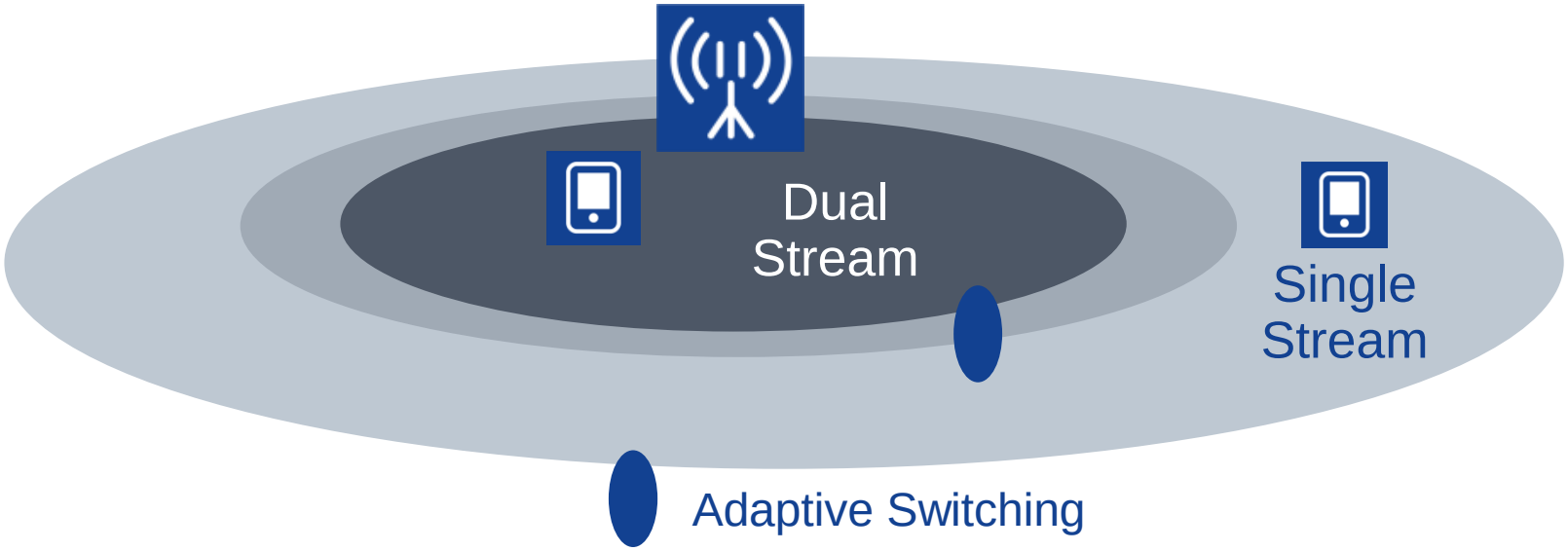
Closed Loop Spatial Multiplexing – Adaptive Switch

- Feature LTE703 defines the use of Adaptive Closed Loop (CL) MIMO.
- The eNB scheduler selects Spatial Multiplexing dynamically while applying closed loop MIMO for two antennas.
- The adaptive algorithm provides the gain of high peak rates (dual stream) when close to the cell and good cell edge performance (single stream).
- Spatial multiplexing is applied only for the PDSCH.



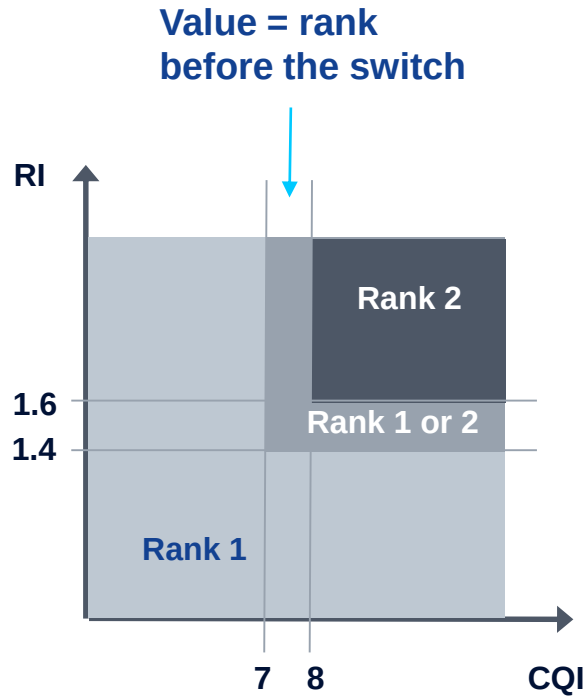
Closed Loop Spatial Multiplexing – Legacy Switch

Various parameters are added to support adaptive switching between **CL MIMO 1 CW Mode** and **CL MIMO 2 CW Mode:**

Can be used with CL 4x2 MIMO

- **mimoClCqiThD** - This defines the CQI Threshold for fallback to closed loop MIMO single codeword transmission (in CQI).
- **mimoClCqiThU** - This defines the CQI Threshold for activation of closed loop MIMO dual codeword transmission (in CQI).
- **mimoClRiThD** - This defines the Rank Threshold for fallback to closed loop MIMO single codeword transmission.
- **mimoClRiThU** - This defines the Rank Threshold for activation of closed loop MIMO dual codeword transmission.

Legacy switch today seldom used in practise



LNCEL/LNCEL_FDD: mimoClCqiThD;

CQI threshold for fallback to CL MIMO 1CW mode;

0...16, step 0.1;

Default: 7

LNCEL/LNCEL_FDD: mimoClCqiThU;

CQI threshold for activation of CL MIMO 2 CW mode;

0...16, step 0.1;

Default: 8

LNCEL/LNCEL_FDD: mimoClRiThD;

Rank threshold for fallback to CL MIMO 1CW mode;

1...2, step 0.05;

Default: 1.4

LNCEL/LNCEL_FDD: mimoClRiThU;

Rank threshold for activation of CL MIMO 2 CW mode;

1...2, step 0.05;

Default: 1.6

Closed Loop Spatial Multiplexing – Fast Switch

"Fast Adaptive MIMO Switching" MIMO Mode Control algorithm is introduced with 4x2 MIMO, but can be used with 2x2 MIMO

eNB will **not override** UE requests regarding the used number of code words and PMI

No filtering /averaging on RI

If no valid CSI report - fallback to Tx diversity

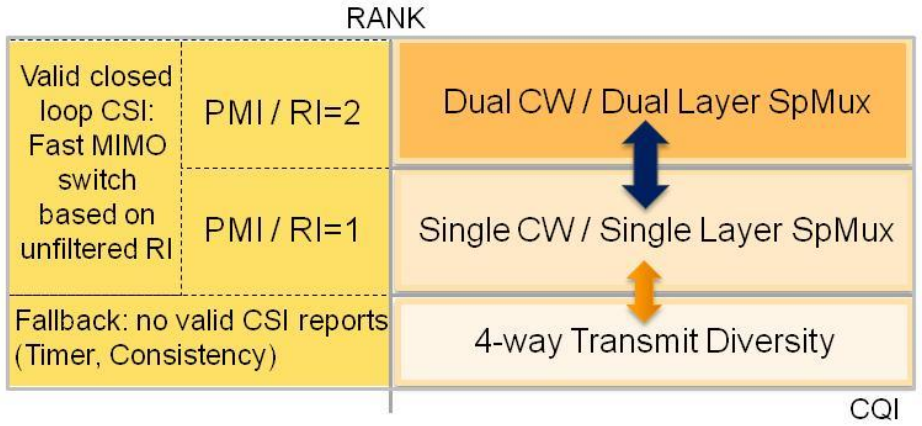
Quick adaptation of MIMO mode used to the reported conditions

Fast switching = CW2 – CW1 – Txdiv

Dynamic switching = CW2 – CW1

Fast switch nowadays much more frequently used than legacy switch

LNCEL/LNCEL_FDD: actFastTmSwitch;
Activate fast adaptive MIMO switch
true, false;
Default: false



- ***For Fast MIMO Switching***, following configuration is needed:
  - **LNCEL-*actFastMimoSwitch = true***
  - **LNCEL-*riPerM*** must be set to **'1'**
  - **LNCEL-*riPerOffset*** must be configured to **'-1'**

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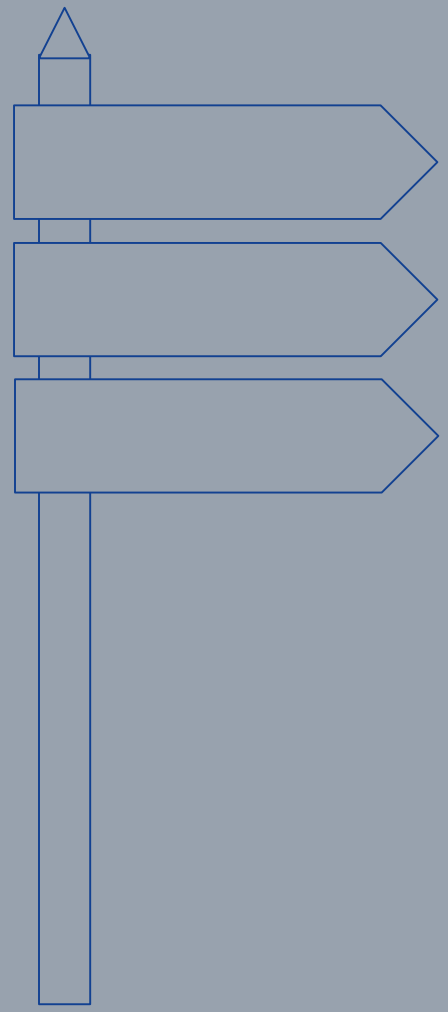

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- **DL Single User MIMO 4x4**

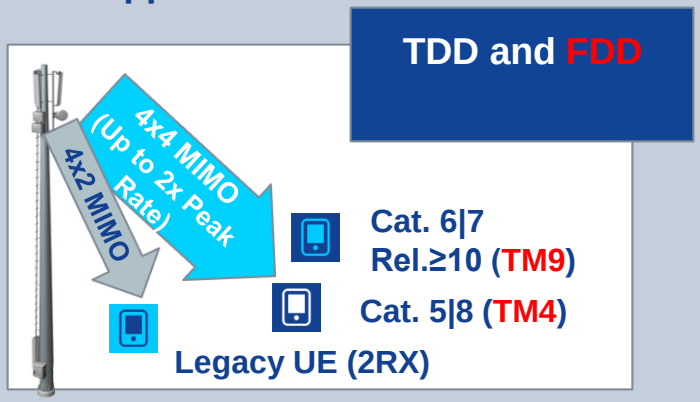
LTE1987: DL Single User MIMO 4x4

LTE568 & LTE569

- LTE568 supports MIMO 4x2 with TM4 for all Release 8 Cat ≥ 2 UEs, TDD and FDD
- LTE569 supports MIMO 4x4 with TM4 for all Cat.5 and Cat.8 UEs, only in TDD

LTE1987

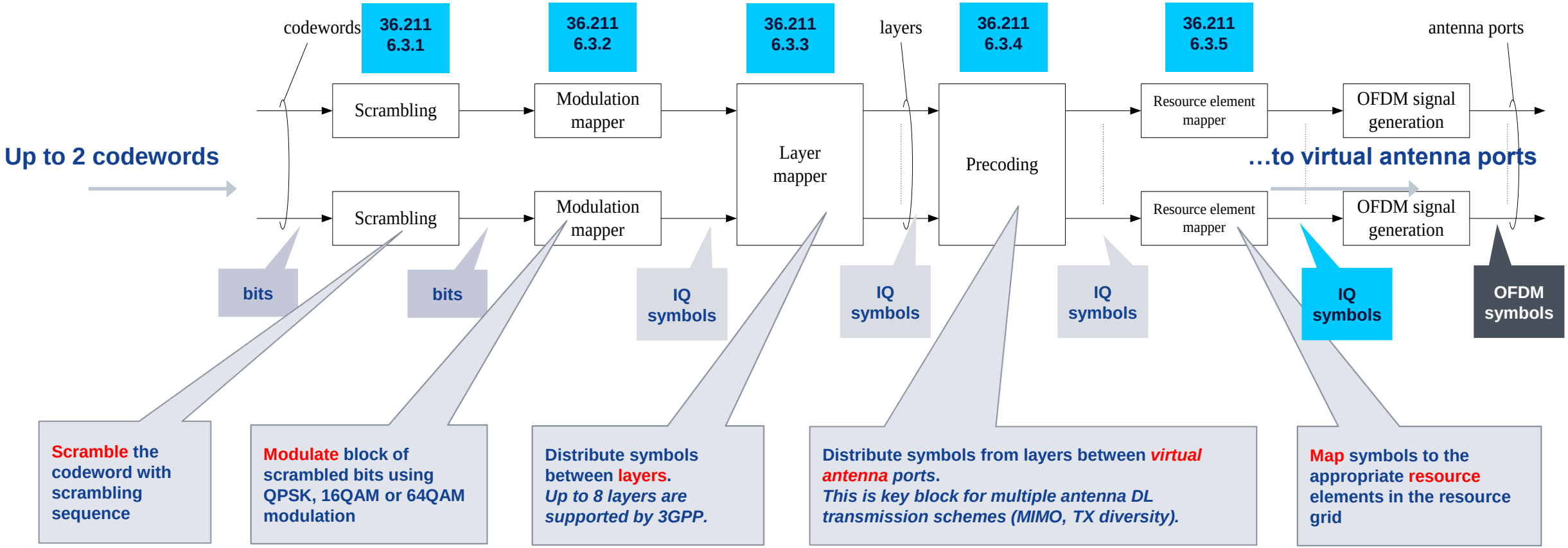
- MIMO 4x4 with TM9 for Release ≥ 10, Cat.6 and Cat.7 is supported
- MIMO 4x4 with TM4 for all Cat. 5 and Cat.8 UEs is supported



LTE1987: DL Single User MIMO 4x4

Physical Channel Processing

- Before bits in DL go on air, they are processed in a way specified in 3GPP TS 36.211
- Processing takes place in baseband
- Besides obvious tasks, like fitting stream of bits into the physical resource grids, scheme allows to host various transmission modes (MIMO among others)



LTE1987: DL Single User MIMO 4x4

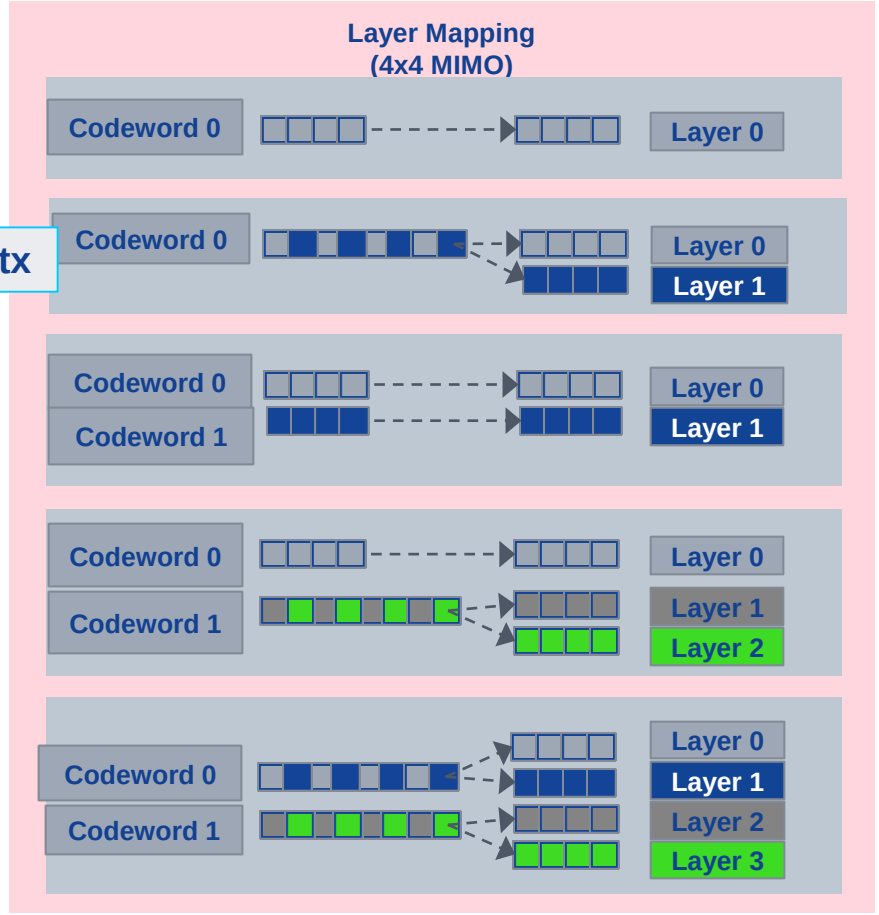
Layer mapping

Number of codeword and layers depends on UE feedback

- **The mapping of a one codeword to two layers is only applicable for the retransmission of a transport block if that transport block has previously been transmitted using 2 layers.**

- **Number of layers determines, how many unique symbols will go on air at the same time**

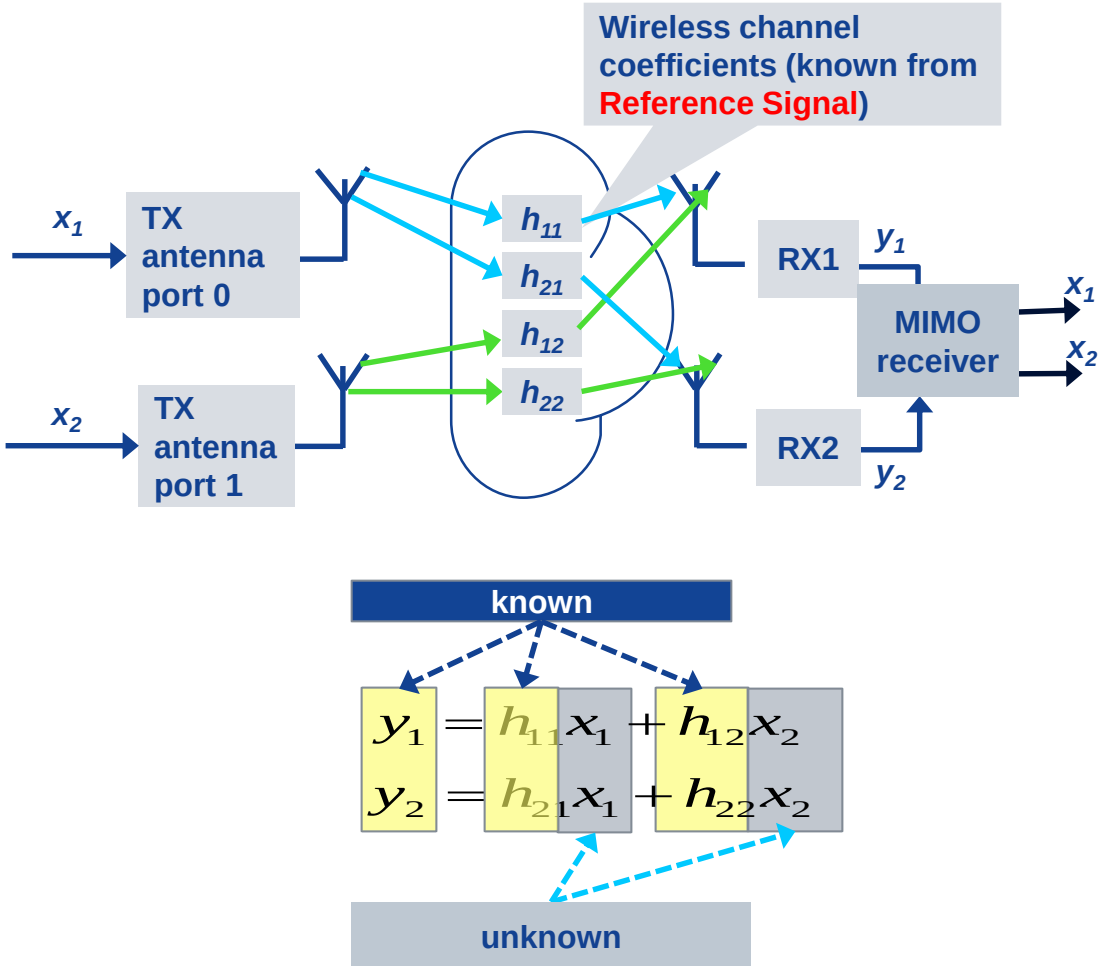
# spatial multiplexing layers	Max TBS
1	75376
2	149776
3	226416
4	299856



LTE1987: DL Single User MIMO 4x4

MIMO 2x2 Principle

- Different symbols are sent by transmit antennas in the same time and frequency
- As symbols propagate over the wireless channel, their phase and amplitude changes according to the channel coefficient (complex value)
- Channel between each pair of the TX and RX antennas is different due to different propagation conditions
- Receiver needs only to solve a set of equations. Channel coefficients are known from pilots (Reference Signals), so the only unknown is the transmitted symbols
- The set will have a solution if the equations are linearly independent. This is best assured by propagation environment rich in multipath (propagation is really different between the antenna pairs)



LTE1987: DL Single User MIMO 4x4

MIMO 4x2 Principle

In case of 4x2 MIMO there are 4 TX antennas at the eNB, but still only 2 RX antennas in the UE.

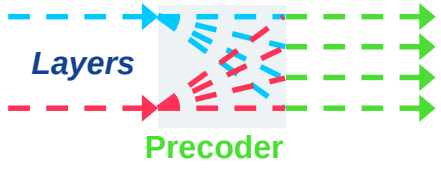
2 equations, 4 unknowns: impossible to solve…

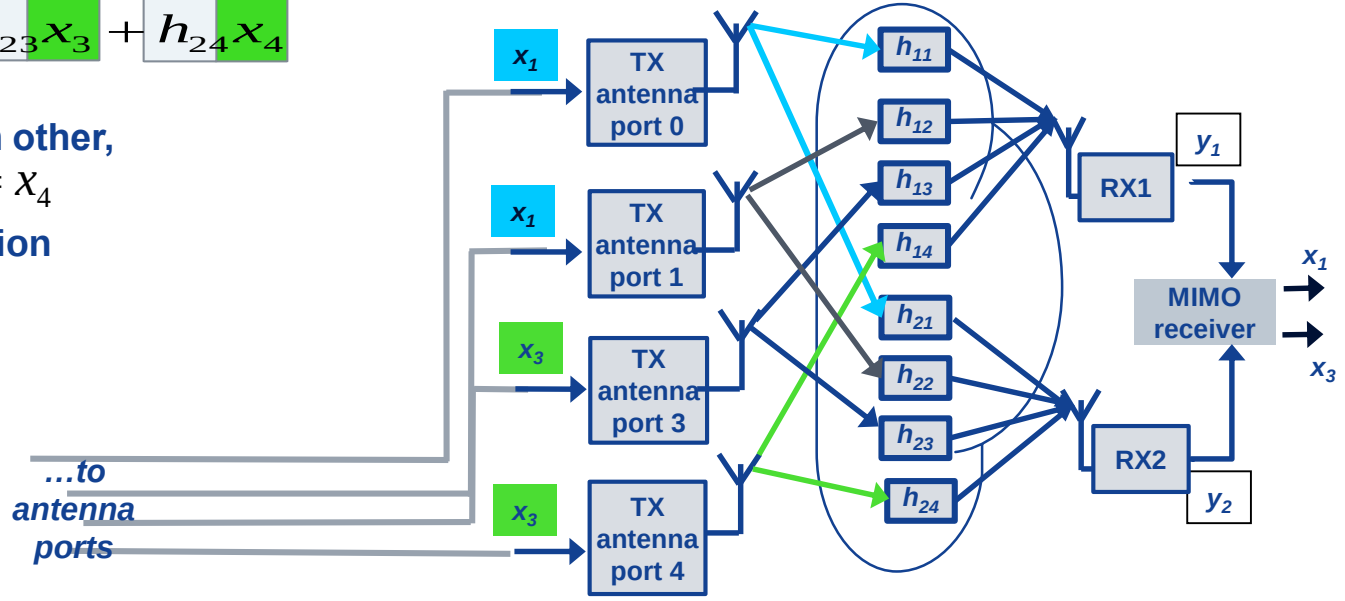
$$y_1 = h_{11}x_1 + h_{12}x_2 + h_{13}x_3 + h_{14}x_4$$
$$y_2 = h_{21}x_1 + h_{22}x_2 + h_{23}x_3 + h_{24}x_4$$

…unless the x's are made dependent of each other, for example: $x_1 = x_2;\ \ x_3 = x_4$

Then we have only 2 unknowns, MIMO equation becomes possible to solve.

That essentially is what the pre-coder does - combining symbols from layers:





- 1st conclusion: 4x2 MIMO can only support up to 2 streams
- 2nd conclusion: the more TX antenna ports, the more combinations of streams can be made by precoder

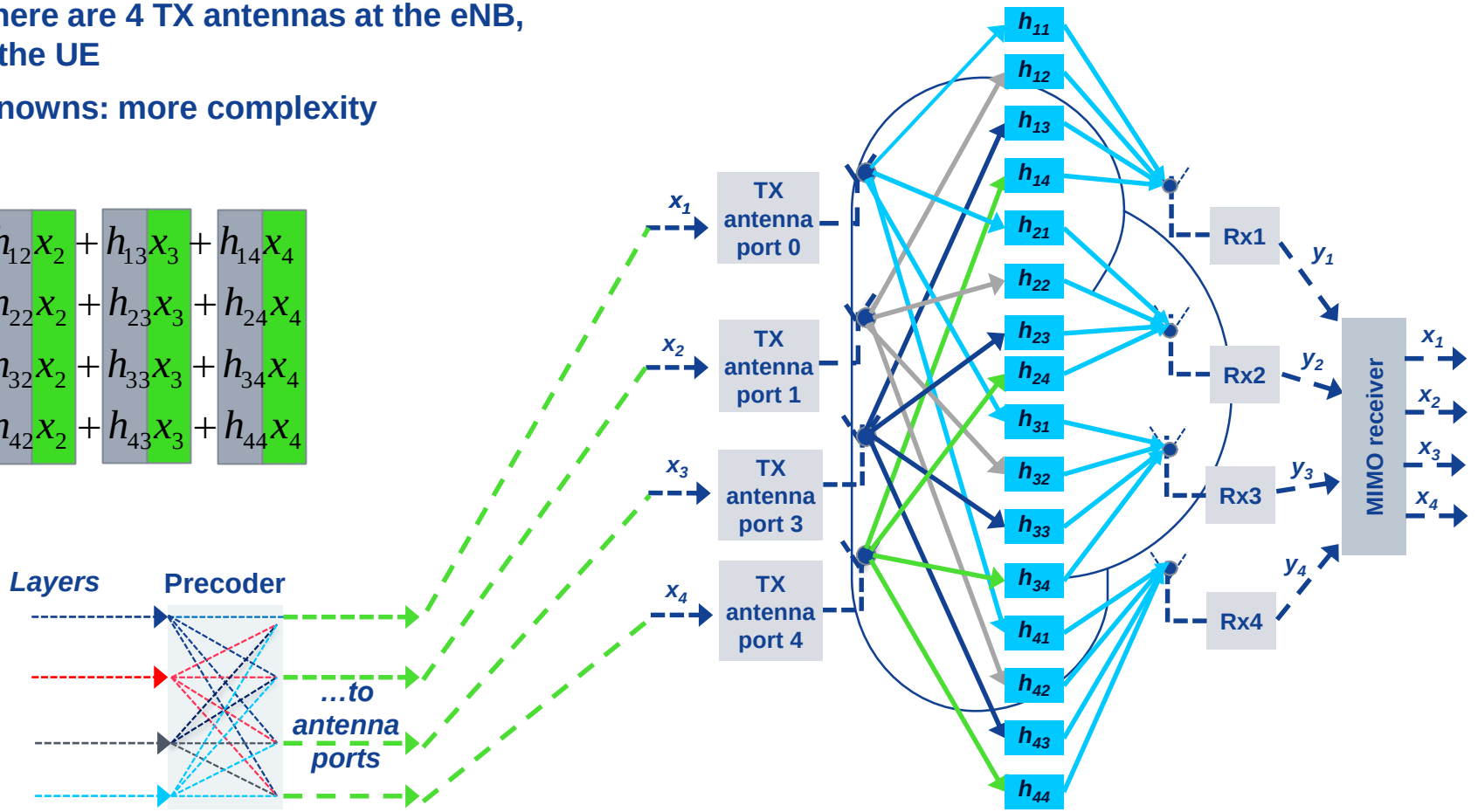
LTE1987: DL Single User MIMO 4x4

MIMO 4x4 Principle

In case of 4x4 MIMO there are 4 TX antennas at the eNB, and 4 RX antennas in the UE

- **4 equations, 4 unknowns: more complexity needed in the UE**

$$
\begin{aligned}
y_1 &= h_{11}x_1 + h_{12}x_2 + h_{13}x_3 + h_{14}x_4 \\
y_2 &= h_{21}x_1 + h_{22}x_2 + h_{23}x_3 + h_{24}x_4 \\
y_3 &= h_{31}x_1 + h_{32}x_2 + h_{33}x_3 + h_{34}x_4 \\
y_4 &= h_{41}x_1 + h_{42}x_2 + h_{43}x_3 + h_{44}x_4
\end{aligned}
$$



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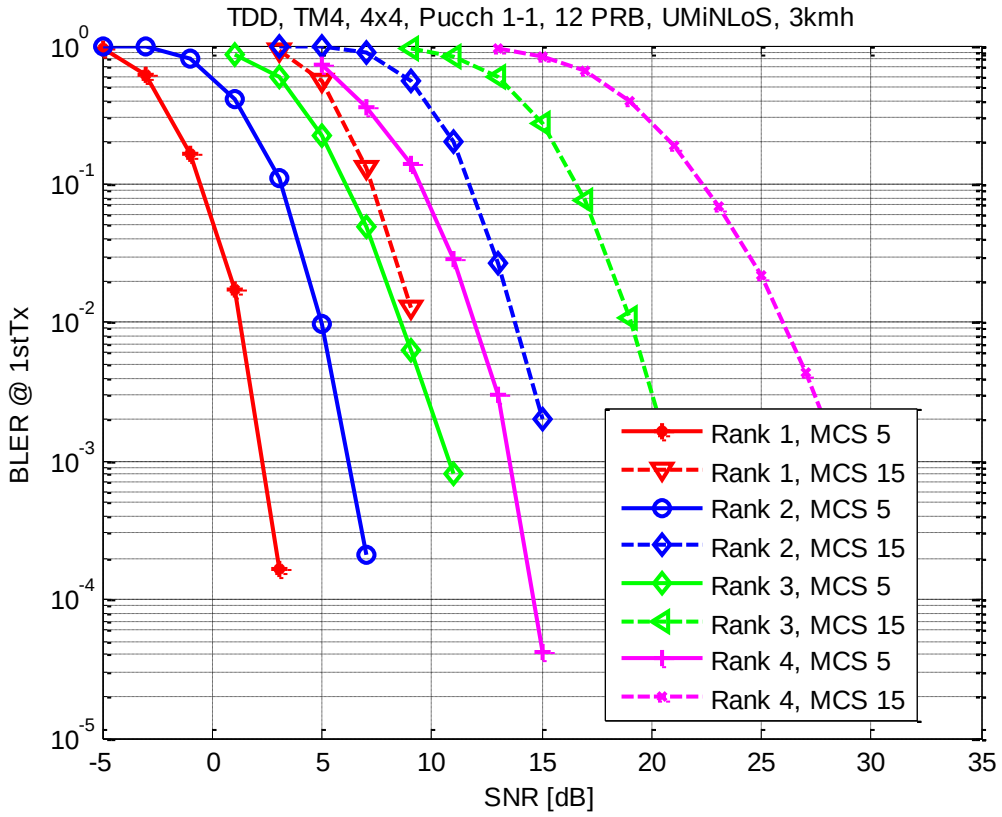
LTE1987: DL Single User MIMO 4x4

Motivation

- Significantly higher SINR requirement for rank 4 transmission
- 4x4 MIMO needs ~11dB higher target than rank 2 with same MCS15. Difference is even bigger with higher MCSs.
- On the other hand rank 2 needs only ~4dB more than rank 1
- Reason is, more streams create more inter-stream interference and it becomes even more difficult to separate them
- In effect, peak rates with 4x4 MIMO possible only very close to eNB antenna, where achieving high SINR is possible.



LTE1987: DL Single User MIMO 4x4

UE types and related UE capabilities

Category	Rel.8,9	Rel.≥ 10	
Cat. 2-4	4x2 –TM4	4x2 – TM4	Cat.1 supports single layer transmissions only
Cat. 5	4x2 – TM4 4x4 – TM4	4x2 – TM4 4x4 – TM4 4x4 – TM4/TM9	Cat.5 UEs support up to 4 layers based on Rel.8 UE-capability. In addition Cat.5 UE based on Rel.10 may support TM9 with up to 4 layers (see 3GPP TS 36.306) if 4 layers are defined based on 'supportedMIMO-CapabilityDL-r10' for respective band combination
Cat. 6/7	n.a.	4x2 – TM4 4x2 – TM9 4x4 – TM9	The standard defines that a Rel.10 category 6/7 UE is mapped to Rel.8,9 category 4 for TM4 leading to a maximum of 2 layers (see 36.306, 4.1). 4 layers may be supported by 'supportedMIMO-CapabilityDL-r10' for respective band combinations for TM9.
Cat. 8	n.a.	4x2 – TM4 4x4 – TM4 4x2 – TM9 4x4 – TM9	The standard defines that a Rel.10 category 8 UE is mapped to Rel.8,9 category 5 for TM4 leading to a maximum of 4 layers

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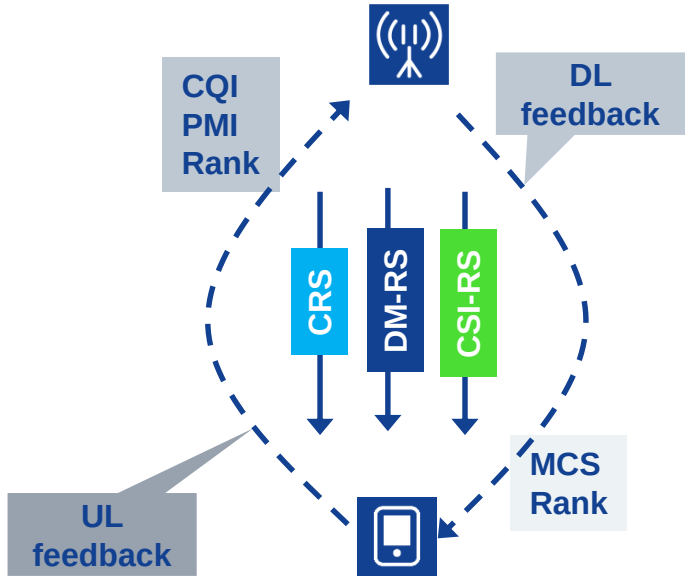
Transmission mode 9

LTE1987 uses Transmission Mode 9 as additional transmission mode based on the following functionality

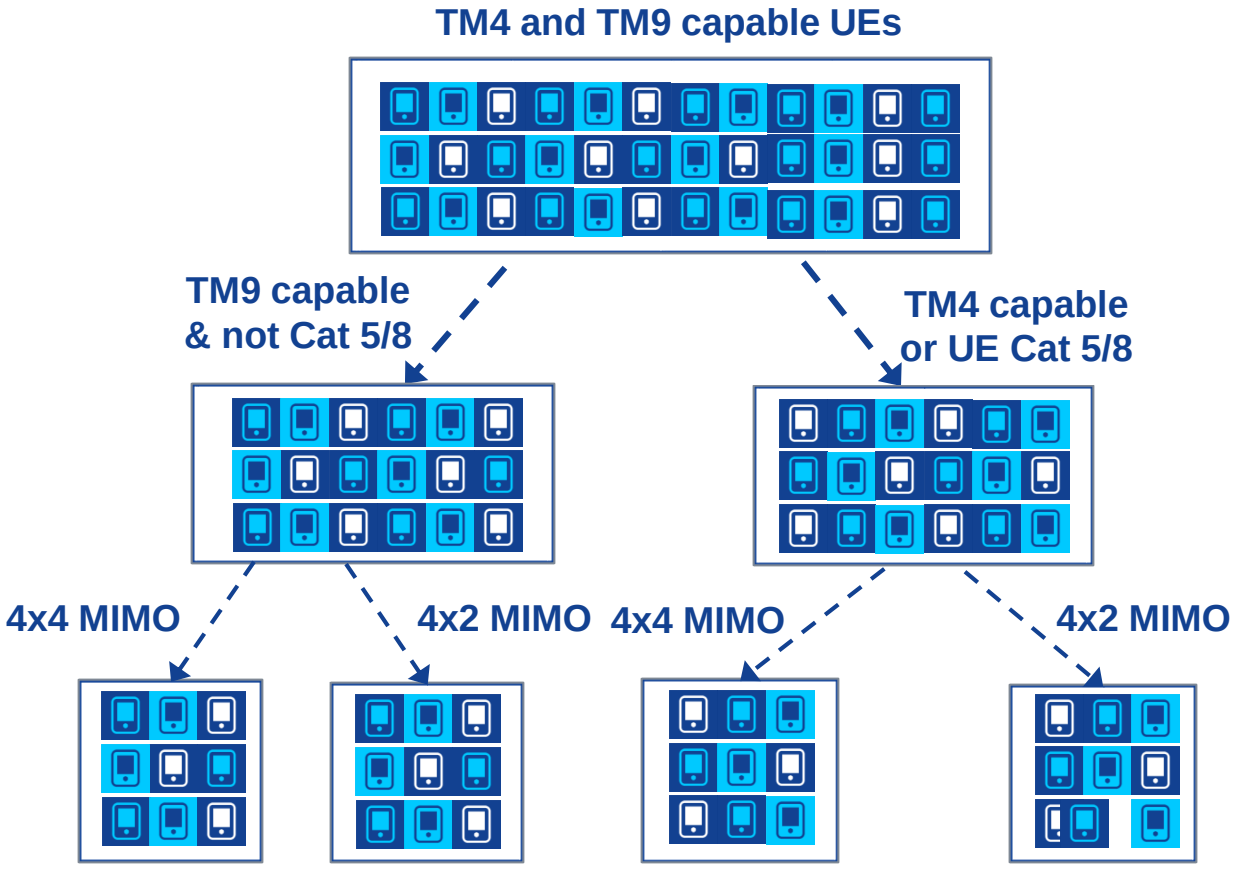
- Closed Loop MIMO feedback in terms of CQI (Channel Quality Indicator), RI (Rank Indicator) and PMI (Precoding Matrix Indicator) channel state information reports are used
- Downlink Control Information (DCI) format 2C
- Channel State Information Reference Signal (CSI-RS) transmitted using antenna ports 15,16,17, 18
- Demodulation Reference Signal (DM-RS) transmitted using antenna ports 7, 8, 9, 10
- Support of Channel State Information (CSI) reporting modes 1-1, 2-1, 2-2, 3-1
- Dynamic activation/deactivation of CSI-RS (CSI-RS is transmitted only if at least one TM9 capable UEs is in a cell)
- Scheduling of non-TM9 capable and TM9 capable UEs during CSI-RS sub-frames



LTE1987: DL Single User MIMO 4x4

Transmission modes selection

- TM9 is selected for all TM9 capable UEs (MIMO 4x4 - TM9 and MIMO 4x2-TM9 capable UEs)
- TM4 is selected when UE doesn't support TM9 or UE is category 5 or 8 (TM4 and 4x4 MIMO provide higher throughput compare to TM9 and 4x4 MIMO)



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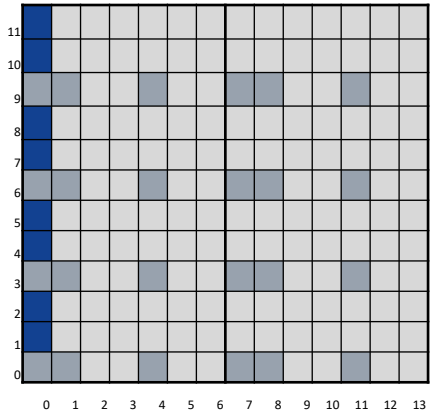
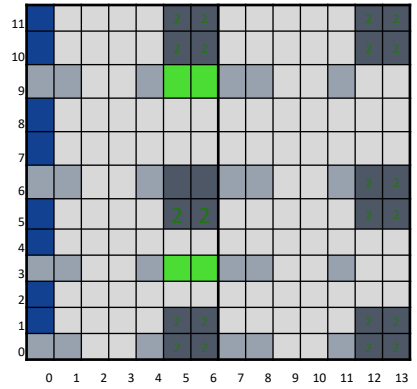
TM4 versus TM9 RE allocation



CRS	24
PDCCH	8
PDSCH	136

TM4
4 layers
4x4 MIMO



CRS	24
DM-RS	24
CSI-RS	4
PDCCH	8
PDSCH	108

TM9
4 layers
4x4 MIMO

TM4 : CRS is used for RSRP/RSRQ (mobility) & CSI (CQI, RI, PMI) calculations

TM9 : CRS is used for RSRP/RSRQ (mobility) calculation & CSI-RS is used for CSI (CQI, RI, PMI) calculation

TM9 will have more overhead due to the additional RE being used for reference symbol allocation.

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PDSCH, DM-RS and CSI-RS

Additional Reference Signals are mapped subsequently:

- **CSI Reference Symbols (CSI-RS) for four antennas (antenna ports 15,16,17,18)**
- **UE specific Demodulation Reference Signals (DM-RS) with antenna ports 7,8,9 and 10 to support up to 4 layers spatial multiplexing based on TM9**

LNCEL/LNCEL_FDD: numOfCsiRsAntennaPorts;

CSI-RS ports number;

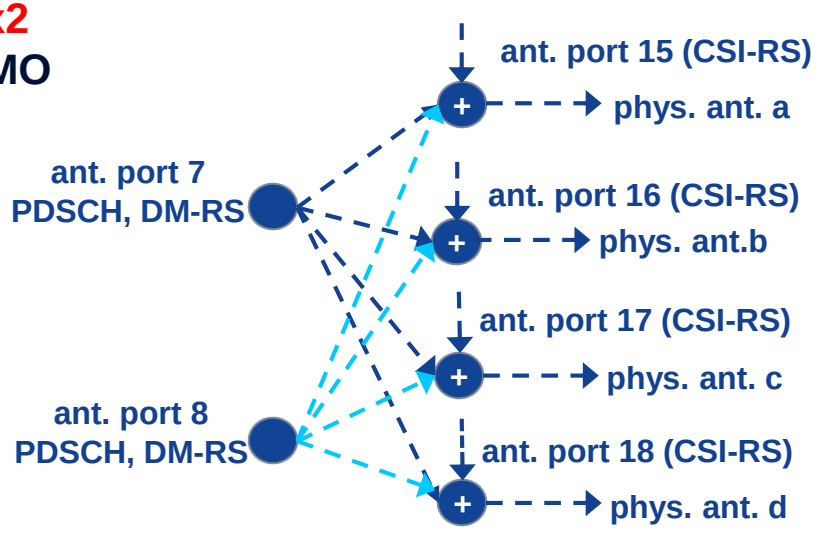
4 (4);

Default: 4 (4)

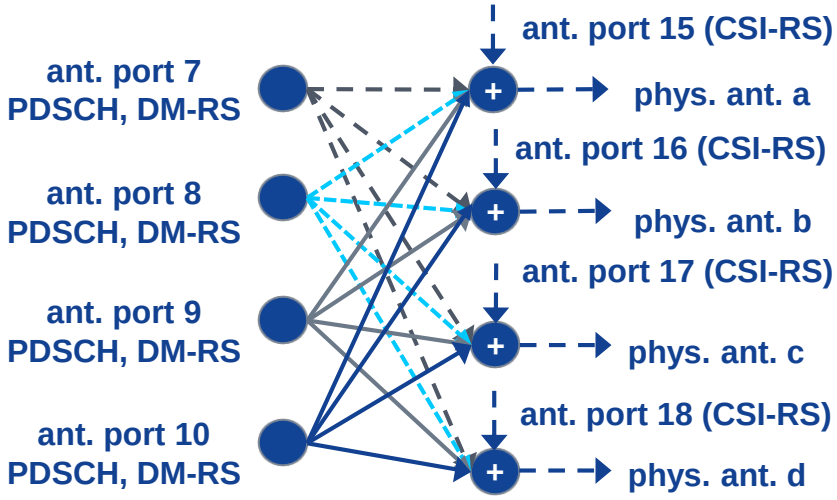
According 3GPP 2,4 or 8 ports for CSI-RS supported

But by Nokia FDD currently 4 only

4x2 MIMO



4x4 MIMO



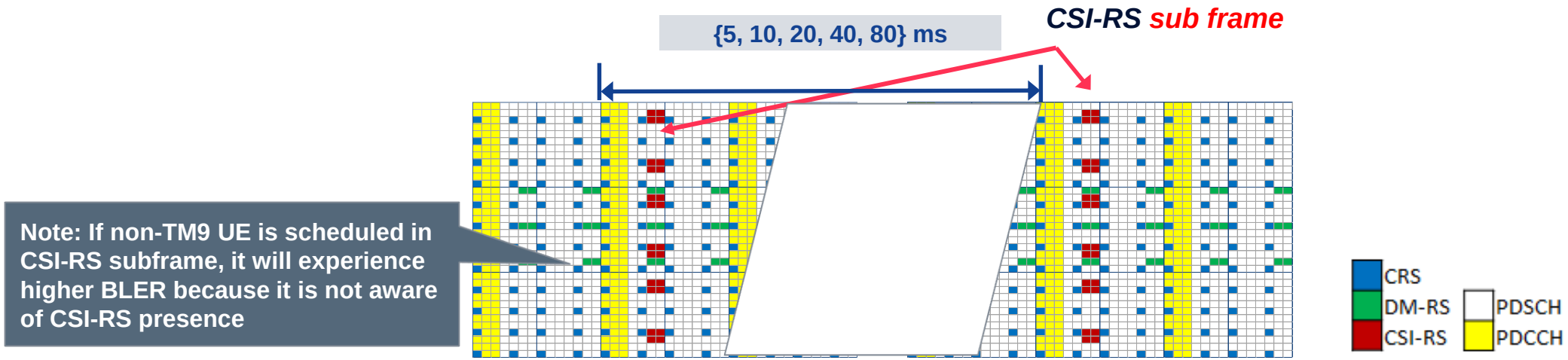
LTE1987: DL Single User MIMO 4x4

CSI-RS sub-frames configurations

CSI-RS based feedback:

- CSI-RS introduced to give better indication of PDSCH interference, Cell specific RS suffers from inter cell interference from control channels and other Cell specific RS
- Channel can be estimated between all eNB-UE antenna pairs
- No limit on how many UEs can use CSI-RS based channel estimate, regardless of CSI-RS periodicity
- No impact on UE battery consumption
- Relatively low and configurable periodicity of CSI-RS subframe
- Also CSI-RS subframe offset is configurable
- Helps to avoid CSI-RS collisions in low loaded networks

LNCEL/LNCEL_FDD: csiRsSubfrConf;
CSI-RS subframe configuration;
3...154, step 1;
Default: 19



LTE1987: DL Single User MIMO 4x4

CSI-RS configurations

CSI-RS subframe resource are defined for 2, 4 and 8 antenna ports

- 1 or 2 CSI-RS ports: 20 configurations
- 4 CSI-RS ports: 10 configurations
- 8 CSI-RS ports: 5 configurations

	CSI reference signal configuration	Number of CSI reference signals configured					
		1 or 2		4		8	
		(k',l')	$n_s \bmod 2$	(k',l')	$n_s \bmod 2$	(k',l')	$n_s \bmod 2$
Frame structure type 1 and 2	0	(9,5)	0	(9,5)	0	(9,5)	0
	1	(11,2)	1	(11,2)	1	(11,2)	1
	2	(9,2)	1	(9,2)	1	(9,2)	1
	3	(7,2)	1	(7,2)	1	(7,2)	1
	4	(9,5)	1	(9,5)	1	(9,5)	1
	5	(8,5)	0	(8,5)	0		
	6	(10,2)	1	(10,2)	1		
	7	(8,2)	1	(8,2)	1		
	8	(6,2)	1	(6,2)	1		
	9	(8,5)	1	(8,5)	1		
	10	(3,5)	0				
	11	(2,5)	0				
	12	(5,2)	1				
	13	(4,2)	1				
	14	(3,2)	1				
	15	(2,2)	1				
	16	(1,2)	1				
	17	(0,2)	1				
	18	(3,5)	1				
	19	(2,5)	1				

LNCEL/LNCEL_FDD: csiRsResourceConf;

CSI-RS resource configuration

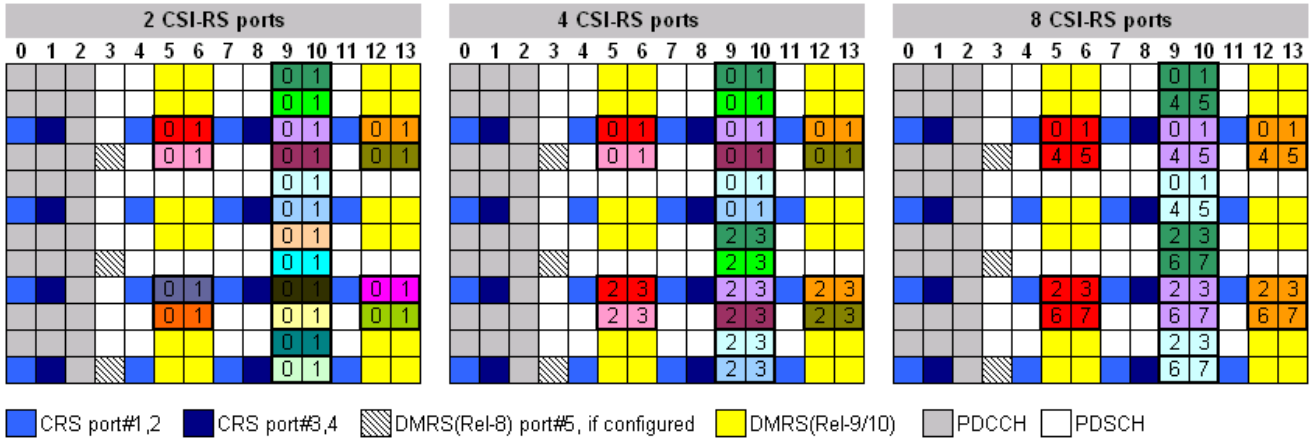
rsc0 (0), rsc1 (1), rsc2 (2), rsc3 (3), rsc4 (4), rsc5 (5), rsc6 (6), rsc7 (7), rsc8 (8), rsc9 (9);

Default: rsc0 (0)

20 different CSI-RS configurations

10 different CSI-RS configurations

5 different CSI-RS configurations



Figures denote a port number. CSI-RS with the same color are transmitted in the same sub frame.

Different CSI-RS configurations are used to avoid CSI-RS collisions in the network

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