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3GPP TSG-RAN1 Meeting #42bis

San Diego, USA, 10th-14th, Oct. 2005

Agenda Item:

Source: Nortel

Title: UL Virtual MIMO Transmission for E-UTRA

Document for: Discussion

>THIS IS **THE WAY**

UL Virtual MIMO Transmission for E-UTRA

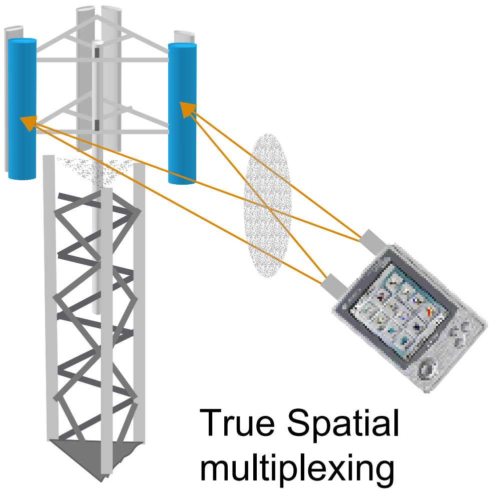
Nortel
October, 2005

>THIS IS **NORTEL**

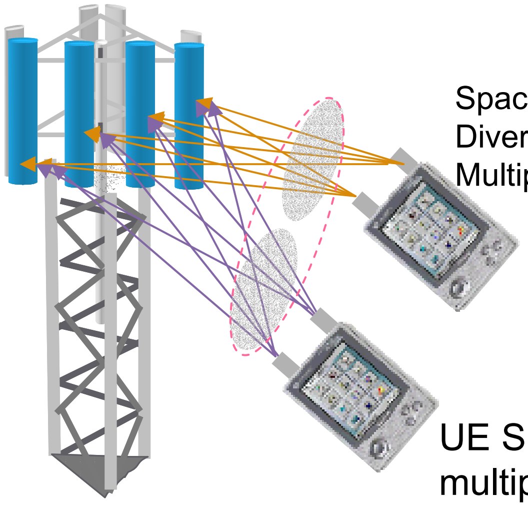
Background

- The realization of UL MIMO is limited by the practical issue of the implementation of multiple power amplifiers in the UE, especially in the hand-set.
- The UL user throughput is also limited by the channel bandwidth and QAM modulation order.
- To mitigate these limitations, we propose to allow two individual UEs, each with single transmit antenna, to transmit independently onto the *same* sub-channel
  - This constitutes the so-called virtual MIMO transmission
  - The Node-B organizes the collaboration of two UE to transmit on the same sub-channel by scheduling
  - Using this configuration, the aggregated UL sector throughput can be increased if the two UE transmit the same power level, the UE transmit power can be reduced if same aggregate UL throughput is maintained
- By exploitation of the best UE pair with scheduling, the multi-user diversity can be explored in conjunction with virtual MIMO
- Virtual MIMO can be applied to UL OFDMA and SC-FDMA

UL MIMO Configuration Scenarios

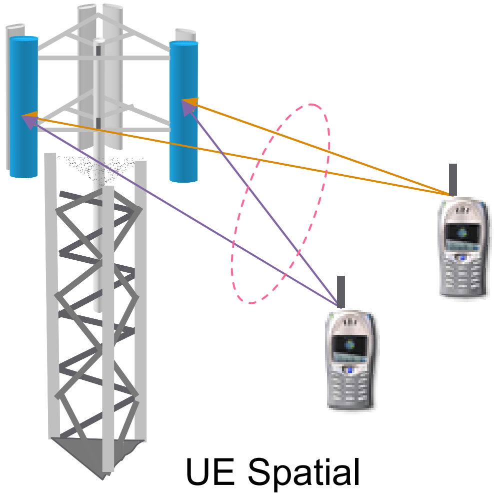


True Spatial multiplexing

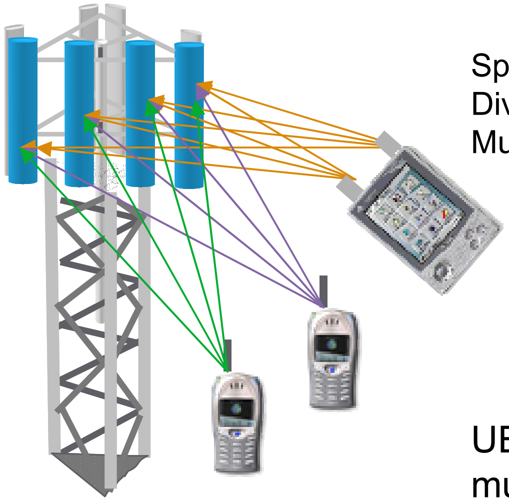


Space Transmit Diversity / Spatial Multiplexing

UE Spatial multiplexing



UE Spatial multiplexing



Space Transmit Diversity / Spatial Multiplexing

UE Spatial multiplexing

Orthogonal UL Transmission Enables Virtual MIMO

> To increase the parallel transmission in UL is the key to increase the UL throughput

- The channel capacity of a MIMO system increases linearly with min{N_{Tx}, N_{Rx}}.
- For practical reception, we usually assume $N_{Tx} \leq N_{Rx}$.
- When there are multiple receive antennas at Node-B, we would like to increase N_{Tx} so that min{N_{Tx}, N_{Rx}} increases as well.

> For single antenna UEs, this means that we need to have several UEs transmitting concurrently on the same sub-channel/sub-carrier

> Orthogonal transmission for multi-user in UL enables the Virtual MIMO

- This is applicable for both OFDMA and SC-FDMA
- Scheduled UEs perform the same transmission as basic SIMO (with the exception of pilot transmission which needs to be orthogonal between the UEs)
- No additional feature required from the UE perspective

Key differences between MIMO and virtual MIMO

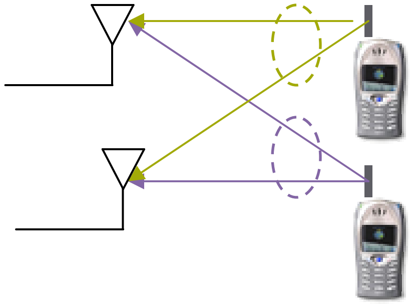
- Improved multi-user diversity:
  - For UL true MIMO, all MIMO signals come from the antennas of the same UE
    - The channel matrix could be weak even though transmit antennas are uncorrelated.
  - Whilst for UL virtual MIMO, signals can come from different UEs
    - The channels can be almost independent
- Scheduler in Node-B selects UEs with close-to-orthogonal channels so as to improve the system throughput while maintaining the robustness of the radio link.
- Spatial multiplexing inter-user decision feedback interference cancellation can be applied at Node-B.
- The available UL transmit power seen by Node-B is increased.

Virtual MIMO UE Collaboration Criterion

ideal example → multi-user orthogonal scheduling

For a [2Tx, 2Rx] virtual MIMO system define by the channel matrix

$$H = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$$



If

$$\begin{bmatrix} h_{11} & h_{21} \end{bmatrix} \begin{bmatrix} h_{12}^{*} \\ h_{22}^{*} \end{bmatrix} = 0$$

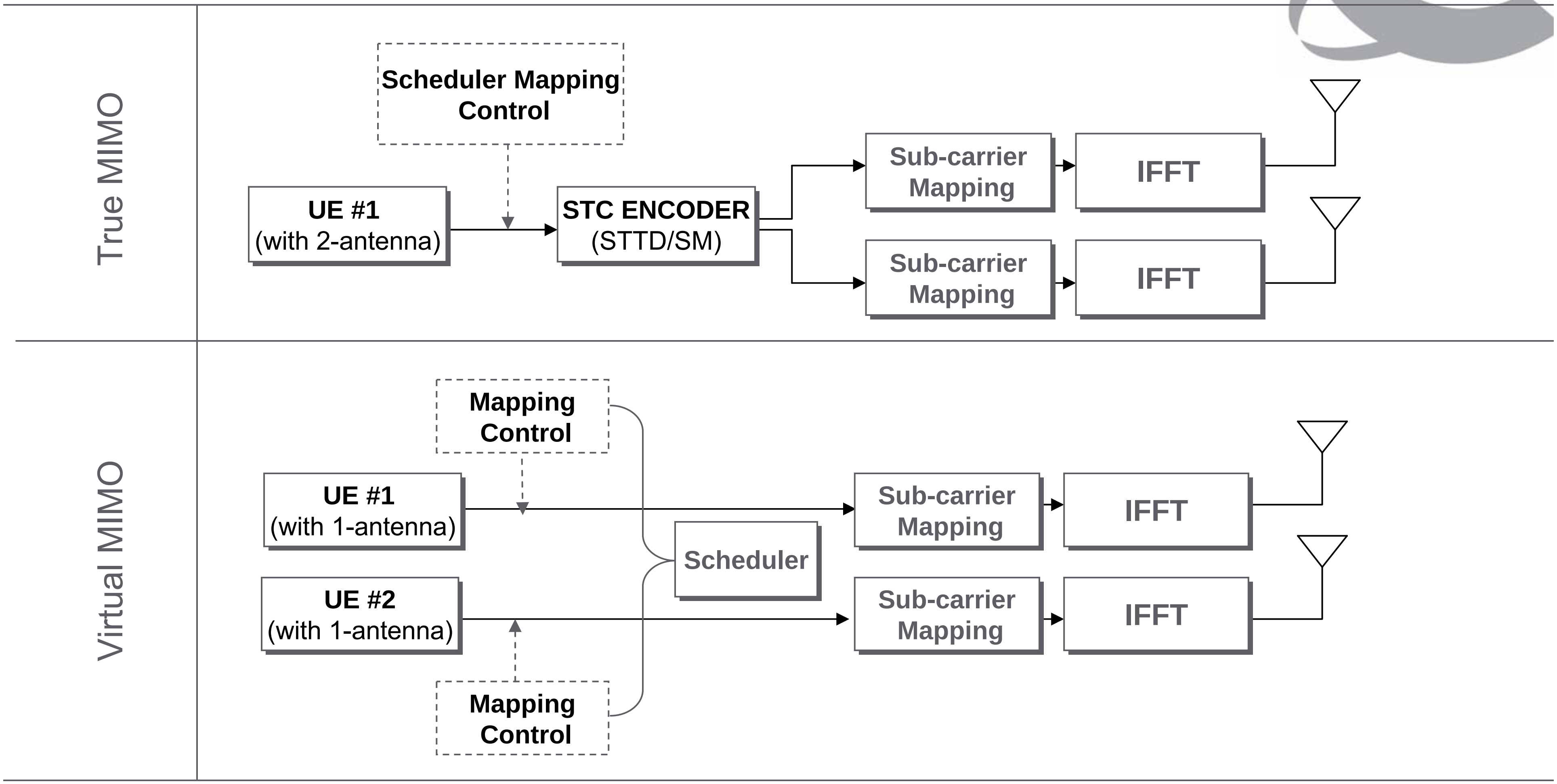
Then we get two equivalent [1Tx, 2Rx] systems, with channel attenuation

$$\sqrt{|h_{11}|^2 + |h_{21}|^2} \qquad \text{and} \qquad \sqrt{|h_{12}|^2 + |h_{22}|^2}$$

respectively. → many practical scheduling criteria can be designed

With Scheduler at Node-B to coordinate UE spatial multiplexing is a MIMO property that can be best exploited in the UL

Virtual MIMO Scheme for OFDMA



True MIMO

Scheduler Mapping Control

UE #1 (with 2-antenna)

STC ENCODER (STTD/SM)

Sub-carrier Mapping

IFFT

Sub-carrier Mapping

IFFT

Virtual MIMO

Mapping Control

UE #1 (with 1-antenna)

UE #2 (with 1-antenna)

Scheduler

Mapping Control

Sub-carrier Mapping

IFFT

Sub-carrier Mapping

IFFT

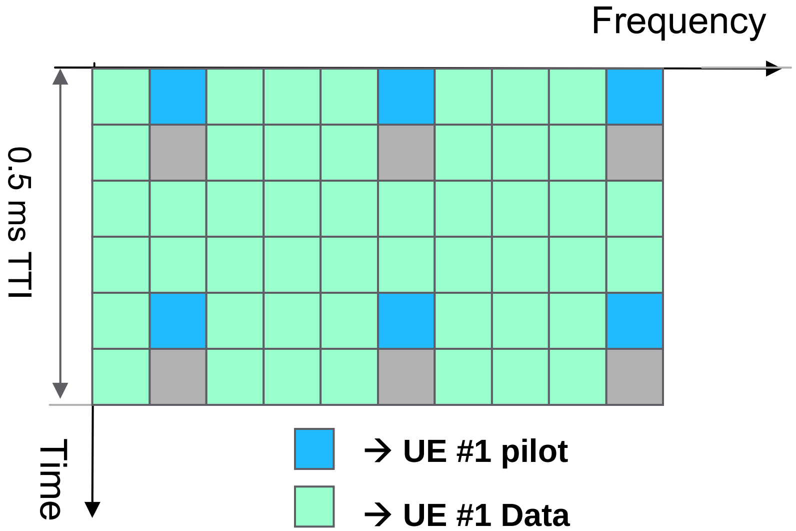
The MMSE/OSIC/ML decoder can be used at the Node-B receiver

Additional comments

- The detection of virtual MIMO is implemented in the frequency domain.
- Virtual MIMO is equally applicable to SC-FDMA and OFDMA.
- Just as in regular MIMO, the pilots for different antennas (UEs) need to be orthogonal to each other
  - To assist and simplify the MIMO channel estimation
- For nomadic user the Node-B scheduler can pair wise allocate two UEs on the same sub-channel to achieve orthogonal scheduling
  - This channel information can be obtained through approaches such as channel sounding
  - This is later referred to as dynamic allocation
- For high speed mobility UEs, Node B scheduler pairs two UEs without relying on the orthogonality criterion
  - This allows to achieve regular MIMO gain
  - This is referred to as “fixed allocation”

Complementary Orthogonal Pilot Pattern for OFDMA

Pilot Pattern-1

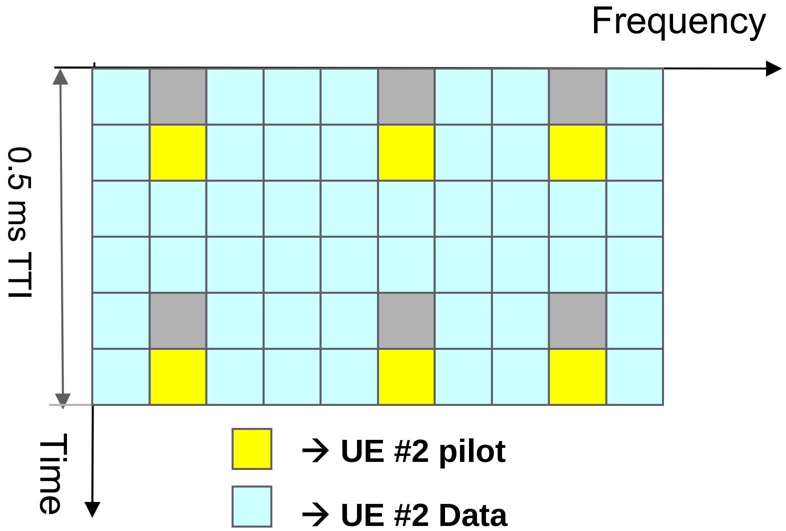


🟦 → **UE #1 pilot**

🟩 → **UE #1 Data**

▨ → **Null**

Pilot Pattern-2



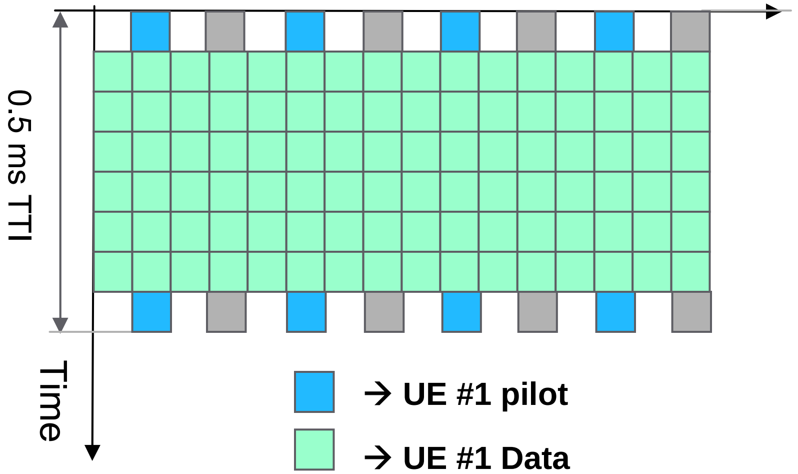
🟨 → **UE #2 pilot**

⬜ → **UE #2 Data**

▨ → **Null**

Complementary Orthogonal Pilot Pattern for SC-FDMA

Pilot Pattern-1

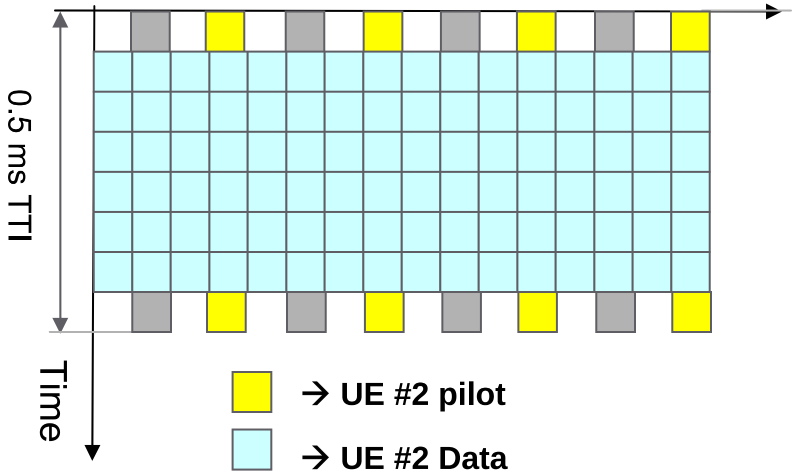


🟦 → **UE #1 pilot**

🟩 → **UE #1 Data**

▨ → **Null**

Pilot Pattern-2



🟨 → **UE #2 pilot**

▢ → **UE #2 Data**

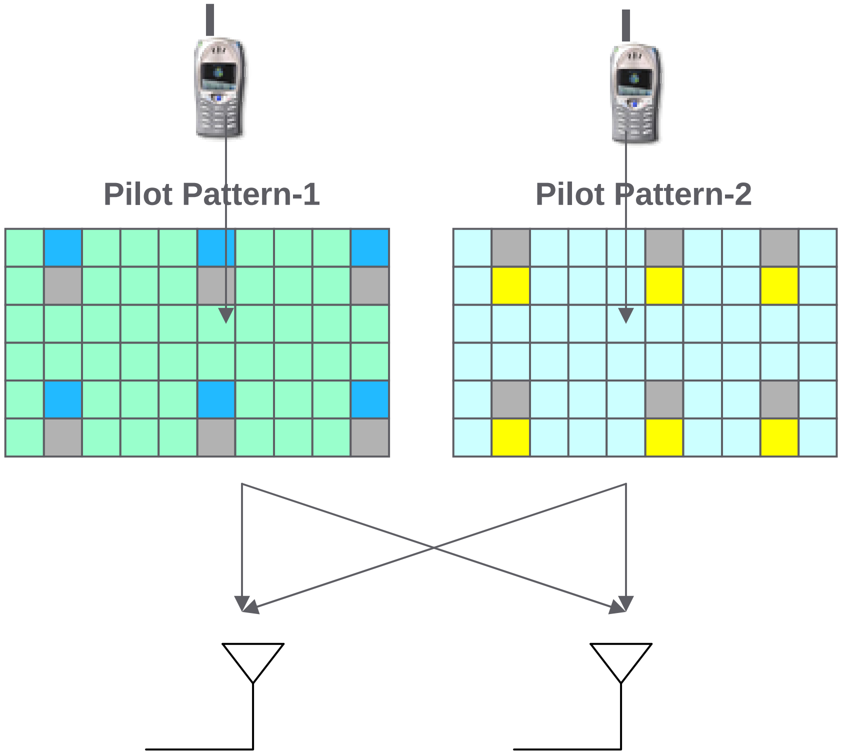
▨ → **Null**

Link-level simulation

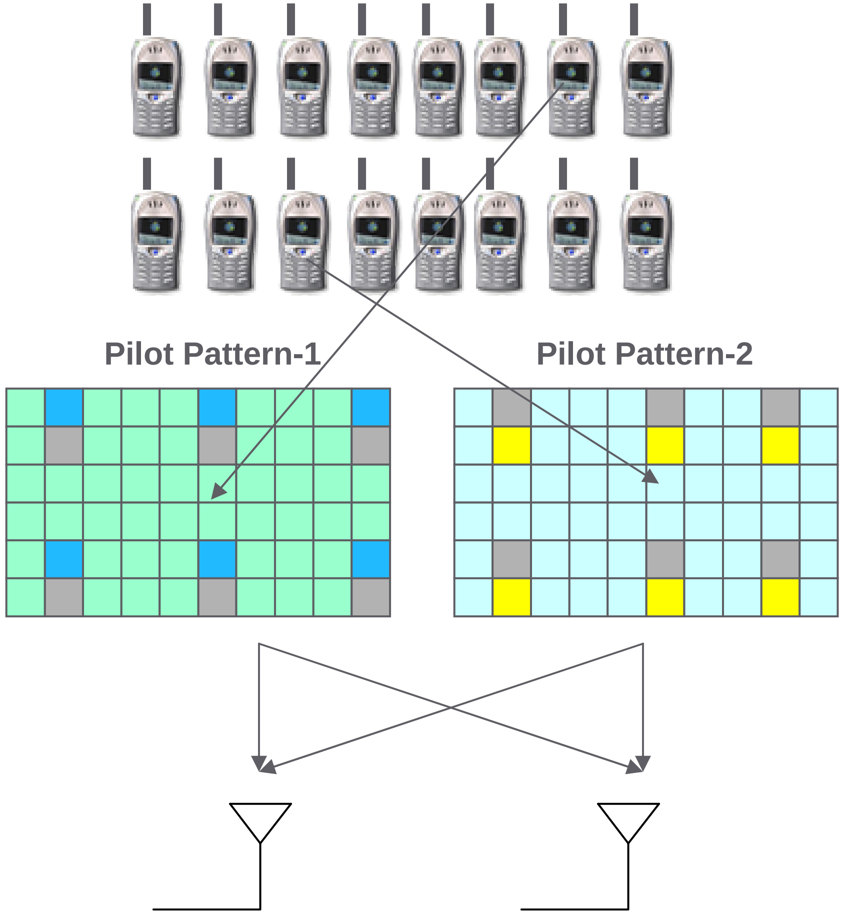
- > 10 MHz bandwidth
- > Ideal channel estimation
- > One sub-channel element allocation
- > Select 2 UEs out of 16
- > User selection period: 2 sub-frames
- > Turbo code block: 2 sub-frames
- > BTS has 2 receive antennas, UE has 1 transmit antenna
- > [1Tx, 2Rx] with maximum SNR scheduling is simulated as a reference
- > Virtual MIMO with maximized orthogonality scheduling

Virtual Scheduling Scenarios

Fixed allocation

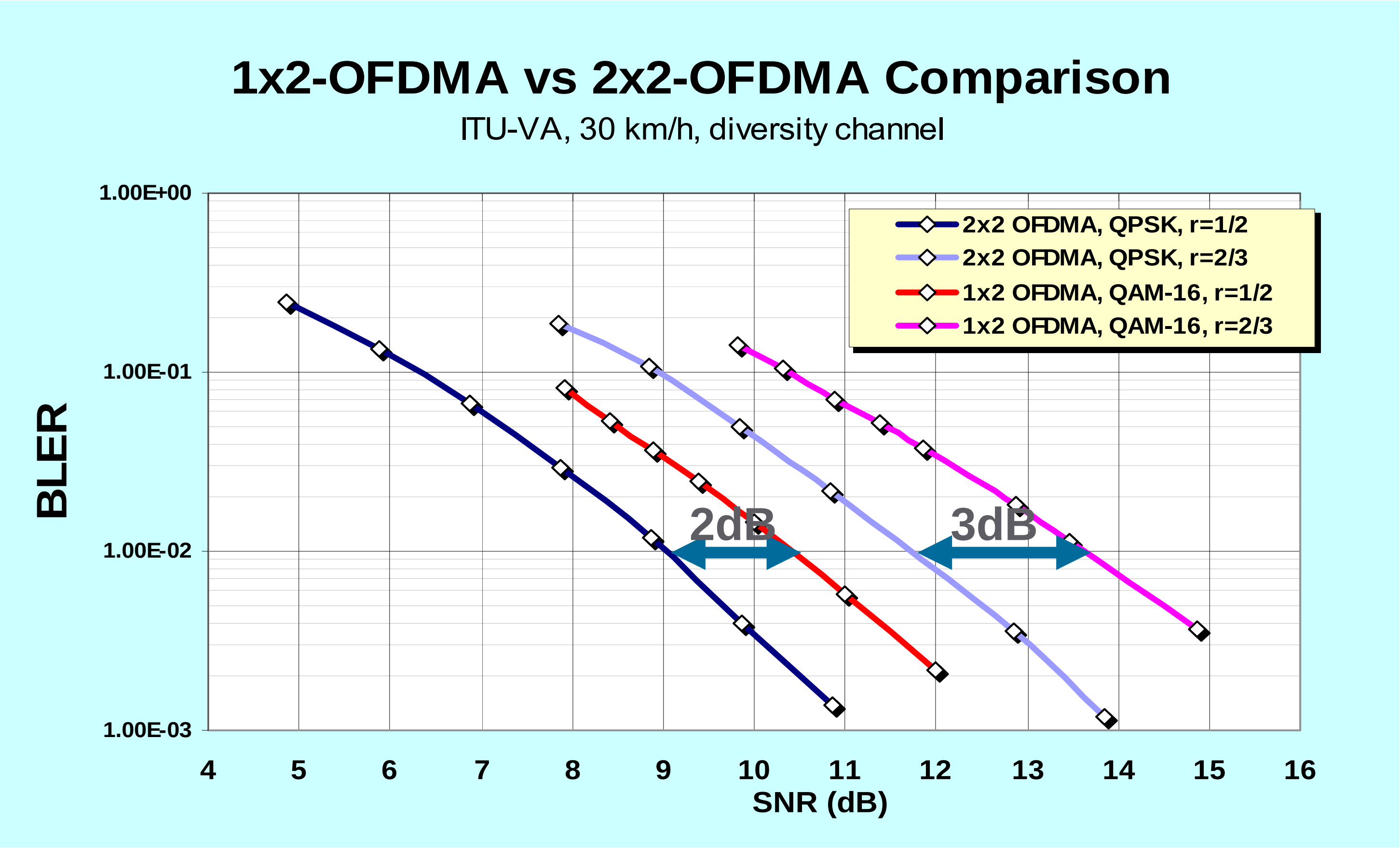


Dynamic allocation



Fixed Allocation V-MIMO Performance

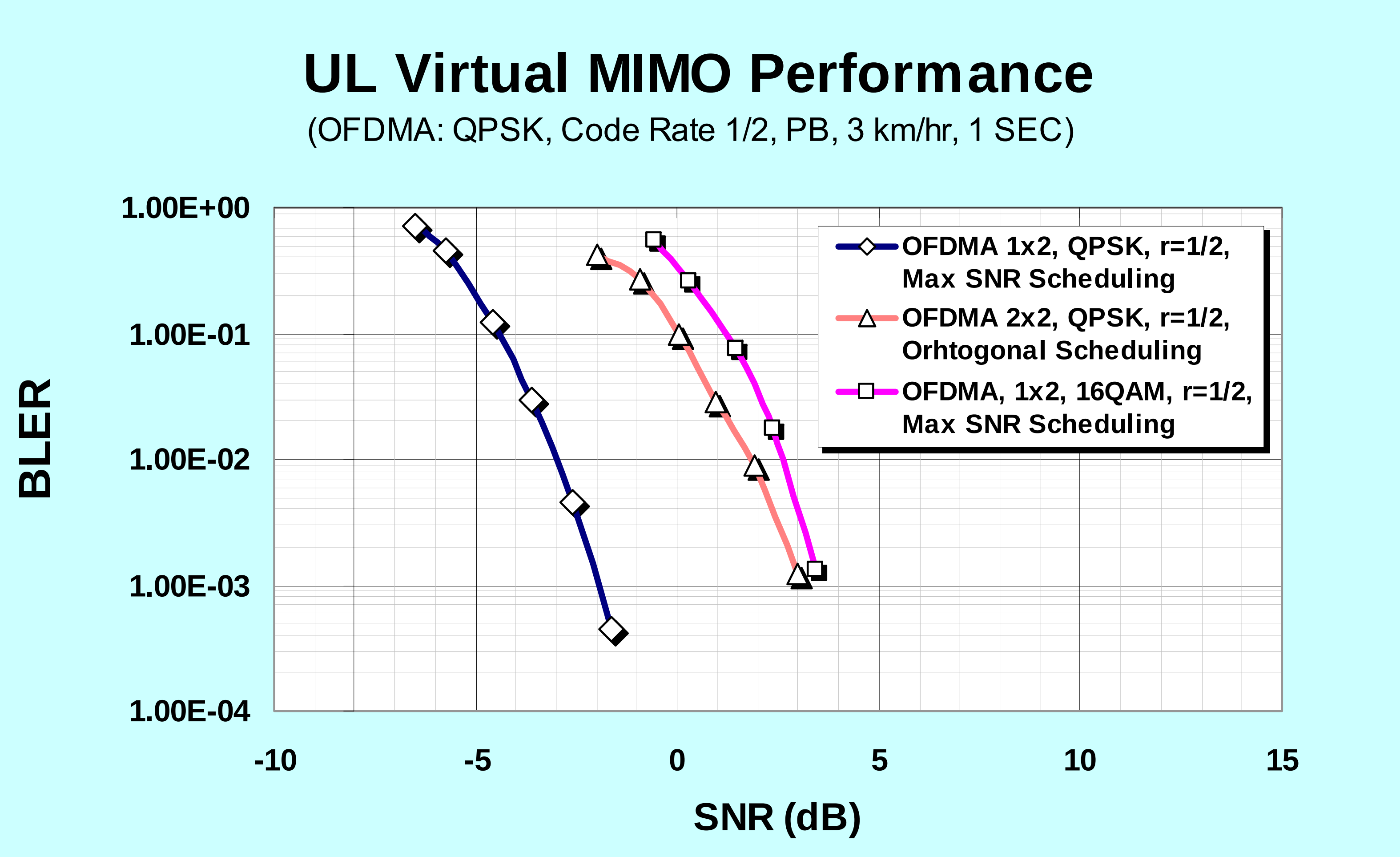
Diversity Channel, Vehicular Speed



Virtual MIMO has gain over the typical 1x2 SIMO reception

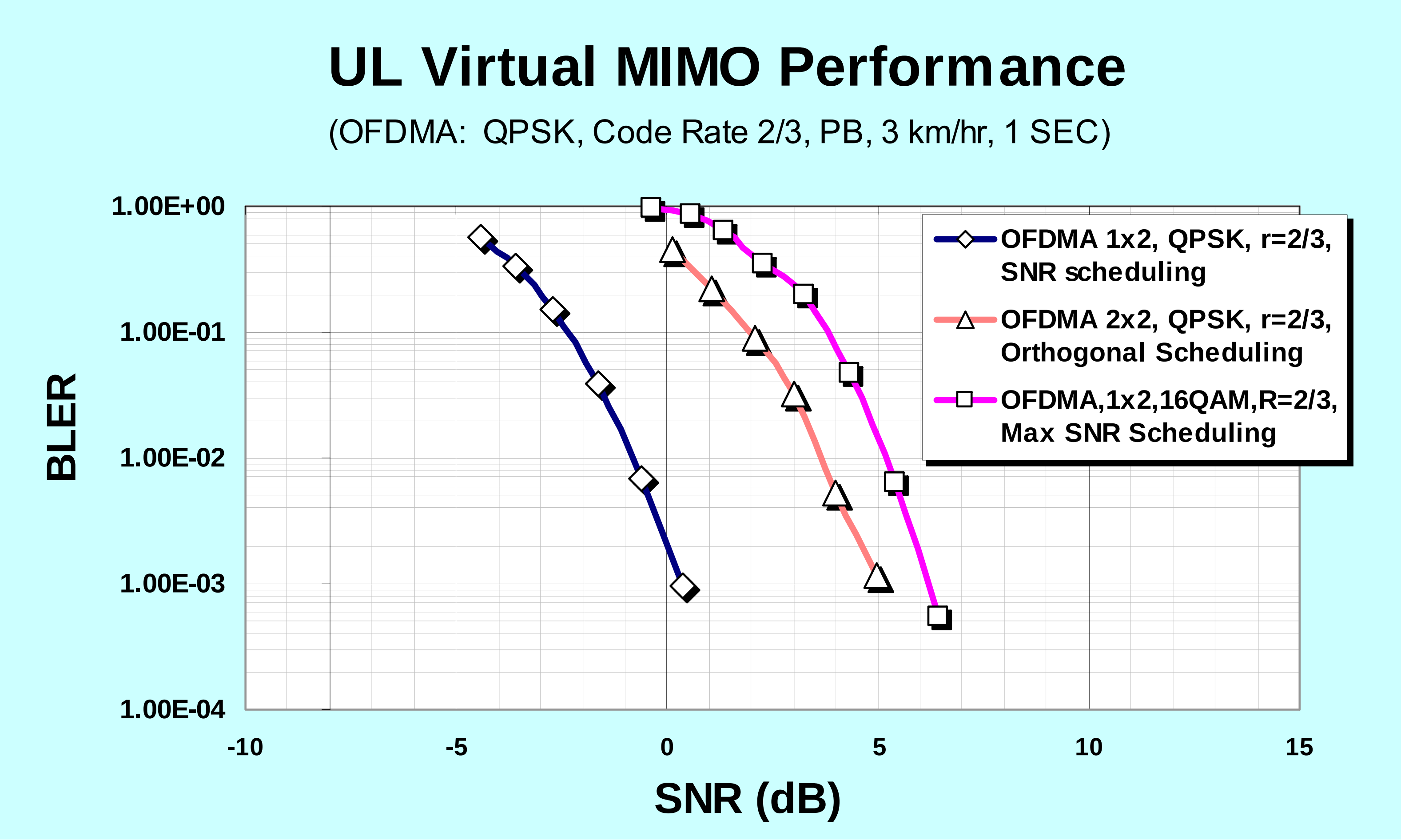
Dynamic Scheduling V-MIMO Performance

OFDMA Diversity Channel, QPSK V-MIMO vs. 16QAM SIMO → R=1/2



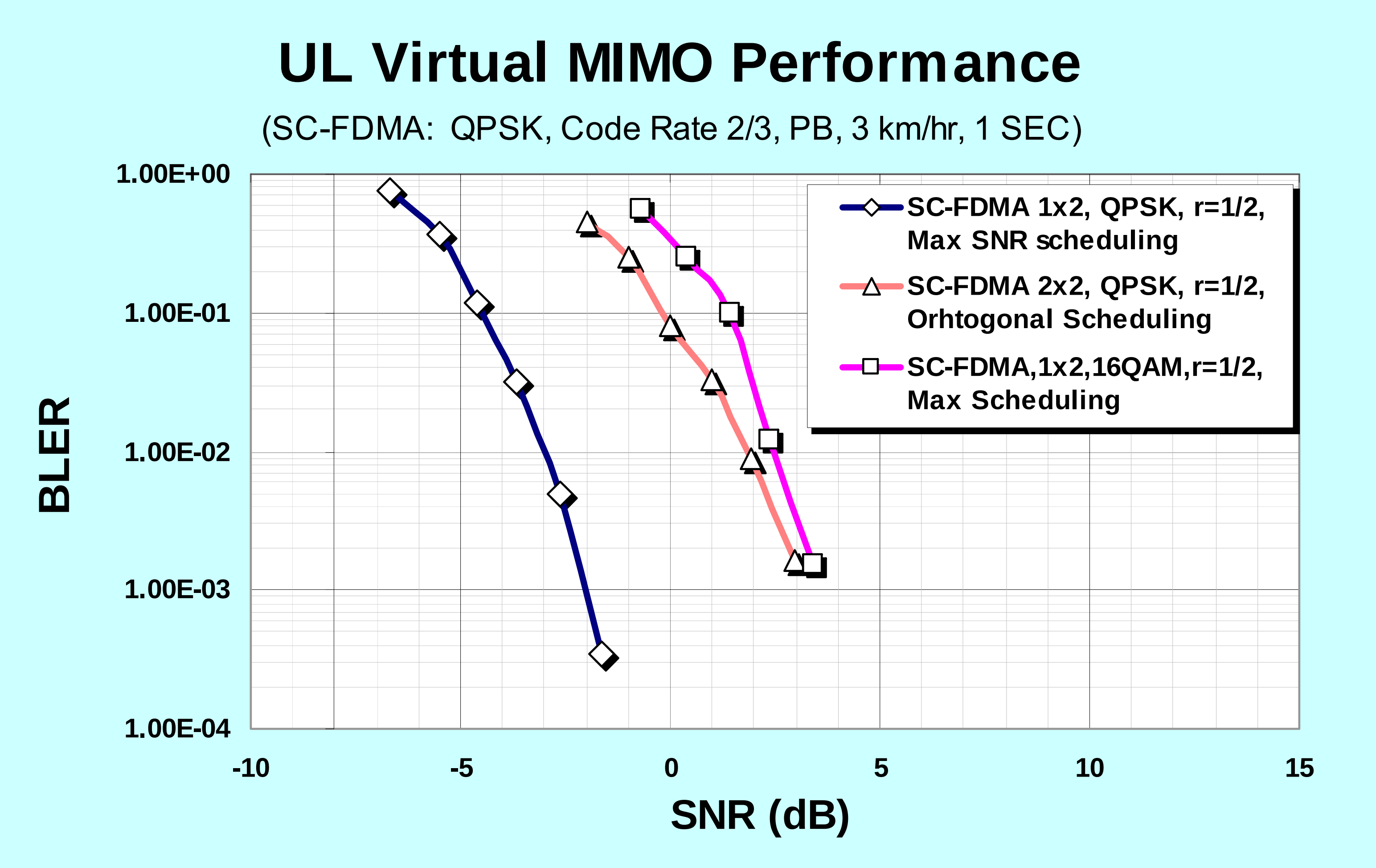
Dynamic Scheduling V-MIMO Performance

OFDMA Diversity Channel, QPSK V-MIMO vs. 16QAM SIMO → R=2/3



Dynamic Scheduling V-MIMO Performance

SC-FDMA Diversity Channel, QPSK V-MIMO vs. 16QAM SIMO → R=1/2



Two comments about the simulation results

- These results assume that the two UEs are transmitting at half of the power of the [1Tx, 2Rx] case. If each UE is transmitting at its full power, the virtual MIMO curves need to be shifted to the left by 3dB.
- The scheduling for virtual MIMO is based on maximum orthogonality. This allows UEs at disadvantaged locations to have equal opportunity to transmit as those at advantaged locations.

Conclusions

- Virtual MIMO enables the MIMO transmission in UL with single PA/antenna at UE.
- Virtual MIMO exploits multi-antenna systems to take the full advantage of channel capacity that is proportional to $\min\{N_{Tx}, N_{Rx}\}$.
- Virtual MIMO exploits the orthogonality among the UEs, and hence improves throughput while maintaining the robustness of the radio link.
- Virtual MIMO is applicable to both SC-FDMA and OFDMA.