>BUSINESS MADE **SIMPLE**

Convergence of Wireless Technologies:
OFDM-MIMO

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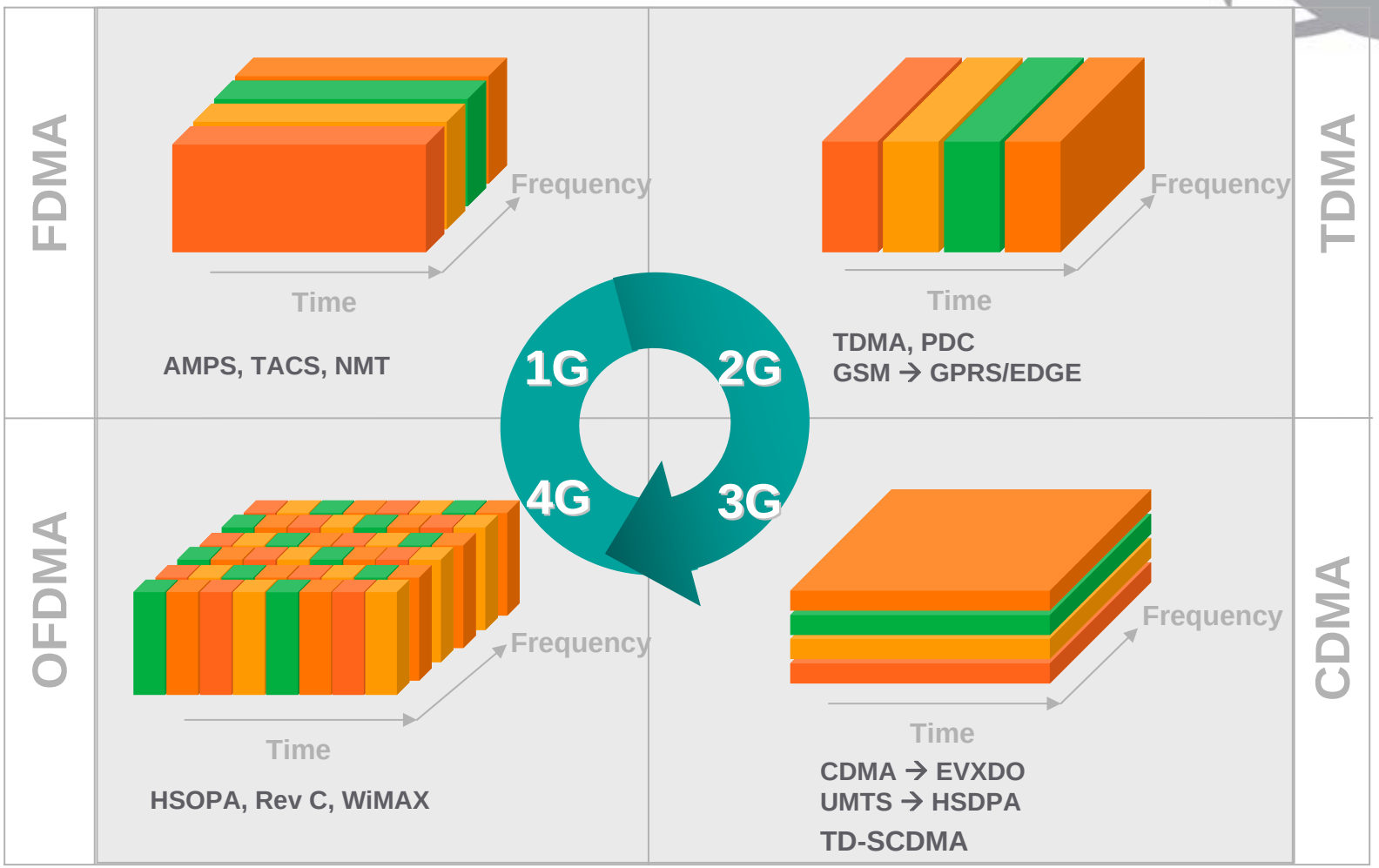
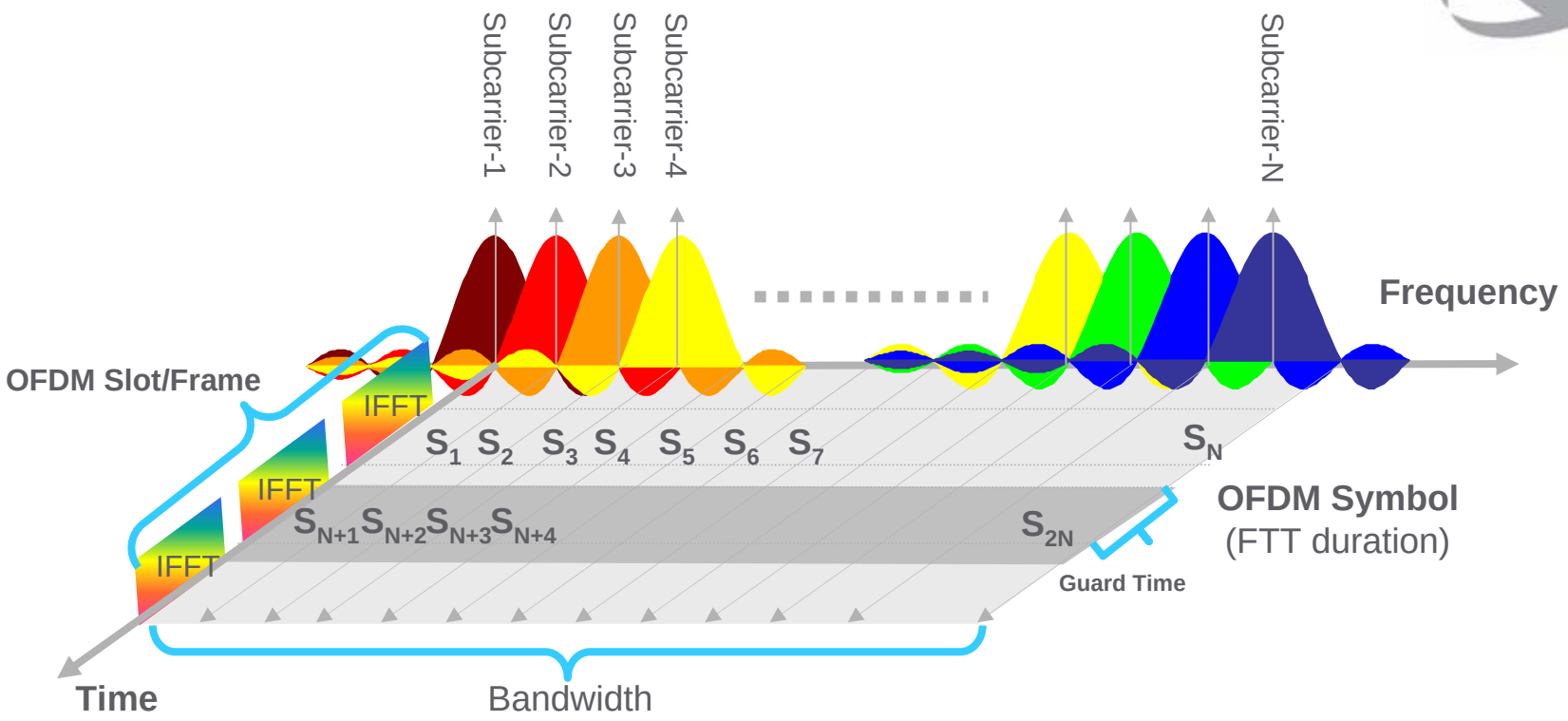
NORTEL

Radio Access Air Interface Principles



OFDM Overview

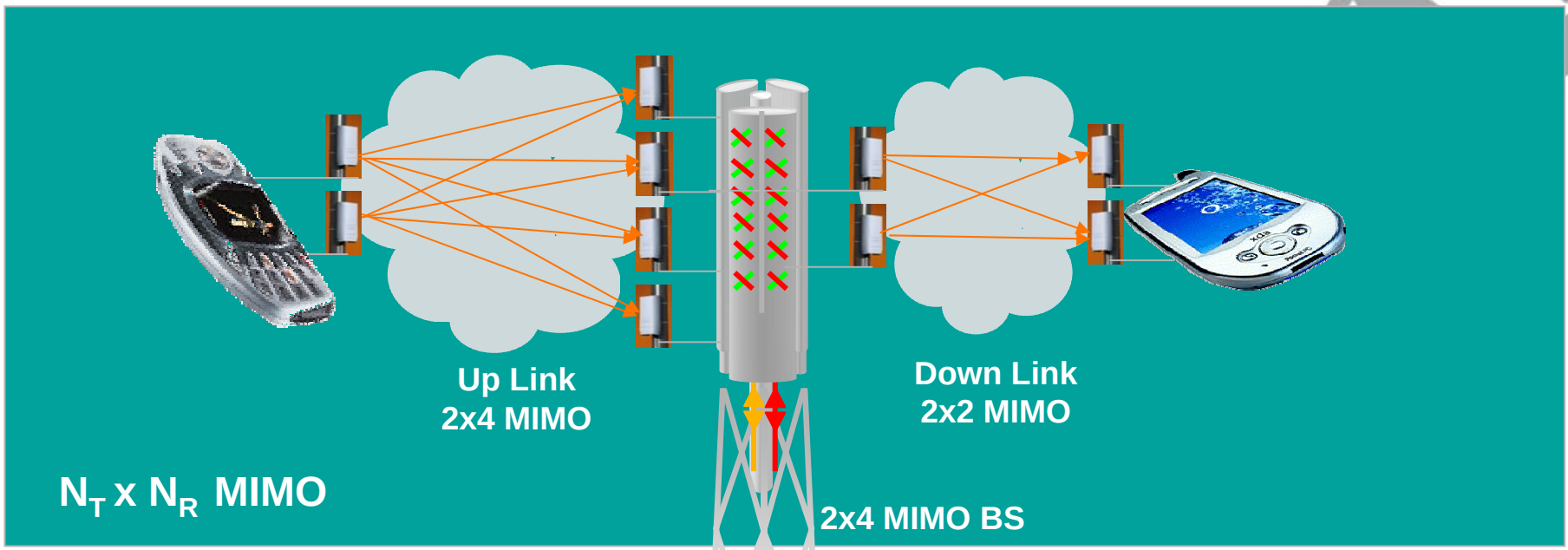
Time-Frequency Domain

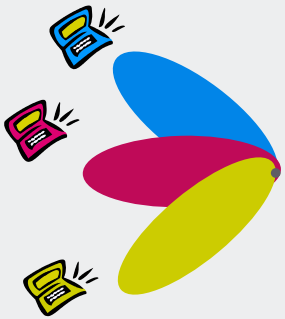


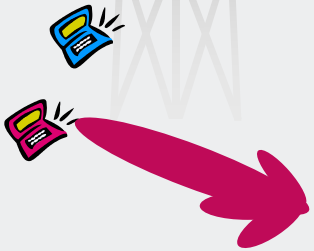
Advantages of OFDM technologies

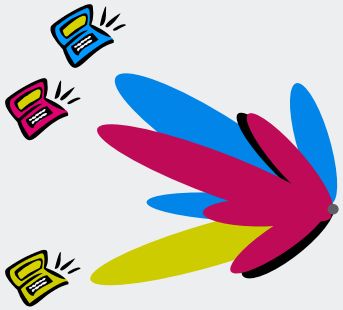
- Higher spectral efficiency in real-life time dispersive channels
- More robust – less multi-path interference
- Easy to integrate MIMO technologies
- Simpler receiver to cope with real-life time dispersive channels → lower cost

Terminology of MIMO and AAS









Adaptive Antenna

Fixed beam: Users served by nearest fixed beam. Beams generated from antenna columns. Example has 3 way SDMA. *(AABS has beams but no SDMA)*

Adaptive beam with SDMA*: Multiple beams maximise C/(I+N) towards each user, nulls the other SDMA users

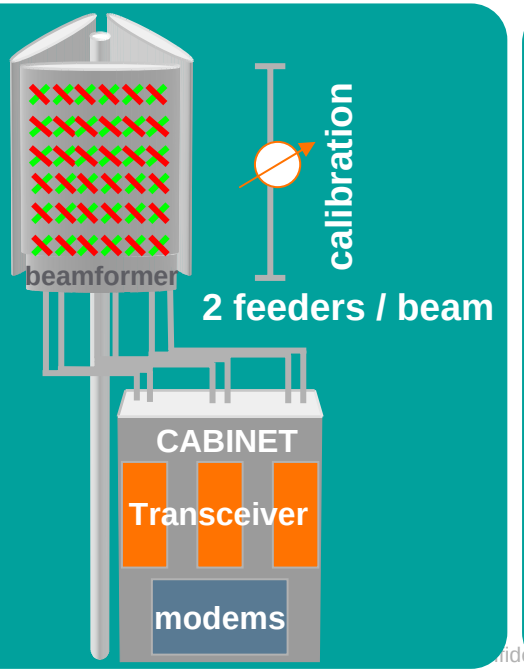
Limitation of AAS and Advantages of MIMO

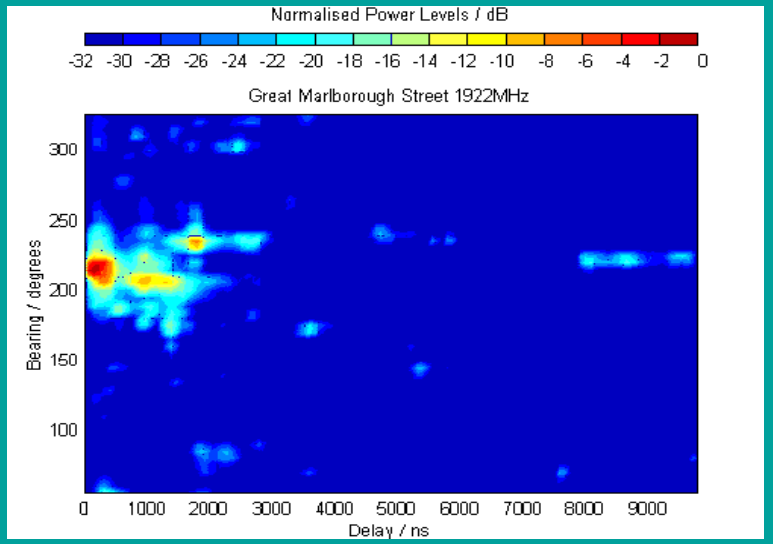
- **The C/I of the link is simply proportional to the width of antenna facet**
  - Approximation from dense urban measurements:

$$\textit{Effective beamwidth}_{3dB} = \textit{designed beamwidth}_{3dB} + 7°$$

- **In dense urban conditions**
  - For 22° beams 86% efficiency was observed
  - However, very narrow beams will give limited performance enhancement, due to angle spread.

Excess Cables and additional calibration results in complex cell site and high CAPEX/OPEX

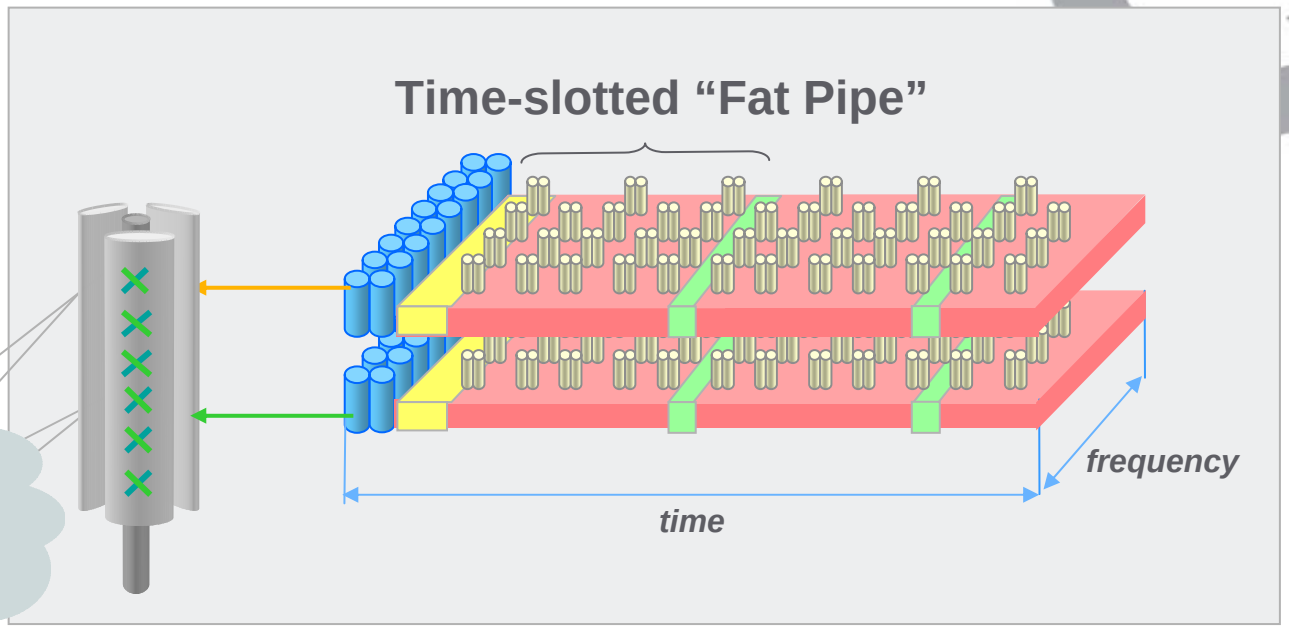




Example measurement of angle/delay spread in Central London

Advantages of Combined OFDM and MIMO

Dual-polar base station antenna supporting 2-branch MIMO



Propagation channel

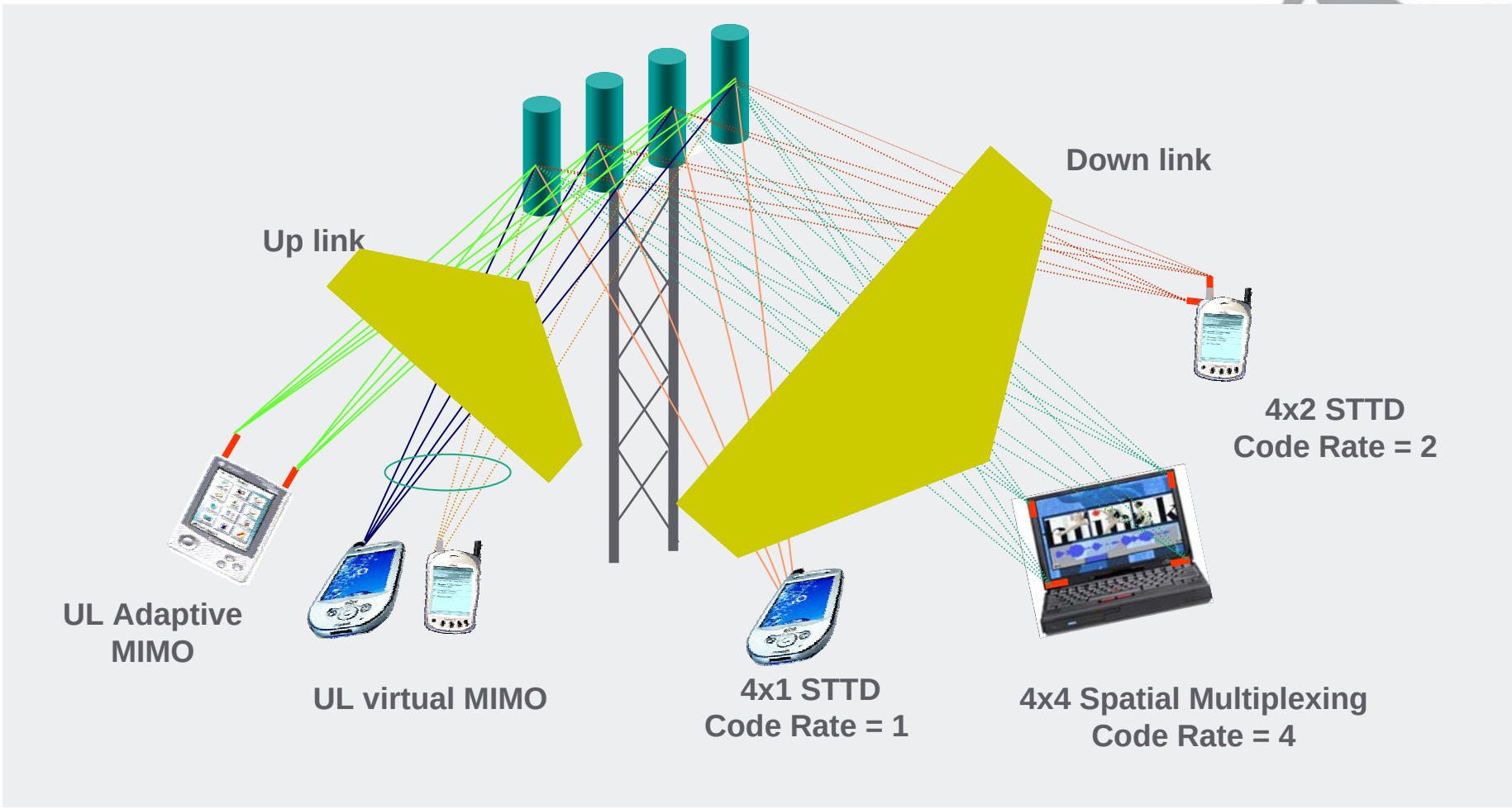
2 or more antennas

OFDM is more naturally Integrated to MIMO

- > Key enabler for high capacity, high peak data rate spectrum efficiency
- > Better coverage and QoS
- > Additional spatial dimension to further exploit multi-user diversity
- > Exploits multi-path fading as advantage
  - Increase maximum achievable diversity

OFDM/MIMO offers best capacity at lowest cost for large throughput systems

MIMO Configurations



MIMO solutions for both DL and UL to deal with diverse BTS and device antenna capabilities and enable ubiquitous interoperability

Technology Data Rates

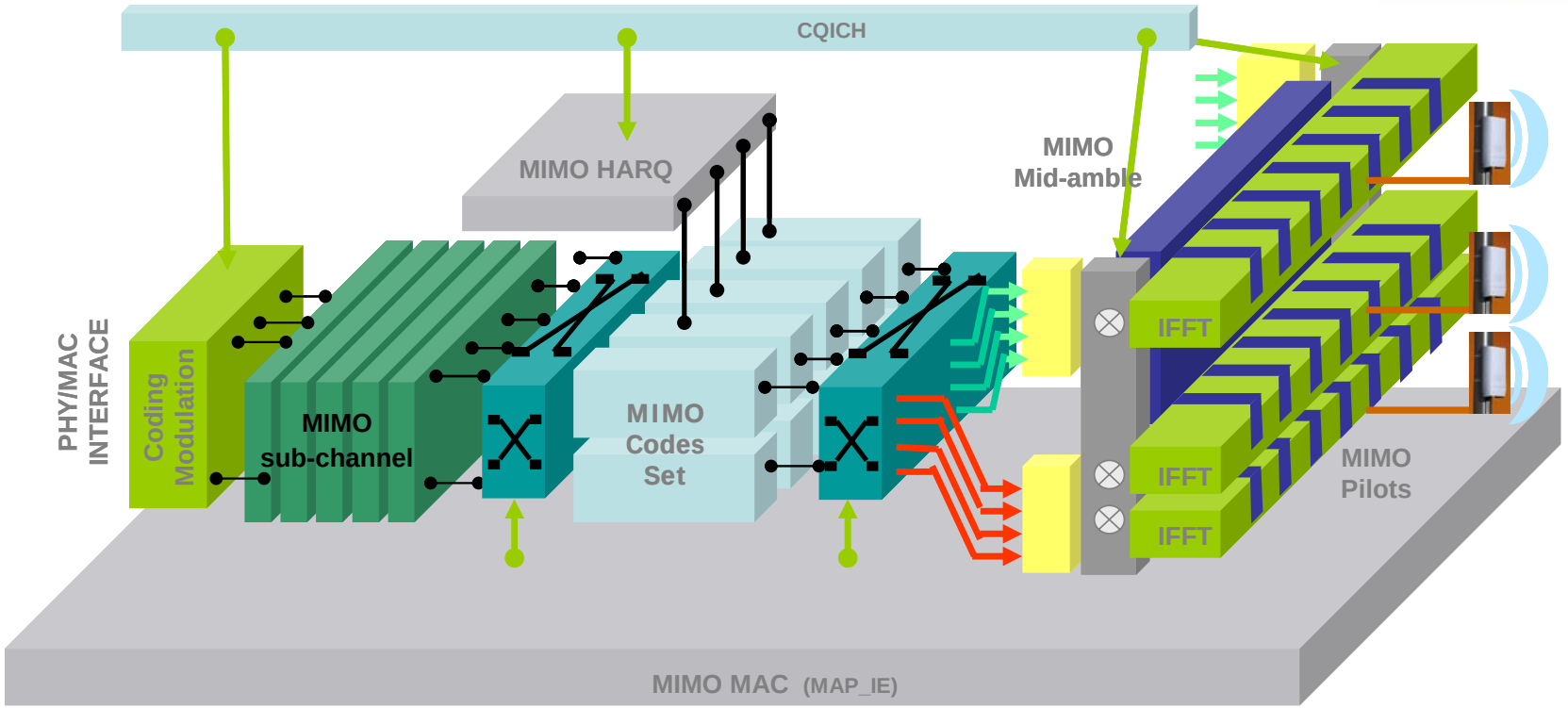
	Peak Data Rate	Average Sector Throughput	Time to download 10MB File*
HSOPA 5MHz Carrier. Target Availability 2008	63 Mbps	14.1 Mbps	28 seconds
HSDPA 14.6 5MHz Carrier. Terminal Dependent.	14.4 Mbps	3.42 Mbps	117 seconds
HSDPA 3.6 5MHz Carrier - Available 2007 5MHz Carrier - Available Now	3.6 Mbps	3.42 Mbps 2.48 Mbps	117 seconds 161 seconds
UMTS (Rel 99) 5MHz carrier - Available Now	0.384 Mbps	0.8 Mbps	500 seconds
EVDO (Rev C) 5MHz carrier - Target availability 2008+	63 Mbps	14.1 Mbps	28 seconds
EVDO (Rev B) 5MHz carrier - Target availability 3Q07	14.7 Mbps	3.93 Mbps	102 seconds
EVDO (REV A) 1.25MHz carrier - Available 4Q06 1.25 MHz carrier x 3 - Available 4Q06	3.1 Mbps (9.3 Mbps)**	1.2 Mbps 3.6 Mbps	111 seconds
EVDO (Rev 0) 1.25 MHz carrier - Available now 1.25 MHz carrier x 3 - Available now	2.4 Mbps (7.2 Mbps)**	1.0 Mbps 3.0 Mbps	133 seconds
WiMAX 5MHz carrier - Available 2007+. Per WIMAX Forum Findings	63 Mpbs	14.1 Mbps	28 seconds

*Assumes 5 users /sector downloading similar file

**Sector peak data rate for 3 x 1.25 MHz is 7.2 Mbps for DO Rev. 0 and 9.1 Mbps for DO Rev. A

WiMAX

IEEE802.16e MIMO-OFDMA Architecture

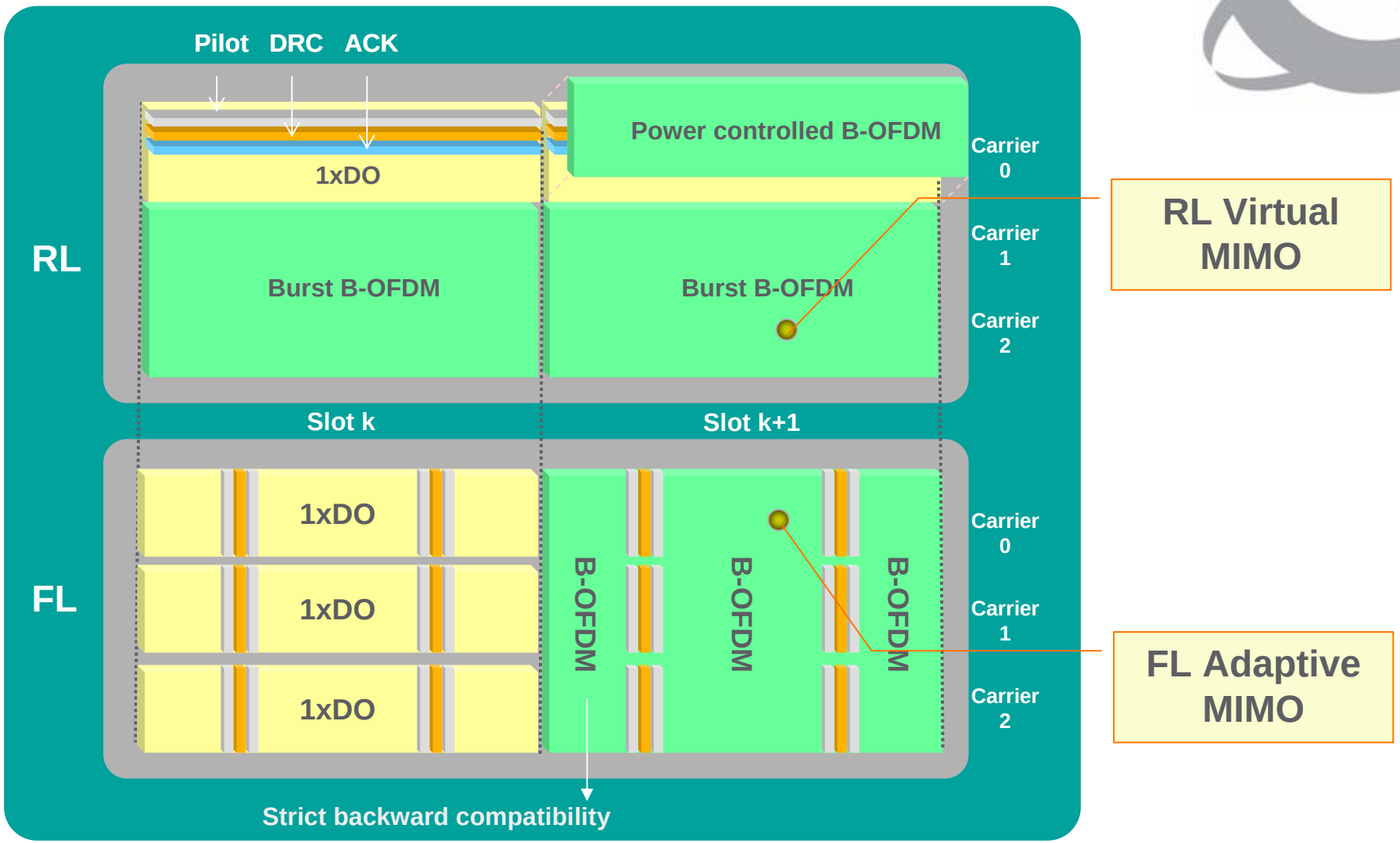


Complete MIMO air-interface is designed and standardized for WiMAX

- **Scalable OFDM-MIMO – simple silicon implementation**
- **Many Adaptive MIMO Modes - Transmit Diversity → Pure MIMO**
- **Open/Closed Loop MIMO to optimize nomadic and vehicular applications**

CDMA-Evolution

CDMA EV-DO Evolution



Nortel, Lucent and Samsung Lead Proposal

UMTS / HSOPA Evolution

UMTS HSOPA Evolution

- HSOPA has three functional entities
  - Evolved Node B (eNode B)
  - Access System Gateway (ASGW)
  - Radio Resource Management (RRM): Load balancing across GSM, UMTS, WiFi and WiMAX
- Open Interfaces
- End to End QoS
- Supports MIMO

Summary

- OFDM-MIMO will be the baseline technology for all next generation air-interface standards
  - OFDM-MIMO High Capacity and high Throughput
  - Low cost per Mbps
- Nortel is the leader in OFDM-MIMO
  - More than 7 years technology R&D investment
  - Defined MIMO in IEEE802.16 standard and WiMAX profile

System Capacity based on MIMO Scalability

IEEE802.16e provides a suite of MIMO capabilities

ITU-PA, 3km/h

2.5GHz, 10MHz,TDD (D:U=2:1), Full Queue FTP	IEEE802.16e OFDMA					
MIMO (Tx:Rx)	1x1	1x2	2x2	2x4	4x2	4x4
Bits/Sec/Hz/Sector	1.2	1.8	2.8	4.4	3.7	5.1
Aggregate Sector Throughput (Mbps)	7.6	11.6	17.8	27.7	23.6	32.6

Results are for open-loop MIMO, further gain can be achieved through closed-loop MIMO or combined beam-forming and MIMO