UNIK4230: Mobile Communications

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Nokia Siemens Networks

Mobile Broadband

Materials used from:
1. **Nokia Siemens Networks**
2. **LTE for UMTS**. Evolution to LTE-Advanced. 2nd Edition. Harri Holma and Antti Toskala

Agenda

Introduction

WCDMA/HSPA/HSPA+

LTE

LTE-Advanced

Summary

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Strong momentum in mobile broadband

Devices

Services

Affordable & exciting MBB offerings

Over 6 billion mobile subscriptions

- Affordable phones for mass market
- Over 1.2billion mobile broadband users, 50% y-o-y growth
- Operators global MBB service revenue grow annually 25%
- 350 million mobile Facebook users, out of 800 million total
- YouTube generates 22% of global mobile data traffic
- Mobile broadband subscriptions expected to exceed wireline broadband users within 2 years

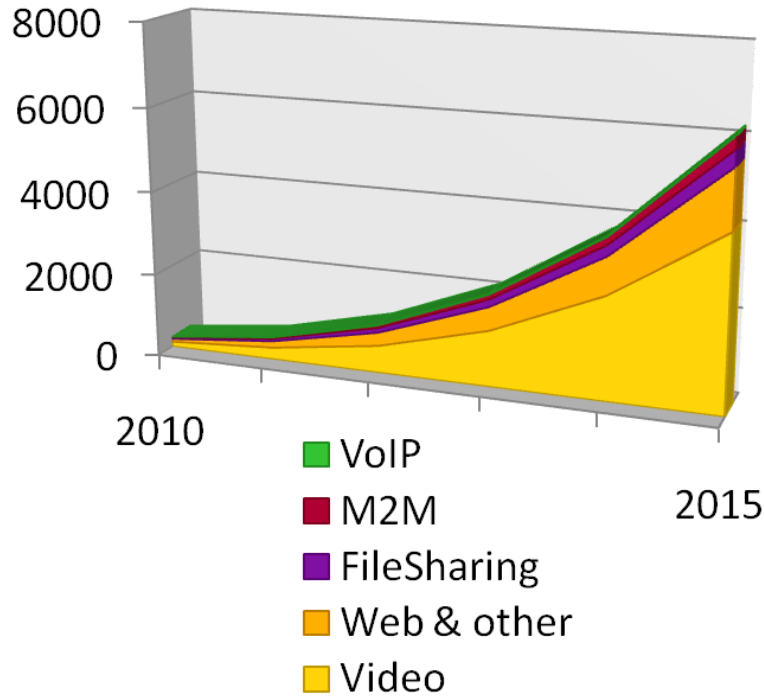**Networks**

Source: NSN BI, Industry analysts

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Networks

Mobile broadband traffic more than doubles every year
Video traffic has overtaken everything else
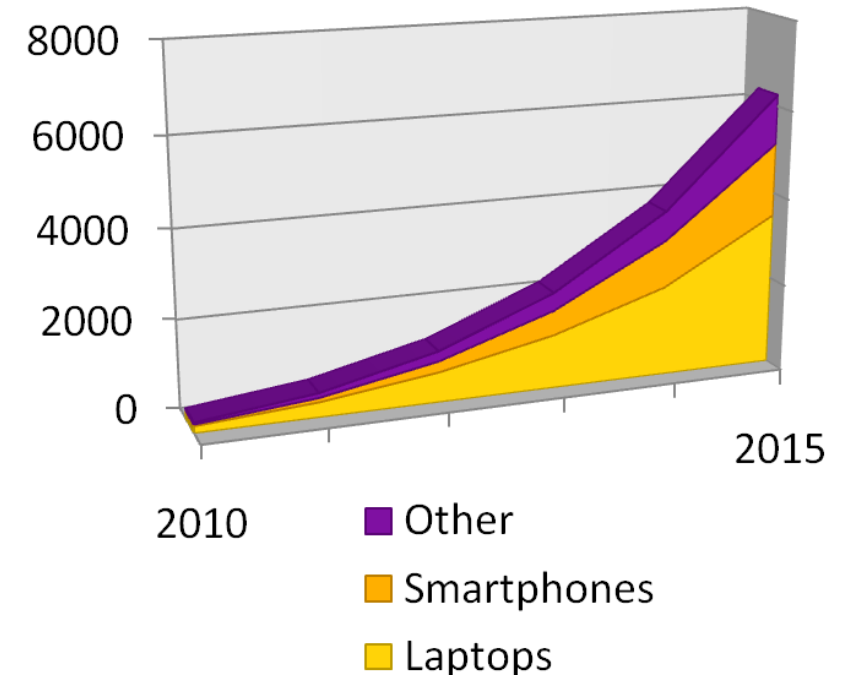
Mobile application traffic
Petabytes per month

8000
6000
4000
2000
0

2010

2015

- 🟩 VoIP
- 🟥 M2M
- 🟪 FileSharing
- 🟧 Web & other
- 🟨 Video

Source: NSN BI, Industry analysts

Mobile data traffic
Petabytes per month

8000
6000
4000
2000
0

2010

2015

- 🟪 Other
- 🟧 Smartphones
- 🟨 Laptops

Source: NSN BI, Industry analysts

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Mobile data traffic generation per device type

Distribution of global mobile data traffic, January 2011

Source: CSC, 2011

Legend:
- % subscribers (orange)
- % data consumption (purple)
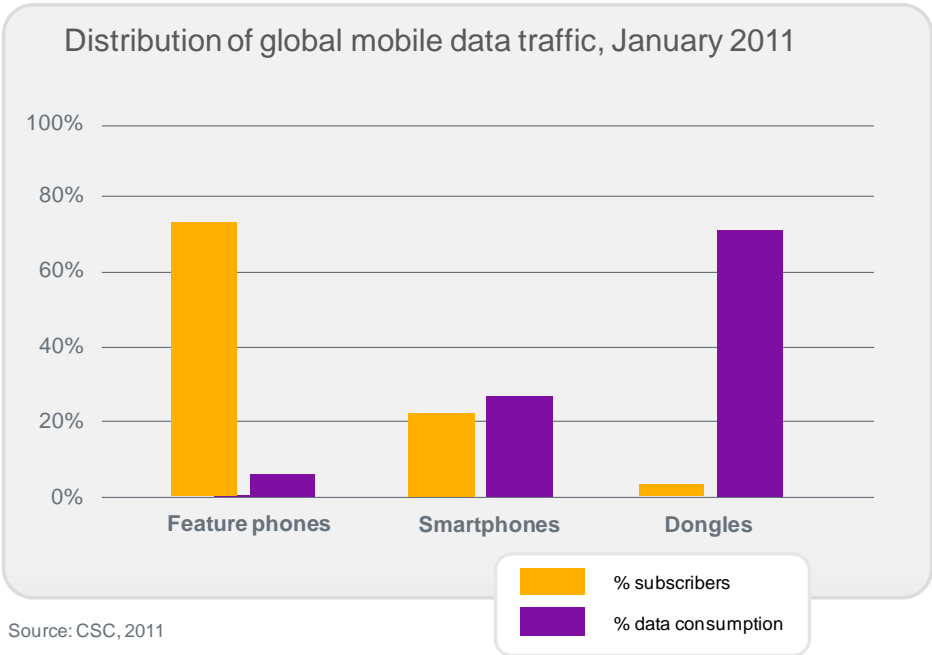
Smart Phone

| 100% Voice |
| Some data |

Voice: 300 min
36 MB

Tablet

| Some voice |
| 100% data |

Laptop

| Some voice |
| 100% data |

Average data usage 2010:

Smart Phone	Tablet	Laptop
150 MB	**400 MB**	**Consumer 2.8 GB** **Enterprise 790 MB**

Average data usage 2015:

Smart Phone	Tablet	Laptop
600 MB	**1.2 GB**	**Consumer 6 GB** **Enterprise 2.1 GB**

Data usage per month, global averages
Source: NSN BI

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Factors impacting MBB/LTE take off & competiveness

Device portfolio
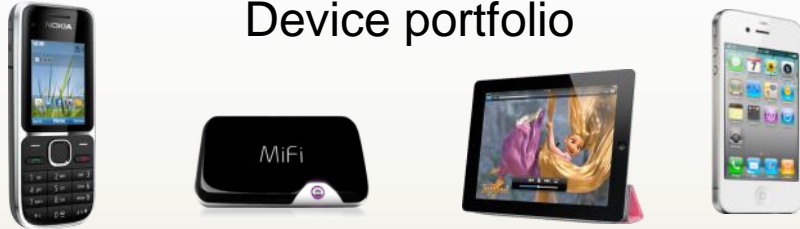
- Smart phones, low end MBB phones
- Sticks, tablets, laptops, Mi-Fi
- Subsidizing usage of 3G/LTE devices

Content & applications

- Own applications, services from Internet
- Partnering with local brands & device vendors
- Foster country specific killer apps

Attractive bundles

- Voice, data, sms, devices, triple/quad play
- Converged fixed and mobile offering
- Content, email, navigation, security

Network capabilities

- Capacity, coverage, quality
- 6-sector, active antenna, site density, spectrum
- Small cells, offloading, traffic management

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HSPA device ecosystem overview

HSPA technology and evolution

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UMTS Air Interface technologies

UMTS Air interface is built based on two technological solutions
- WCDMA – FDD
- WCDMA – TDD

WCDMA – FDD is the more widely used solution
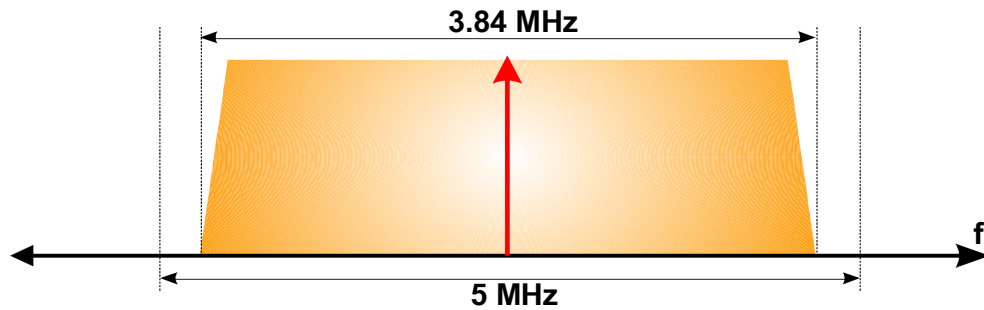- FDD: Separate UL and DL frequency band

WCDMA – TDD technology is currently used in limited number of networks
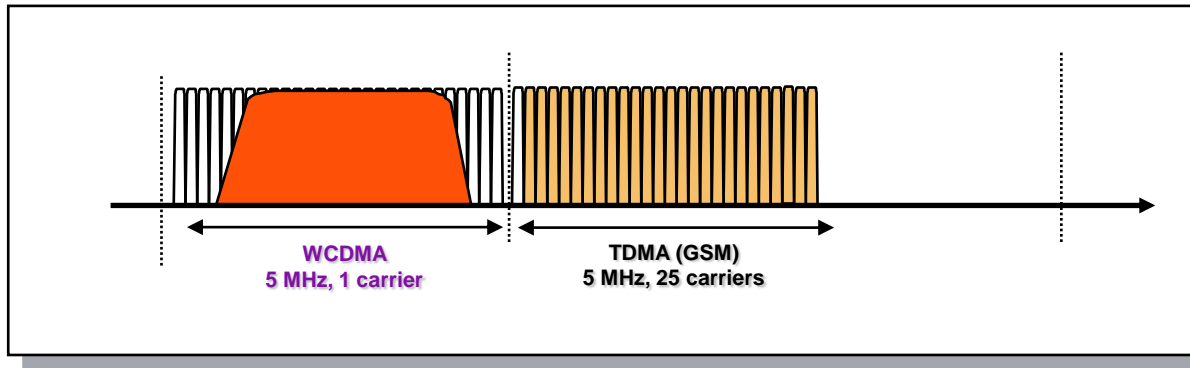- TDD: UL and DL separated by time, utilizing same frequency

Both technologies have own dedicated frequency bands

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WCDMA Technology

WCDMA Carrier

3.84 MHz

5 MHz

5+5 MHz in FDD mode
5 MHz in TDD mode

f

Users share same time and frequency

Frequency

Time

Direct Sequence (DS) CDMA

WCDMA
5 MHz, 1 carrier

TDMA (GSM)
5 MHz, 25 carriers

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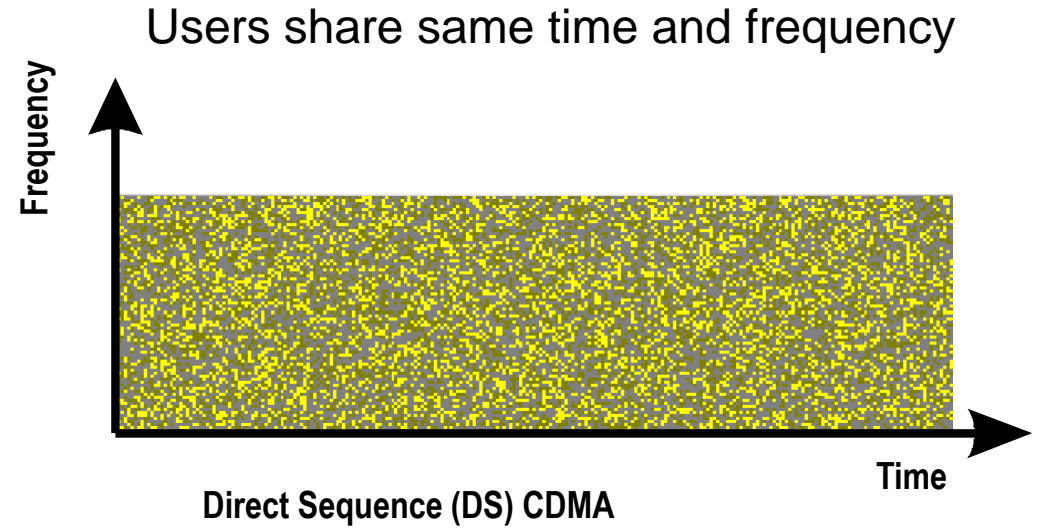
UMTS & GSM Network Planning

GSM900/1800:

3G (WCDMA):

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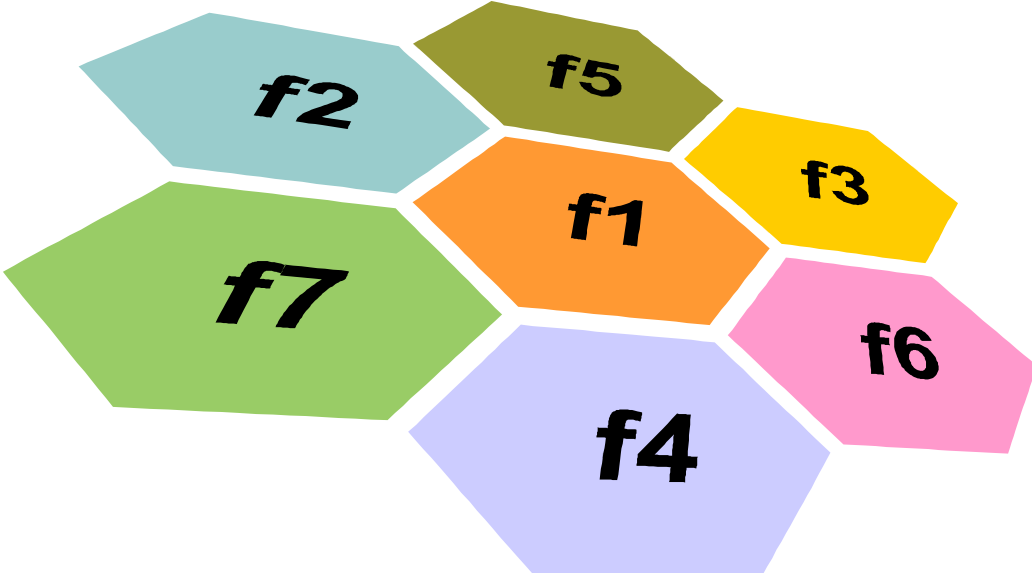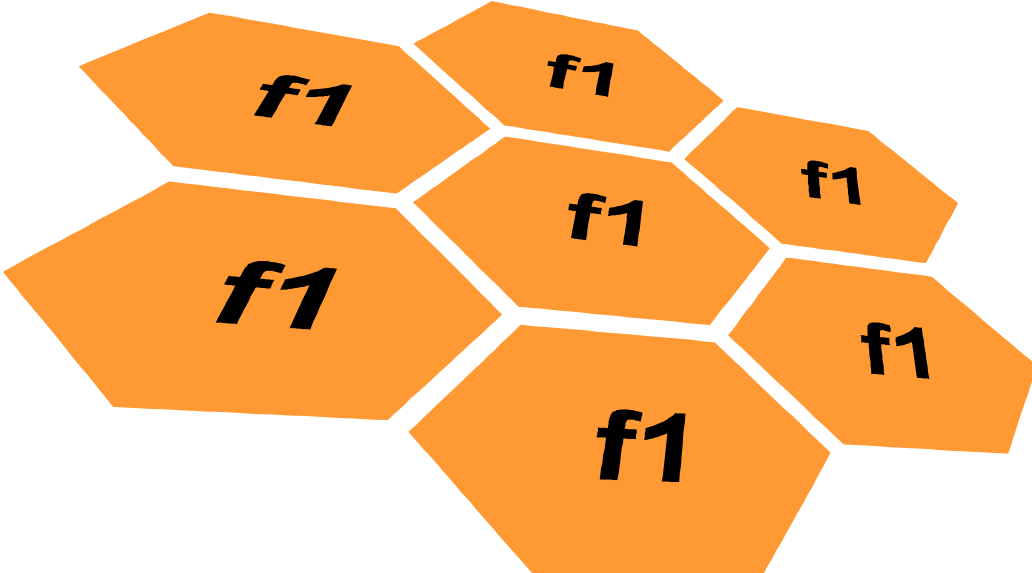
CDMA principle - Chips & Bits & Symbols

Bits (In this drawing, 1 bit = 8 Chips ➜ SF=8)

Baseband Data

Spreading Code

Spread Signal

Air Interface

Despreading

Data

Chip

Chip

+1

-1
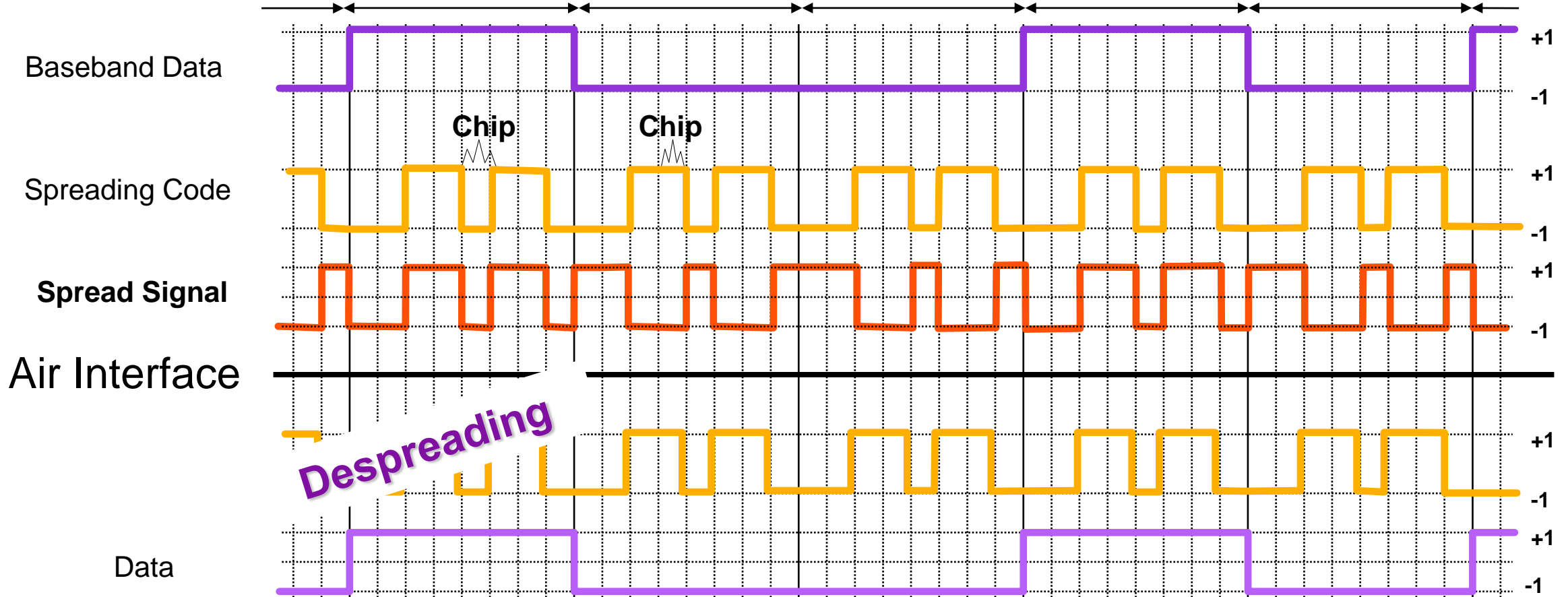
Global HSPA subscriber numbers

Mobile broadband subscriptions
Per technology in millions

Legend: ■ Other ■ LTE ■ HSPA ■ EVDO
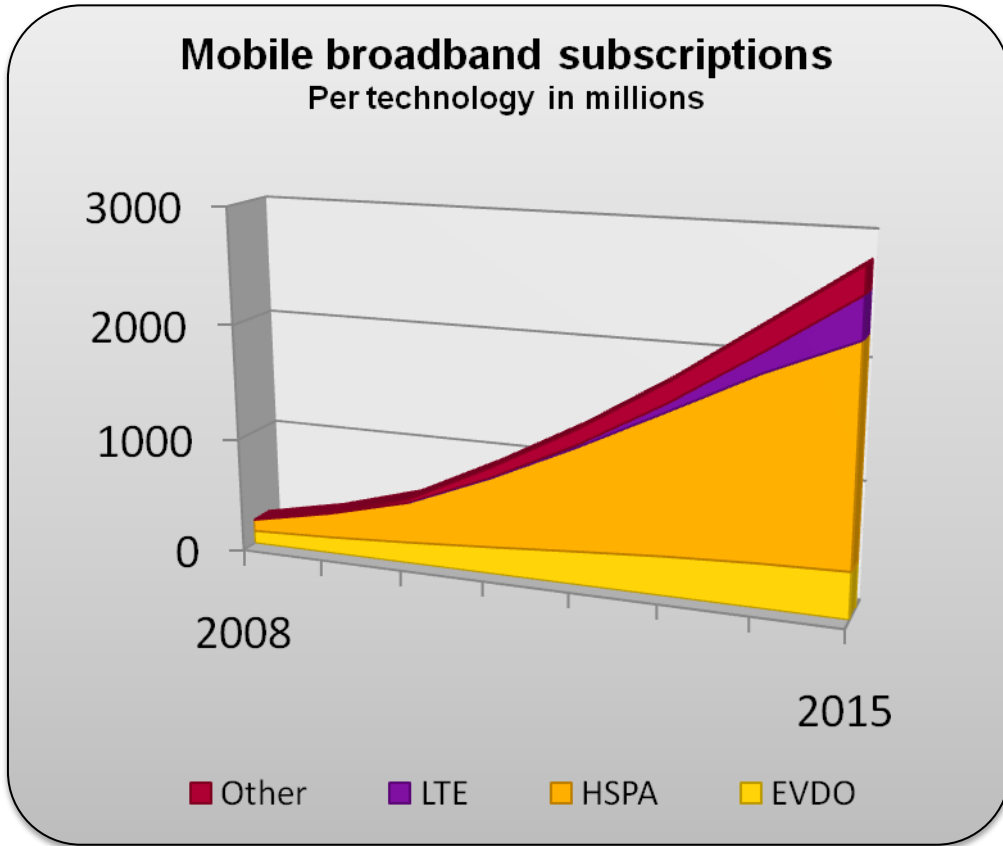
Source: Ovum

- HSPA overtook EVDO as top mobile broadband technology in 2008

- HSPA technology track will dominate for many years to come

- Lead markets USA, Japan, South Korea, Australia and West Europe

- China, India, Indonesia and Brazil with biggest growth

- Operators are aligned on LTE as the future technology for HSPA and EVDO networks

- WiMAX networks will not gain a significant share of global users

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HSPA "World Map" Overview

446 commercial HSPA operators in **170** countries/territories
136 commercial HSPA+ systems launched

Over 99% of commercial WCDMA operators has launched HSPA !

High WCDMA/HSPA penetration in all Western European countries

Russia biggest Eastern European WCDMA/HSPA market with 12 Million subs. 3-digit growth especially in Turkey

World's leading HSPA market is Japan with >85 Million subs

USA leading MBB with > 70 Million WCDMA/HSPA subs + big CDMA2000

Saudi-Arabia biggest WCDMA/HSPA market in ME

In China HSPA fast growing

South-Korea also big

In India HSPA just launched

Fairly low subscriber numbers but 3-digit annual growth rates !

TOP-market = Brazil, 21M subs Very fast growth in Brazil, Argentina, Colombia, Chile, Peru and Mexico

TOP3 WCDMA/HSPA-countries South-Africa (7.7 M), Egypt (4.7 M) Nigeria (4.2 M) Other countries still in pretty early stages of HSPA-market

APAC a mixture of mature WCDMA/HSPA markets (e.g. Australia >80% penetration) + countries with high growth phase (e.g. Philippines, Vietnam)

Countries with commercial 3G/HSPA operators
Countries with 3G/HSPA network commitments/deployments

Source: GSA July 2011

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WCDMA/HSPA/HSPA+
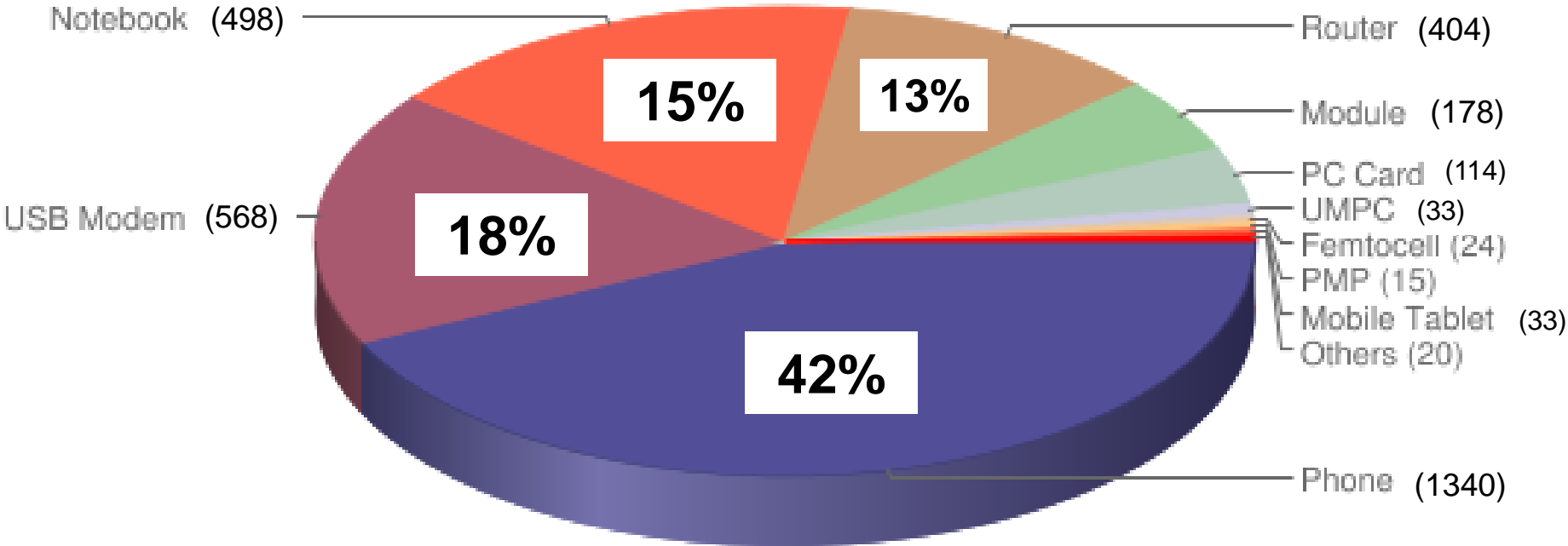
LTE

LTE-Advanced

Summary

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HSPA device ecosystem overview

HSPA technology and evolution

HSPA device landscape (GSA July, 2011)

3227 different kind of HSPA-enabled devices

Notebook (498)

Router (404)

Module (178)

PC Card (114)

UMPC (33)

Femtocell (24)

PMP (15)

Mobile Tablet (33)

Others (20)

USB Modem (568)

Phone (1340)

15%

13%

18%

42%

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TRUE world-market HSPA devices available
Examples:

850/900/1900/2100

iPad 2

iPhone 4
iPhone 4S

Nokia C6

Samsung Galaxy S II

Nokia Lumia 800

Sierra Wireless 504

Option Globetrotter 441

Option ICON 452

850/AWS/1900/2100

Five-band !!

850/900/AWS/1900/2100

Nokia C7

Nokia N8

Samsung Galaxy Nexus

Nokia E7

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Clearly below 100 Euros HSPA phones now available

Samsung Hero E3210
Dual-band HSPA 3.6 Mbps
Quad band EDGE
~ 40 €

Samsung Hero E3213
Dual-band HSPA 3.6 Mbps
Quad band EDGE
~ 50 €

Nokia Asha 300
Quad-band HSPA 10.2 Mbps
Quad EDGE, Dual SIM
~ 75 €

Huawei Ideos X1
Dual-band HSPA 7.2 Mbps
Android 2.2
~ 90 €

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HSPA device categories and max theoretical data rates

HSDPA Categories (Downlink)

Cat6	3.6 Mbps, with 16QAM
Cat8	7.2 Mbps, with 16QAM
Cat9	10.1 Mbps, with 16QAM
Cat10	14.4 Mbps, with 16QAM
Cat14	21 Mbps, with 64QAM
Cat18	28 Mbps, with MIMO and 16QAM
Cat20	42 Mbps, with MIMO and 64QAM
Cat24	42 Mbps, DC-HSDPA and 64QAM
Cat28	84 Mbps, DC-HSDPA and 64QAM and MIMO
Cat32	168 Mbps, MC-HSDPA and 64QAM and MIMO

HSUPA Categories (Uplink)

Cat2	1.4 Mbps
Cat5	2.0 Mbps
Cat6	5.76 Mbps
Cat7	11.5 Mbps, with 16QAM
Cat8	11.5 Mbps, DC-HSUPA, 2x Cat6
Cat9	23 Mbps, DC-HSUPA, 2x Cat7

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DC-HSPA on 2100, 900 and 2100+900 MHz (dual-band DC)

2100 MHz
2100 MHz

900 MHz
900 MHz
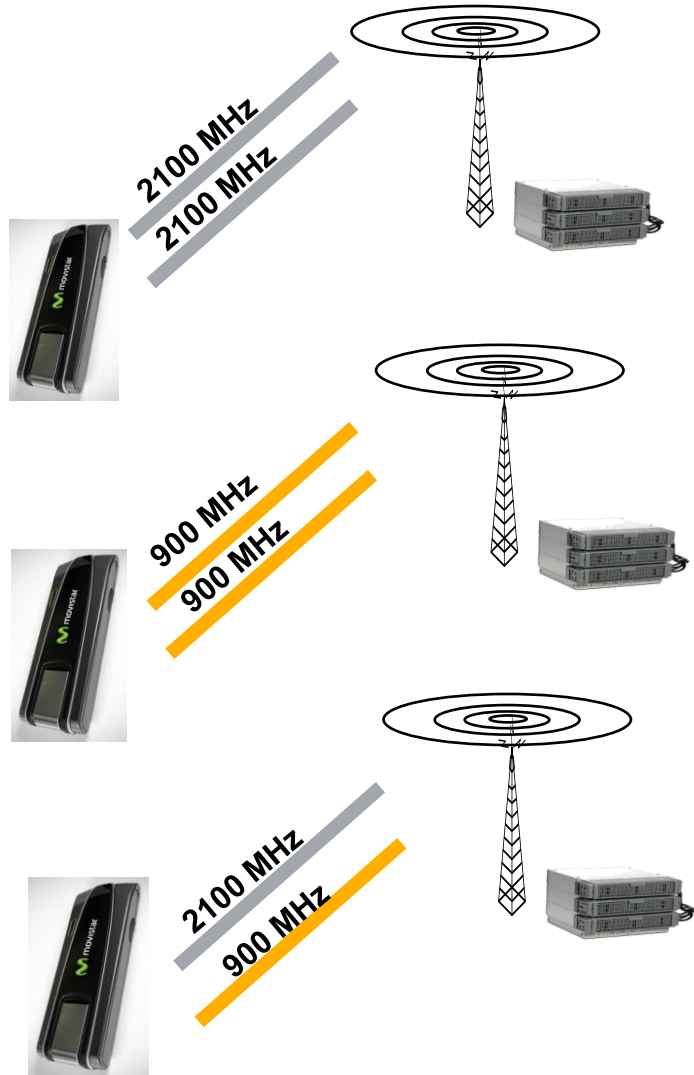
2100 MHz
900 MHz

- DC-HSPA 42 Mbit/s device available currently in the market can support aggregation of two HSPA-carriers on the 2100 MHz band

- Technology-wise DC-HSPA on 900 MHz could be done but typically not included to the early devices/ chipset due lack of operator demand
  (not many operators that can free 900 for two HSPA-carriers)

- Devices capable for dual-band DC-HSPA 42 Mbit/s are expected earliest year 2013

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HSPA+ radio performance basics

- HSDPA peak rate depends on adaptive modulation, coding and UE category

- BTS selects modulation and coding based on reported signal quality
(affected by e.g. distance from BTS, load in neighboring cells and UE performance)
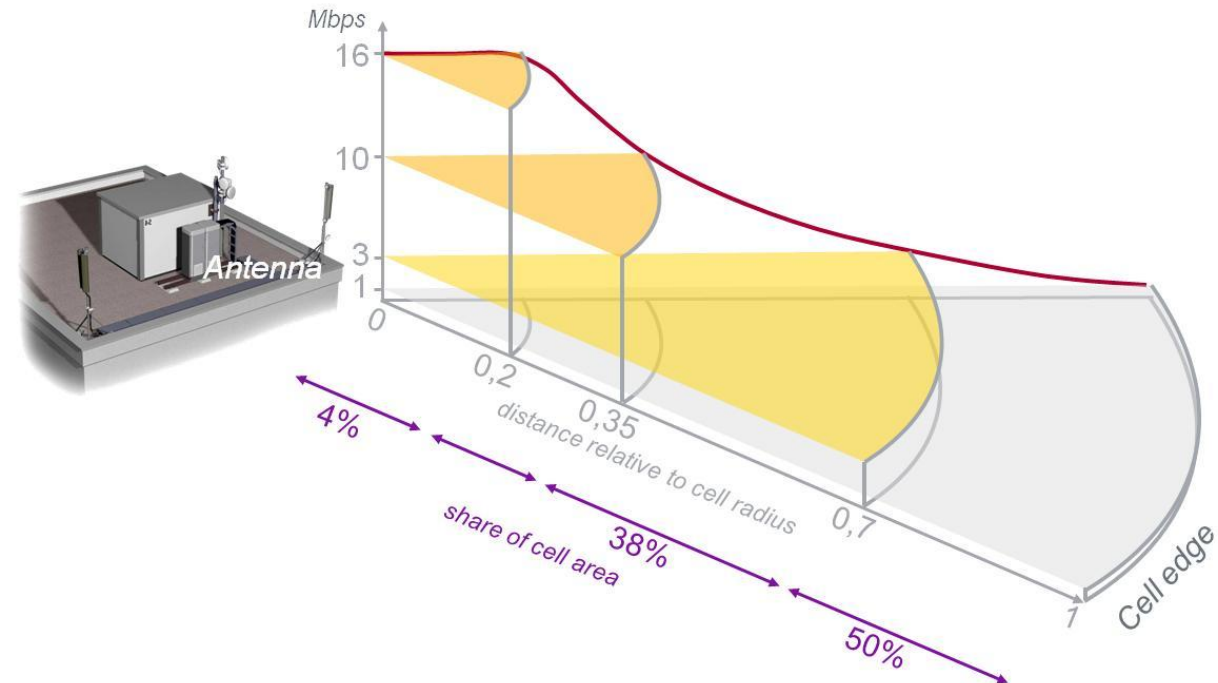
HIGH LOAD neighboring cells
64 QAM, no MIMO, no DC-HSPA
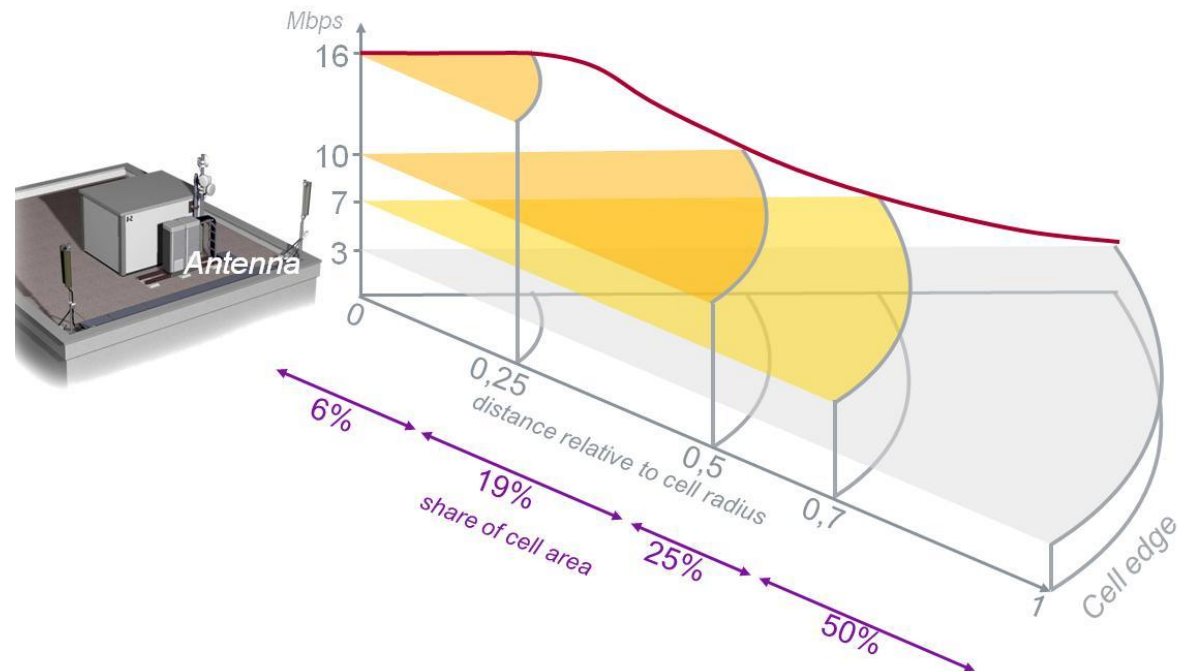
LOW LOAD neighboring cells
64 QAM, no MIMO, no DC-HSPA

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64QAM improves HSPA throughput,
Live networks indicate 64QAM benefit is better than in simulations

Cat 14 device can benefit from 64QAM in fairly large area. Some 17-28% throughput benefit compared to Cat 10 device, except at cell edge. Max. 21 Mbps only close to BTS, otherwise more robust coding needed with 64QAM.

Category 14 device:
max 21 Mbit/s

Category 10 device:
max 14 Mbit/s

Old category 12 device:
max 1.8 Mbit/s

Typically CQI > 26 needed in order to get benefit from 64QAM
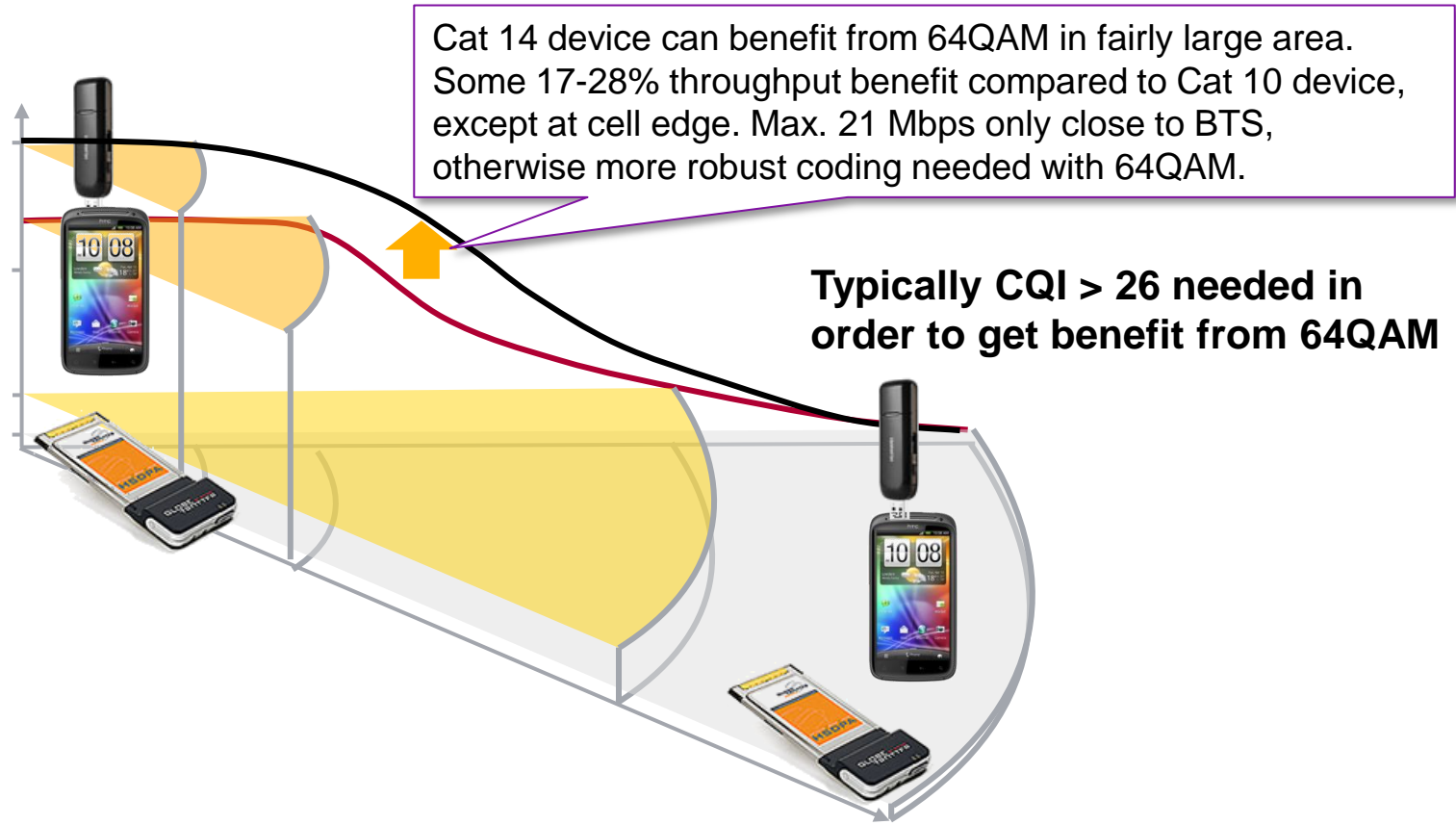
Clear difference close to base station

Noticeable difference in the middle

Similar at the cell edge

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Spectral Efficiency Evolution
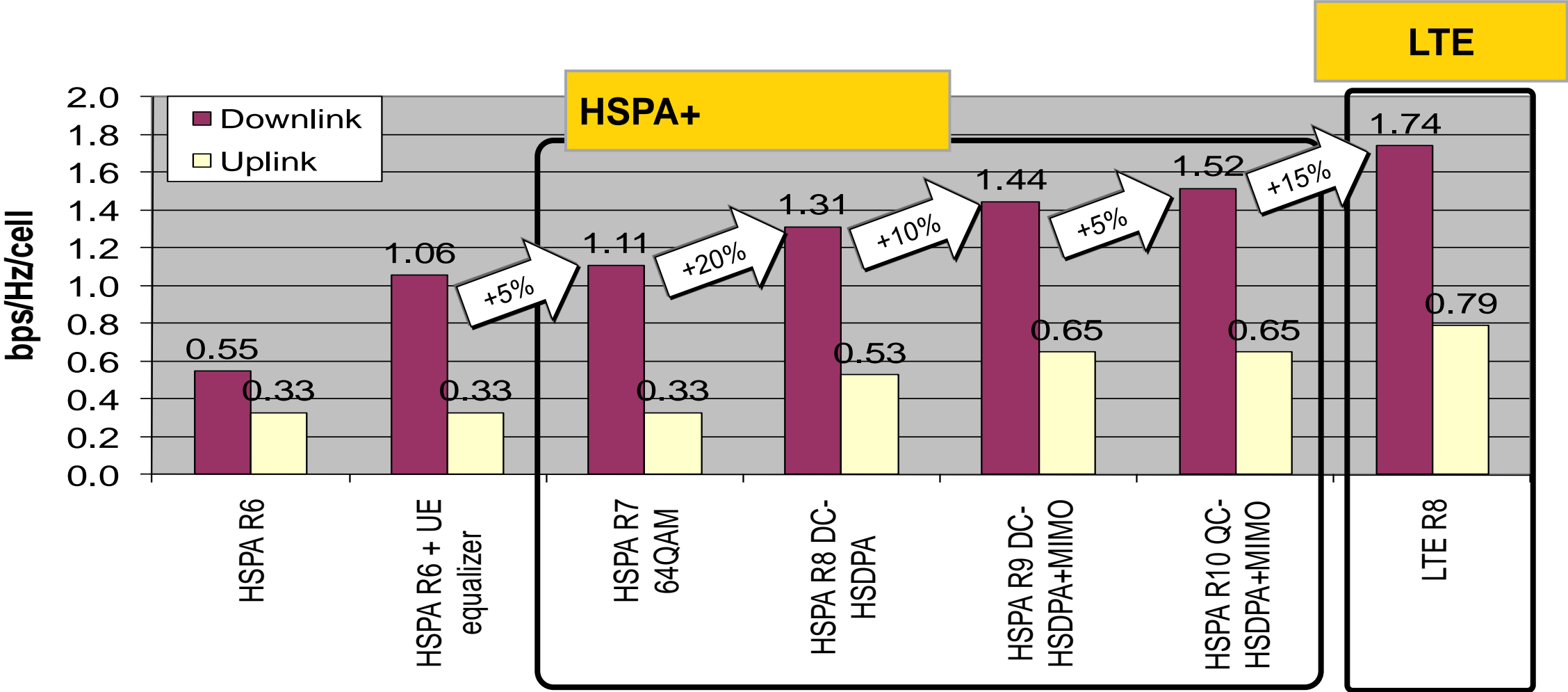
Long Term HSPA Evolution – Technology Components

8 x 5 MHz — **Bandwidth extension**

4x   2x — **MIMO**

Multi-cell transmission

HSPA   LTE — **HSPA + LTE aggregation**
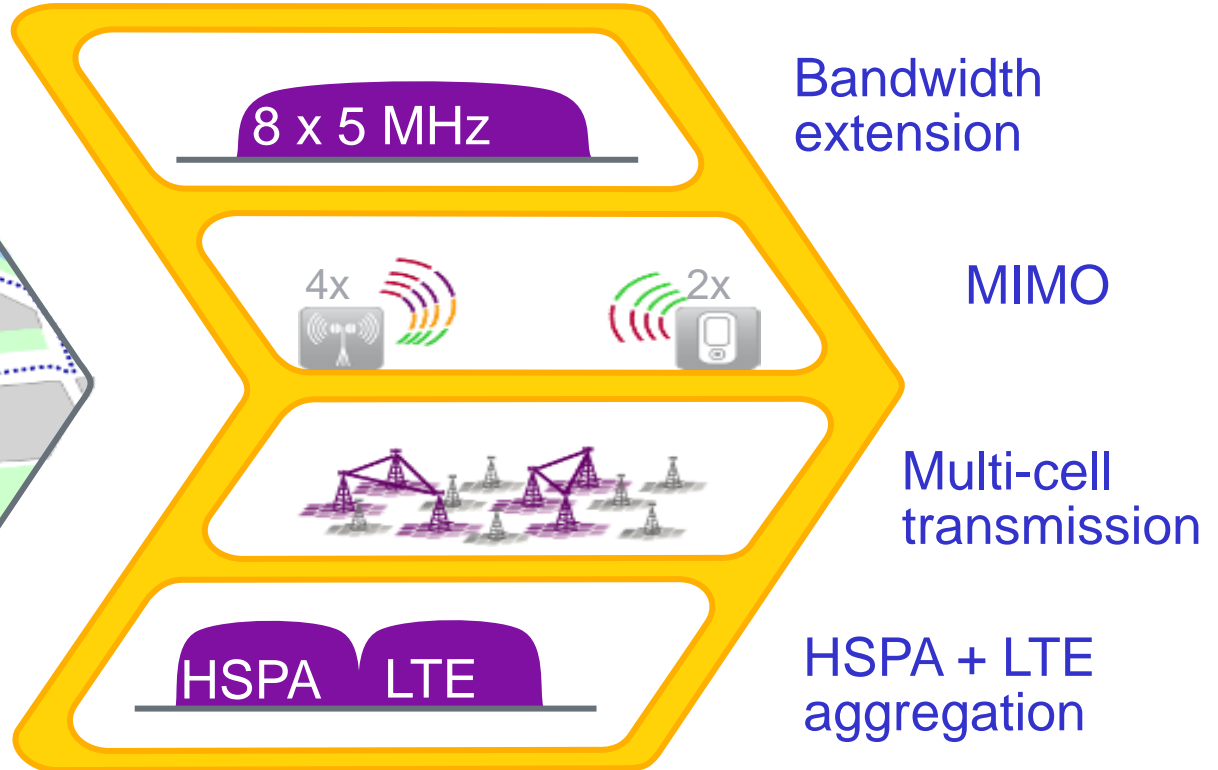
Similar technical solutions in Long Term HSPA Evolution and in LTE Advanced

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HSPA Peak Data Rate Evolution

- Downlink peak rate 672 Mbps with 4x4 MIMO
- Downlink peak rate 336 Mbps with 2x2 MIMO

Release 11+

336 - 672 Mbps

40 MHz 2x2 / 4x4 MIMO

Release 10

168 Mbps

20 MHz 2x2 MIMO

Release 9

84 Mbps

10 MHz 2x2 MIMO

Release 8

42 Mbps

10 MHz No MIMO

Release 7

28 Mbps

5 MHz 2x2 MIMO

Release 5

14 Mbps

5 MHz No MIMO

DOWNLINK

Release 11+

70 Mbps

10 MHz 64QAM MIMO

Release 9

23 Mbps

10 MHz 16QAM

Release 7

11.52 Mbps

5 MHz 16QAM

Release 6

5.76 Mbps

5 MHz QPSK

UPLINK

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HSPA Peak Data Rate Evolution

3GPP R10

672 Mbps

LT HSPA EVO

3GPP R5   **3GPP R7**   **3GPP R8**   **3GPP R9**

168 Mbps

4-carrier HSPA

3GPP R11+

DC-HSPA

84 Mbps

DC-HSPA + Rel9 MIMO

42 Mbps

70 Mbps

LT HSPA EVO

14 Mbps   21 Mbps

64QAM

3GPP R11+

DOWNLINK

3GPP R9

23 Mbps

DC-HSUPA

3GPP R7

11 Mbps

16QAM

3GPP R6

HSUPA   5.8 Mbps

UPLINK

0.4 Mbps

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Multicarrier aggregation of up to 8 carriers on two bands for up to 672 Mbps

Band A DL 2 x 5 MHz — 10 MHz

+

Band B DL 2 x 5 MHz — 10 MHz

HSPA+ (3GPP Rel-10)

Total of 20 MHz on two bands

From 4 to 8 carriers

Band A DL 4 x 5 MHz — 20 MHz

+

Band B DL 4 x 5 MHz — 20 MHz

HSPA Evolution

Total of 40 MHz on two bands
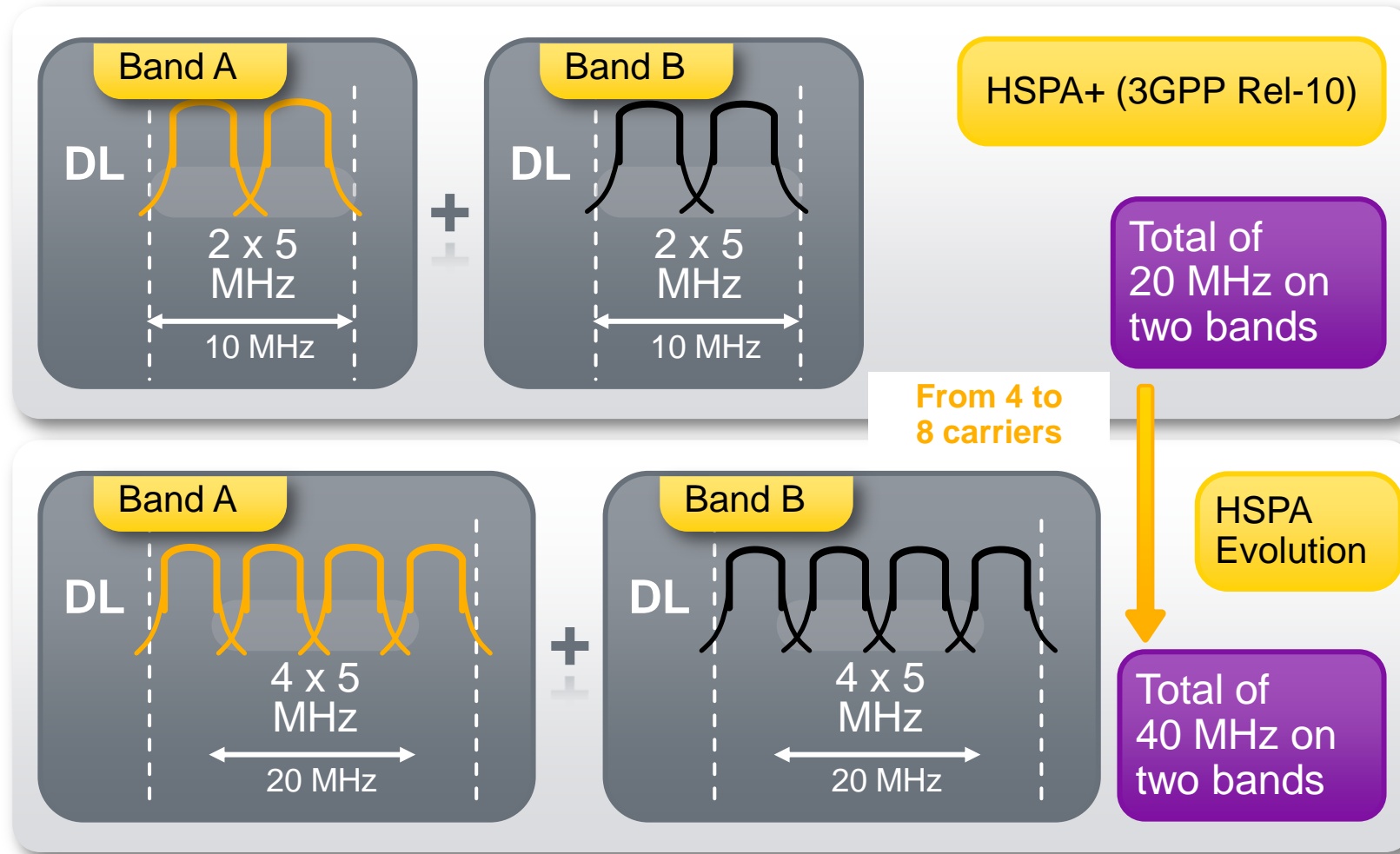
Expected band combinations

Band A	Band B
1900 MHz	2100/1700 MHz
1900 MHz	850 MHz
2100 MHz	1500 MHz
2100 MHz	900 MHz
2100 MHz	850 MHz

- 8-carrier with 4x4 MIMO: 672 Mbps peak rate
- Spectral efficiency improvement of up to 100%

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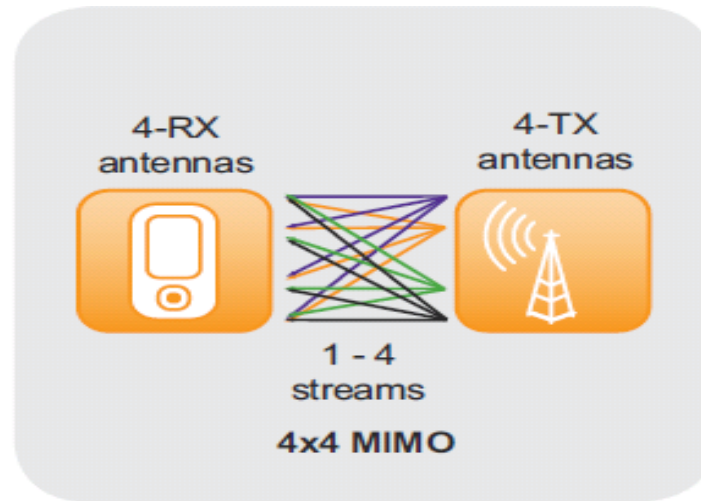
© Nokia Siemens Networks

MIMO Evolution

- Multi-antenna transmission and reception increases
  - peak data rates,
  - cell throughput and
  - cell edge data rates

Downlink Multiuser MIMO
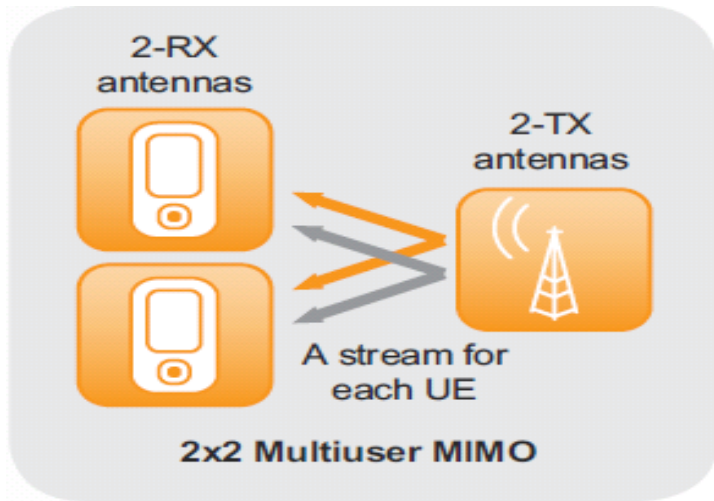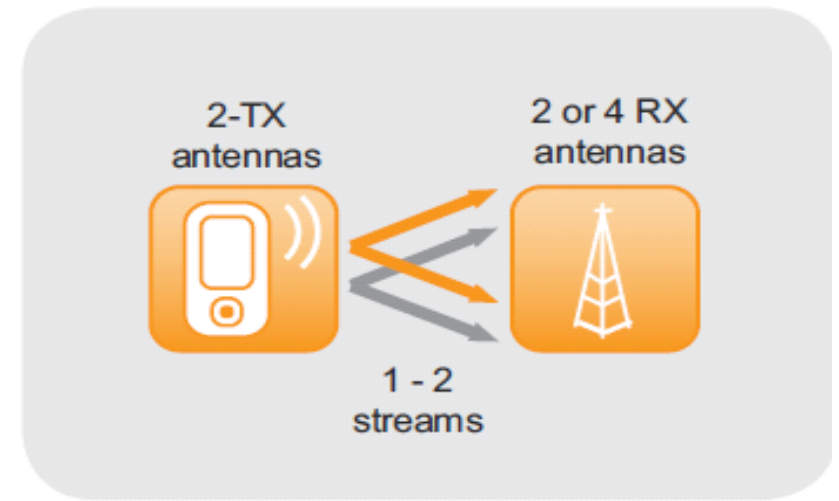
2-RX antennas

2-TX antennas

A stream for each UE

2x2 Multiuser MIMO

Downlink 4x4 MIMO

4-RX antennas

4-TX antennas

1 - 4 streams

4x4 MIMO

Uplink 2x2 MIMO

2-TX antennas

2 or 4 RX antennas

1 - 2 streams

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Agenda

Introduction

WCDMA/HSPA/HSPA+

LTE

LTE-Advanced

Summary

- **Introduction**
- LTE Spectrum
- Radio Access Overview
- Core Network Overview
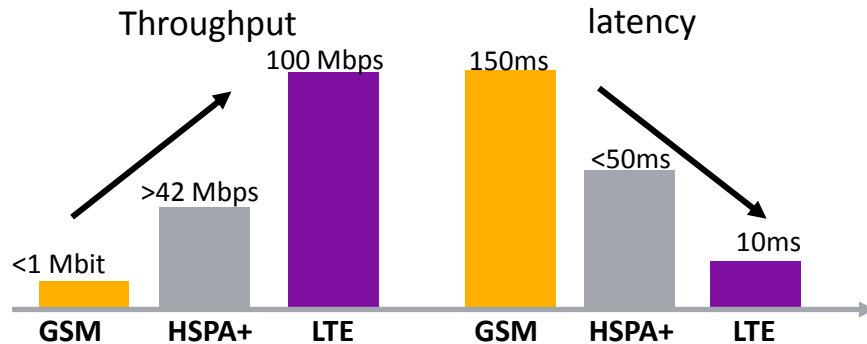- Voice over LTE (VoLTE)
- QoS in LTE
- Self Organizing Network (SON)

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WHY LTE?

Superior mobile broadband user experience

Throughput   latency

- 100 Mbps — LTE
- >42 Mbps — HSPA+
- <1 Mbit — GSM
- 150ms — GSM
- <50ms — HSPA+
- 10ms — LTE

Industry commitment behind the ecosystem

> 380 million LTE subscribers by 2015
Forecast for LTE lead markets by Research and Markets

119 LTE networks expected to be in commercial operation by end 2012

226 LTE network operator commitments in 76 countries

Technology convergence

- GSM
- WCDMA
- CDMA
- WiMAX
- TD-SCDMA

→ **FDD LTE** / **TD-LTE**

>90% harmonized in 3GPP

LTE Advanced
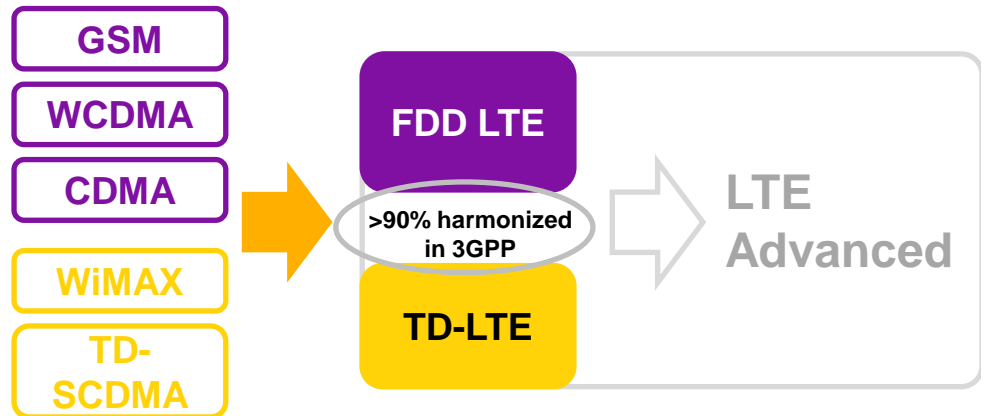
Extensive range of radio spectrum support

23 different FDD frequency band options
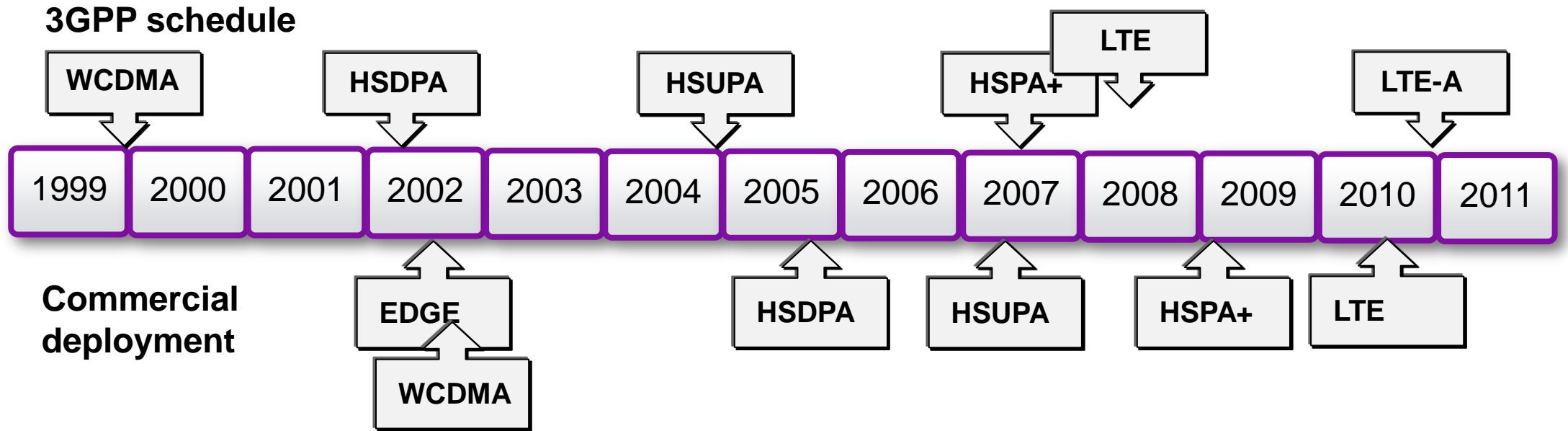**11 different TDD frequency band options**

Single operator may deploy both FDD+TDD LTE
for maximum utilization of spectrum assets

+ new ones still being specified both for new band deployment and re-farming cases

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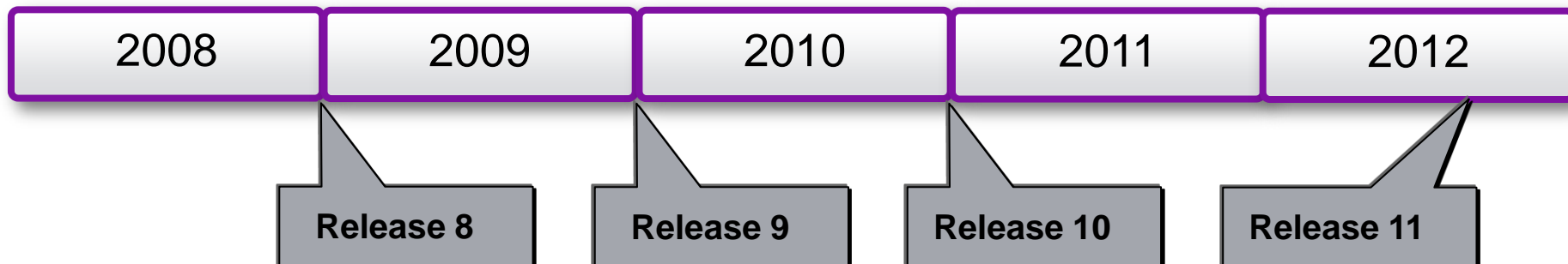# Motivation and Targets for LTE

- Spectral efficiency 2 to 4 times more than with HSPA Rel-6
- Peak rates exceed 100 Mbps in downlink and 50 Mbps in uplink (which is 10 times more than HSPA Rel-6)
- Enable a round trip time of < 10 ms
- Packet switched optimized
- High level of mobility and security
- Optimized terminal power efficiency
- Frequency flexibility with allocations from below 1.5 MHz up to 20 MHz

3GPP Standard and Release schedule

3GPP schedule

| WCDMA | | | HSDPA | | | HSUPA | | | HSPA+ | LTE | | LTE-A |

| 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |

Commercial deployment

EDGE

WCDMA

HSDPA

HSUPA

HSPA+

LTE

3GPP LTE Release schedule

| 2008 | 2009 | 2010 | 2011 | 2012 |

Release 8

Release 9

Release 10

Release 11

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LTE market status

285 operators in 93 countries investing in LTE
- 226 commercial LTE network commitments in 76 countries
- 59 pre-commitment trials in additional 17 countries
- *49 commercial LTE networks launched in 29 countries*

GSA
www.gsacom.com

GSA – Evolution to LTE report
January 5, 2012
www.gsacom.com

- Countries with commercial LTE service
- Countries with LTE commercial network deployments on-going or planned
- Countries with LTE trial systems (pre-commitment)

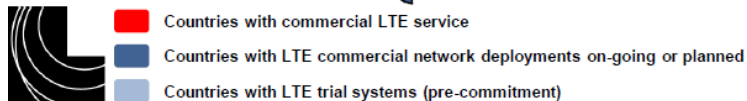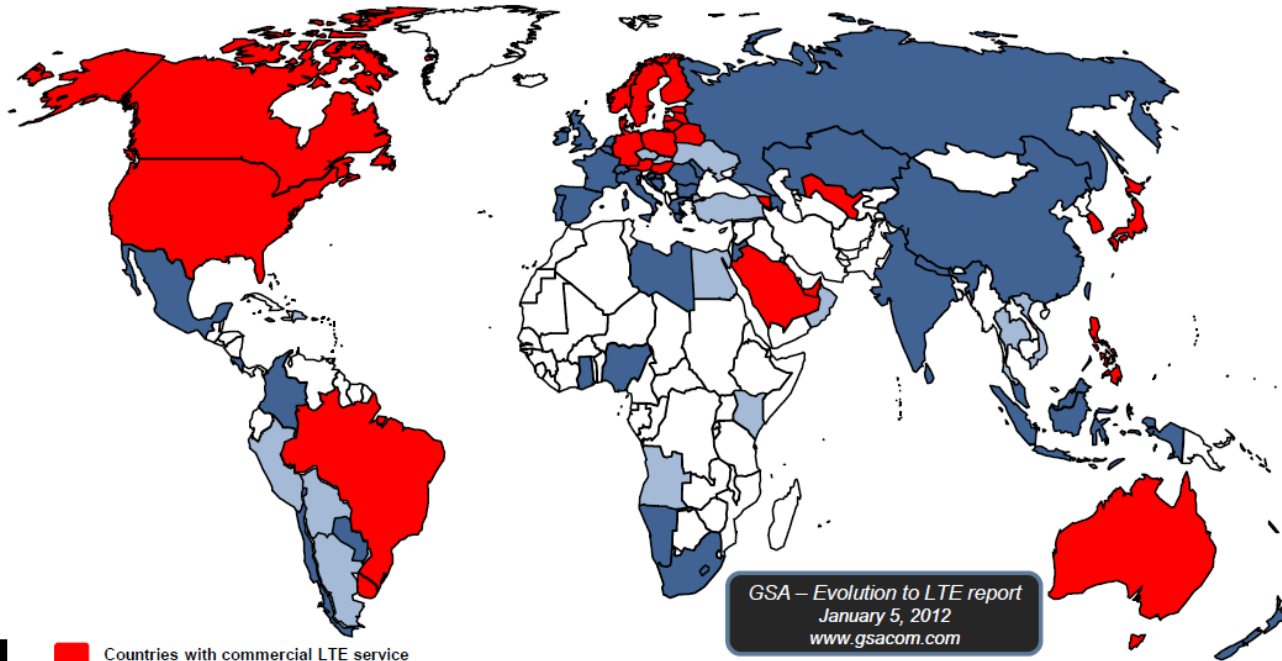© Global mobile Suppliers Association – GSA

- 49 operators have commercially launched LTE

- 119 commercial LTE networks in 53 countries expected by end 2012

- 226 commercial LTE network commitments in 76 countries

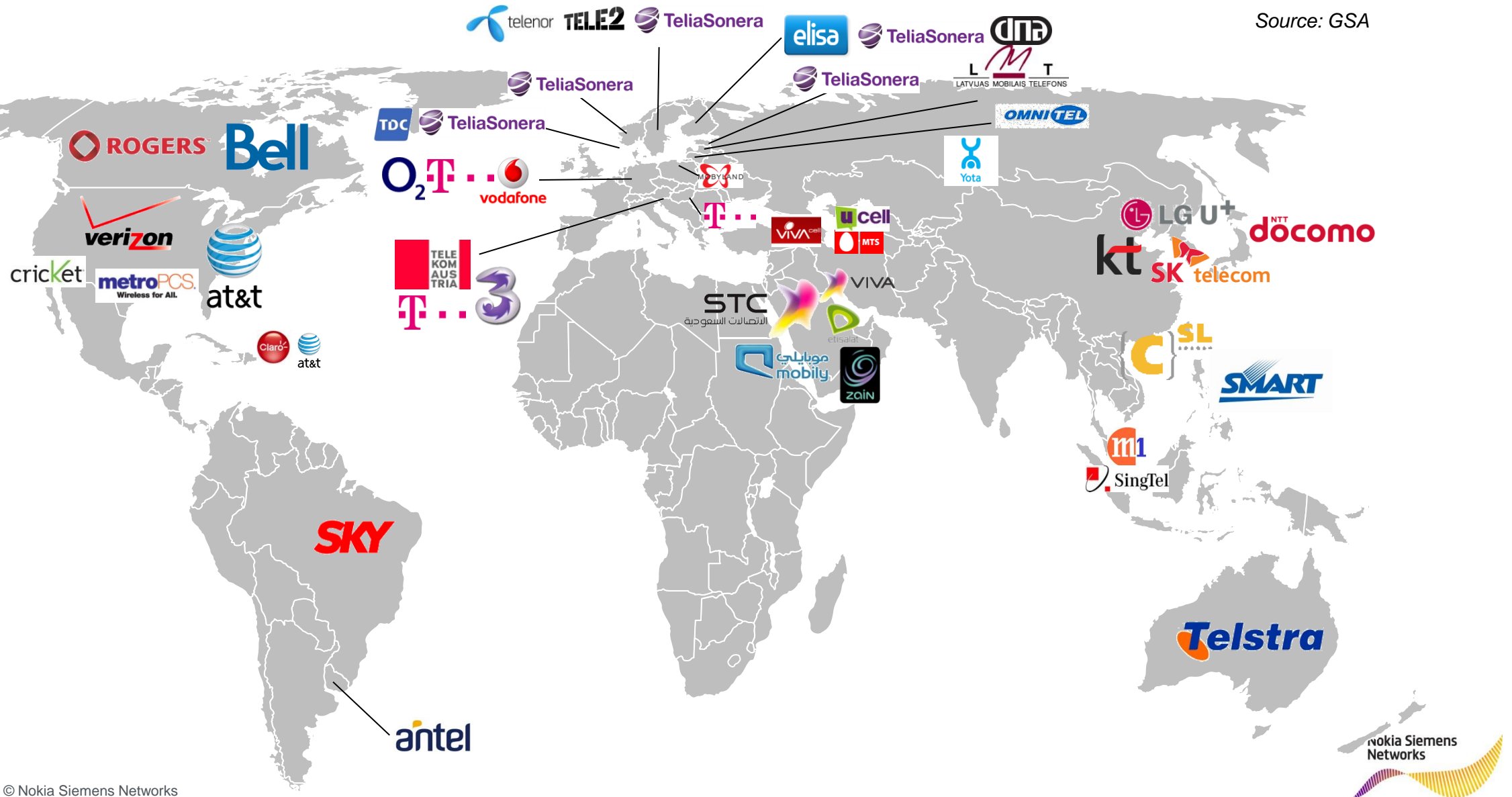326mn dual-mode (LTE+3G) and 260mn (LTE-FDD + TD-LTE) devices activated by 2016
Forecast by Maravedis (May 2011)

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49 commercially launched LTE networks, Jan 5th 2012

Basic Concepts / Architecture

LTE / SAE introduces the mechanism to fulfill the requirements of a next generation mobile network

Flat Overall Architecture

- 2-node architecture
- IP routable transport architecture

Access   **Core**   **Control**

LTE BTS (eNodeB)   MME SAE-GW   IMS   HLR/HSS

Improved Radio Principles

- peak data rates [Mbps] 173 DL , 58 UL
- Scalable BW: 1.4, 3, 5, 10, 15, 20 MHz
- Short latency: 10 – 20 ms

RF Modulation:

- OFDMA in DL
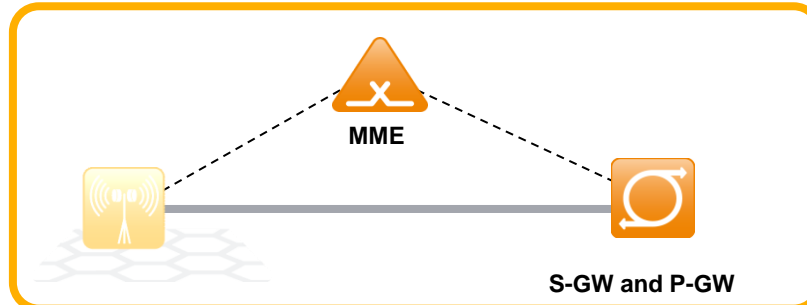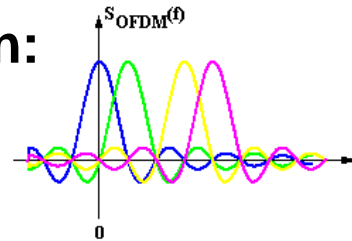- SC-FDMA in UL

$S_{OFDM}(f)$

0   f

New Core Architecture

- Simplified Protocol Stack
- Simple, more efficient QoS
- UMTS backward compatible security

MME

S-GW and P-GW
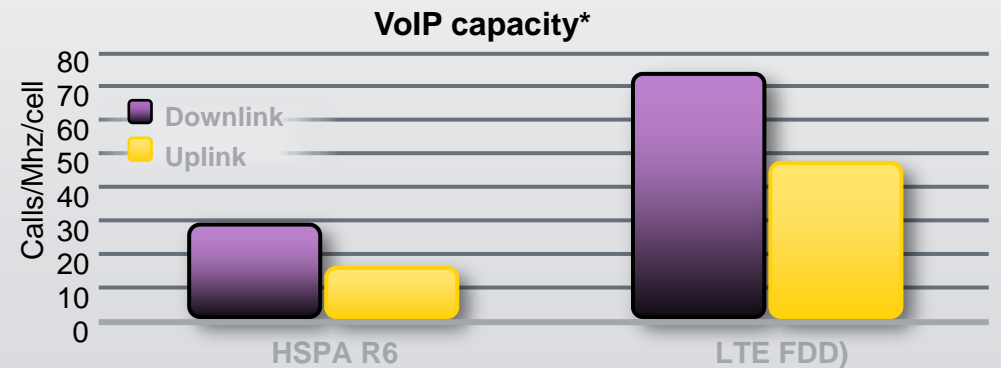
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LTE for best Mobile Broadband end-user performance
Superior data rates, capacity and latency

Max. peak data rate

Mbps

350
300
250
200
150
100
50
0

- Downlink (uncoded)
- Uplink (uncoded)
- Downlink (coded)
- Uplink (coded)

2x5MH
HSPA R6

2x5MHz
HSPAevo
(2x2 MIMO/64QAM)

2x20MHz
LTE
(2x2 MIMO/64QAM)

2x20MHz
LTE
(4x4 MIMO/64QAM)

Average cell throughput
(macro cell, 2x20 MHz or equivalent)*

Mbps/cell

70
60
50
40
30
20
10
0

- Downlink
- Uplink

4 carriers,
each 2x5 MHz
HSPA R6

4 carriers,
each 2x5 MHz
HSPAevo
(2x2 MIMO/64QAM)

1 carriers,
2x20 MHz
LTE
(2x2 MIMO/64QAM)

1 carriers,
2x20 MHz
LTE
(4x4 MIMO/64QAM)

Latency (Roundtrip delay)**

GSM/EDGE
HSPA Rel.6
HSPAevo (Rel.8)
LTE

0   20   40   60   80   100   120   140   160   180   200   ms

DSL (~20-50 ms, depending on provider)

VoIP capacity*

Calls/Mhz/cell

80
70
60
50
40
30
20
10
0

- Downlink
- Uplink

HSPA R6

LTE FDD)

* LTE values according to Nokia and Nokia Siemens Network simulations for NGMN performance evaluation report V1.3 (macro cell, full buffer, 500m ISD, pedestrian speed)
** Server near RAN

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LTE user devices
Ecosystem growing faster than with any previous technology

269 LTE devices have been announced by 57 suppliers
(GSA, January 20, 2012)

… **devices announced by Verizon Wireless at CES for 1H2011**

HTC Thunderbolt
LTE+CDMA
HTC Sense, Skype with video

LG Revolution
LTE+CDMA
Android 2.2, hot spot capability

Moto Droid Bionic
LTE+CDMA
Android , See What I See Video

Samsung smartphone
LTE+CDMA
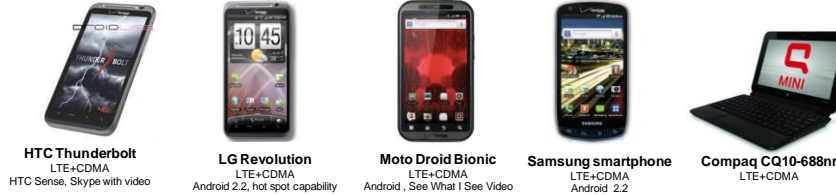Android 2.2

Compaq CQ10-688nr
LTE+CDMA

Motorola XOOM
LTE+WiFi (2Q/11)
Android 3.0 Honeycomb

Samsung Galaxy
LTE+CDMA, Android 2.2

Novatel MiFi 4510L
LTE+CDMA → WiFi

Samsung Mobile Hotspot
LTE+CDMA → WiFi

HP Pavilion dm1-3010nr
' TE+CDMA

… **and for new segments**

Cisco Cius Business Tablet
LTE-capable

Netgear MBR1000
LTE+CDMA

Cradlepoint
6 different router/adapter
models with Pantech UML290

BL Healthcare
TCx-I terminal with LTE
for HD-video enabled telemedicine

4Home monitoring solution

Ionicis home monitoring & control GW

Cisco ISR2 G2 WAN-card
LTE-capable card to routers
for small and medium enterprises

SierraWireless MC7750
LTE+CDMA embedded module

Onstar car solution
e.g. video over LTE

EA's Rockband
multiplayer online
gaming over LTE

SerComm LTE-enabled IP camera

NVIDIA and Acer tablets

… **devices launched in 2010**

Samsung B3730, TeliaSonera,
multimode **Fully integrated in
NSN LTE**

LG single mode trial
device **Fully
integrated in
NSN LTE**

LG Adrenaline, ATT,
multimode

Huawei, 2G, 3G, LTE multimode
(Qualcomm-based)
Tele 2 Sweden

Qualcomm-based
multimode LTE terminals
– commercial availability
expected in 4Q10

Docomo LTE
PCMCIA Card

Samsung Craft, LTE/CDMA,
MetroPCS

Samsung
TD-LTE
prototype **Fully
integrated in NSN LTE**

Sequans TD-LTE trial
device

Nokia LTE prototype
modem RD-3

Smartphones for GSM/HSPA/LTE in 2H/2011

GALAXY Tab 10.1 LTE
SC-01D

ARROWS Tab LTE F-01D

GALAXY S II LTE
SC-03D

Optimus LT
L-01D

ARROWS X LTi
F-05D

MEDIAS LTE
N-04D

TD-LTE devices

Cat. 3 USB-modems launched during 2010

LTE in smartphones, notebooks, tablets, MiFi, … during 2011

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Agenda

Introduction

WCDMA/HSPA/HSPA+

LTE

LTE-Advanced

Summary

Introduction

LTE Spectrum

Radio Access Overview

Core Network Overview

Voice over LTE (VoLTE)

QoS in LTE

Self Organizing Network (SON)

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LTE spectrum & ecosystem

LTE FDD

- **Early FDD LTE ecosystem (commercial networks)**
  - → **2600** (Europe, APAC)
  - → **2100** (Japan)
  - → **1900 PCS** (US)
  - → **1800** (GSM refarming)
  - → **1700/2100 AWS** (NAM incl. Canada)
  - → **850** (South Korea)
  - → **800 Digital Dividend** (Europe, MEA)
  - → **Upper 700 MHz, C** (Verizon)
  - → **Lower 700 MHz, B/C** (AT&T)

TD-LTE

- **Early TD-LTE ecosystem mainly building on**
  - → **2300** (MEA, India, China, APAC, Russia)
  - → **2600** (China, LatAM, Europe)

LTE FDD

Band	MHz	Uplink MHz	Downlink MHz	
1	**2x60**	**1920-1980**	**2110-2170**	**UMTS core**
2	**2x60**	**1850-1910**	**1930-1990**	**US PCS**
3	**2x75**	**1710-1785**	**1805-1880**	**GSM 1800**
4	**2x45**	**1710-1755**	**2110-2155**	**NAM AWS**
5	**2x25**	**824-849**	**869-894**	**850**
7	**2x70**	**2500-2570**	**2620-2690**	**2600 FDD**
8	2x35	880-915	925-960	GSM 900
9	2x35	1749-1784	1844-1879	Japan, Korea 1700
10	2x60	1710-1770	2110-2170	US AWS extension.
11	2x20	1427.9-1447.9	1475.9-1495.9	Japan 1500
12	2x18	698-716	728-746	US
13	**2x10**	**777-787**	**746-756**	**Verizon**
14	2x10	788-798	758-768	US – Public Safety
17	**2x12**	**704-716**	**734-746**	**AT&T**
18	2x15	815-830	860-875	Japan – 800 (KDDI)
19	2x15	830-845	875-890	Japan – 800 (DoCoMo)
20	**2x30**	**832-862**	**791-821**	**EU 800 DD, MEA**
21	2x15	1448-1463	1496-1511	Japan 1500
22	2x80	3410-3490	3510-3590	3.5 GHz FDD
23	2x20	2000-2020	2180-2200	US S-band
24	2x34	1626.5-1660.5	1525-1559	US (LightSquared)
25	2x65	1850-1915	1930-1995	US PCS extension (Sprint)
26	2x35	814-849	859-894	850 extension (Korea-KT, Sprint)

TD-LTE

Band	MHz	Uplink MHz	Downlink MHz	
33	1x20	1900-1920	1900-1920	UMTS core – TDD
34	1x15	2010-2025	2010-2025	UMTS core – TDD, China TD/SCDMA
35	1x60	1850-1910	1850-1910	US (band 2 – TDD variant)
36	1x60	1930-1990	1930-1990	US (band 2 – TDD variant)
37	1x20	1910-1930	1910-1930	US PCS centre-gap
38	**1x50**	**2570-2620**	**2570-2620**	**China, LatAM, Europe**
39	1x40	1880-1920	1880-1920	China PHS
40	**1x100**	**2300-2400**	**2300-2400**	**MEA, India, China, Russia**
41	1x194	2496-2690	2496-2690	US (Clearwire)
42	1x200	3400-3600	3400-3600	3.4/5 GHz – TDD
43	1x200	3600-3800	3600-3800	3.7/8 GHz – TDD

Source: TS 36.101; *commercialized bands*

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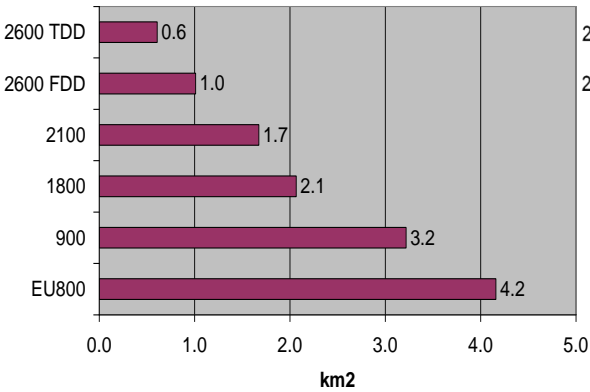# Coverage – Low Band and FDD best for wide area LTE - FDD 800 MHz

Example: LTE 800 Coverage (Germany)
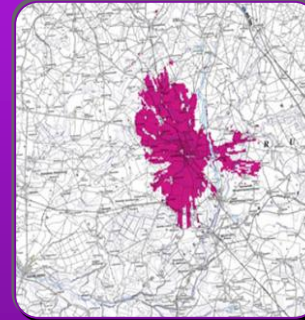
Typical site coverage area in urban area

Band	km2
2600 TDD	0.6
2600 FDD	1.0
2100	1.7
1800	2.1
900	3.2
EU800	4.2

Typical site coverage area in suburban area

Band	km2
2600 TDD	1.3
2600 FDD	1.9
2100	3.2
1800	4.0
900	9.2
EU800	10.0

3G at 2100 MHz   **LTE at 800 MHz**
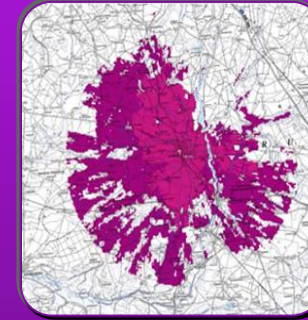
> 3 – times more coverage on 800 MHz

Source: Deutsche Telekom

BS antenna height [m]	30
MS antenna height [m]	1.5
Standard Deviation [dB]	8.0
Location Probability	95 %
Slow Fading Margin [dB]	8.8
Correction factor [dB]	-5
Indoor loss [dB]	15

- **Government regulation (USO):** -> specific rollout requirements within 800 MHz spectrum license
- Service provided outside wireline-DSL areas

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Coverage – Low Band and FDD best for wide area WCDMA/HSPA – FDD 900MHz

Example: UMTS 900 Coverage (Finland)

- **Government regulation (USO):**

  -> provide access to 1 Mbps broadband for every household – either wireline or wireless

- Target date: July 1, 2010

- HSPA900 chosen in view of time-line and 800 MHz spectrum availability

- > 500 devices in all form-factors & price-points

U900 rollout completed in 1.5 years

90% of area covered with 30% sites (U900)
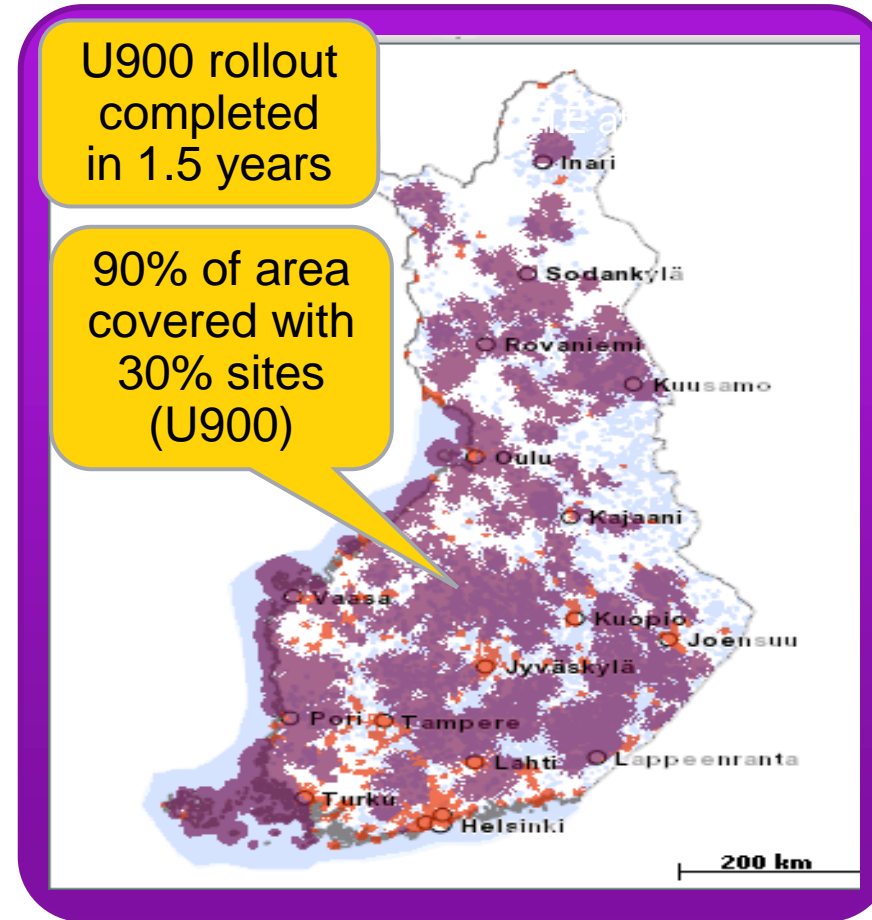
3 – times more coverage on 900 MHz

= UMTS900

= UMTS2100

Source: TeliaSonera

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TeliaSonera

Coverage – Low Band and FDD
The power of 700/800/900 MHz for urban indoor coverage

Dramatic increase of data rates for cell edge & indoor coverage with lower band spectrum
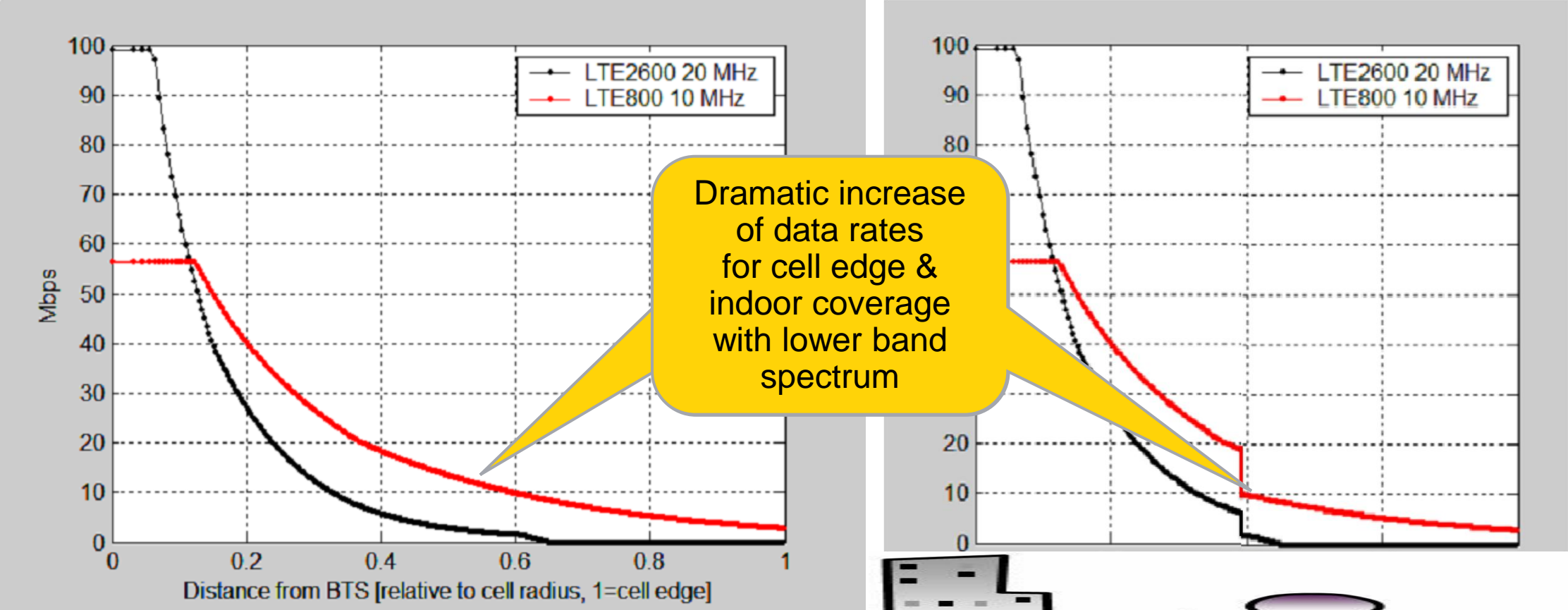
LTE 800 & LTE 2600 data rates (normalized onto LTE-800 cell size)

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More bandwidth = Superior data rates across cell range

LTE Downlink Bit Rates
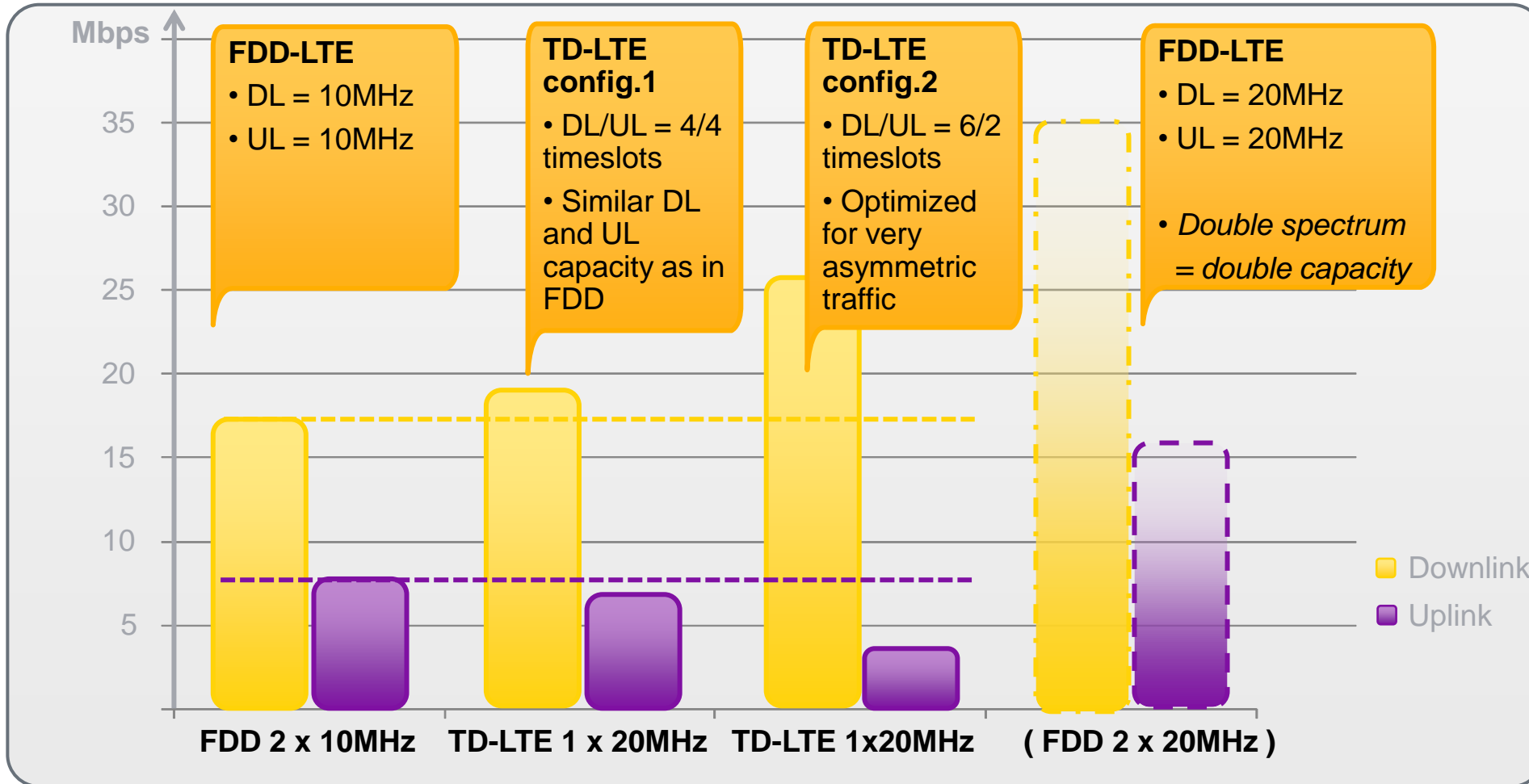### – Interference Limited, Other Cells 100% Loaded

LTE on 1800, 2600 MHz

LTE on EU800-DD

LTE on 900 MHz*

HSPA+ on 900 MHz*

Legend:
- LTE 20 MHz
- LTE 10 MHz
- LTE 5 MHz
- HSDPA 5 MHz

Median data rate 10-20 Mbps for 10-20 MHz LTE

Clear benefit of larger bandwidth over the whole cell area

Distance from BTS [relative to cell radius, 1=cell edge]
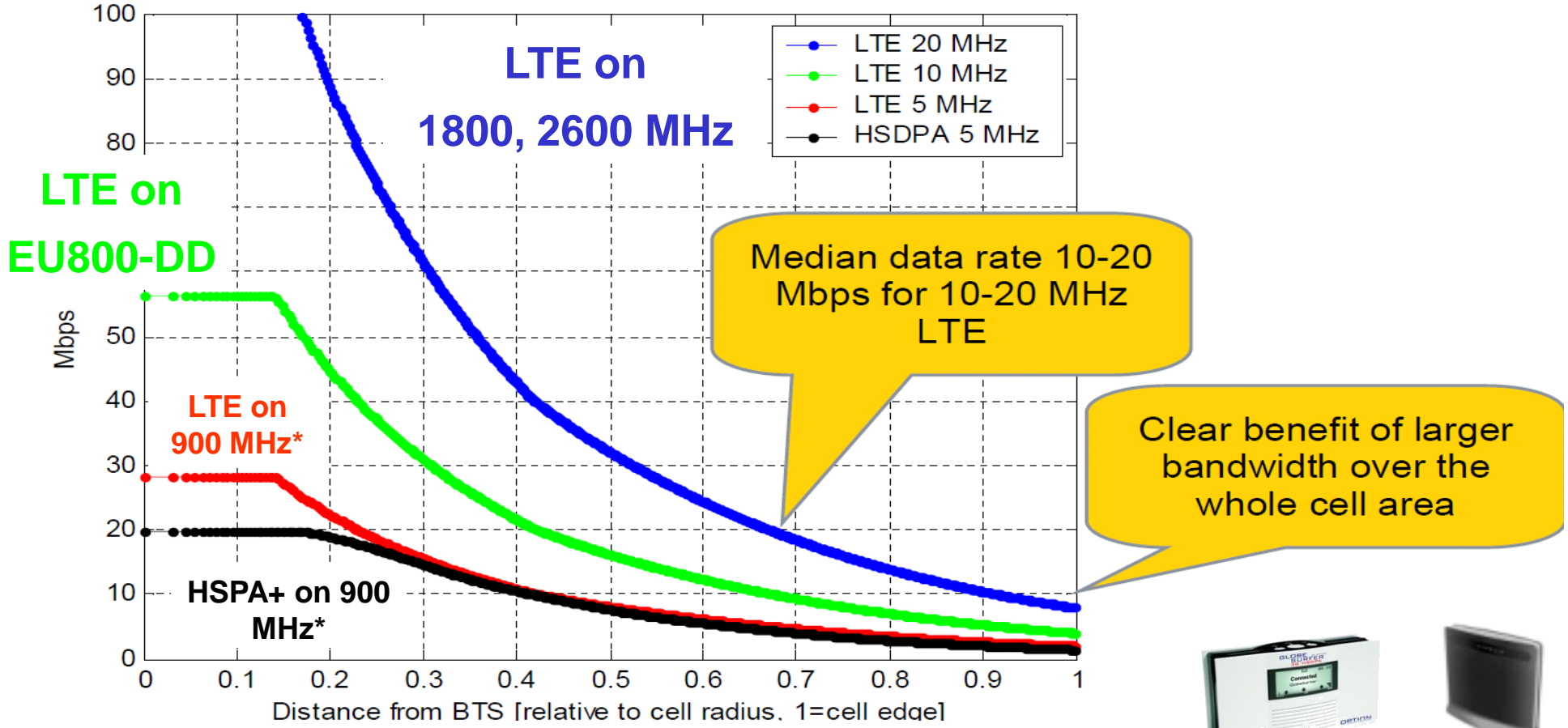
* GSM operation in parallel

10 km
(indicative range for 30m antennas)

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TD-LTE Capacity
Similar spectral efficiency for TD-LTE and LTE-FDD

FDD-LTE
- DL = 10MHz
- UL = 10MHz

TD-LTE config.1
- DL/UL = 4/4 timeslots
- Similar DL and UL capacity as in FDD

TD-LTE config.2
- DL/UL = 6/2 timeslots
- Optimized for very asymmetric traffic

FDD-LTE
- DL = 20MHz
- UL = 20MHz
- *Double spectrum = double capacity*

Legend:
- Downlink
- Uplink

X-axis: FDD 2 x 10MHz | TD-LTE 1 x 20MHz | TD-LTE 1x20MHz | (FDD 2 x 20MHz)

Y-axis: Mbps (5, 10, 15, 20, 25, 30, 35)

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Practical Data Rate Evolution – End-user experience

Spectral efficiency
+200% — EDGE → LTE
+100% — CDMA EVDO → LTE
+20% — HSPA+ → LTE
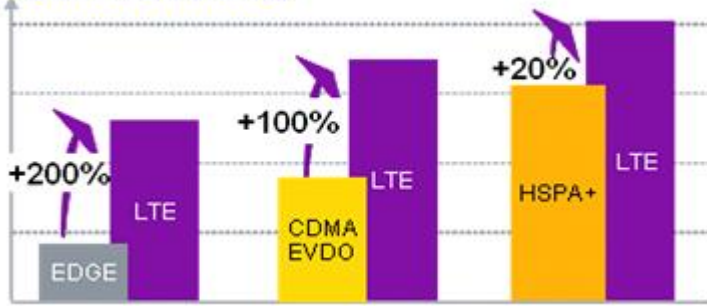
LTE improves data rates compared to HSPA
- with *wider bandwidth*, and
- with *higher spectral efficiency* (20-40%)

	Peak rates	**Typical drive test rates**	
HSPA+ 5 MHz	21 Mbps (42 Mbps)	7 Mbps	
DC-HSPA 10 MHz	42 Mbps (84 Mbps)	14 Mbps	DC-HSPA doubles data rates
LTE **10 MHz**	74 Mbps	**20 Mbps**	= 2 x more spectrum + 40% vs HSPA
LTE **20 MHz**	100 (150) Mbps	**40 Mbps**	= 4 x more spectrum + 40% vs HSPA

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Peak data rates
Driven by LTE terminal capabilities

All LTE devices which have been launched during 2010

	Class 1	Class 2	Class 3	Class 4	Class 5
Peak rate DL/UL	10/5 Mbps	50/25 Mbps	100/50 Mbps	150/50 Mbps	300/75 Mbps
RF bandwidth	20 MHz*	20 MHz*	20 MHz*	20 MHz*	20 MHz*
Modulation DL	64 QAM	64 QAM	64 QAM	64 QAM	64 QAM
Modulation UL	16 QAM	16 QAM	16 QAM	16 QAM	64 QAM
Rx diversity	yes	yes	yes	yes	yes
MIMO DL	optional	2 x 2	2 x 2	2 x 2	4 x 4

* All 3GPP Rel.8 LTE terminals can receive 20 MHz bandwidth, but (baseband) processing power is variable

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Spectrum Resources – Europe

- Main LTE bands in **Europe:** *800, 1800 and 2600 MHz*

Overall spectrum available

Typical future CSP deployment scenario

Available spectrum		Deployment	
2600 (2x70 MHz + 50 MHz)	*new spectrum*	LTE 20 MHz TD-LTE 20 MHz	**LTE capacity & highest data rates**
2100 (2 x 60 MHz)	*WCDMA/HSPA*	Multicarrier HSPA	*HSPA capacity*
1800 (2 x 75 MHz)	*GSM*	LTE 10+MHz & GSM (defragmentation)	**LTE capacity +** *GSM capacity*
900 (2 x 35 MHz)	*GSM*	HSPA 5+MHz & GSM (defragmentation)	*HSPA coverage + GSM maintenance*
EU800 (2 x 30 MHz)	*new spectrum, Digital Dividend / TV-transition*	LTE 10 MHz	**LTE coverage**

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Capacity - Highest spectral efficiency with LTE
LTE maintains highest efficiency down to 5 MHz bandwidth

LTE maintains high efficiency with bandwidth down to 3.0 MHz, e.g. for band refarming scenarios

LTE spectral efficiency for 1.4 MHz similar to HSPA with 2x2 MIMO and 64-QAM

Differences between bandwidths come from frequency scheduling gain and different overheads

Spectral Efficiency Relative to 10 MHz
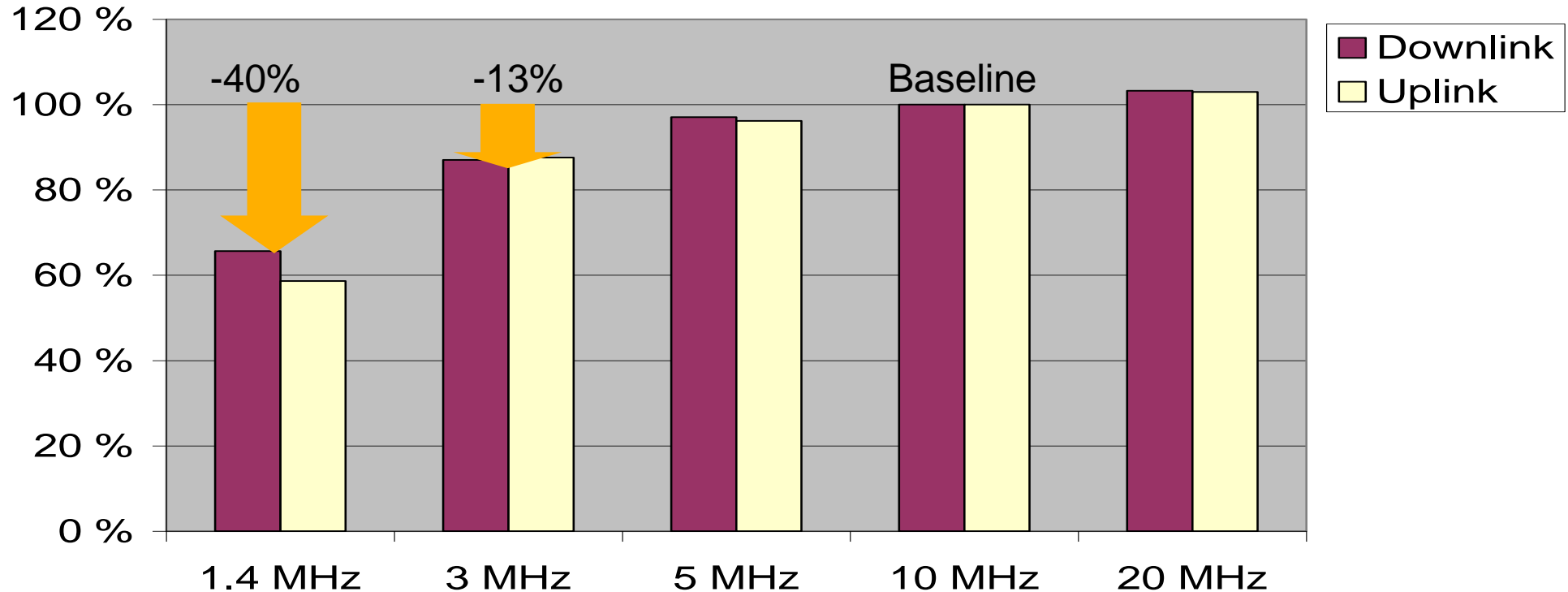
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Agenda

Introduction

WCDMA/HSPA/HSPA+

LTE

LTE-Advanced

Summary

- Introduction
- LTE Spectrum
- **Radio Access Overview**
- Core Network Overview
- Voice over LTE (VoLTE)
- QoS in LTE
- Self Organizing Network (SON)

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Multiple Access Methods
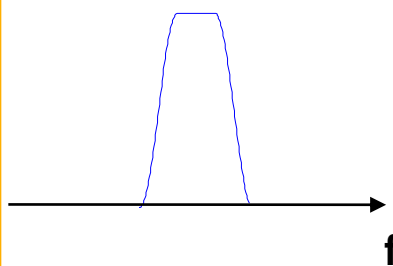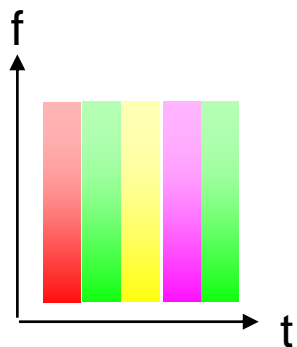
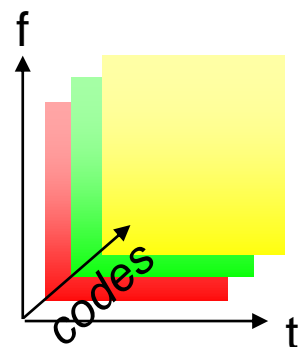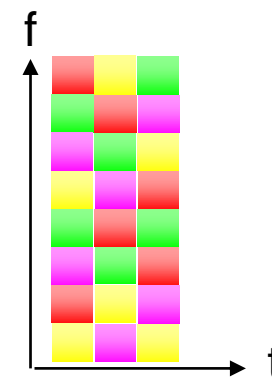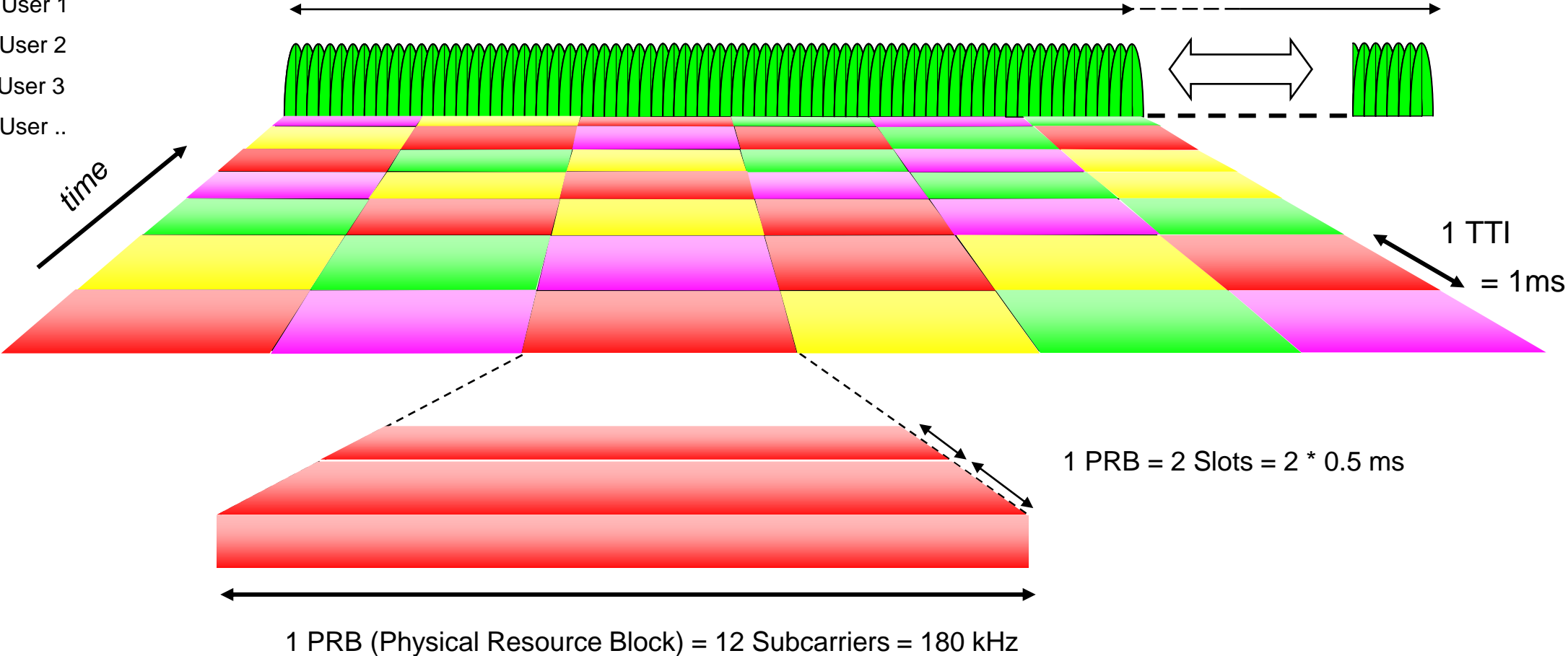| TDMA	FDMA	CDMA	OFDMA
• Time Division	• Frequency Division	• Code Division	• Frequency Division • Orthogonal subcarriers
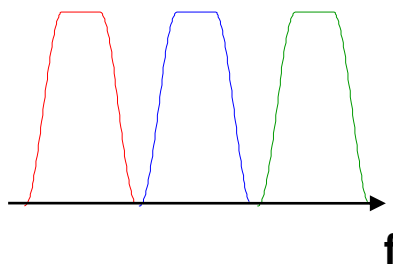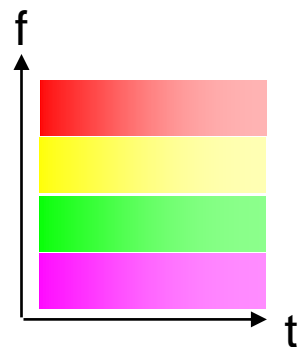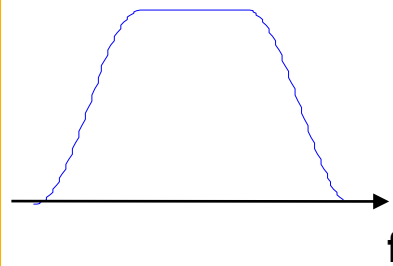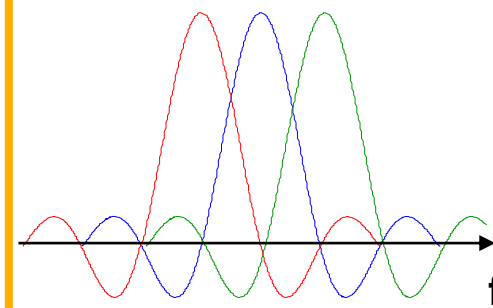
User 1 User 2 User 3 User ..

Downlink - OFDM

Subchannels / Tones (each 15 kHz)
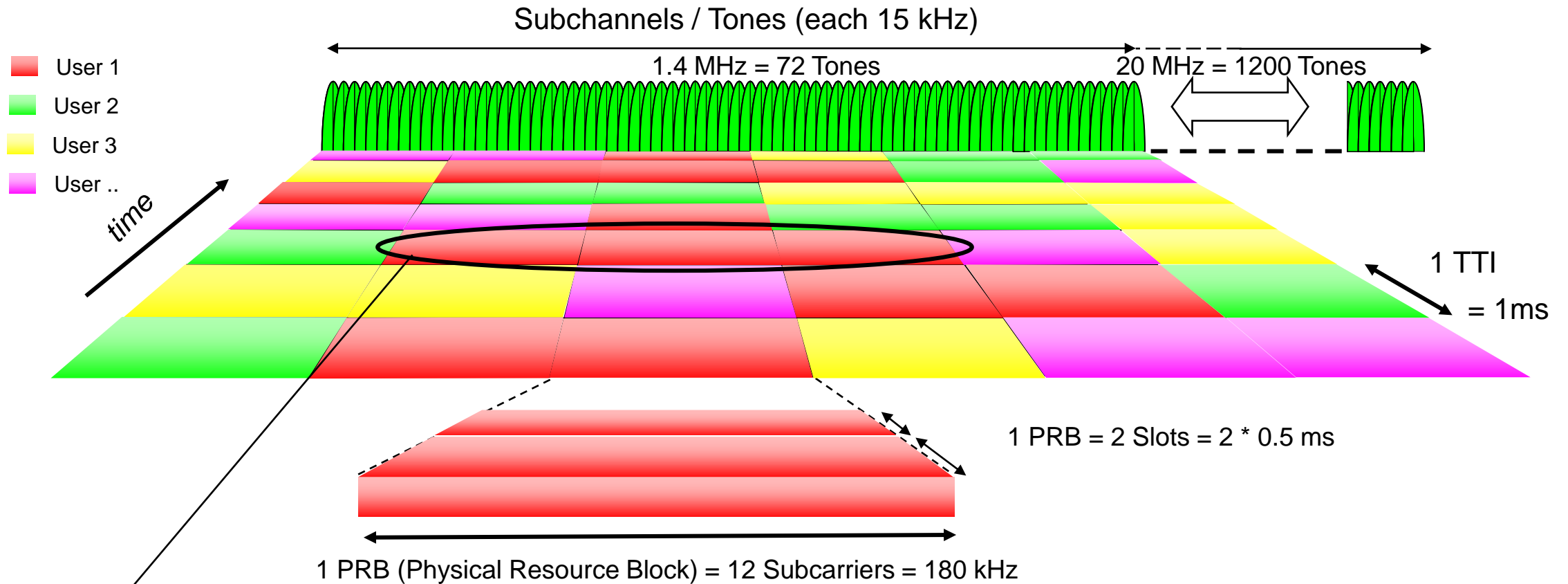
1.4 MHz = 72 Tones

20 MHz = 1200 Tones

User 1
User 2
User 3
User ..

time

1 TTI

= 1ms

1 PRB = 2 Slots = 2 * 0.5 ms

1 PRB (Physical Resource Block) = 12 Subcarriers = 180 kHz

Uplink – Single Carrier FDMA

Subchannels / Tones (each 15 kHz)

1.4 MHz = 72 Tones   20 MHz = 1200 Tones

User 1
User 2
User 3
User ..

time

1 TTI = 1ms

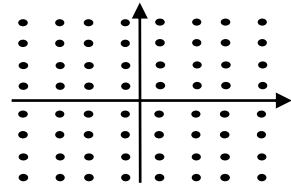1 PRB = 2 Slots = 2 * 0.5 ms

1 PRB (Physical Resource Block) = 12 Subcarriers = 180 kHz

SC-FDMA: PRB's are grouped to bring down Peak to Average Power Ratio (PAPR)
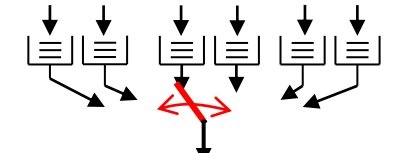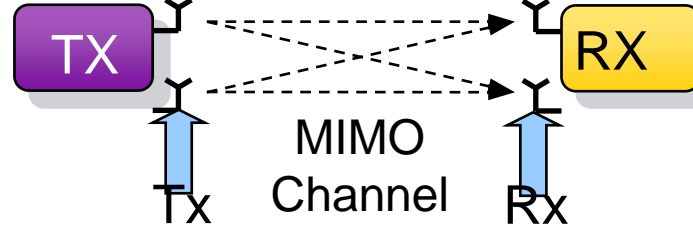→ better power efficiency at the terminal

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LTE Radio highlight
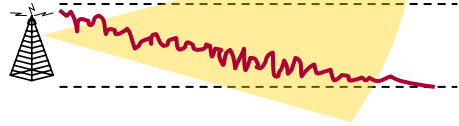
Fast Link Adaptation due to channel behaviour

64QAM Modulation

TX

RX

MIMO Channel

Tx ... Rx

Advanced Scheduling Time & Freq. (Frequency Selective Scheduling)

scalable

DL: OFDMA

UL: SC-FDMA

Short TTI = 1 ms Transmission time interval
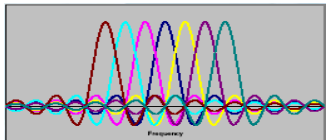
HARQ: Hybrid Automatic Repeat Request

1   2   ACK

NACK

Combined decoding

Rx Buffer

Available bandwidth

Sub-carriers

OFDM symbols

Guard intervals

Time

Frequency

Σ
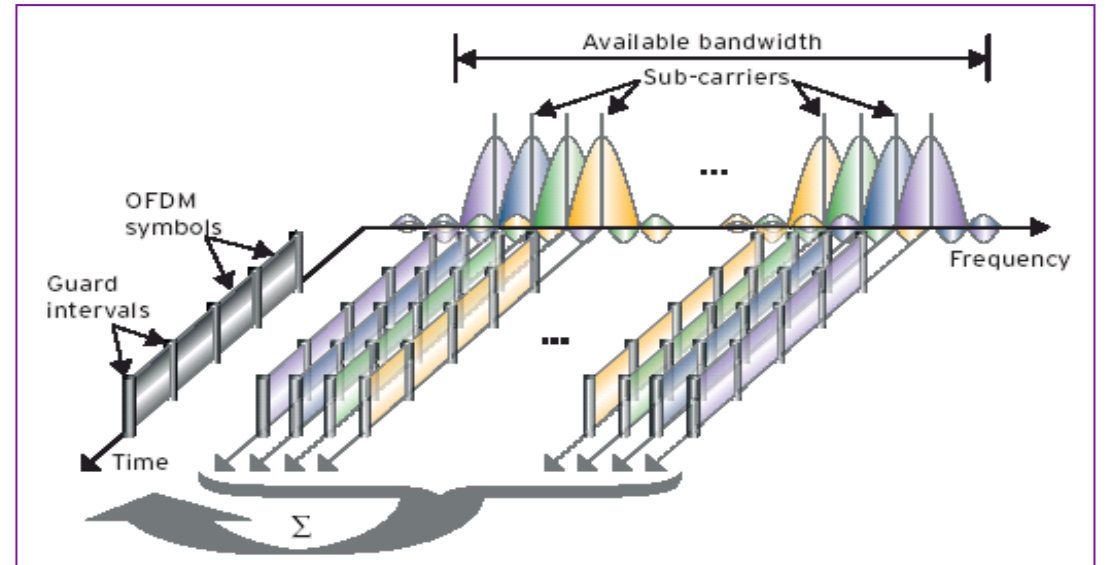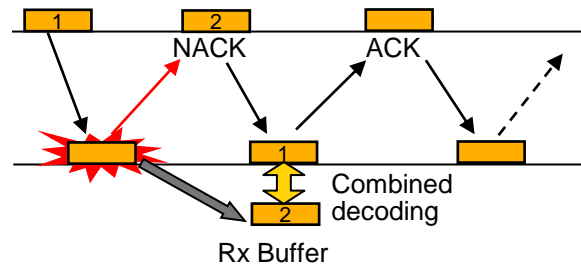
LTE: Most efficient Radio Access Technology

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LTE Radio principles

Downlink:
OFDMA

- Improved spectral efficiency
- Reduced interference
- Very well suited for MIMO

Subchannels / Tones (each 15 kHz)

User 1
User 2
User 3
User ..

time

1 TTI = 1ms

1 PRB = 2 Slots = 2 * 0.5 ms

1 PRB (Physical Resource Block) = 12 Subcarriers = 180 kHz

Uplink:
SC-FDMA

- Power efficient uplink increasing battery lifetime
- Improved cell edge performance by low peak to average ratio
- Reduced Terminal complexity

- Enabling peak cell data rates of 173 Mbps DL and 58 Mbps in UL *
- Scalable bandwidth: 1.4 / 3 / 5 / 10 /15 / 20 MHz also allows deployment in lower frequency bands (rural coverage, refarming)
- Short latency: 10 – 20 ms **
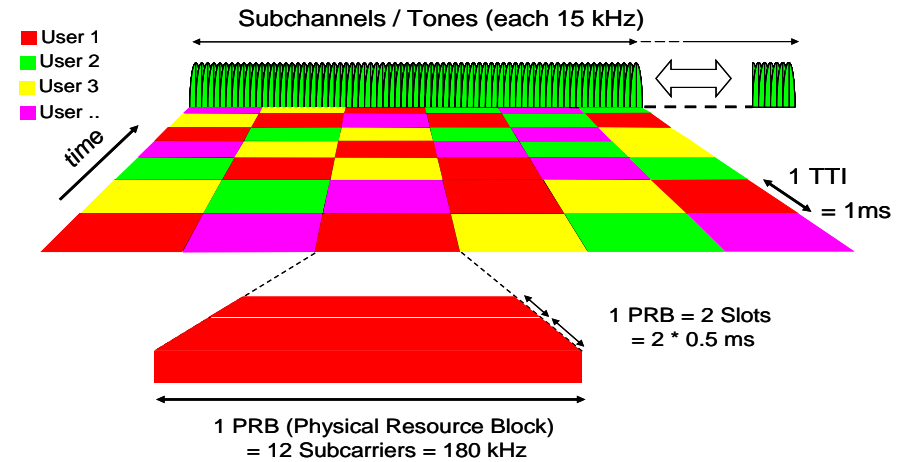
* At 20 MHz bandwidth, FDD, 2 Tx, 2 Rx, DL MIMO, PHY layer gross bit rate   ** roundtrip ping delay (server near RAN)

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MIMO Technology Overview

Several antenna technologies are summarized under the term MIMO (Multiple Input / Multiple output):

- Single user DL MIMO
  - DL MIMO - transmit diversity
  - DL MIMO - spatial Multiplexing

- Multi-user MIMO

- Virtual MIMO (UL MIMO)

DL single user MIMO – with 2 antennas

DL MIMO – Transmit diversity

> **Enhanced cell edge performance, capacity increase**

- 2 TX antennas
- Single stream (code word)
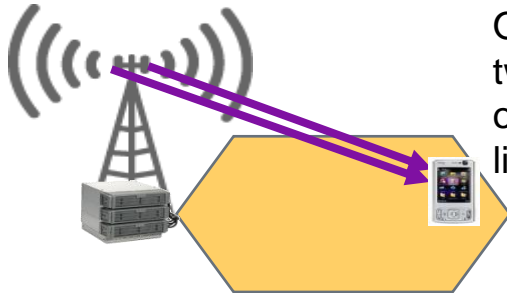
One code word A is transmitted via two antennas on the same PRB to one far away UE which improves the link budget / SNIR.

DL MIMO – Spatial multiplexing

> **Doubles the peak rate at good channel quality (near BTS)**

- 2 TX antennas
- Spatial multiplexing with two code words
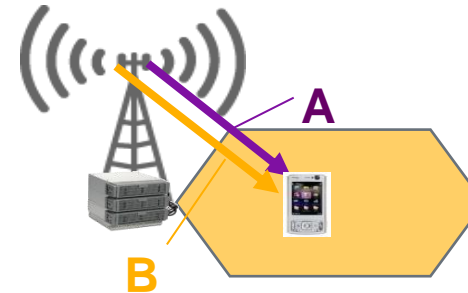
Two code words (A+B) are transmitted in parallel on the same PRB to one UE which doubles the peak rate.

Optimum solution: Dynamic selection between

- Spatial multiplexing with two code words (UE nearthe BTS)
- Transmit diversity with one code word (UE far away from BTS to improve link budget / SNIR)

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DL **multi user** MIMO

- Higher number of simultaneous users
- Dynamic selection of a pair of UEs using the same PRBs
- One stream has user data meant for particular UE
- Second stream meant for other UE, ignored by particular UE
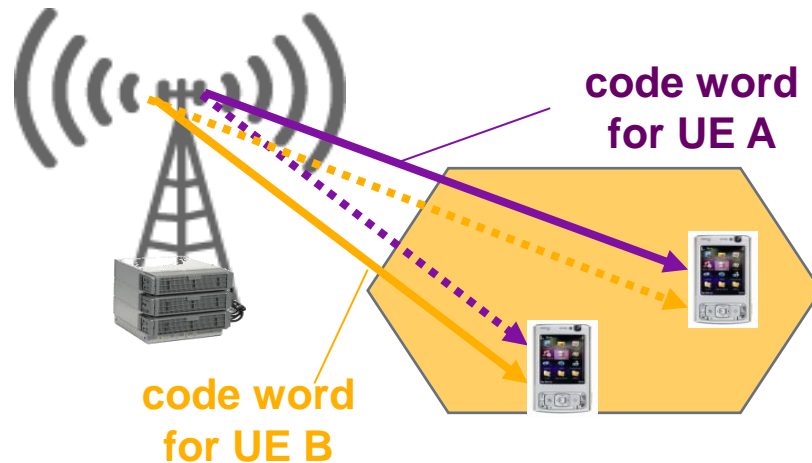
- Improved coverage when compared to 2 Tx Antenna case
- 2 user data streams for particular UE (redundancy)
- Other 2 streams meant for other UE, ignored by particular UE
- 2 code words only (4 code words not standardized)

code word for UE A

code word for UE B
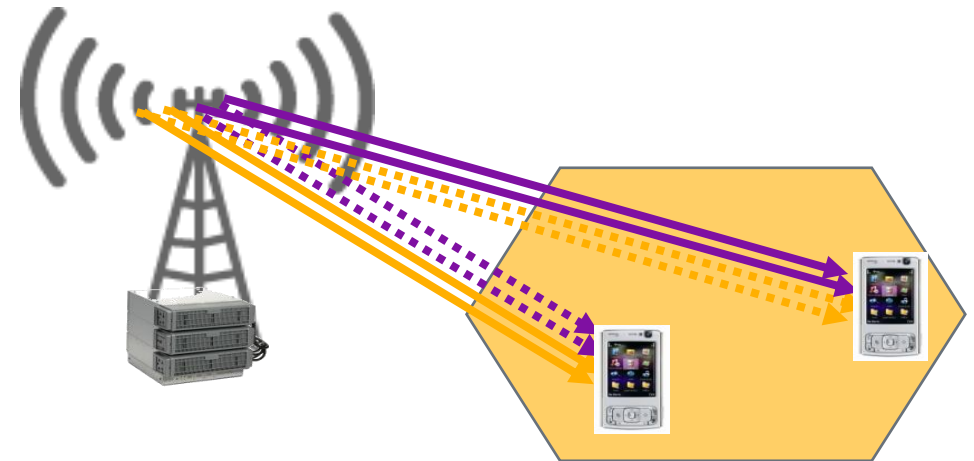
Multi – User MIMO potentially not in Rel 8 standards
Gains relatively small (<10% at fully loaded network)

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UL multi user MIMO (virtual MIMO)

- In uplink, multi-stream transmission from single UE is not supported.
  - single Tx antenna and power amplifier at UE
- So-called virtual MIMO or UL MU-MIMO is used instead
  - Two users are scheduled to use the same resource so the base station receives multi-stream transmission on the same PRB
- ➔ Increased UL cell throughput by multi user diversity gains

UE A data stream

UE B data stream

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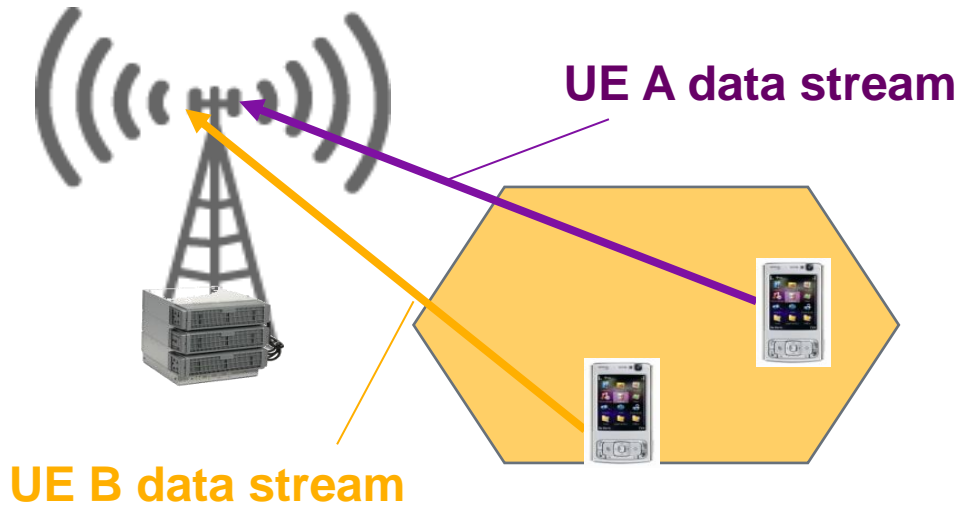
E-UTRAN Node B (eNodeB)

- eNodeB is the only node that controls all radio related functions:

  - Acts as layer 2 bridge between UE and EPC
    - Termination point of all radio protocols towards UE
    - Relaying data between radio connection and corresponding IP connectivity towards EPC
  - Performs ciphering/deciphering of the UP data and IP header compression/decompression
  - Responsible for **Radio Resource Management** (RRM)-
    - allocating resources based on requests
    - prioritizing and scheduling traffic according to required Quality of Service (QoS).
  - **Mobility Management-**
    - controls and analyses radio signal level measurements by UE, makes similar measurement itself and based on those makes HO decision.

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Self Organizing Network (SON)

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Key architectural concept.
Flat and cost effective Mobile Network
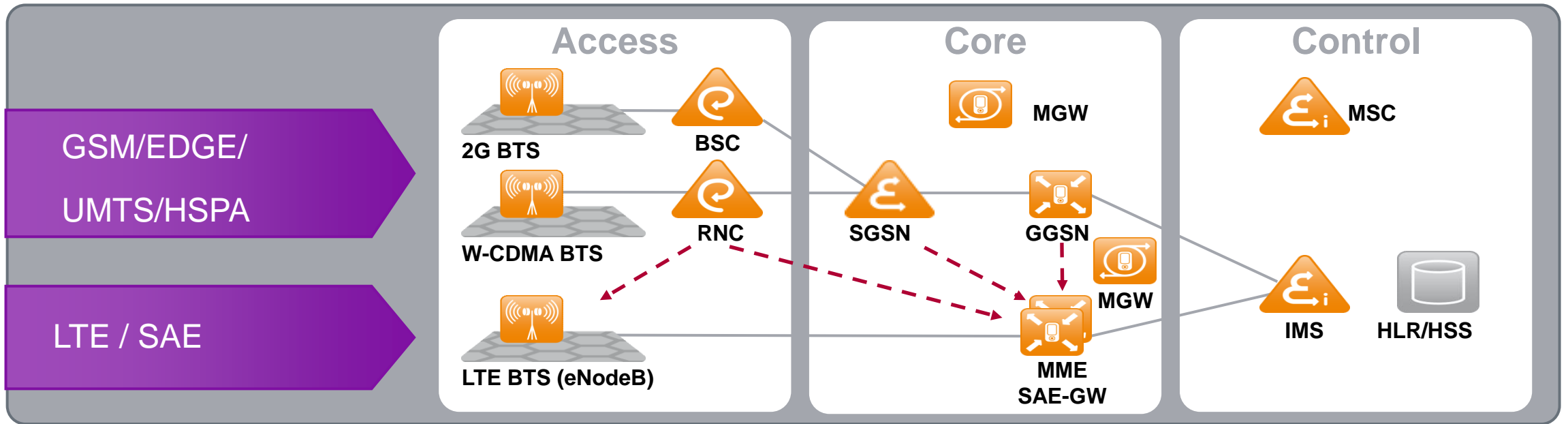
Improved flexible radio technology

- New air I/F providing higher data throughputs
- LTE provides flexibility for spectrum re-farming and new spectrum
- LTE can operate in a number of different frequency bands

Simpler architecture for reduced OPEX

- Simplified, flat network architecture based on IP reduces operators' cost per bit significantly
- Interworking with legacy systems is an integral part of service continuity
- Re-use of existing equipment as much as possible

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Main EPS Standards: 23.401

- Defines EPS architectures for 3GPP accesses using GTP protocol (GTP on S5/S8)
  - One example is given below
- Defines role of MME, SGW and PGW
- Two GW configurations: standalone SGW and PGW, co-located SGW/PGW
- Defines high level procedures (mobility management, session management, interworking with existing accesses, etc.)
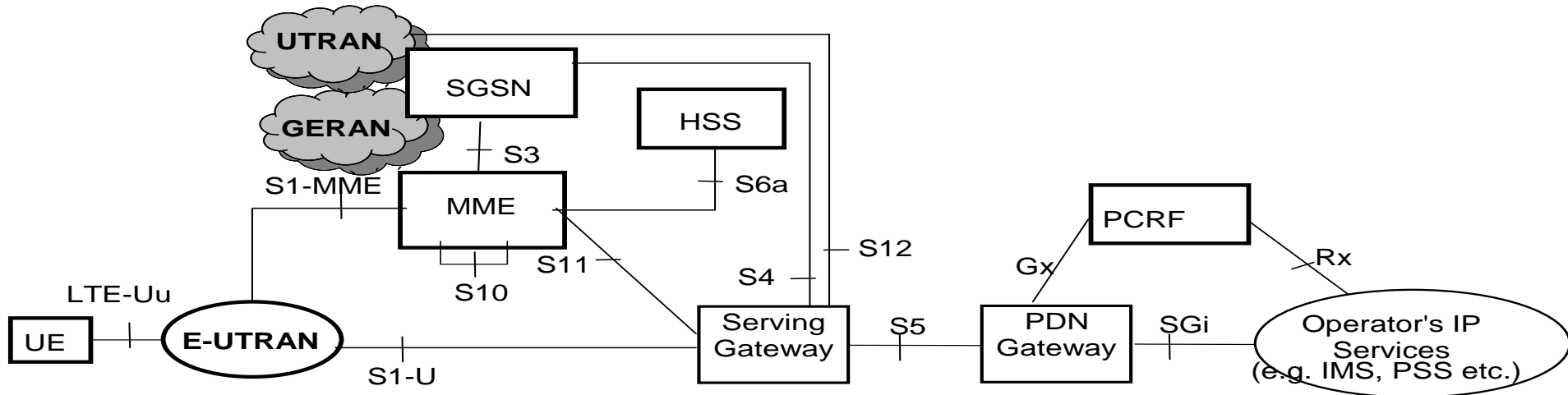
Non-roaming architecture for 3GPP accesses

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3GPP R8 Architecture:
Flat architecture for high efficiency

Evolved Packet Core (EPC)

Radio Access Network
Other access networks

HLR/HSS   AAA   Charging   PCRF

Services in Packet
Data Network

IMS Operator services

BSC

2G

RNC

3G

SGSN

LTE

eNode-B

S-GW   P-GW

MME

Internet

Company intranets

CDMA Access Network

Untrusted Non-3GPP IP Access

Trusted Non-3GPP IP Access

HSGW   ePDG

.... Control plane
——— User plane

65

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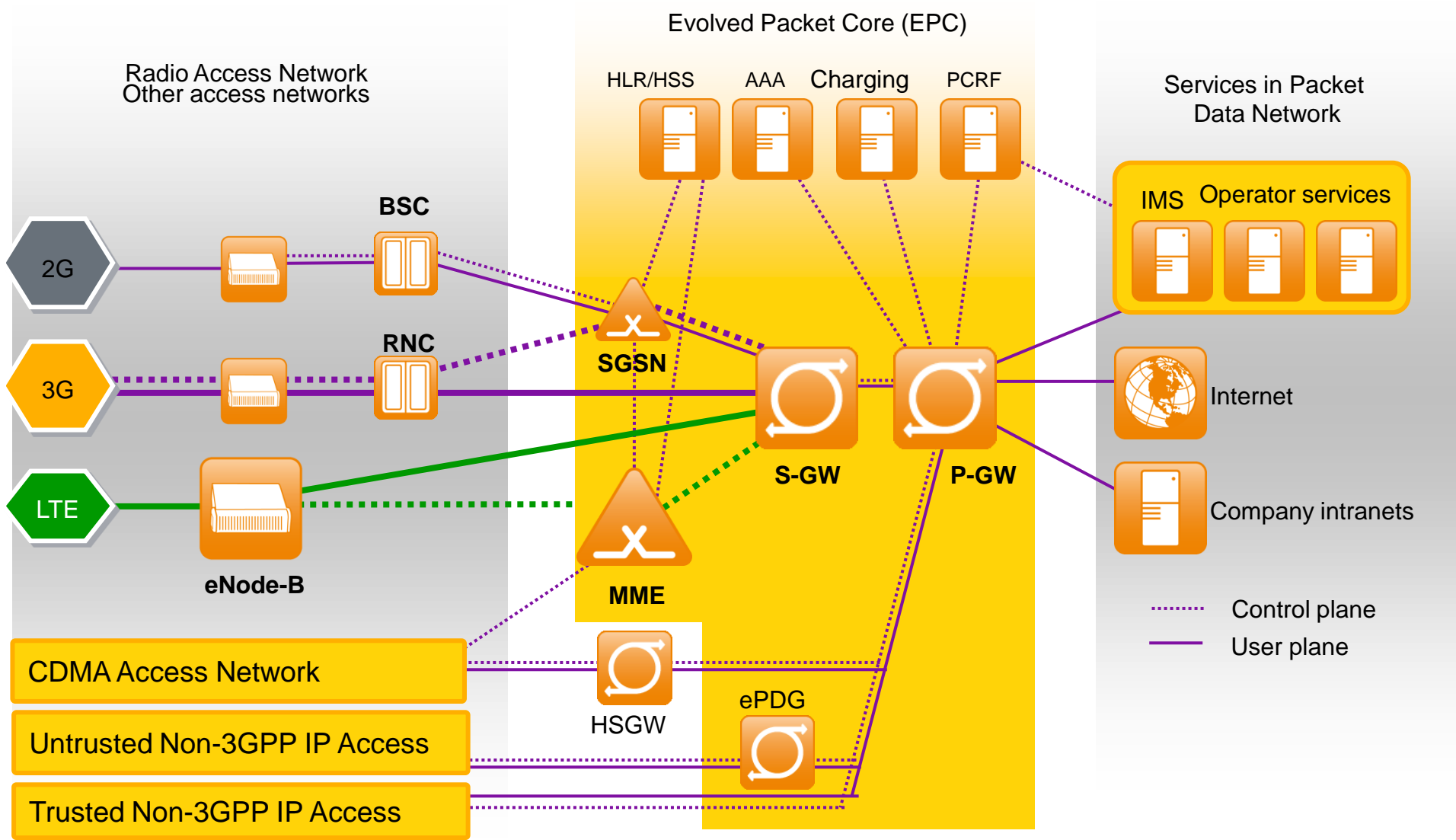
Core Technology Overview

Mobility Management Entity

- C-Plane Part
- Session & Mobility management
- Idle mode mobility management
- Paging
- AAA Proxy

Serving Gateway

- User plane anchor for mobility between the 2G/3G access system and the LTE access system.
- Resides in visited network in roaming cases
- Lawful Interception

Packet Data Network Gateway

- Gateway towards Internet/Intranets
- User plane anchor for mobility between 3GPP and non-3GPP access systems (HA).
- Charging Support
- Policy and Charging Enforcement (PCEF) *)
- Packet Filtering
- Lawful Interception

MME

HLR/HSS (AAA)

SAE-GW

PCEF

PCRF

Serving GW

PDN GW

PDN

IMS
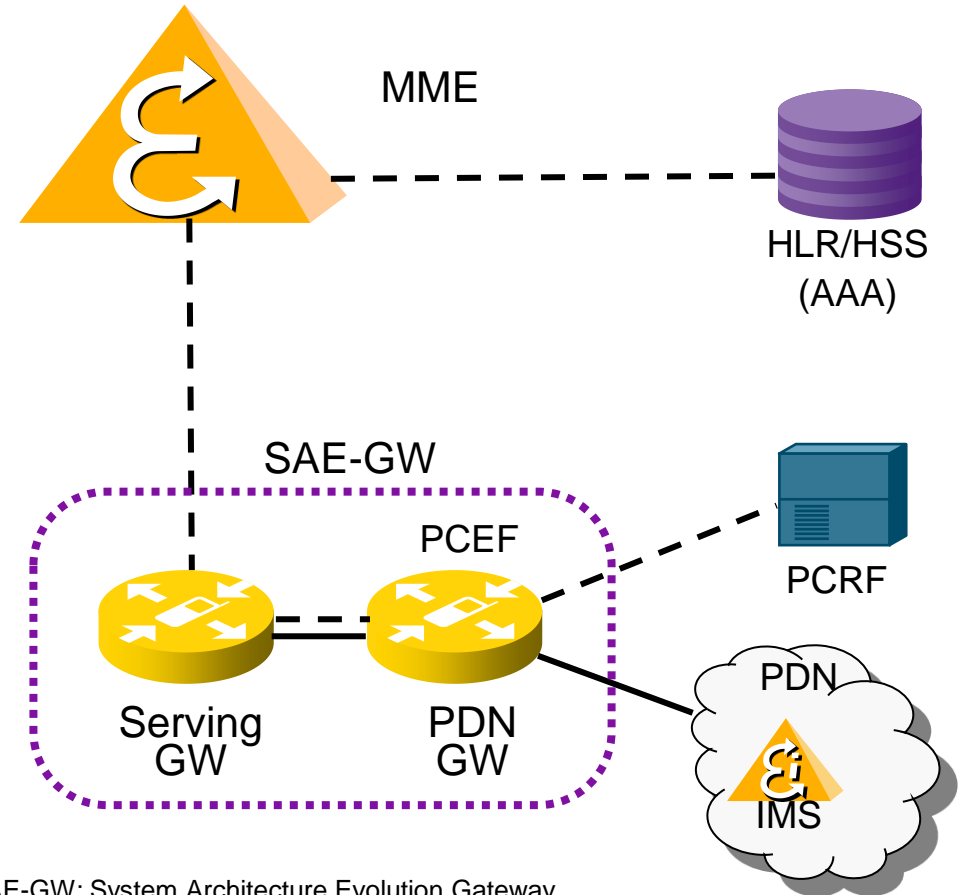
SAE-GW: System Architecture Evolution Gateway
= S-GW + PDN-GW

*) PCRF: Policy and Charging Rules Function communicates with PCEF (Policy and Charging Enforcement Function within PDN SAE GW)

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LTE is here already

LTE is happening

> 285 operators are investing in LTE in 93 countries
>
> 226 operator commitments in 76 countries
> 59 pre-commitment trials in 17 more countries
>
> 49 commercial networks in 29 countries
>
> GSA forecasts 119 commercial LTE networks in 53 countries by end 2012
>
> *GSA Janauary 5, 2012*

LTE as the fastest developing mobile system technology ever. *GSA Janauary 5, 2012*

Voice remains an essential service

Year	Voice	SMS	Other
2009	76%	10%	14%
2014	64%	10%	26%

Revenue source ■ Voice ■ SMS ■ Other   Source: Pyramid Research, Heady Reading 12/2010

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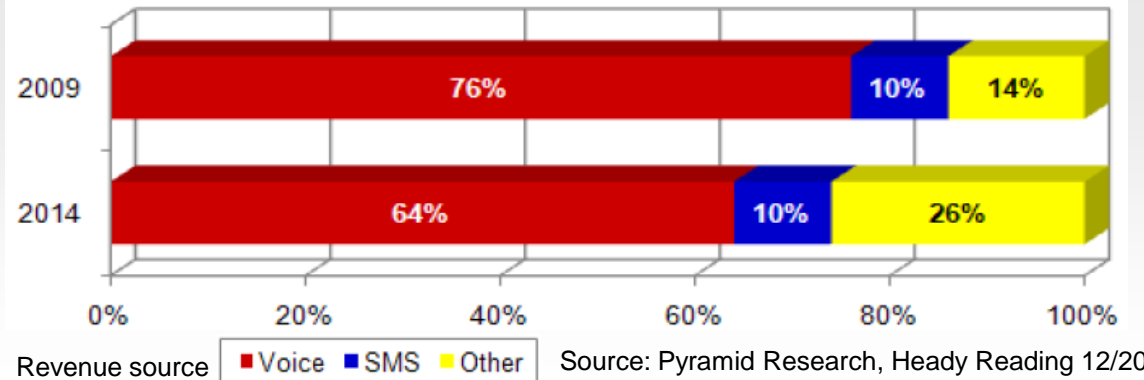
Drivers for Voice over LTE (VoLTE)

- LTE is driven by mobile data growth
- Voice service is mandatory and desirable with increased voice efficiency with LTE
- LTE is full-IP thus voice must be handled over IP
- Although Internet players may enter LTE networks, operators have unique proposition to offer:
  - Same end-user experience and QoS regardless of used access
  - Voice service continuity between different accesses
- Over time Voice over LTE will grow to become the mainstream mobile voice technology

% of voice subscribers (illustrative)

3GPP

LTE

3GPP2

201x   202x

User per MHz

GSM EFR	
GSM AMR	
GSM DFCA	
WCDMA CS voice 5.9 kbps	
HSPA VoIP/CS 12.2 kbps	
HSPA CS 5.9 kbps	
LTE VoIP 12.2 kbps	

15 x more users per MHz with LTE than with GSM EFR!

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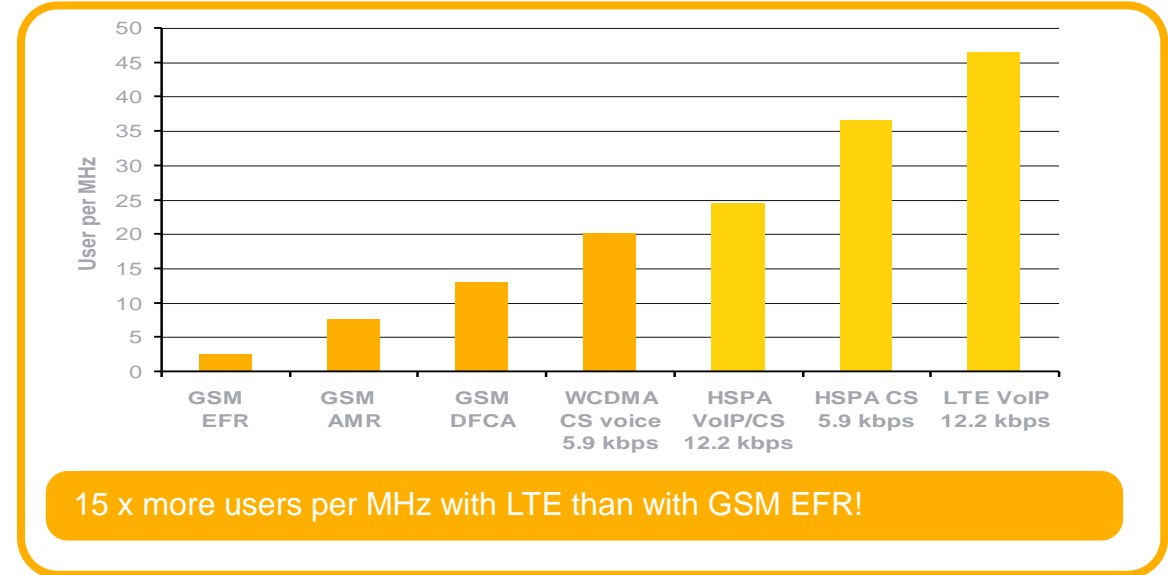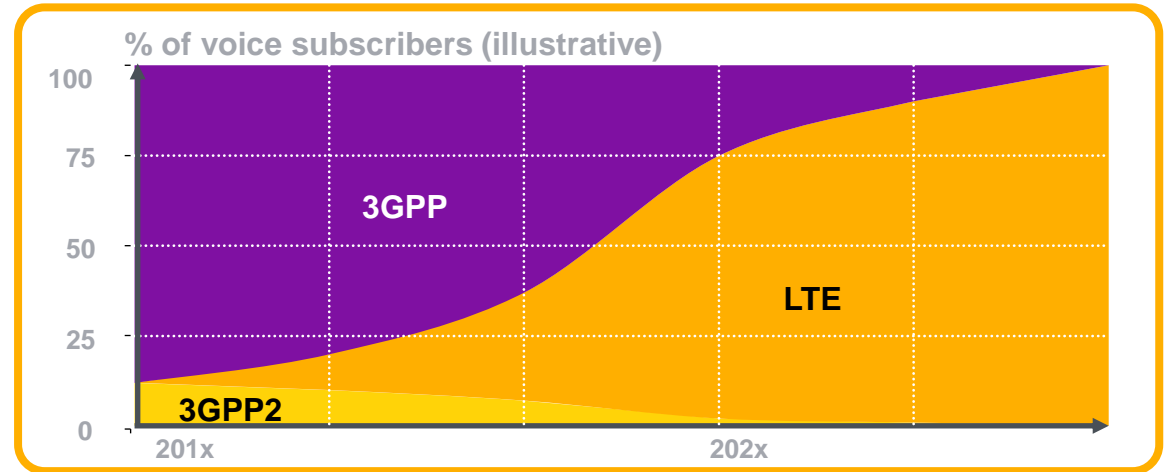
Potential voice evolution steps in LTE

LTE used for high speed packet data access only
- – Operator voice service provided over CS network

Fallback to CS voice
- – LTE network is used for data only
- – Terminal is simultaneously registered to both LTE and 2G/3G CS network
- – Voice calls are initiated and received over CS network

Single radio Voice Call Continuity (VCC)
- – Operator provides VoIP over LTE
- – IMS acts as control machinery
- – Voice calls can be handed over to CS network

All-IP network
- – Operator provides VoIP over LTE
- – IMS acts as control machinery
- – Voice calls can be handed over to other packet switched networks

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The transition to VoLTE technology

CSFB → **SRVCC VoLTE**
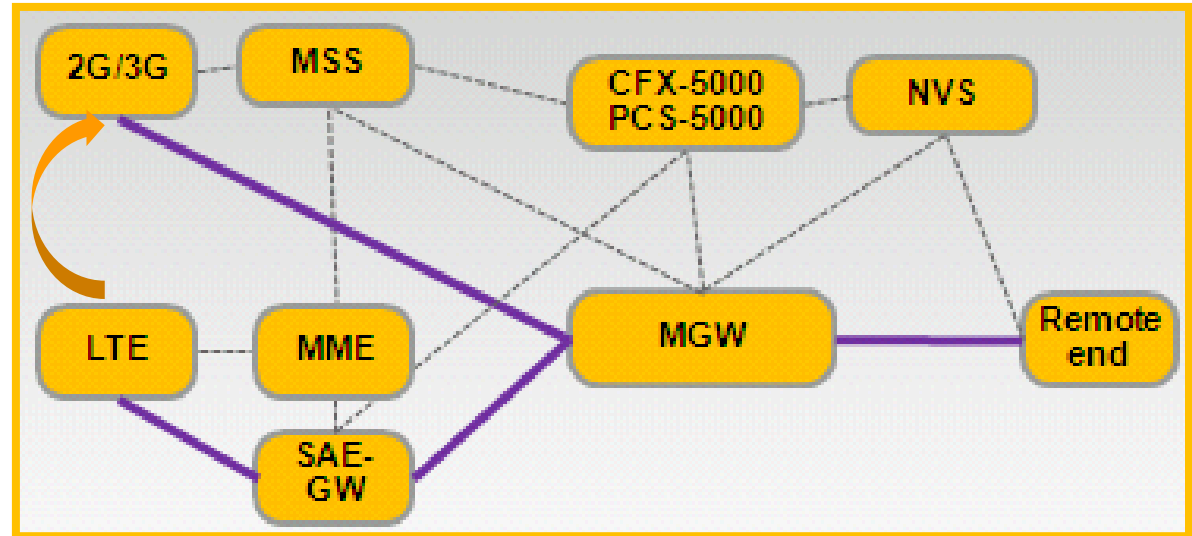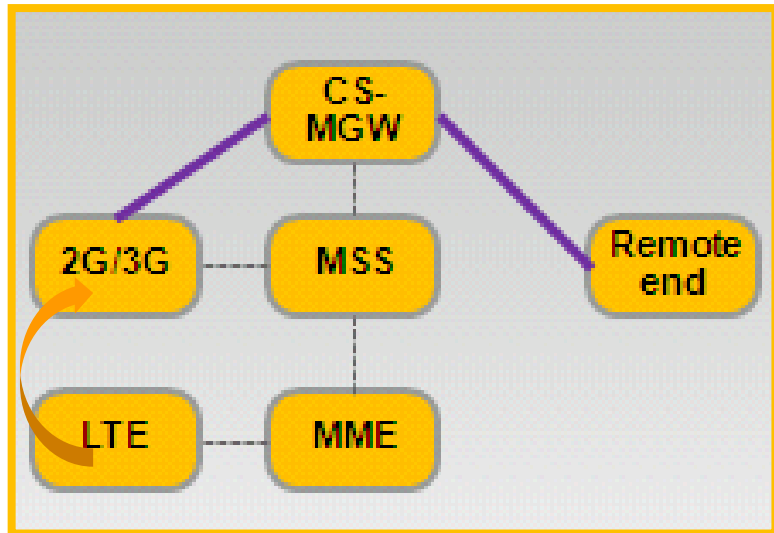
- Fallback to 2G/3G/CDMA access for voice
- LTE SMS
- MSC Server / MSC for voice

- Voice over LTE
- IMS for voice and Telecom Application Server for voice
- Rich Communication Services

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LTE data and voice evolution

Broad Band

Data oriented terminals

CSFB

Data & voice oriented terminals

LTE 2G/3G

data voice

SRVCC

Single radio terminals

2G/3G LTE

LTE terminals

LTE
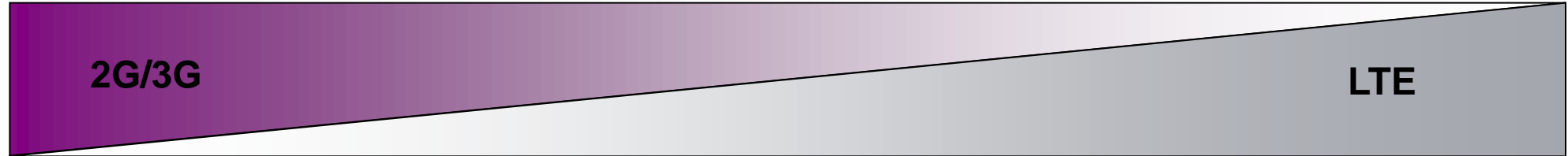
2010 (Commercial) – VoLTE

Operator VoIP in laptops + LTE dongles in LTE hot spots or rural areas i.e. VoIP (fixed voice replacement) + velco terminals for LTE/CDMA operators

2H11 (Commercial) – CSFB

LTE smartphones with CSFB capability available.

1H12 (Commercial) – VoLTE with QoS

Operator VoIP in laptops + LTE dongles and smatrphones in LTE hot spots with QoS.

2013 (Commercial) – SR-VCC

LTE smartphones with VoLTE and SR-VCC.

2010 **2012** **2013** **20XX**

2G/3G **LTE**

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How many bands can current LTE device chipsets support ?

Multimode chipset platforms

ST-Ericsson   M710   [LTE/HSPA/EDGE,
                                4 LTE, 3 HSPA, 4 GSM]

Qualcomm MDM9200   [LTE/DC-HSPA+/GSM]

Qualcomm MDM9600   [LTE/DC-HSPA+/CDMA/GSM]

Nvidia Espresso 410   [LTE/HSPA+/GSM]

- 1 - 4 LTE bands with

  - up to 4 HSPA bands

  - up to 4 GSM bands

  - up to 3 CDMA2000 bands

- **Possible band combinations vary between chipset vendors**

- **All leading platform vendors are including TDD support on their multimode solutions**

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LTE QoS Overview

SAE GW

S1

eNode-B

UE

QoS parameters in open S1 interface are standardized

QoS is bearer based – not packet based

QoS algorithms in radio network are not standardized

Full network control without UE QoS requirements

Similar to 3G

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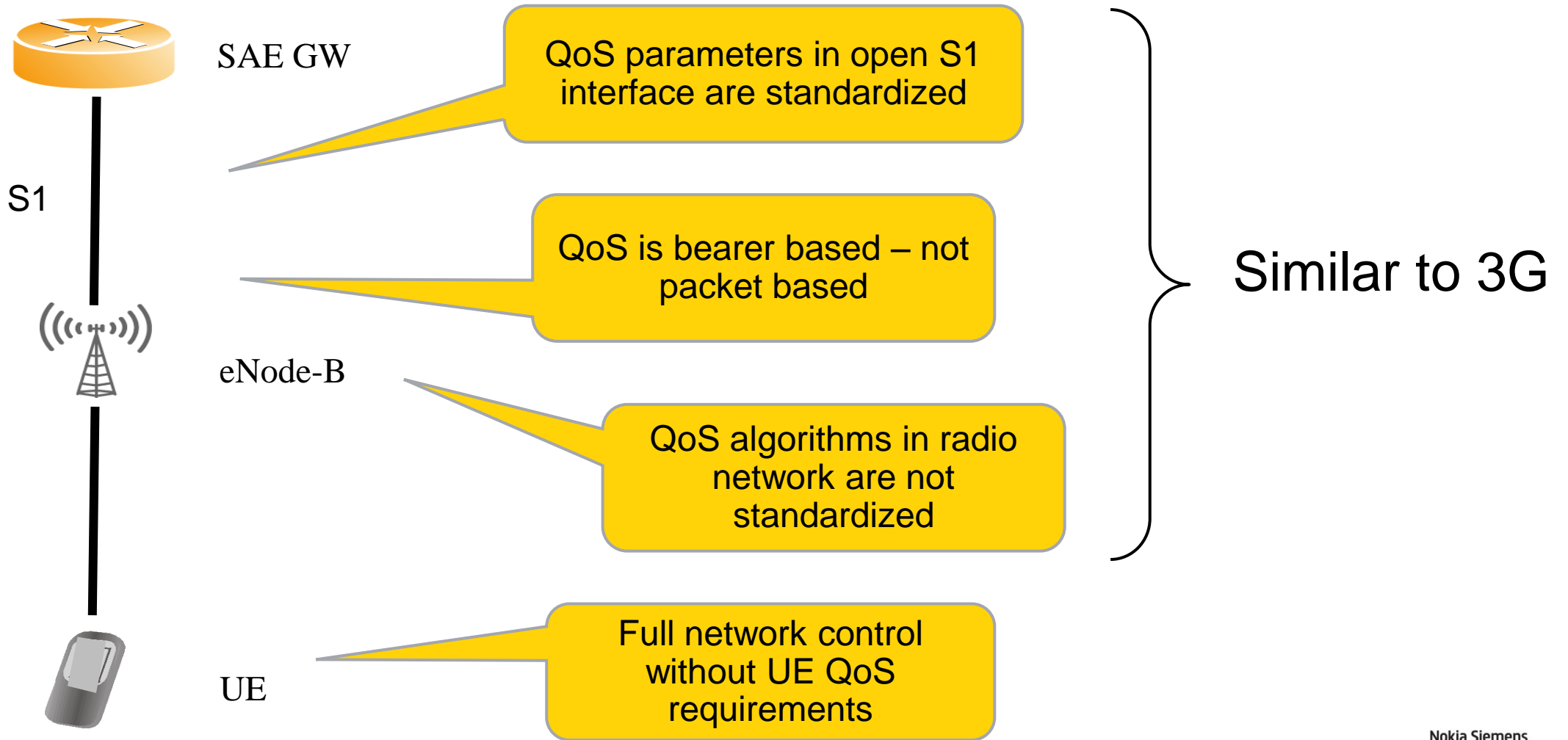
Network-centric QoS scheme

3G

Residual BER
SDU error rate
Delivery of erroneous SDUs
Max SDU size
Delivery order
Transfer delay
Traffic class
Traffic priority handling

ARP
Max. bit rate
Guaranteed bit rate

QoS Aware

LTE

QCI

ARP
Max. bit rate
Guaranteed bit rate

Aggregate max. bit rate (AMBR)

Non-QoS Aware

Substantially optimized Bearer handling compared to 3G networks

Single scalar label (QCI) is a pointer to a set of QoS parameters

Network-centric QoS scheme reduces complexity of UE implementations

- Always on default EPS bearer available after initial access
- Further dedicated EPS bearer setup on network request (e.g. for VoIP calls)
- Does not require support from terminal application clients or device operating system

QCI... QoS control identifier
ARP… Allocation/Retention priority

QoS Class Indentifier (QCI) Table in 3GPP 23.203

QCI	Guarantee	Priority	Delay budget	Loss rate	Application
1	GBR	2	100 ms	1e-2	VoIP
2	GBR	4	150 ms	1e-3	Video call
3	GBR	5	300 ms	1e-6	Streaming
4	GBR	3	50 ms	1e-3	Real time gaming
5	Non-GBR	1	100 ms	1e-6	IMS signalling
6	Non-GBR	7	100 ms	1e-3	Interactive gaming
7	Non-GBR	6	300 ms	1e-6	TCP protocols : browsing, email, file download
8	Non-GBR	8	300 ms	1e-6	
9	Non-GBR	9	300 ms	1e-6	

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Mapping of 3G and LTE QoS Parameters

LTE	UMTS QoS			
QCI	Traffic class	Traffic handling priority	Signalling indication	Source statistic descriptor
1	Conversational	-	-	Speech
2	Conversational	-	-	Unknown
3	Streaming	-	-	Speech
4	Streaming	-	-	Unknown
5	Interactive	1	Yes	-
6	Interactive	1	-	-
7	Interactive	2	-	-
8	Interactive	3	-	-
9	Background	-	-	-

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Network Initiated Bearer in LTE

- Guaranteed bit rate QoS requires its own bearer
- New bearer must be initiated by UE in 3G
- New bearer can be initiated by network in LTE $\Rightarrow$ less requirements for the terminal and better network control
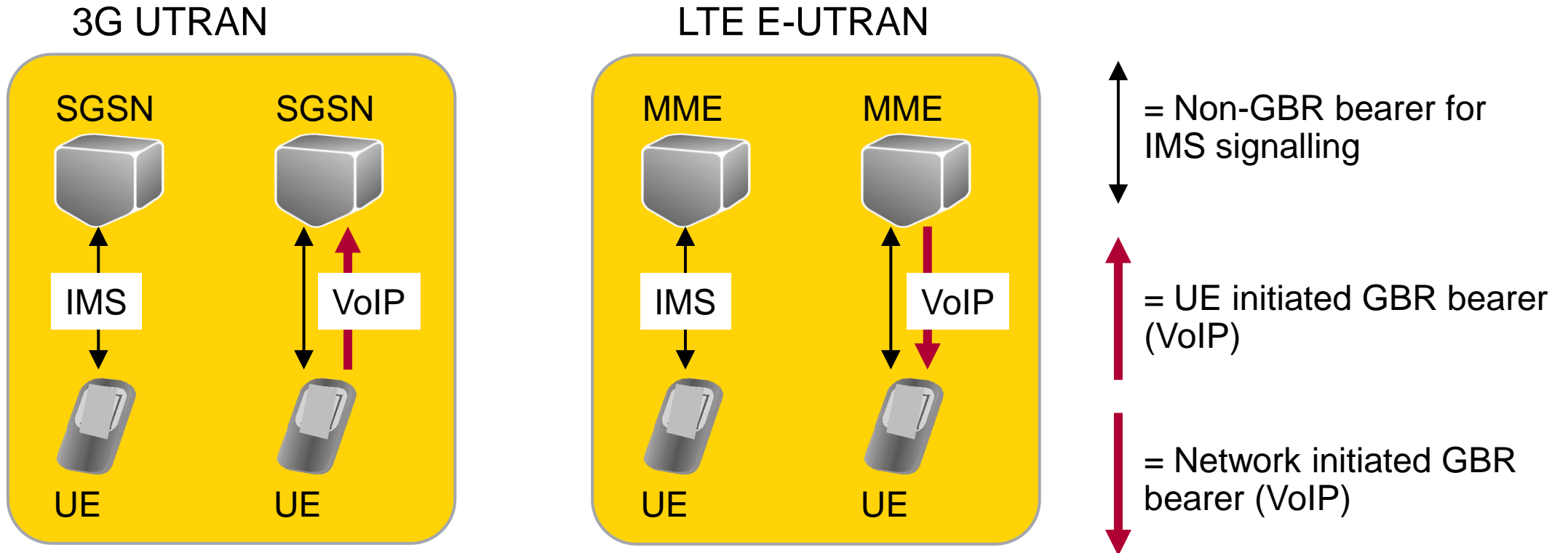
3G UTRAN

LTE E-UTRAN

= Non-GBR bearer for IMS signalling

= UE initiated GBR bearer (VoIP)

= Network initiated GBR bearer (VoIP)

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What is SON?

- SON originally refers to a network that can organize itself in the form of
  - **Self-Configuration**, e.g. initial parameter deployment,…
  - **Self-Optimization**, e.g. tuning the handover thresholds, …
  - **Self-Healing**, e.g. recovering from eNB failures automatically,…
- This is implemented as closely network related automation by
  - **Centralized SON:** associated with slow update rate and based on long term statistics where many cells are involved in optimization process. Implemented using network/element management system (OAM).
  - **Distributed SON:** require fast reaction time which affect only few cells, parameters have only local impact but configuration or status about neighbour cells are required. Optimization algorithms are implemented in eNodeB
  - **Localized SON:** require fast reaction time and only single cell involved- no impact on neighbour cells. Implemented by Radio Resource Management (RRM) in eNodeB
  - **Hybrid SON:** all the above 3 processes are used simultaneously for different use cases.

- SON can be considered as a specific type of automation

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Why SON has been developed

- Group of leading CSP's indentified and specified in 2006 NGMN forum the Self Organising Networks as an important, new solution to meet the challenges of
  - data traffic growth
  - declining voice ARPU
  - investments to new technologies and network expansions

- SON is today 3GPP standardised for LTE

- Standardisation defines concept, interfaces and measurements for SON leaving e.g. implementation methods open.

- SON key objectives
  - Reduce complexity and cost of network operations
  - Maintain and improve quality of the networks
  - Cost effective introduction of new technologies
  - Protect network investments

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Self-Organizing Networks
Intelligent Automation e2e

SON

Healing

Configuration

Optimisation

Quality

Coverage

Capacity

Self-Healing
- Error detection
- Error mitigation
- Alarm Mgt.
- Root cause analysis

Self-Configuration
- Site Creation
- Connection
- Configuration
- Neighbours

Self-Optimization
- Interference
- Mobility
- Load/Capacity
- Measurement Collection
- Energy
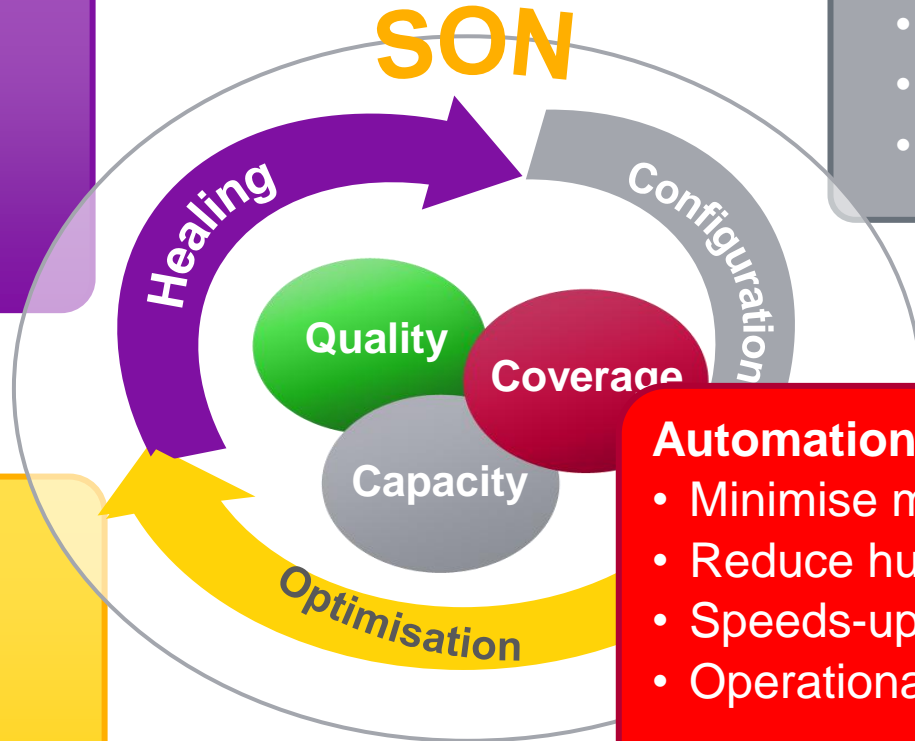
Automation
- Minimise manual tasks
- Reduce human errors
- Speeds-up operations
- Operational efficiency

QoE

OPEX

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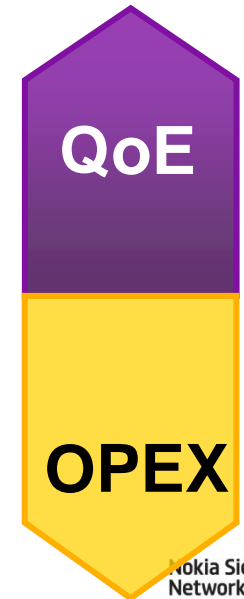
SON- some important use cases

- Configuration of Physical Cell ID   (*self configuration*)

- Automatic Neighbor Relations (ANR)   (*self configuration*)

- Mobility Load Balancing (MLB)   (*self optimization*)

- Mobility Robustness Optimization (MRO) (*self optimization*)

- Energy Saving   (*self optimization*)

- Minimization of Drive Test (MDT)

SON framework in 3GPP

- Release 8 functionality
  - Self-configuration procedures

- Release 9 enhancements
  - Self-optimization procedures
  - LTE Energy Saving Intra-RAT

- Release 10 objectives
  - Extend Self-optimization procedures , including inter-RAT
  - Minimization of Drive Test (MDT)
  - Energy Saving extension, including Multi-RAT (Study Item)
  - 3G-ANR
  - SON Conflict Resolution

- Release 11 proposals on hold until in June 2011 (RAN#52)
  - LTE SON extensions
  - MDT enhancements
  - HSDPA SON

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Use Cases in 3GPP

RAN

SA 5

| | SON Conflict Resolution | **Rel.10** |

Self-healing
- Cell Outage Compensation — **Rel.10**

Self-optimization extensions
- Mobility Robustness Optimization
- Mobility Load Balancing
- Coverage and Capacity Optimization
- 3G ANR

Rel.10

Self-optimization
- Mobility Robustness Optimization
- Mobility Load Balancing
- Energy Saving
- RACH Optimization

Rel.9
Rel.10

Self-configuration
- SON Plug and Play
- Automated Neighbor Relations Management (also Self-Opt)
- Automatic SW Mgmt and Automatic Radio Configuration (R9)

Rel.8

Rel.10 — *left column markers:* Rel.10, Rel.9, Rel.8

Minimization of Drive Tests — **Rel.10**

Networks

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Why do we now talk about LTE-Advanced?

- ITU-R has issued a Circular Letter early 2008 to invite candidate Radio Interface Technologies (RIT) for IMT-Advanced

- ITU-R requires "enhanced peak data rates" for IMT-Advanced:
  - 100 Mbit/s for high mobility
  - 1 Gbit/s for low mobility

- World Radio Conference (WRC-07) took decisions on Frequency Band identifications in November 2007 impacting IMT-2000 and IMT-Advanced

- In March 2008 3GPP has started a new Study Item on LTE-Advanced to enhance LTE to fulfill all IMT-Advanced requirements and to become IMT-Advanced candidate

- Currently, 3GPP RAN is studying and evaluating the performance of the new relevant technology components.

LTE-Advanced – Requirements and expectations:
Performance improvement and Backward Compatibility

➢ Meet and exceed capabilities requested for IMT-Advanced
➢ Meet 3GPP operators' requirements for LTE evolution
➢ Backward compatibility:
  • Release 8 UEs work in LTE-Advanced network
  • LTE-Advanced UEs work in Release 8 network
➢ Flexible and optimized spectrum usage
➢ Enable heterogeneous networks incl. Relays, HeNBs, etc.
➢ Bandwidth extension up to 100 MHz

➢ Enhanced performance
  • Peak data rates of 1 Gbps DL and 500 Mbps UL
  • 50% higher average cell spectral efficiency than LTE Release 8

LTE-A provides a toolbox of solutions improving radio performance:

	Peak rate	Average rate (capacity)	Cell edge rate (interference)	Coverage (noise limited)
Carrier aggregation	++	+	++	+
MIMO enhancements[1]	++ (o)	++ (+)	++ (+)	o
CoMP[2]	o	+	+	++
Heterogeneous networks	o	++	++	+
Relays	o	o	+	++

= clear gain   = moderate gain

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LTE-Advanced: Carrier aggregation
More dynamic spectrum usage for better user experience

Peak data rate addition

Example:

spectrum assets   **peak data rate**

                              on Cat.4 device   with carrier aggregation

20MHz in 2.6GHz band   →   150 Mbps

                                                  >200 Mbps

10MHz in 800MHz band   →   75 Mbps
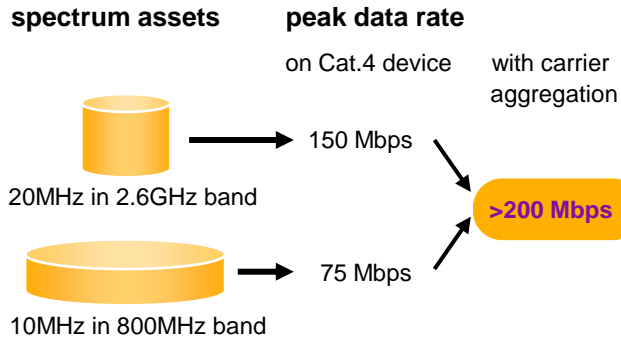
- enables **competitive peak data rates** on non-contiguous spectrum
- Mitigates the challenge of fragmented spectrum

Resource allocation gain
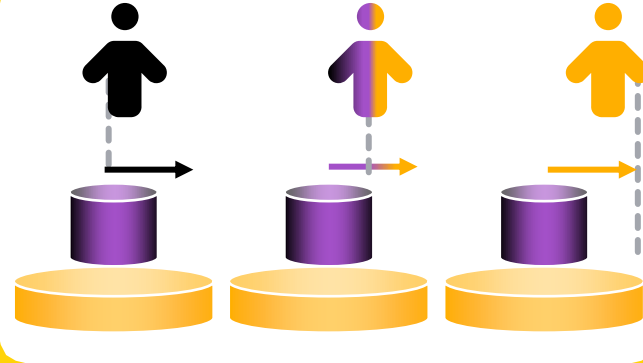
- Ultrafast resource allocation by scheduler instead of handover
- Users dynamically get the best resources of aggregated carrier
- **Higher average data rates**

3 Gbps

20MHz → 600Mbps
20MHz → 600Mbps
20MHz → 600Mbps   **3Gbps**
20MHz → 600Mbps
20MHz → 600Mbps
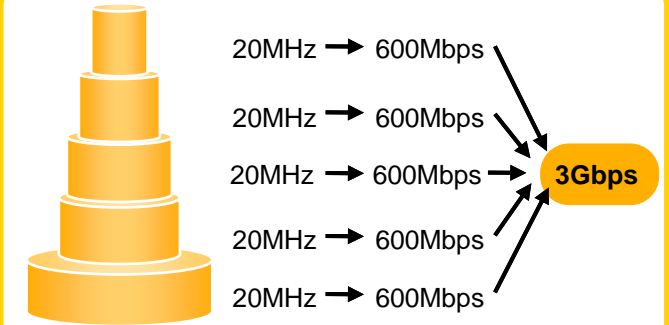
- Will be specified in **3GPP Rel.11 or later**
- Most operators have significantly less spectrum for LTE
- Even HD streaming services demand less than 20Mbps

Relevant scenarios under standardisation (3GPP Rel.10/11)

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LTE-Advanced: Carrier aggregation
Initial focus on Downlink

- Downlink carrier aggregation for 2 component carriers
- Up to 40 MHz combined bandwidth
  - Inter-band
  - Intra-band contiguous allocation
- PCC* based mobility
- 3GPP defined band combinations

*Primary component carrier:
  (from 3GPP Rel.8) -> mobility, data

*Secondary component carrier:
  where available -> add-on data speed

Carrier aggregation bands in 3GPP rel 10 (Source: TS36.104, version 10.4.0)

Intra-band CA:

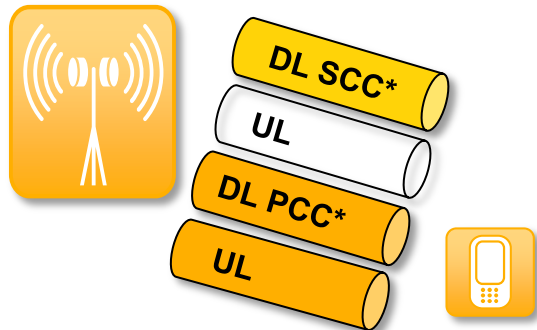| CA Band	E-UTRA operating band
CA_1	1 (generic example)
CA_40	40 (generic example)

Inter-band CA:

CA Band	E-UTRA operating bands
CA_1-5	1 + 5 (generic, Korea)

CA band WI (planned for Dec. 2012)

Inter-band CA:

CA Band	E-UTRA operating band
CA_3-7	3 + 7 (TeliaSonera)
CA_4-13	4 + 13 (Verizon)
CA_4-17	4 + 17 (AT&T)
CA_20-7	20 + 7 (Orange etc.)
CA_5-12	5 + 12 (US Cellular)
CA_4-12	4 + 12 (Cox)
CA_2-17	2 + 17 (AT&T)
CA_4-5	4 + 5 (AT&T)
CA_5-17	5 + 17 (AT&T)
CA_1-7	1 + 7 (China Telecom)
CA_3-5	3 + 5 (SK Telecom)
CA_4-7	4 + 7 (Rogers)
CA_20-3	20 + 3 (Vodafone)
CA_20-8	20 + 8 (Vodafone)

Intra-band CA:

CA Band	E-UTRA operating band
CA_41	41 (Clearwire, CMCC)
CA_38	38 (CMCC)
CA_7	7 (CUC,CTC,Telenor, etc.)
CA_25	25 (Sprint; target June 2013)

LTE FDD

Band	MHz	Uplink MHz	Downlink MHz	
1	2x60	1920-1980	2110-2170	UMTS core
2	2x60	1850-1910	1930-1990	US PCS
3	2x75	1710-1785	1805-1880	GSM 1800
4	2x45	1710-1755	2110-2155	NAM AWS
5	2x25	824-849	869-894	850
7	2x70	2500-2570	2620-2690	2600 FDD
8	2x35	880-915	925-960	GSM 900
9	2x35	1749-1784	1844-1879	Japan, Korea 1700
10	2x60	1710-1770	2110-2170	US AWS extension.
11	2x20	1427.9-1447.9	1475.9-1495.9	Japan 1500
12	2x18	698-716	728-746	US
13	2x10	777-787	746-756	Verizon
14	2x10	788-798	758-768	US – Public Safety
17	2x12	704-716	734-746	AT&T
18	2x15	815-830	860-875	Japan – 800 (KDDI)
19	2x15	830-845	875-890	Japan – 800 (DoCoMo)
20	2x30	832-862	791-821	EU 800 DD, MEA
21	2x15	1448-1463	1496-1511	Japan 1500
22	2x80	3410-3490	3510-3590	3.5 GHz FDD (band 42–FDD variant)
23	2x20	2000-2020	2180-2200	US S-band
24	2x34	1626.5-1660.5	1525-1559	US (LightSquared)
25	2x65	1850-1915	1930-1995	US PCS extension (Sprint)
26	2x35	814-849	859-894	850 extension (Korea-KT, Sprint)

TD-LTE

Band	MHz	Uplink MHz	Downlink MHz	
33	1x20	1900-1920	1900-1920	UMTS core – TDD
34	1x15	2010-2025	2010-2025	UMTS core – TDD, China TD/SCDMA
35	1x60	1850-1910	1850-1910	US (band 2 – TDD variant)
36	1x60	1930-1990	1930-1990	US (band 2 – TDD variant)
37	1x20	1910-1930	1910-1930	US PCS centre-gap
38	1x50	2570-2620	2570-2620	China, LatAM, Europe
39	1x40	1880-1920	1880-1920	China PHS
40	1x100	2300-2400	2300-2400	MEA, India, China, Russia
41	1x194	2496-2690	2496-2690	US (Clearwire)
42	1x200	3400-3600	3400-3600	3.4/5 GHz – TDD
43	1x200	3600-3800	3600-3800	3.7/8 GHz – TDD

Source: TS 36.101; *commercialized bands*

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LTE-Advanced: Carrier aggregation
Terminal categories for LTE-Advanced

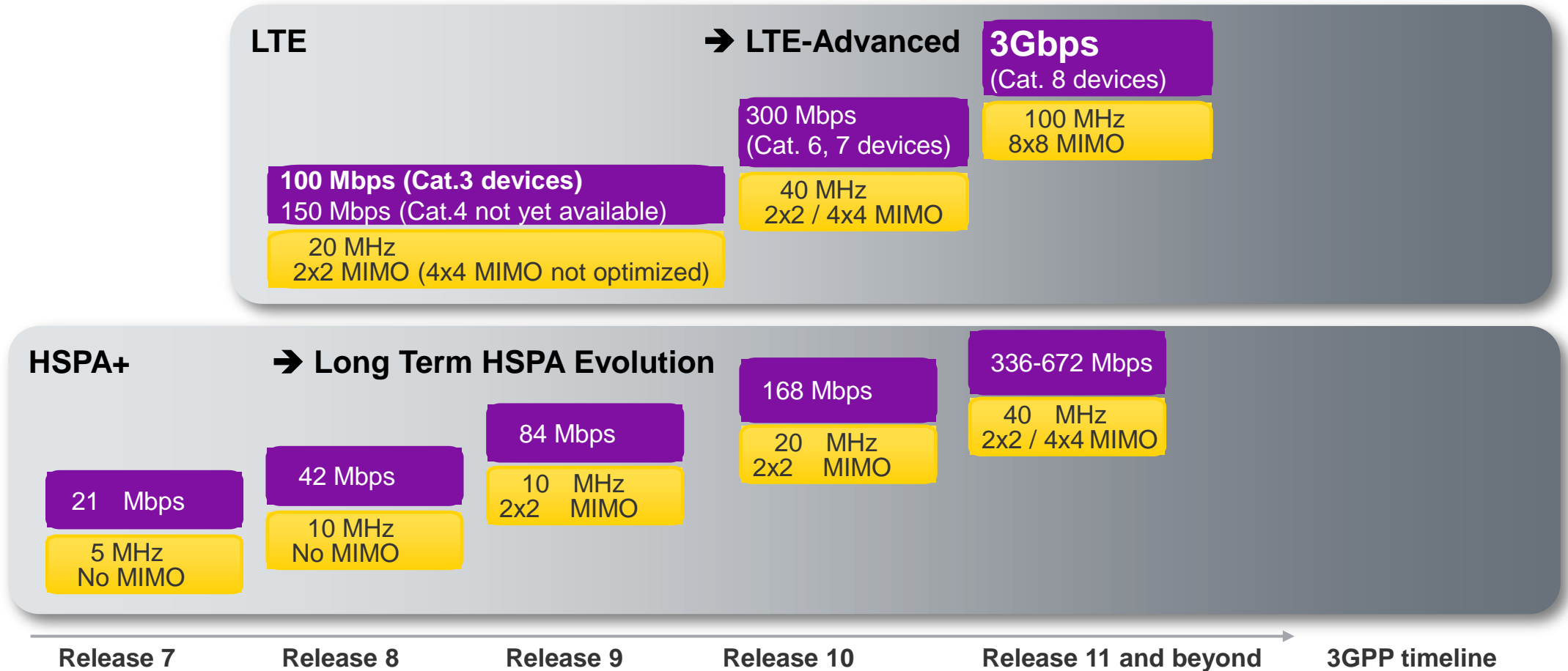|	LTE (Rel.8) UE categories		All commercial LTE devices in the market 2010 / 2011			LTE-Advanced devices based on these User Equipment categories		
	Class 1	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**	**Class 7**	**Class 8**
Peakrate DL/UL	10/5 Mbps	50/25 Mbps	**100/50 Mbps**	150/50 Mbps	300/75 Mbps	**300/50 Mbps**	**300/100 Mbps**	**3000/1500Mbps**
RF Bandwidth	20 MHz	20 MHz	**20 MHz**	20 MHz	20 MHz	**40 MHz**	**40 MHz**	**100 MHz**
Modulation DL	64 QAM	64 QAM	**64 QAM**	64 QAM	64 QAM	**64 QAM**	**64 QAM**	**64 QAM**
Modulation UL	16 QAM	16 QAM	**16 QAM**	16 QAM	64 QAM	**16 QAM**	**16 QAM**	**64 QAM**
MIMO DL	optional	2 x 2	**2 x 2**	2 x 2	4 x 4	**2x2(CA) or 4x4**	**2x2(CA) or 4x4**	**8 x 8**
MIMO UL	no	no	**no**	no	no	**no**	**2 x 2**	**4 x 4**

Defined in initial LTE release (3GPP Release 8)

Defined in initial LTE-A release (3GPP Rel. 10)

Carrier aggregation of up to 40MHz

Source: TS 36.306

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Overview - Mobile Broadband Downlink peak data rate evolution

LTE ➔ **LTE-Advanced** **3Gbps**
(Cat. 8 devices)

100 MHz
8x8 MIMO

300 Mbps
(Cat. 6, 7 devices)

40 MHz
2x2 / 4x4 MIMO

100 Mbps (Cat.3 devices)
150 Mbps (Cat.4 not yet available)

20 MHz
2x2 MIMO (4x4 MIMO not optimized)

HSPA+ ➔ **Long Term HSPA Evolution**

336-672 Mbps

40   MHz
2x2 / 4x4 MIMO

168 Mbps

20   MHz
2x2   MIMO

84 Mbps

10   MHz
2x2   MIMO

42 Mbps

10 MHz
No MIMO

21   Mbps

5 MHz
No MIMO

Release 7   **Release 8**   **Release 9**   **Release 10**   **Release 11 and beyond**   **3GPP timeline**

Agenda

Introduction

WCDMA/HSPA/HSPA+

LTE

LTE-Advanced

Summary

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Summary (1/3)

WCDMA/HSPA/HSPA+

- Strong momentum and growth in Mobile Broadband with terminals, network technology and applications

- WCDMA has both FDD (widely used) and TDD variant with FDD using 5+5 MHz and TDD 5 MHz as single carrier

- HSPA/HSPA+ is a mature technology with broad ecosystem support, which will further evolve and will remain dominant technology for many years to come

- Carrier aggregation and MIMO pushes the peak data rates and cell throughput

LTE

- Motivation of LTE is need for higher peak data rate, spectral efficiency, less round trip delay, packet optimized network, high degree of mobility and spectrum flexibility

- LTE has both FDD and TDD variant with frequency allocation flexibility with 1.4, 3, 5, 10, 15 and 20 MHz spectrum

- LTE frequency bands for Europe are 2600 (capacity), 1800 (capacity) and 800 (coverage) MHz

- LTE uses OFDMA in DL and SC-FDMA UL for multiple access technology. OFDMA in DL minimizes receiver complexity while SC-FDMA improves battery life time in receiver

- LTE is packet oriented flat network with minimum no. of nodes- only eNodeB in access and MME, SAE-GW (S-GW/P-GW) in core networks. (additionally, HLR/HSS, PCRF and IMS is required in core)

- Voice in LTE is accomplished by CS Fallback (initially) and SR-VCC (later).

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Summary (3/3)

SON

- SON is a set of network algorithms for simplifying network configuration, optimization and healing
- SON algorithms can be centralized targeting multi-cell optimization or distributed for fast and local optimization or a hybrid (combination of all)
- SON is not limited to LTE only but many of these SON algorithms are applied to 3G/HSPA networks as well

LTE-Advanced

- LTE-A in Rel-10 adds several enhancements in LTE
- Improvements in peak and average data rates using carrier aggregation, increased number of antennas and advanced antenna technologies
- Further improvements by use of relay and interference management
- LTE-A with Rel-10 fulfills and exceeds requirements for IMT-Advanced
- LTE-A can achieve peak data rates as high as 3 Gbps in DL and 1.5 Gbps in UL direction with 100 MHz spectrum

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