Mobilné technológie GSM, 3G, LTE - prehľad, návrh a implementácia

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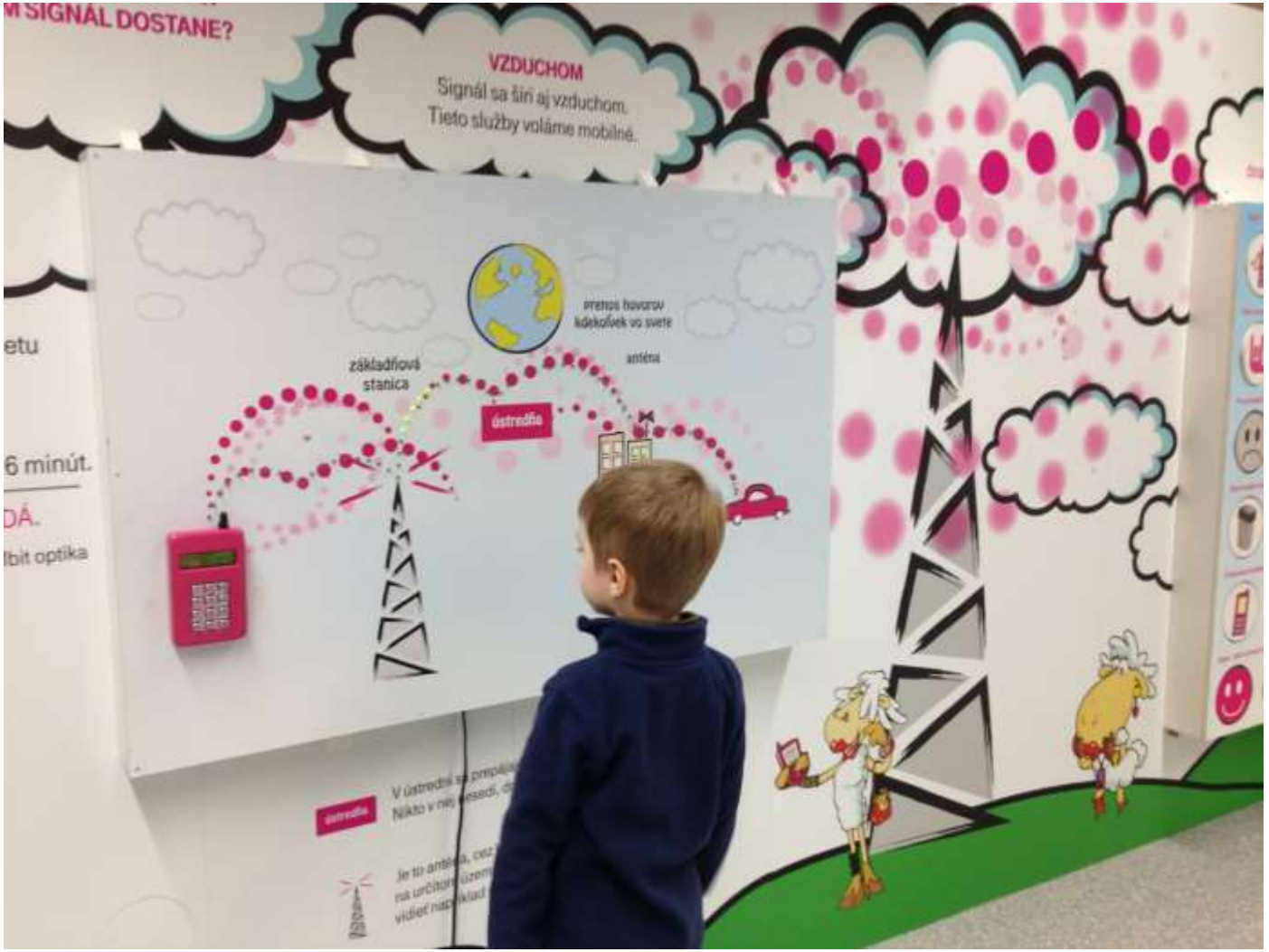
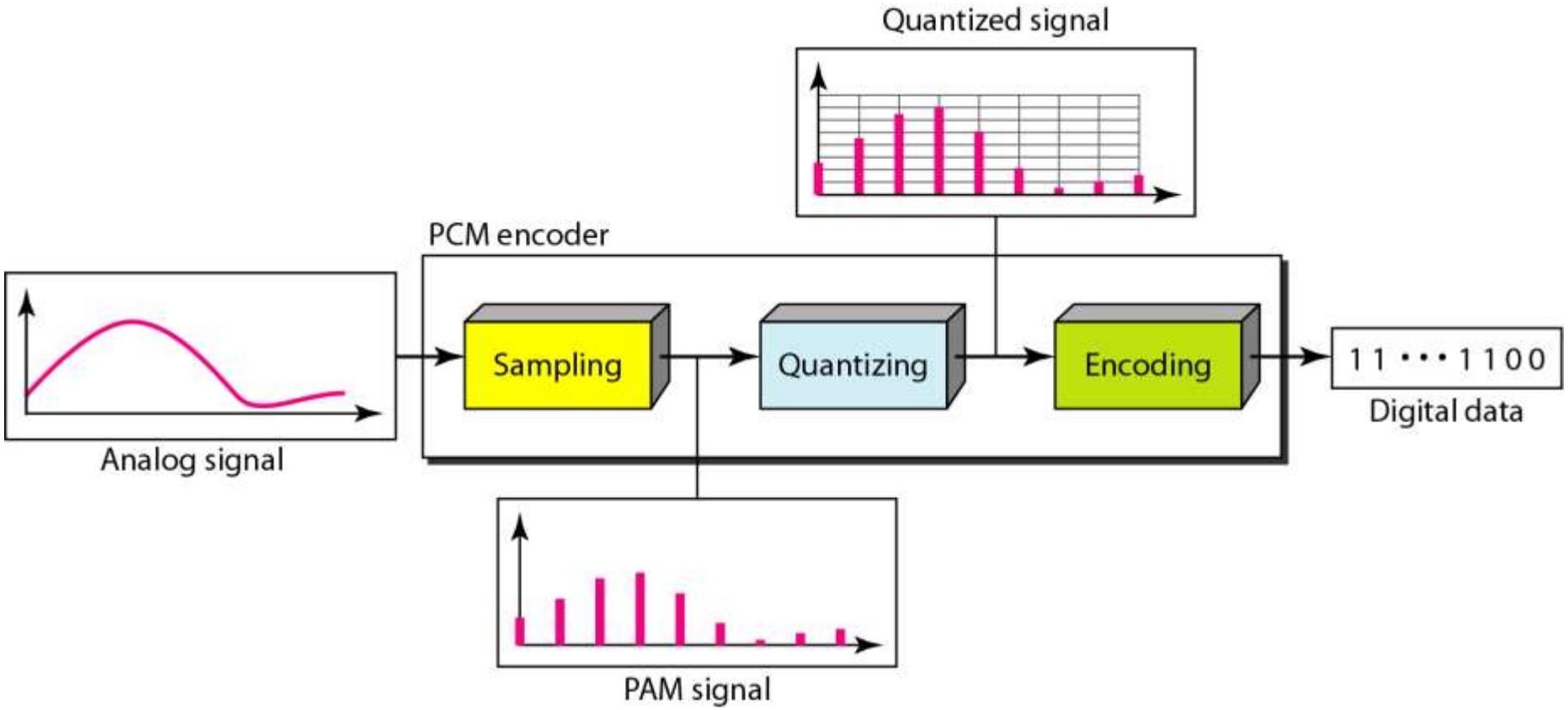
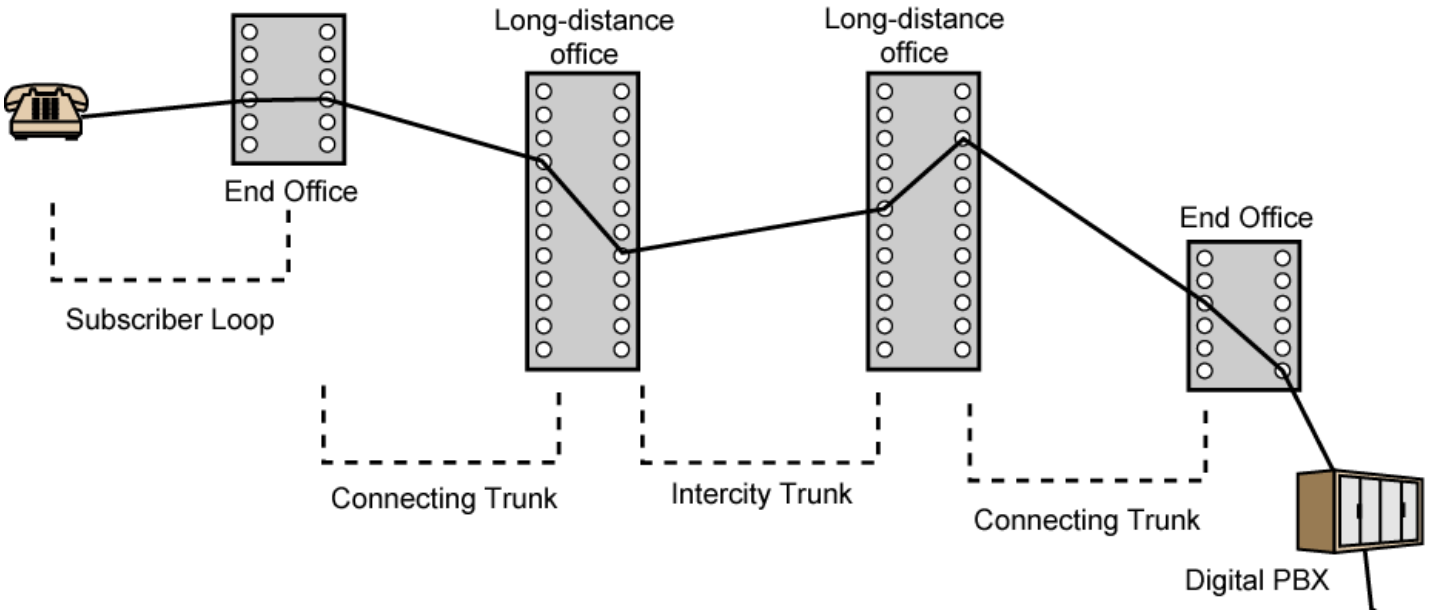
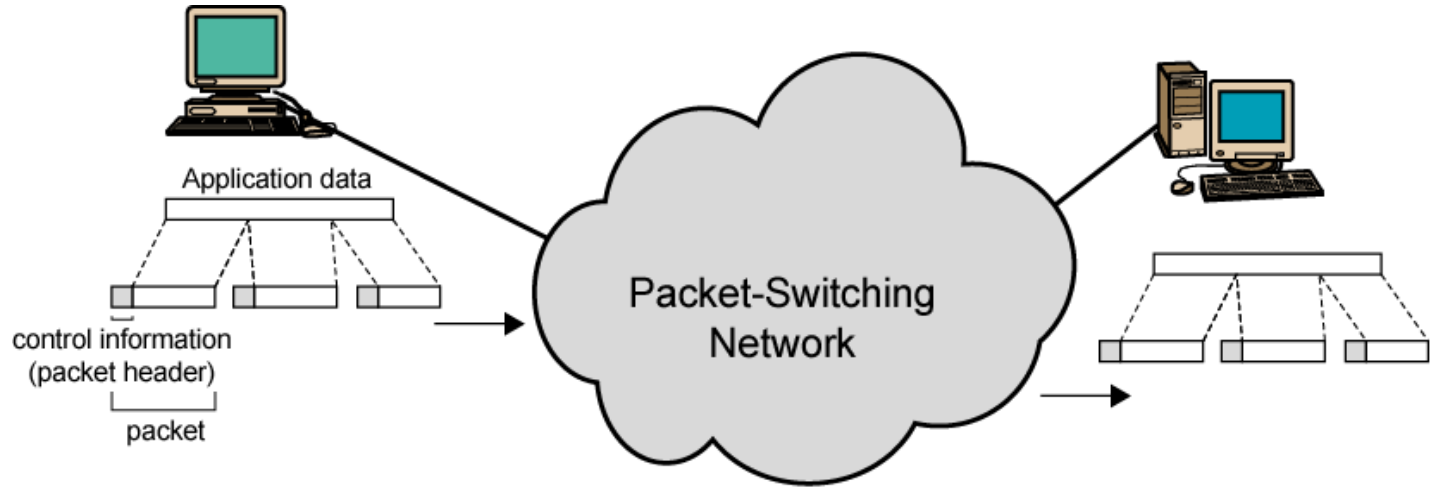

M SIGNÁL DOSTANE?
VZDUCHOM
Signál sa šíri aj vzduchom.
Tieto služby voláme mobilné.
prenos hovorov
kdekoľvek vo svete
anténa
základňová
stanica
ústredňa
etu
6 minút.
DÁ.
bit optika

Analog to digital conversion
Pulse Code Modulation



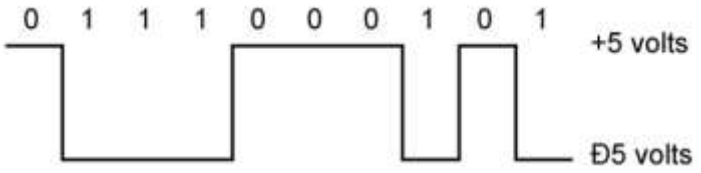
Circuit switching vs Packet switching





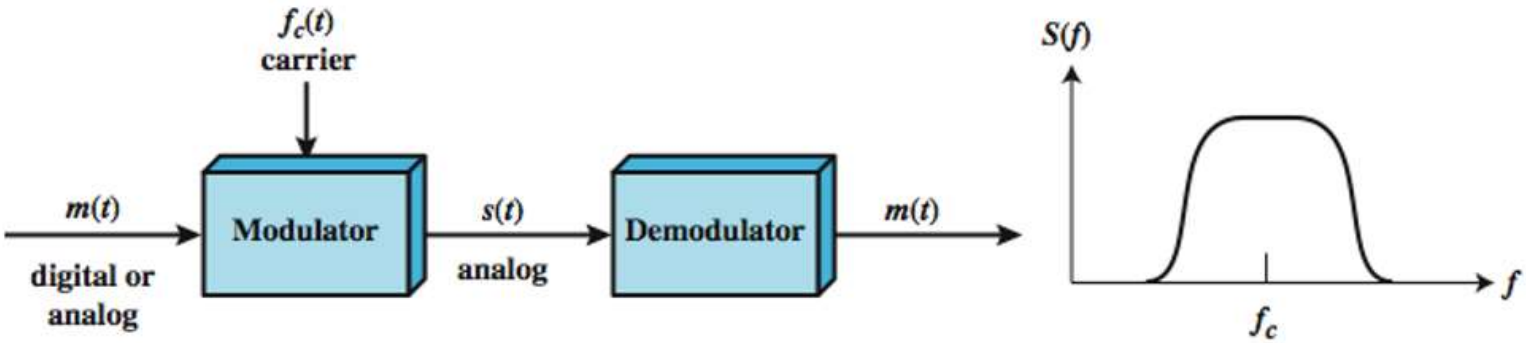
Digital signals

- discrete, discontinuous voltage pulses
- each pulse is a signal element
- binary data encoded into signal elements



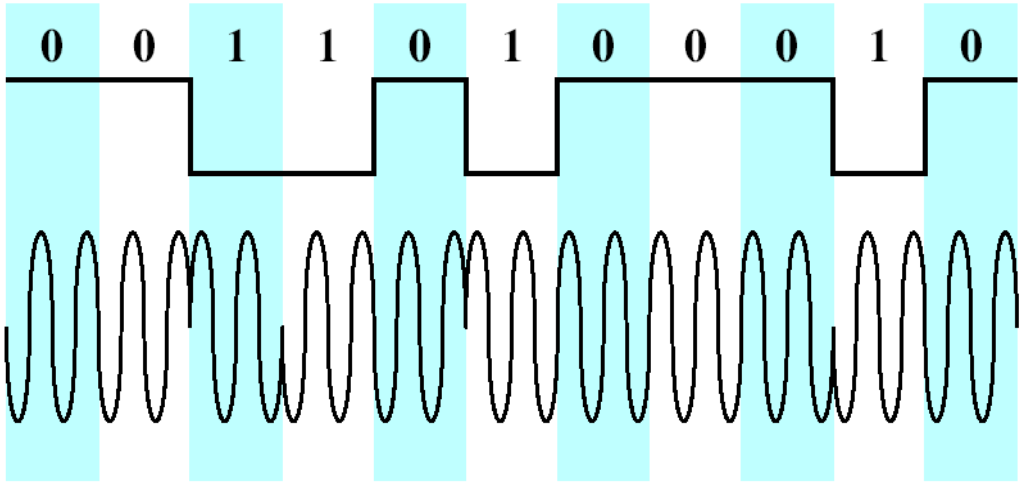
Digital Data, Analog Signal

- Main use is public telephone system
  - has freq range of 300Hz to 3400Hz
  - use modem (modulator-demodulator)
- The digital data modulates the amplitude A, frequency f_c, or phase θ of a carrier signal



Modulation

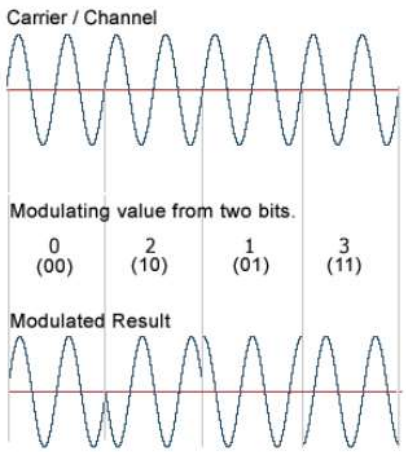
- In DPSK, the phase shift is with reference to the previous bit transmitted rather than to some constant reference signal
- Binary 0:signal burst with the same phase as the previous one
- Binary 1:signal burst of opposite phase to the preceding one

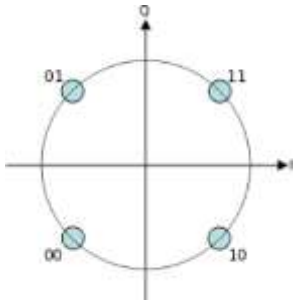


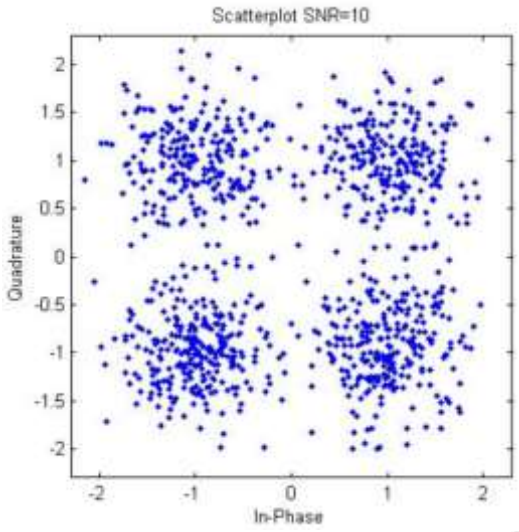
- In QPSK, instead of a phase shift of 180˚ as allowed in BPSK, it uses phase shifts separated by multiples of π/2 (90˚).

Modulation

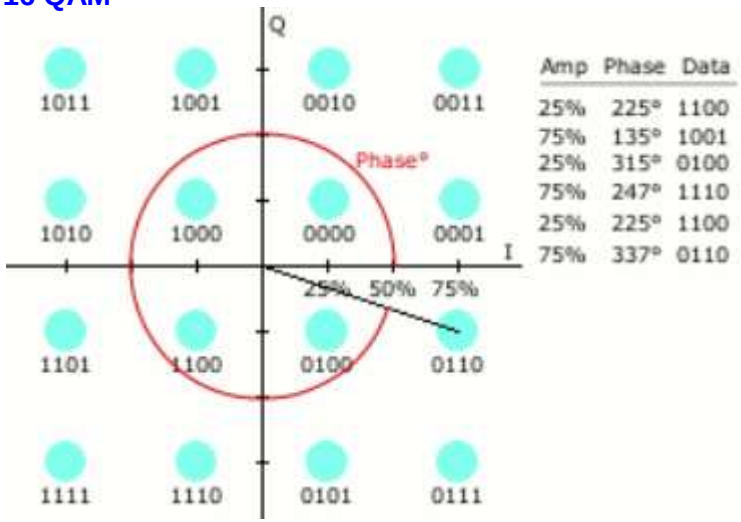
QPSK



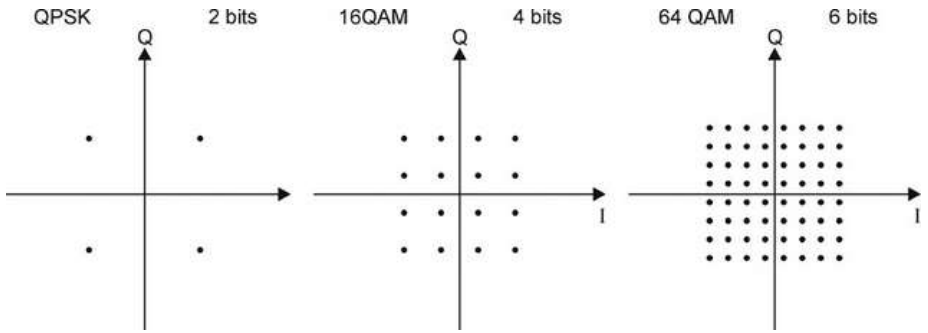




16 QAM

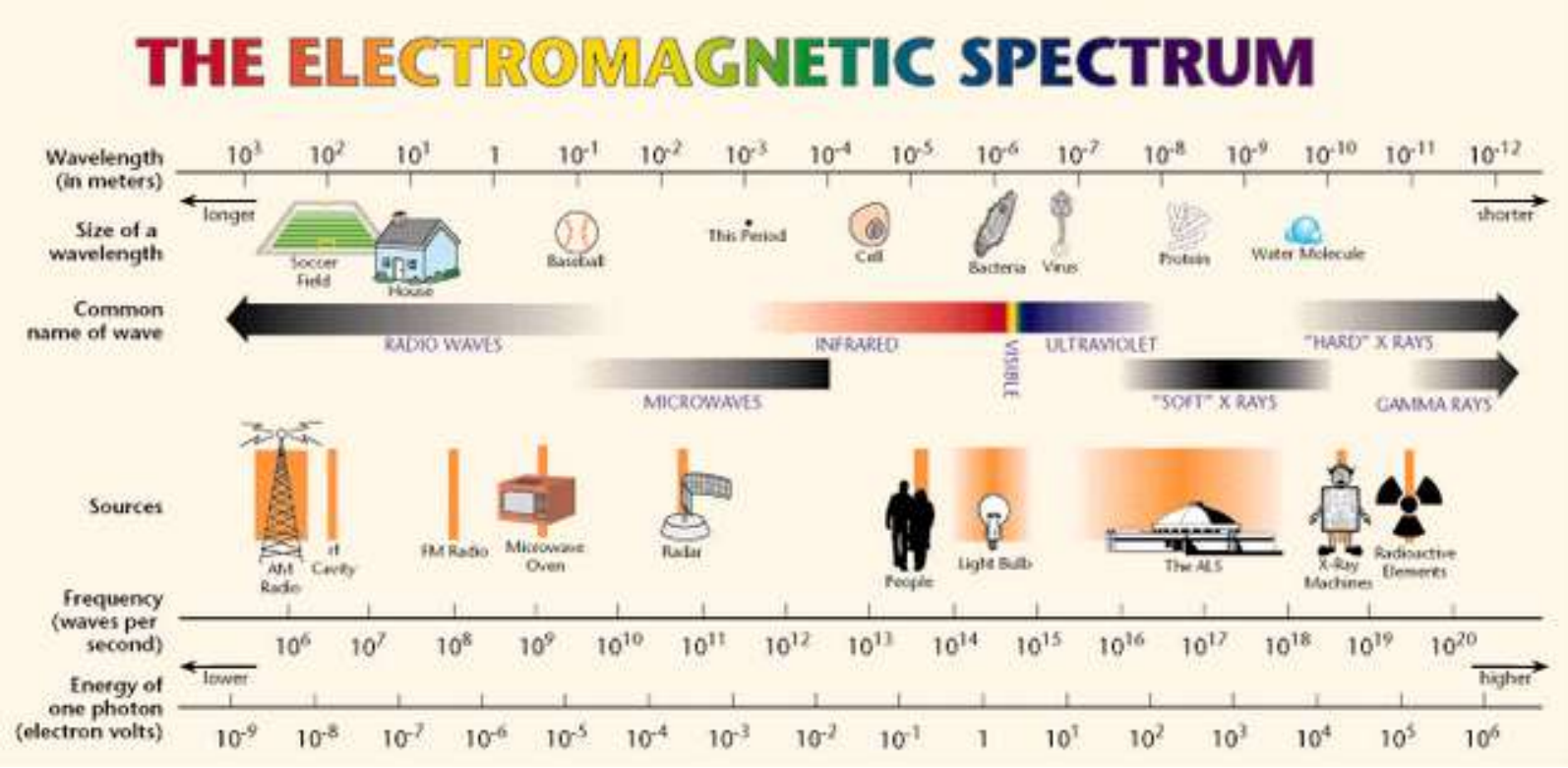


Amp	Phase	Data
25%	225°	1100
75%	135°	1001
25%	315°	0100
75%	247°	1110
25%	225°	1100
75%	337°	0110



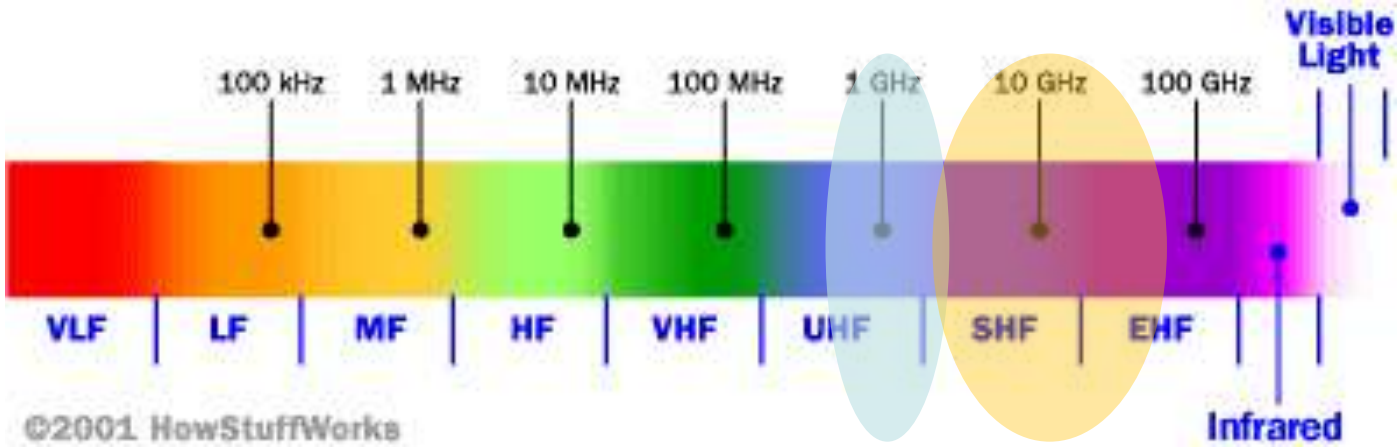
Wireless Network Basics

- Wireless network data/telephony is a *radio*-based technology; radio waves are electromagnetic waves that *antennas* propagate



Wireless Network Basics

- Cellular frequencies in Europe are in 800 MHz, 900 MHz, 1800 MHz, 2100MHz and 2600 MHz frequency band

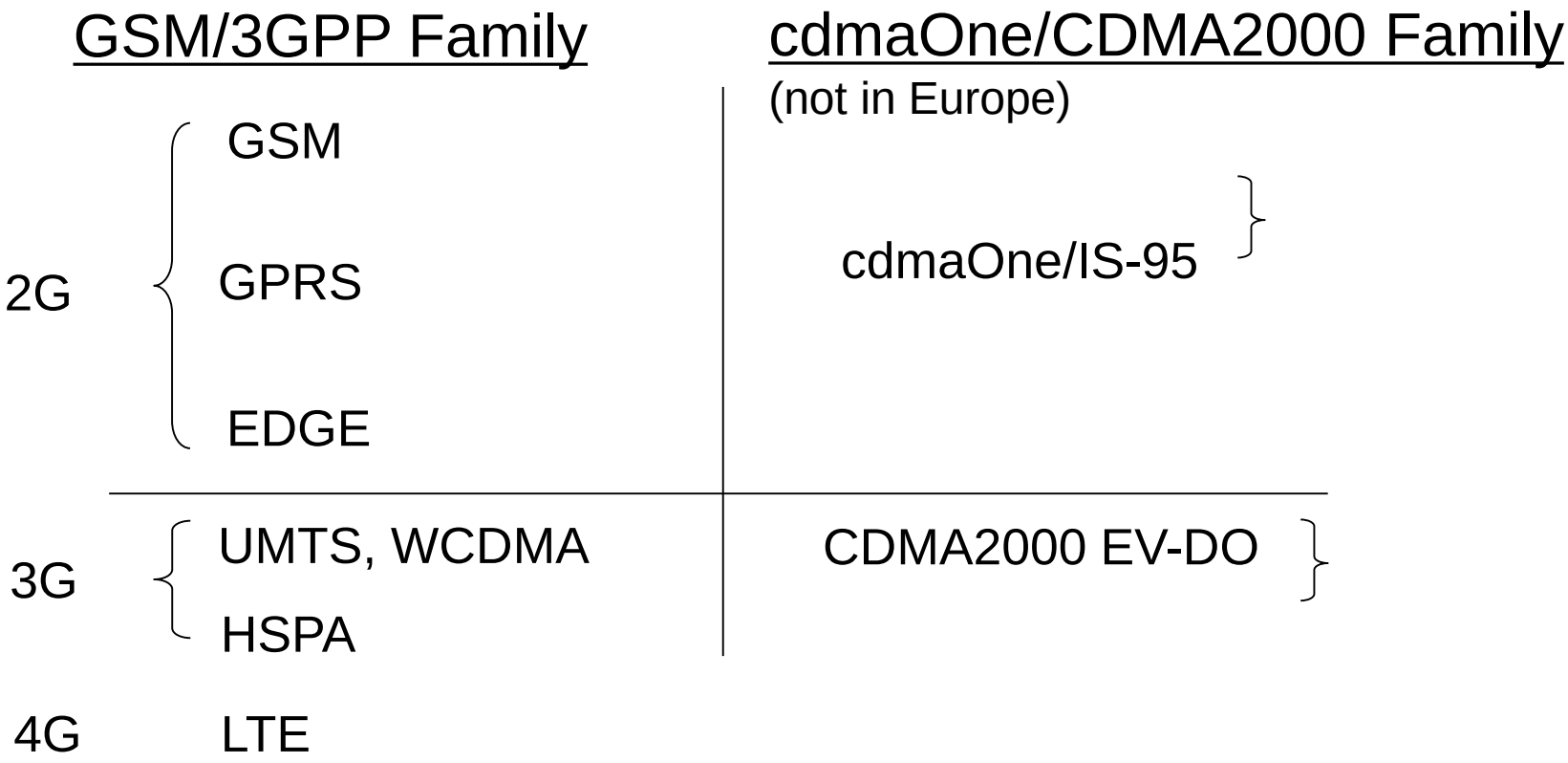


Microwaves

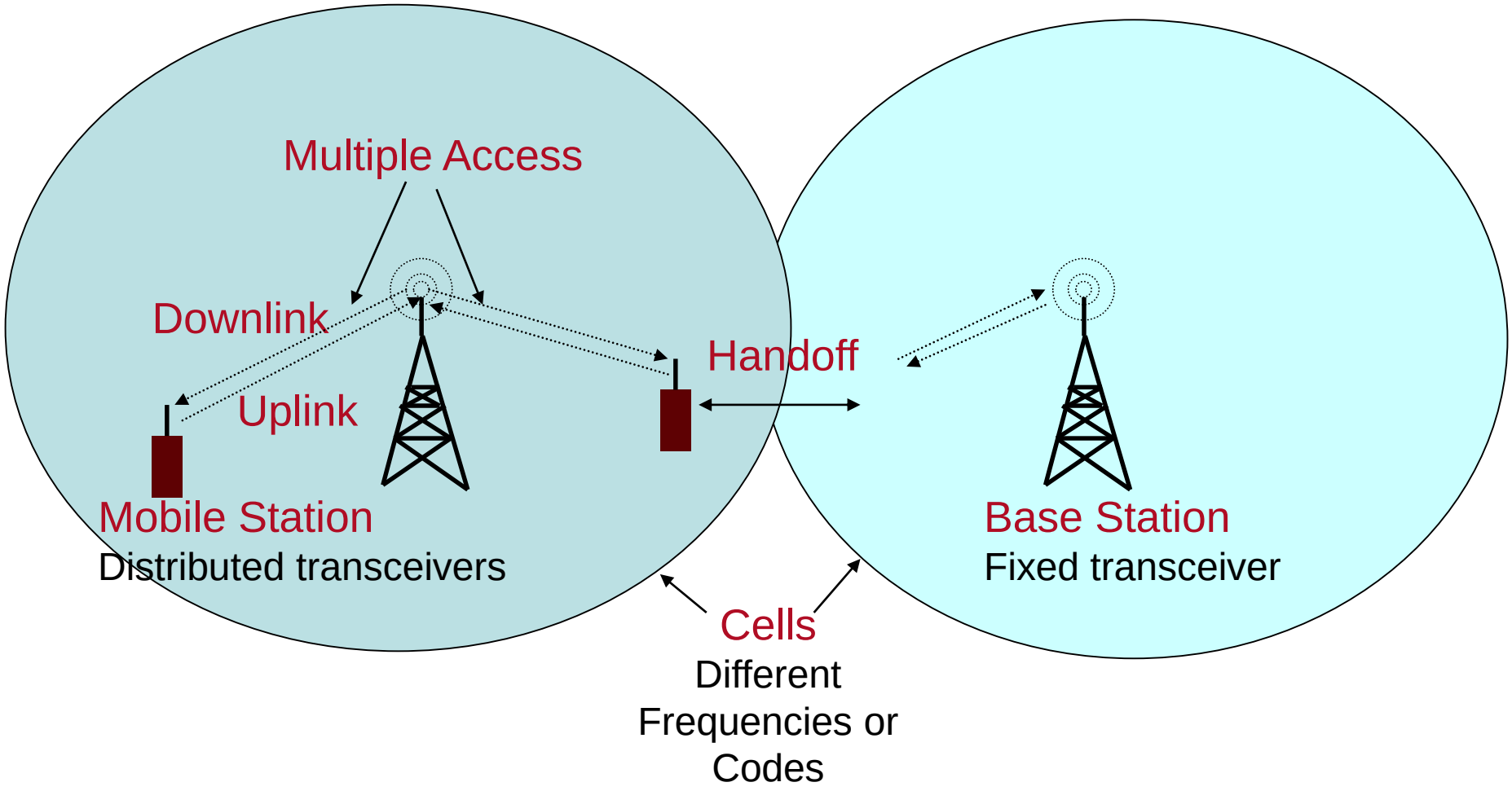
Mobile phones

Cellular Technology Evolution

- 1G: Analog
- 2G/3G: Digital
- 4G: Packet data



Cellular networks (2G,3G,4G)



Cellular networks - technology

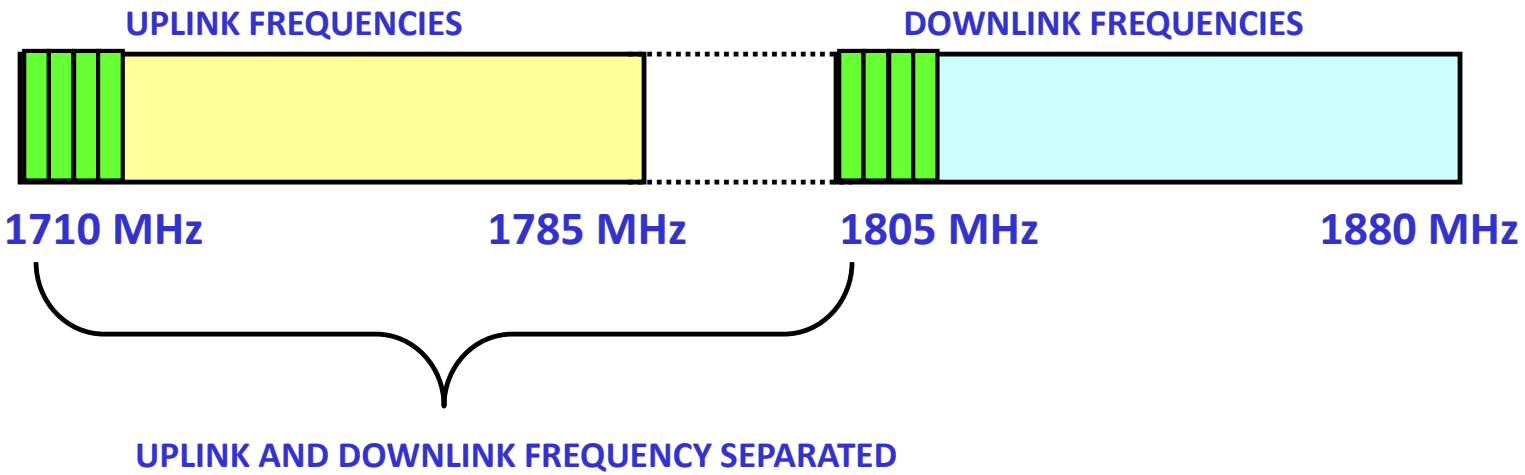
- Uplink & Downlink separated in
  - Time: Time Division Duplex (TDD), or
  - Frequency: Frequency Division Duplex (FDD)
- Information (voice, data) is digitized and bit streams modulated onto carrier
- Modulation, data redundancy (coding), transmission power adapted to varying wireless channel quality
- Spatial attenuation of signal
  - Frequency can be reused (frequency reuse)

2G: Global System for Mobile communications (GSM)

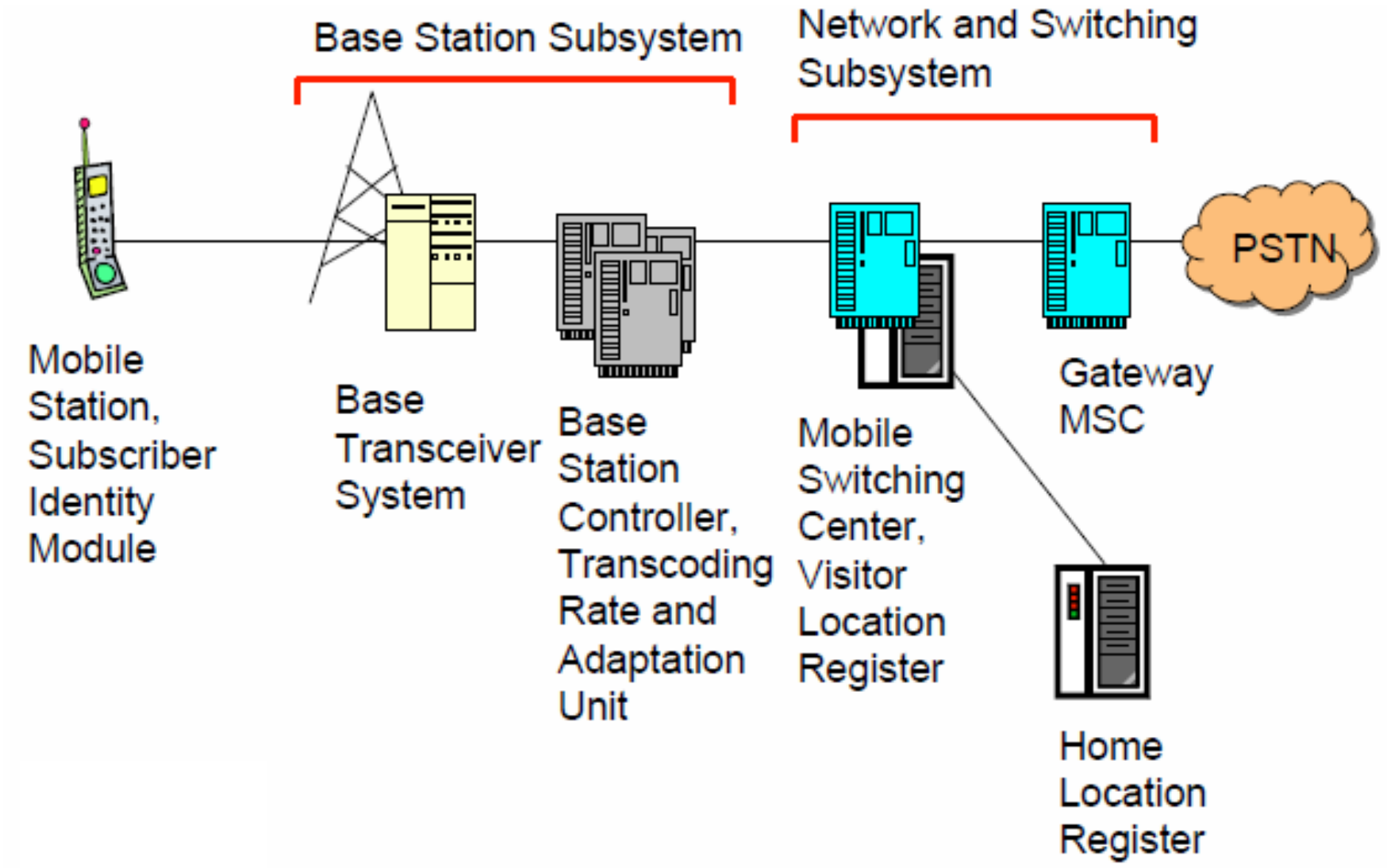
- 900/1800 MHz band (US: 850/1900 MHz)
- For 900 MHz band
  - Uplink: 890-915
  - Downlink: 935-960
- 25 MHz bandwidth - **124** carrier frequency channels, spaced 200KHz apart
- Time Division Multiplexing for **8** full rate speech channels per frequency channel 0,2 MHz.
- Handset transmission power limited to 2 W in GSM850/900 and 1 W in GSM1800/1900.

GSM Frequencies

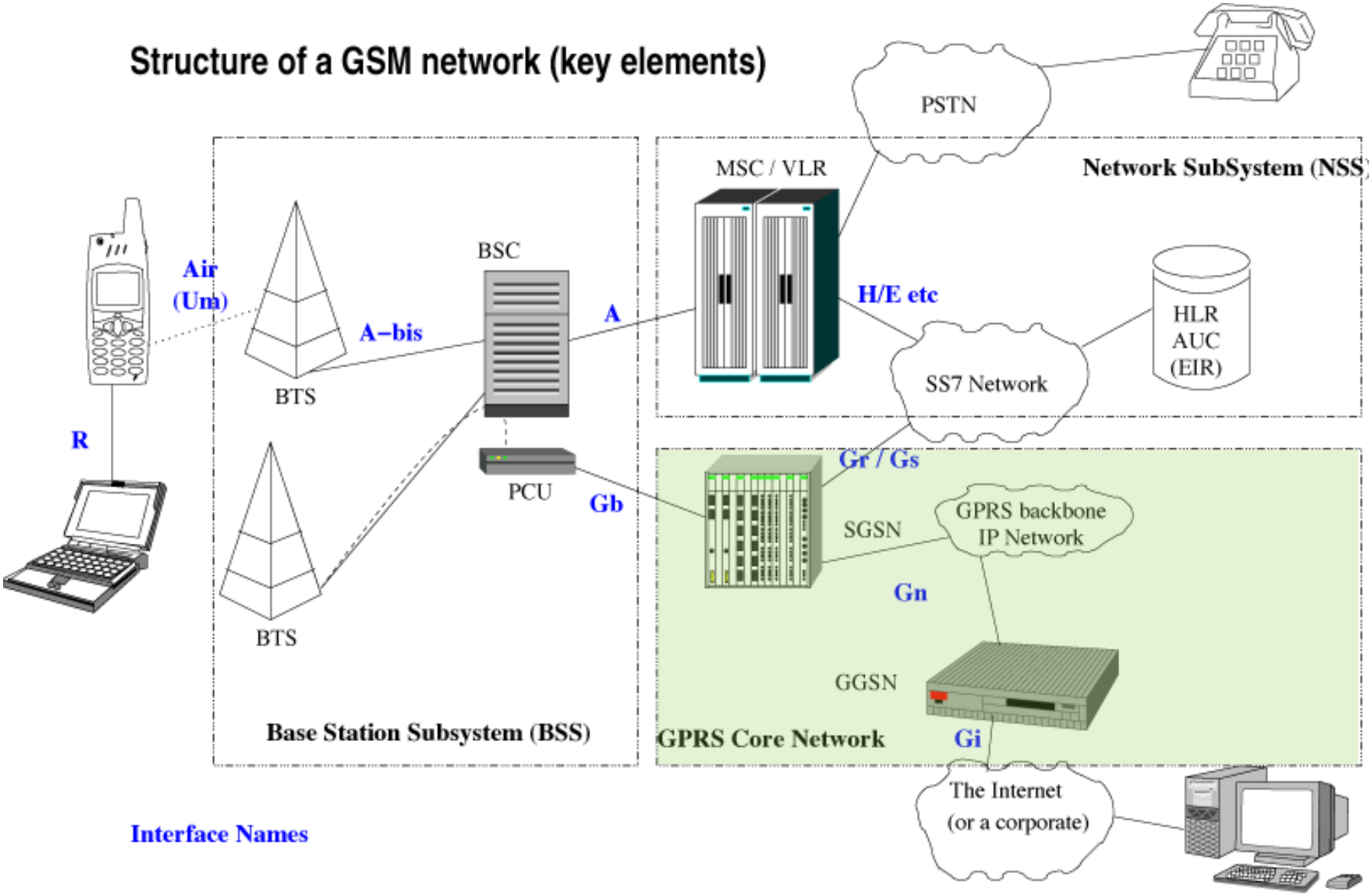
- Originally designed on 900MHz range, now also available on 800MHz, 1800MHz and 1900 MHz ranges.
- Separate Uplink and Downlink frequencies
  - One channel 0,2 MHz on the 1800 MHz frequency band



GSM Architecture



Structure of a GSM network (key elements)



Interface Names

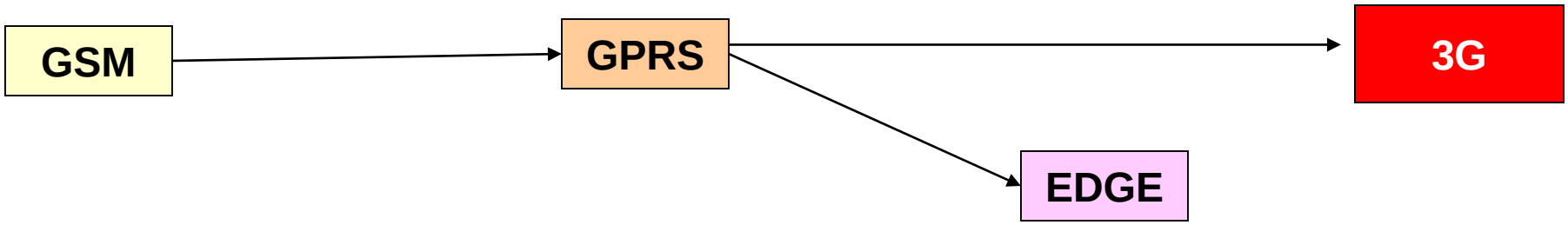
3G, 3.5G and 4G (LTE)

focused on the DATA transmission

GSM Evolution to 3G

GSM
9.6kbps (one **timeslot**)
GSM Data
Also called CSD

Enhanced Data Rates for Global Evolution
Uses 8PSK modulation
3x improvement in data rate on short distances
Can fall back to GMSK for greater distances
Combine with GPRS (EGPRS) ~ **384** kbps



General Packet Radio Services
Data rates up to ~ **115** kbps
Max: 8 **timeslots** used as any one time
Packet switched; resources not tied up all the time
Contention based. Efficient, but variable delays
GSM / GPRS core network re-used by WCDMA (3G)

3G - UMTS

- Universal Mobile Telecommunications System (UMTS)
- UMTS is an upgrade from GSM via GPRS or EDGE
- The standardization work for UMTS is carried out by Third Generation Partnership Project (3GPP)
- Data rates of UMTS are:
  - 144 kbps for rural
  - 384 kbps for urban outdoor
  - **2048** kbps for indoor and low range outdoor

3.5G (HSPA/HSPA+)

High Speed Packet Access (HSPA) is an amalgamation of two mobile telephony protocols, High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA), that extends and improves the performance of existing WCDMA protocols

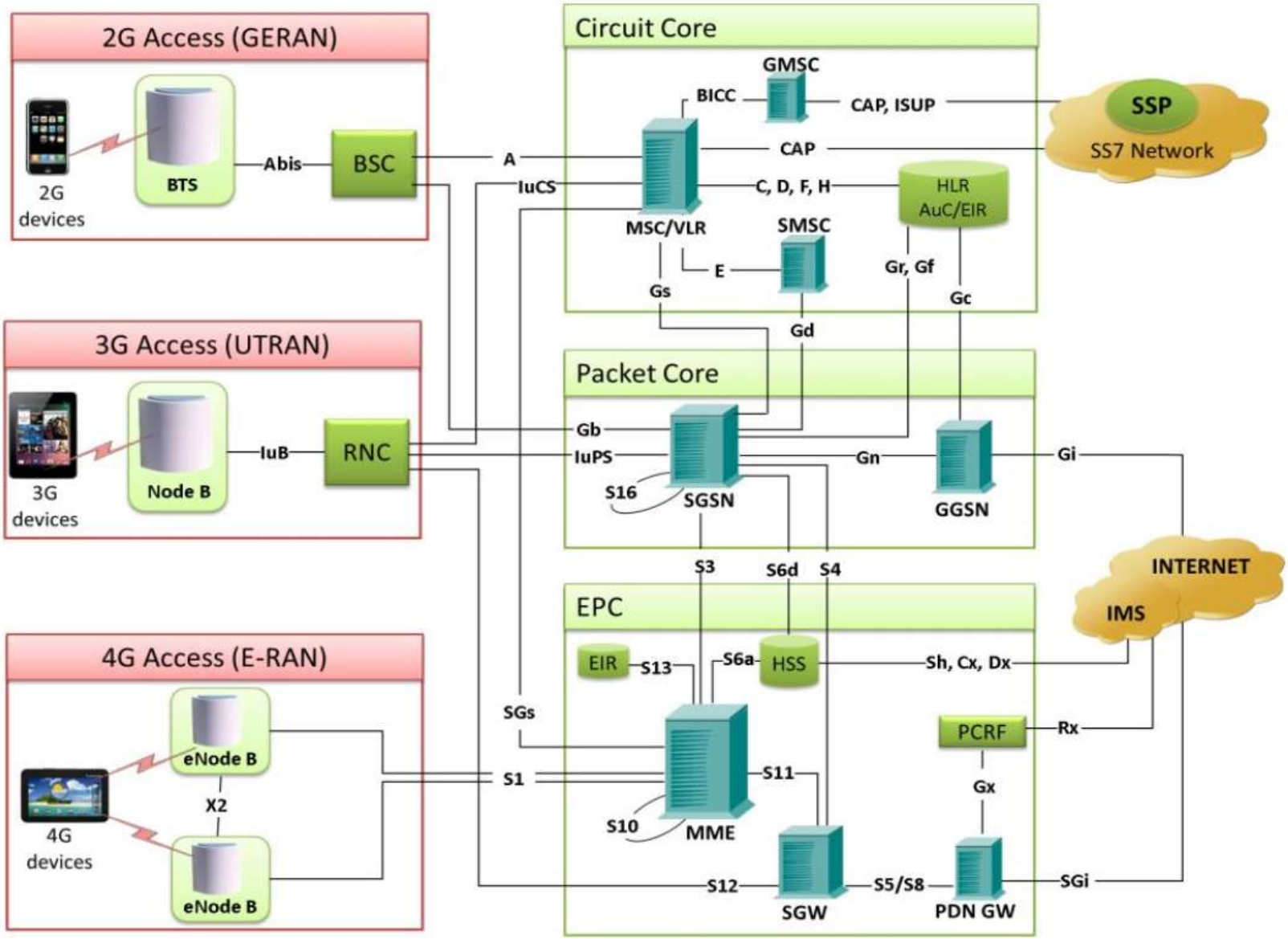
3.5G introduces many new features that will enhance the UMTS technology in future. These include:

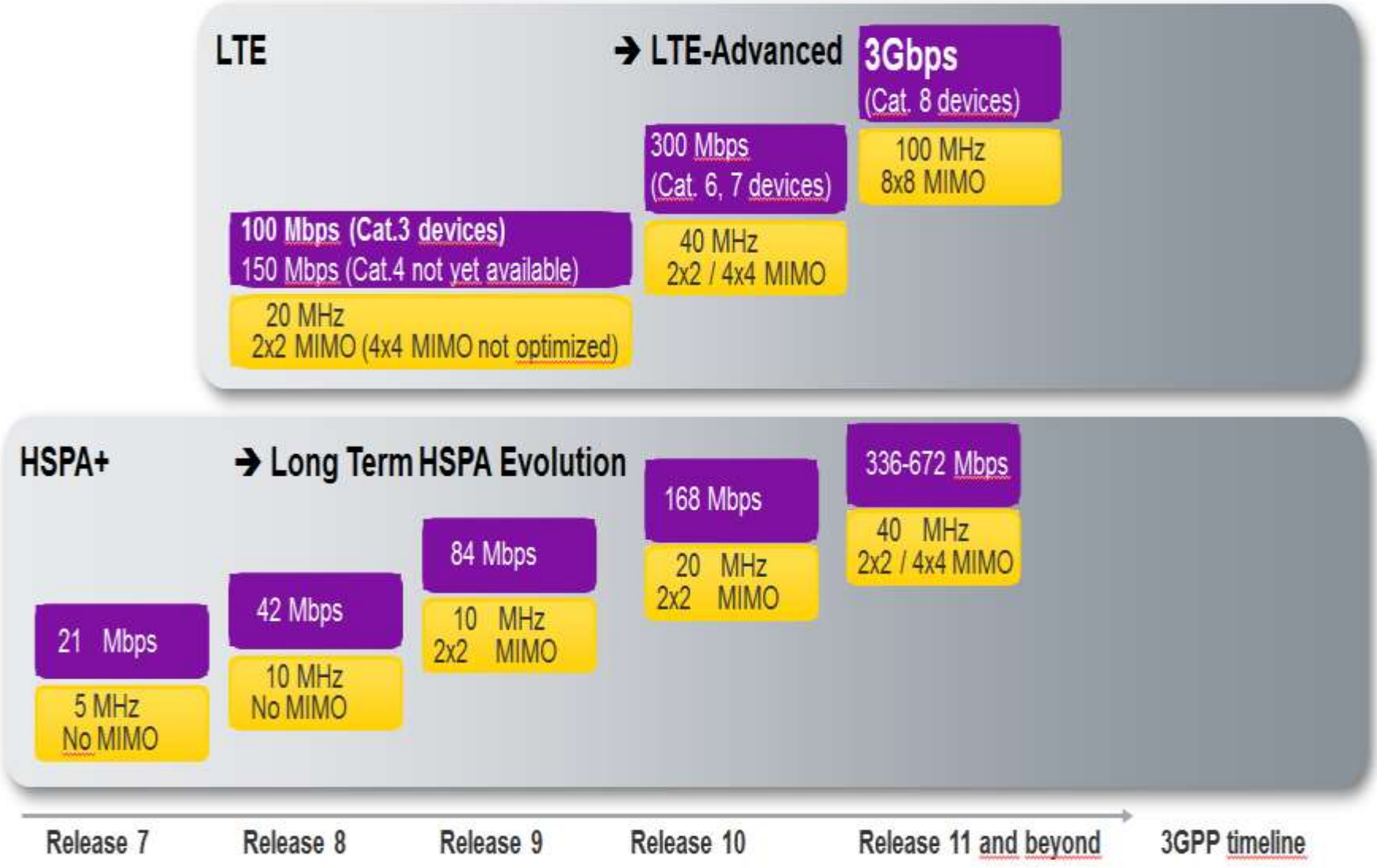
- Adaptive Modulation and Coding
- Fast Scheduling
- Backward compatibility with 3G
- Enhanced Air Interface

4G (LTE)

- stands for Long Term Evolution
- Optimized for All-IP traffic

for Network Operators	*for* End Users
High network throughput Low latency Plug & Play architecture Low Operating Costs All-IP network Simplified upgrade path from 3G networks	Faster data downloads/uploads Improved response for applications Improved end-user experience


2G Access (GERAN)
2G devices
BTS
Abis
BSC
A
IuCS
Circuit Core
GMSC
BICC
CAP, ISUP
SSP
SS7 Network
CAP
MSC/VLR
C, D, F, H
HLR AuC/EIR
SMSC
E
Gs
Gr, Gf
Gc
Gd
3G Access (UTRAN)
3G devices
Node B
IuB
RNC
Packet Core
Gb
IuPS
S16
SGSN
Gn
GGSN
Gi
S3
S6d
S4
INTERNET
IMS
EPC
EIR
S13
S6a
HSS
Sh, Cx, Dx
4G Access (E-RAN)
SGs
eNode B
X2
4G devices
eNode B
S1
S10
MME
S11
PCRF
Rx
Gx
S12
SGW
S5/S8
PDN GW
SGi


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

LTE UE Categories

	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	64QAM	64QAM	64QAM	64QAM	64QAM
Modulation UL	16QAM	16QAM	16QAM	16QAM	64QAM
Rx diversity	Yes	Yes	Yes	Yes	Yes
MIMO DL	Optional	2x2	2x2	2x2	4x4

LTE Throughput in Test Network

Base station located at **X**.

L1 Throughput
Max: 154 Mbps
Mean: 78 Mbps
Min: 16 Mbps

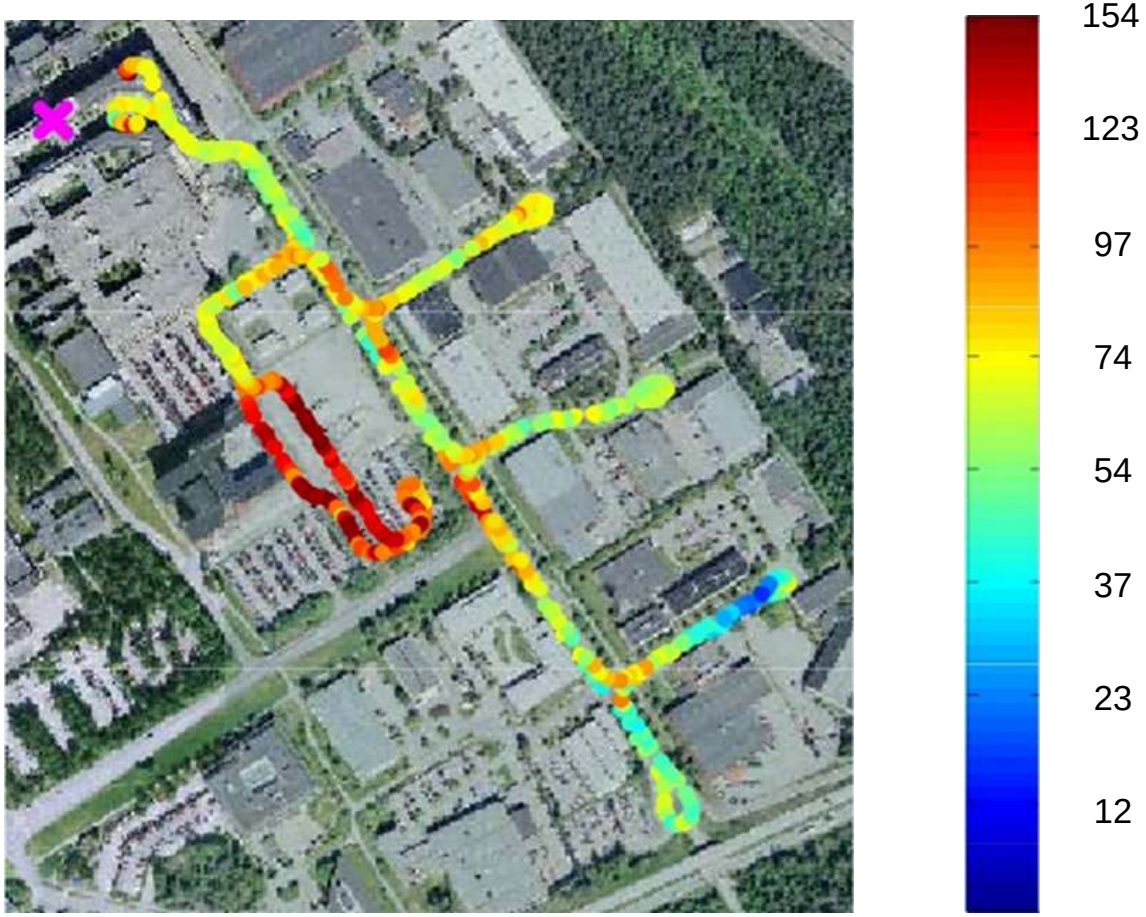
User Speed
Max: 45 km/h
Mean: 16 km/h
Min: 0 km/h

Sub-urban area with line-of-sight: less than 40% of the samples

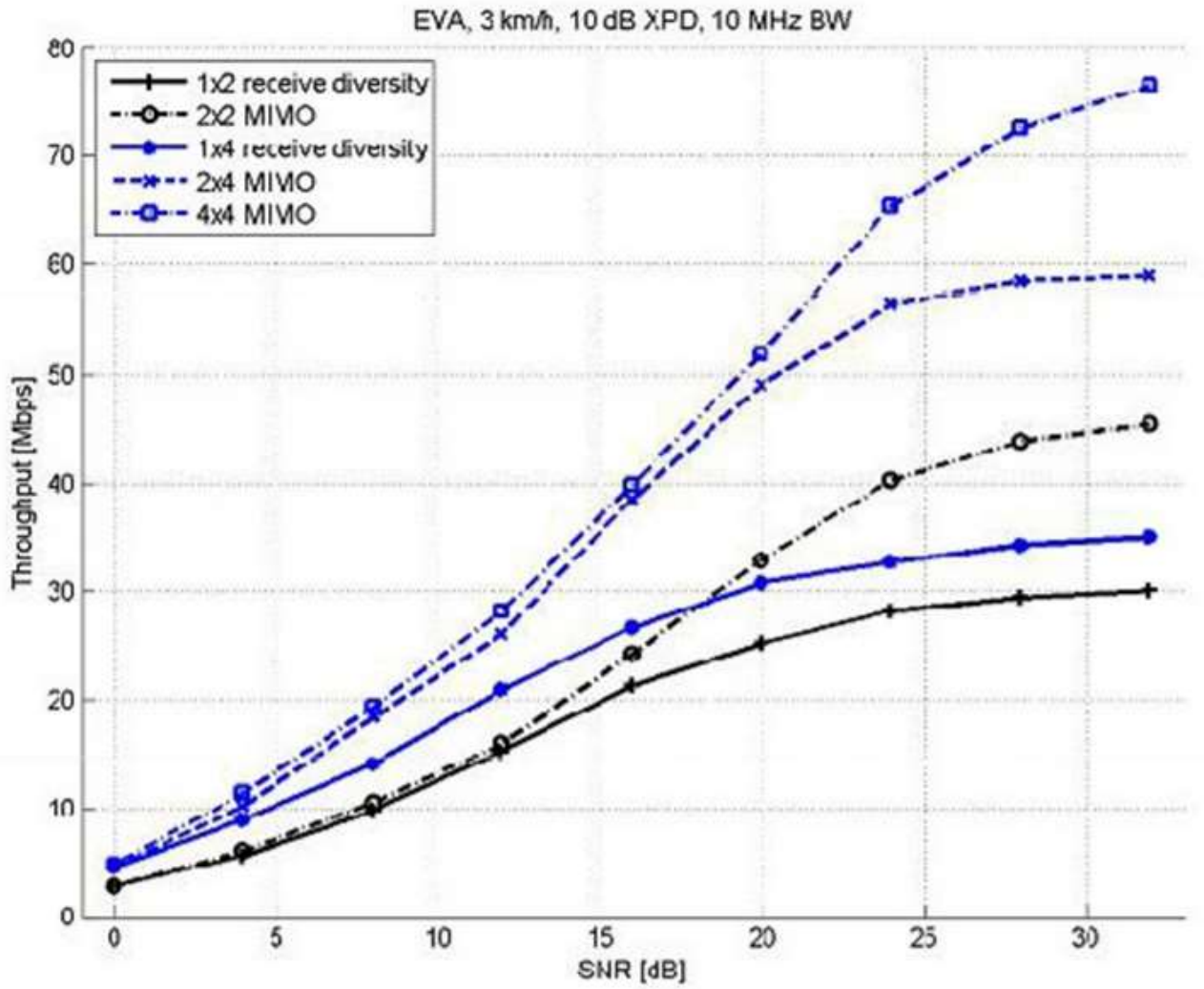
Heights of surrounding buildings: 15-25 m

20 MHz Channel

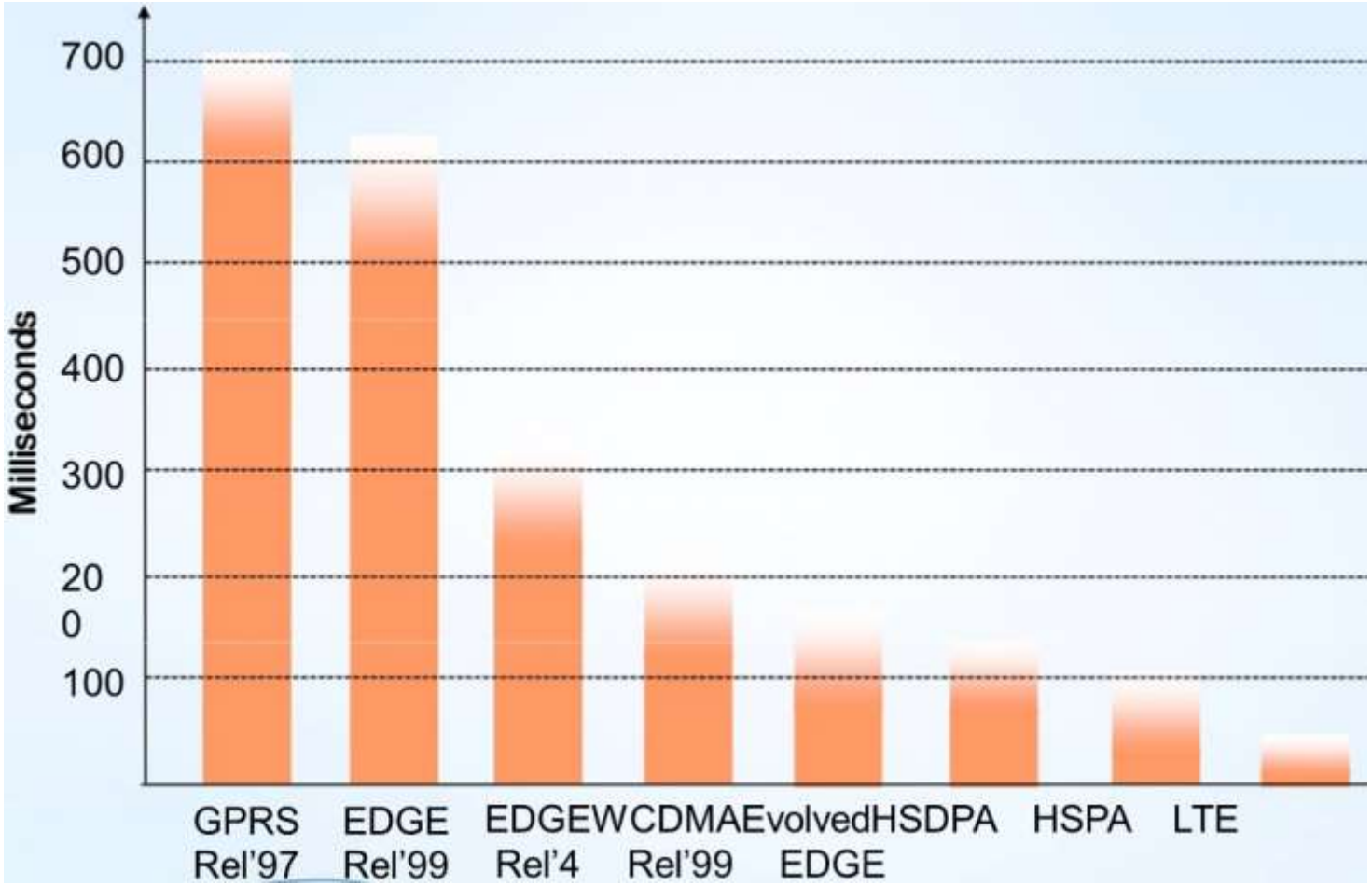
2X2 MIMO



LTE Throughput in various Modes

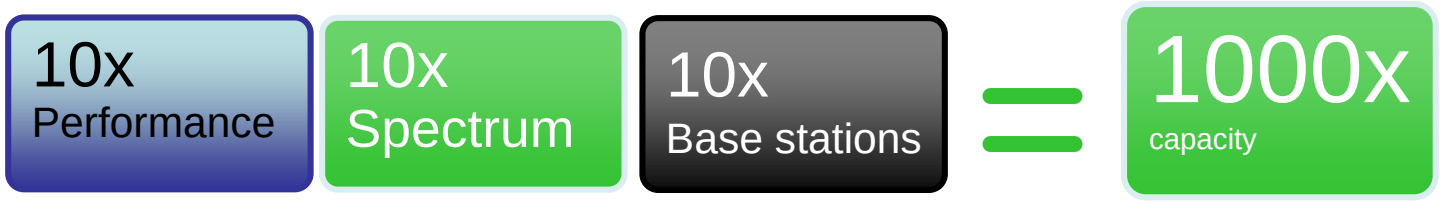


Latency of Different Technologies



Year 2020: Mobile Broadband Beyond 4G

1000 times more mobile traffic



Core and access joint QoS

Radio brings congestion indication to packet core for traffic management via policy control

Mobile Broadband Access

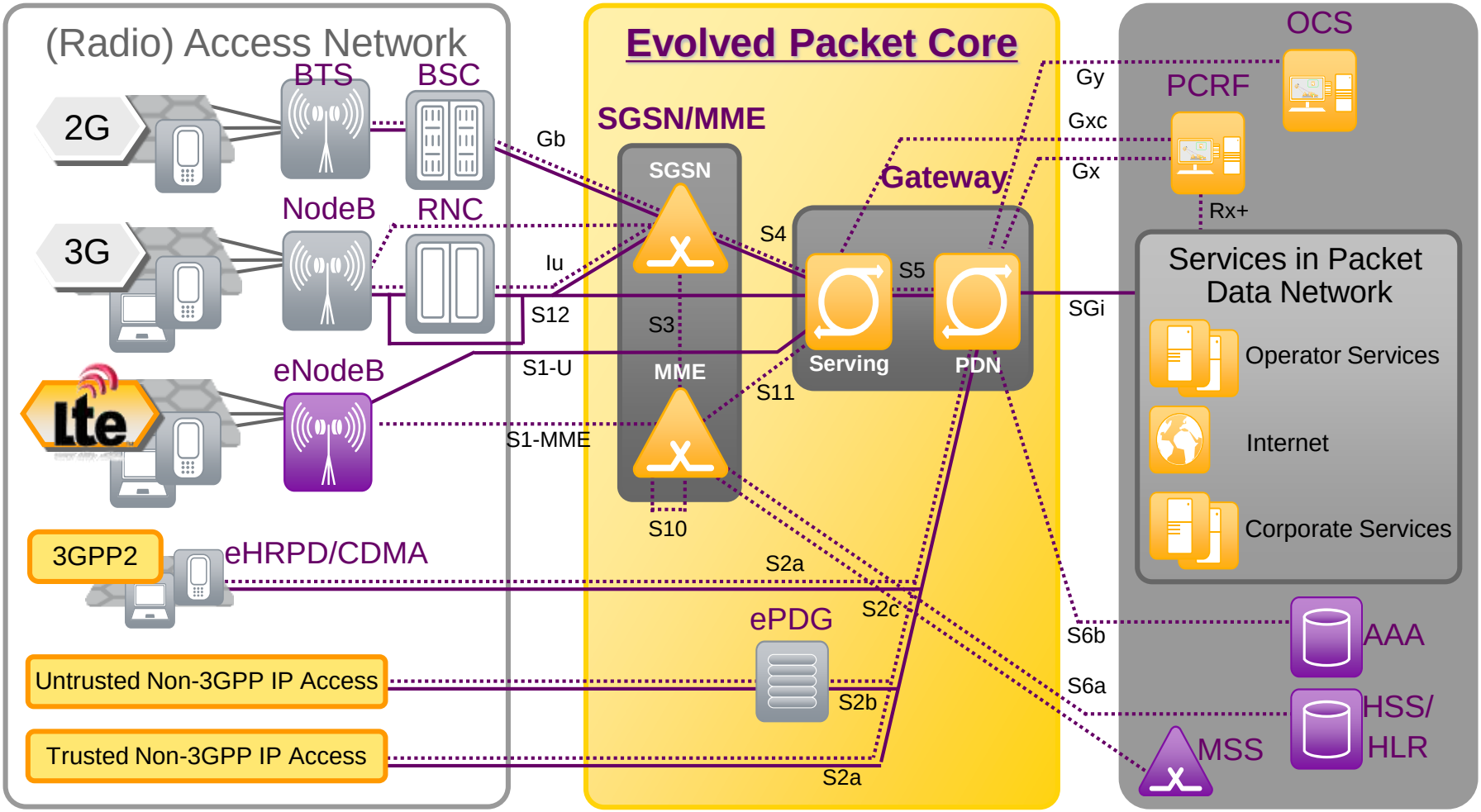
SPR
PCRF
Reporting
Charging
FlexiNS
(MME and/or SGSN)
2G
3G
LTE
Application Aware Radio
FlexiNG
(SGW, PGW and/or GGSN)

Services Anywhere

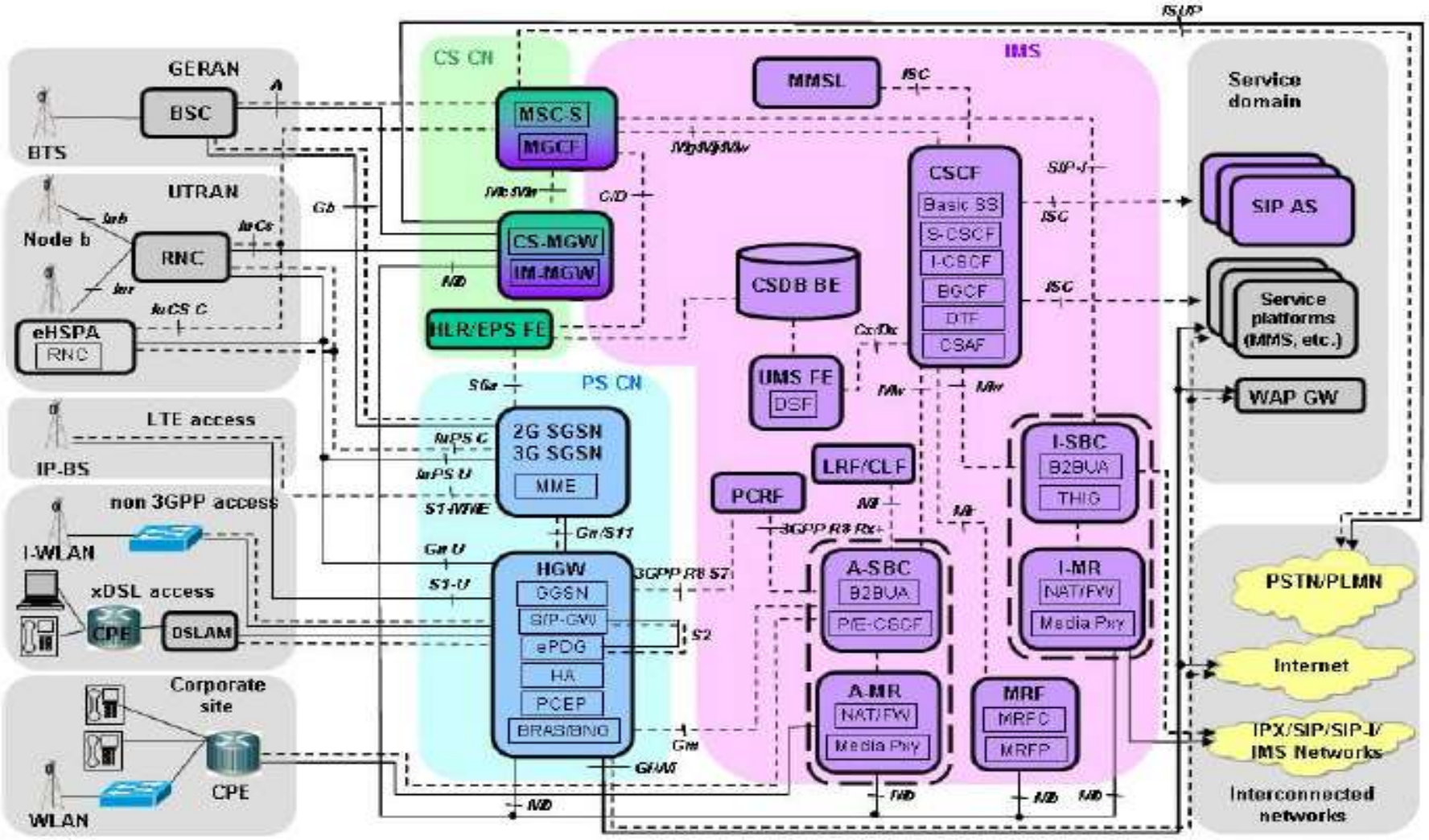
Packet core empowers radio with service and subscriber awareness for differentiation and efficient resource utilization

Resource consuming Smart phone (signaling) impacts can be mitigated by radio
- based on Packet core intelligence

Core and access joint QoS



Mobile broadband can be seen like this …

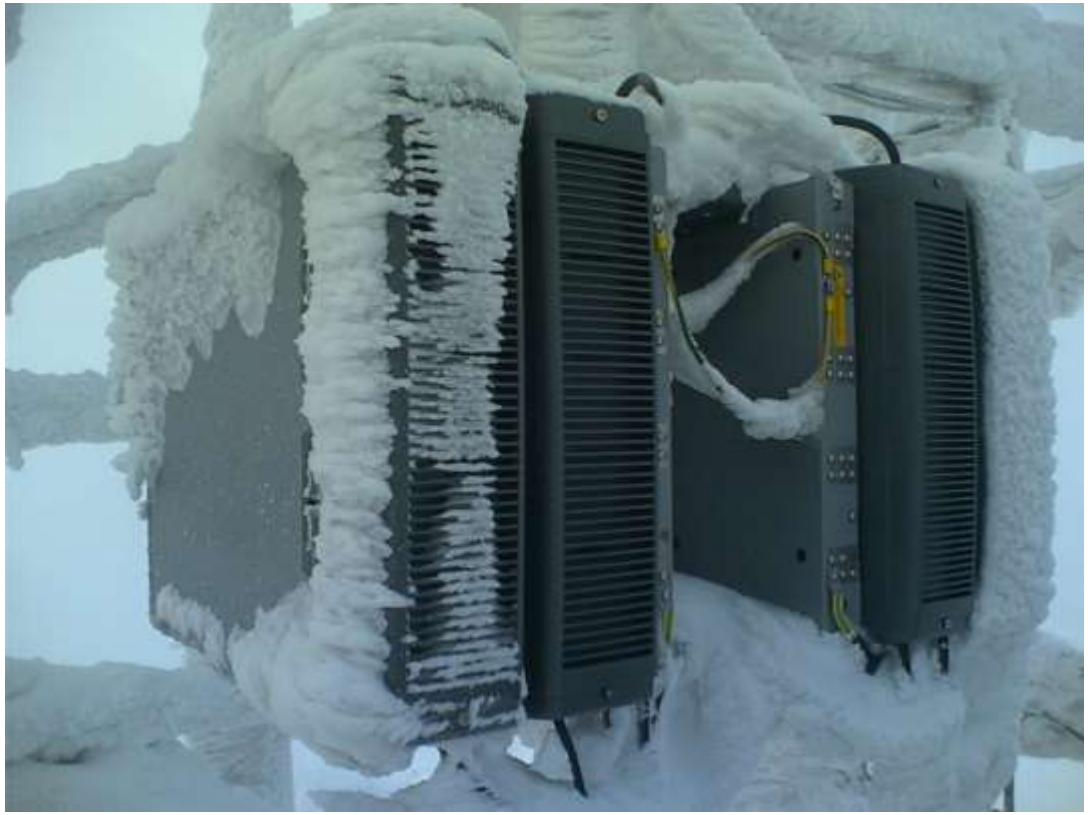


… or like this

LTE site solution

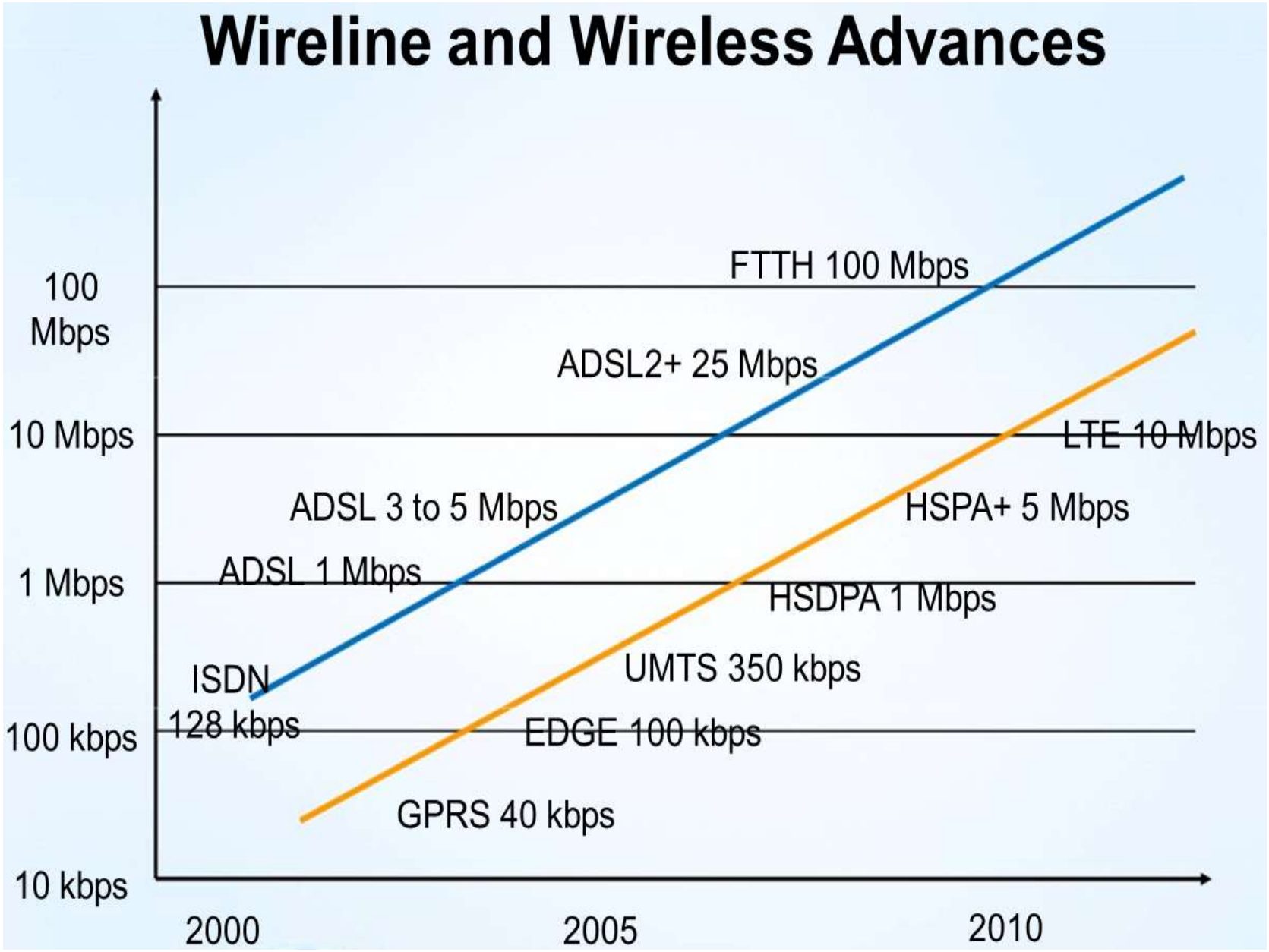
3-sector Outdoor site with Nokia Flexi BTS

... and also



Broadband approaches

	Strength	Weakness
Mobile broadband (EDGE, HSPA, LTE)	Constant connectivity Broadband capability across extremely wide areas Good access solution for areas lacking wireline infrastructure Capacity enhancement options via FMC **Excellent voice** communications	**Lower capacity** than wireline approaches Inability to serve high-bandwidth applications such as IP TV
Wireline broadband (DSL, DOCSIS, FTTH …)	**High capacity** broadband at very high data rates Evolution to extremely high throughput rates	**Expensive** to deploy new networks, especially in developing economies lacking infrastructure


Wireline and Wireless Advances
100 Mbps
10 Mbps
1 Mbps
100 kbps
10 kbps
2000
2005
2010
FTTH 100 Mbps
ADSL2+ 25 Mbps
LTE 10 Mbps
ADSL 3 to 5 Mbps
HSPA+ 5 Mbps
ADSL 1 Mbps
HSDPA 1 Mbps
ISDN
128 kbps
UMTS 350 kbps
EDGE 100 kbps
GPRS 40 kbps

Frekvenčné spektrum

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

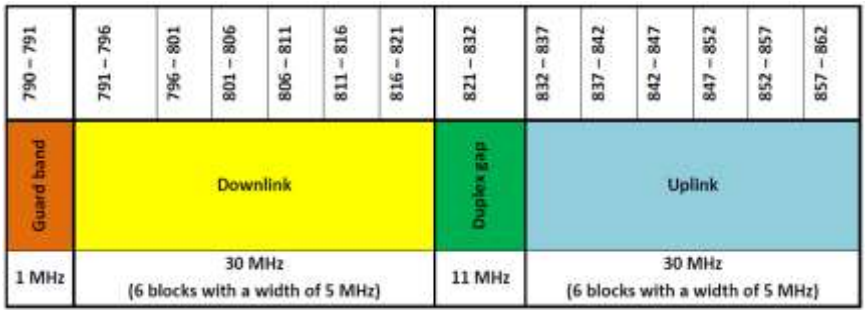
LTE pásma v SR

Pásmo	Označenie pásma	O2	Orange	Telekom	Swan
800 MHz	20	Áno	Áno	Áno	Nemá
1 800 MHz	3	Áno	Áno	Áno	Áno
2 600 MHz	7	Nemá	Áno	Áno	Nemá
2 600 MHz (TDD)	38	Nemá	Nemá	Áno	Nemá

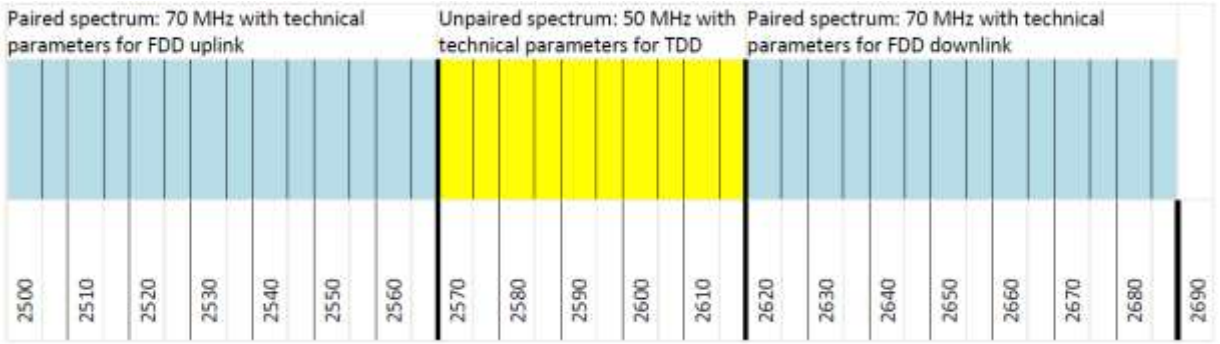
Frekvencie v SR

Tradičné

Operator	GSM 900	GSM 1800	UMTS – FDD	UMTS – TDD	**Total**
Orange Slovensko plc	10.2 MHz X 2	15.2 MHz X 2	20 MHz X 2	5 MHz	95.8 MHz
Slovak Telekom plc	10.2 MHz X 2	15.2 MHz X 2	20 MHz X 2	5 MHz	95.8 MHz
Telefonica Slovakia Ltd	10.2 MHz X 2	15.2 MHz X 2	20 MHz X 2	5 MHz	95.8 MHz
Total	**61.2 MHz**	**91.2 MHz**	**120 MHz**	**15 MHz**	**287.5 MHz**

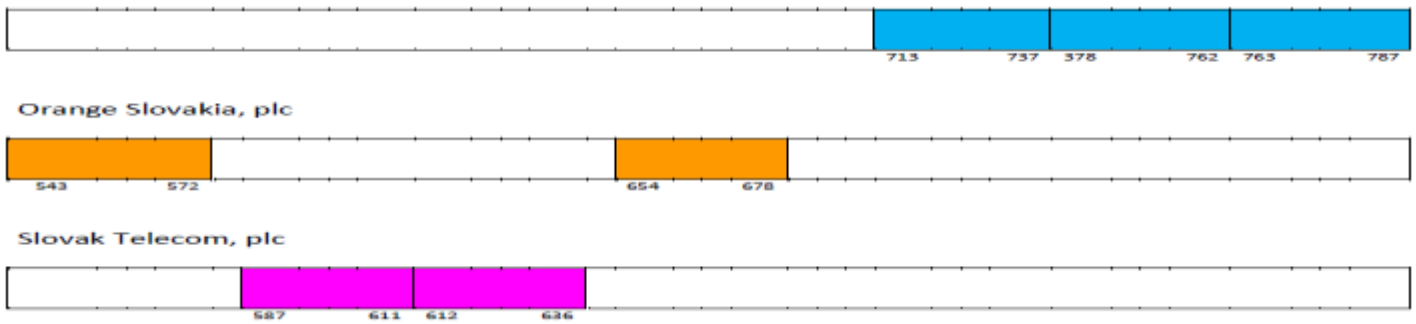


Nové ´2014



Frekvencie v SR

1800 MHz pred aukciou ´2014:



Aukcia ´2014:

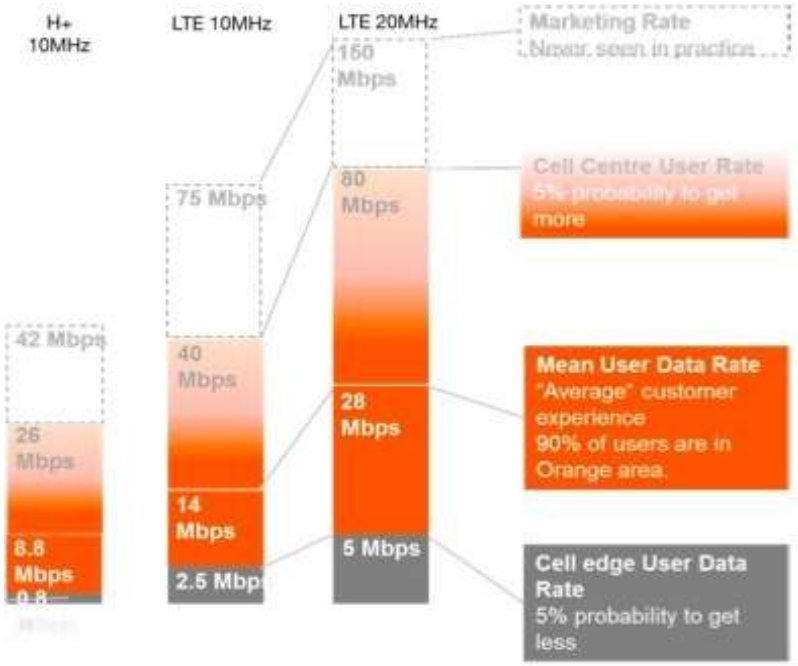
Orange **dva 10 MHz** bloky v pásme 800 MHz, **dva 4,8 MHz** bloky v pásme 1 800 MHz a **dva 30 MHz** bloky v pásme 2 600 MHz

Slovak Telekom **dva 10 MHz** bloky v pásme 800 MHz, **dva 40 MHz** bloky v pásme 2600 MHz FDD a **50 MHz** v pásme 2 600 MHz TDD

O2 **dva 10 MHz** bloky v pásme 800 MHz, **dva 0,6 MHz** bloky v pásme 1 800 MHz

Štvorka (Swan) **dva 15 MHz** bloky v pásme 1 800 MHz

1800 MHz LTE Allocation – for diverse LTE bandwidth options

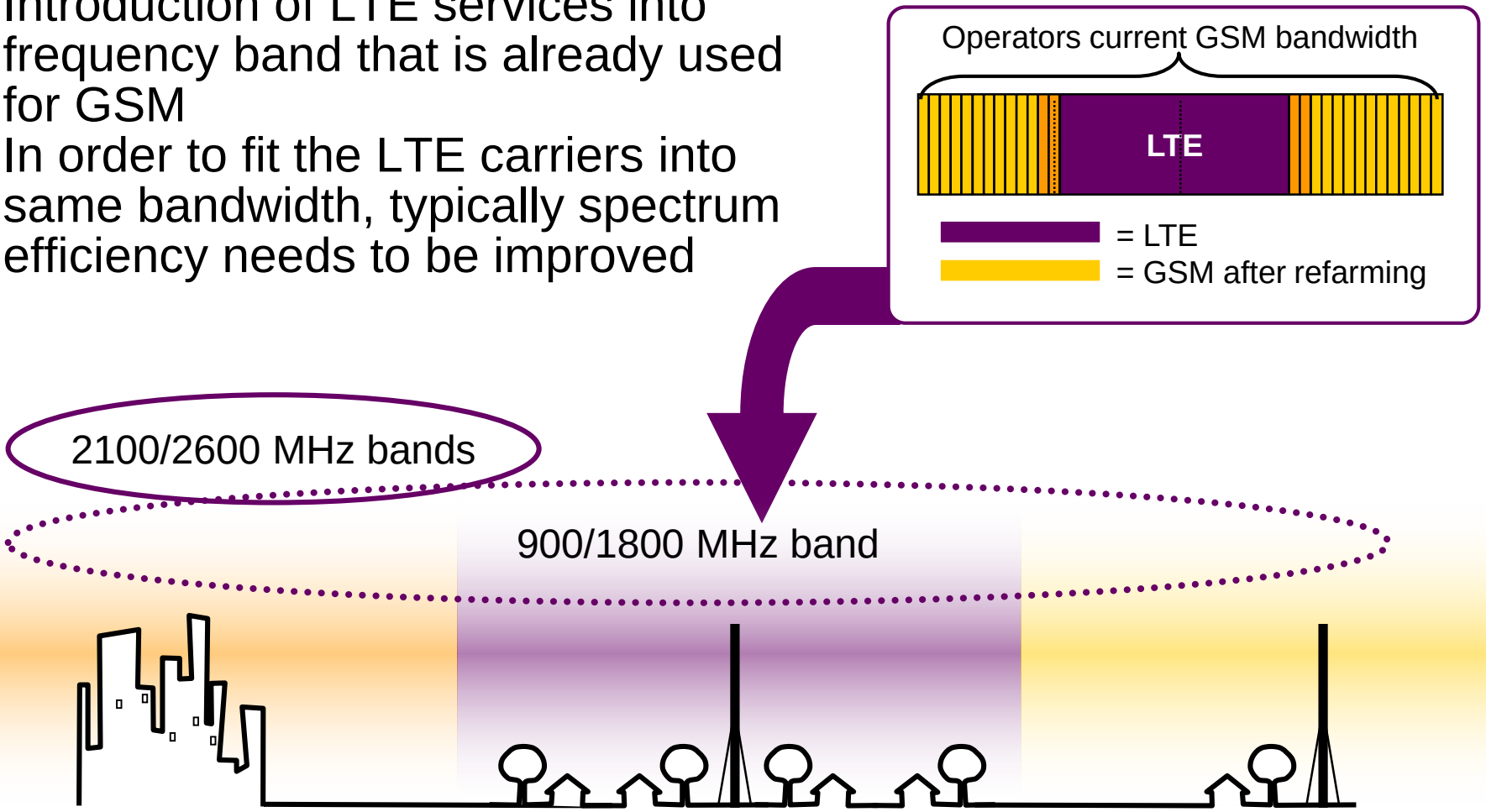


Šírka pásma (MHz)	Maximálne teoretické rýchlosti sťahovania (MIMO 2x2) v Mbit/s	Maximálne teoretické rýchlosti sťahovania (MIMO 4x4) v Mbit/s
20	150	300
15	110	220
10	73	147
5	36	73

	Spectrum required for LTE deployment		Achievable peak data rates on LTE bandwidth
	Coordinated case		
	Uplink	Downlink	
20 MHz LTE (100 RBs)	18.2 MHz	18.4 MHz	150 / 47 Mbps
15 MHz LTE (75 RBs)	13.6 MHz	13.8 MHz	110 / 35 Mbps
10 MHz LTE (50 RBs)	9.2 MHz	9.4 MHz	74 / 23 Mbps
5 MHz LTE (25 RBs)	4.6 MHz	4.8 MHz	37 / 11 Mbps
3 MHz LTE (15 RBs)	2.8 MHz	3.0 MHz	22 / 7 Mbps
1.4 MHz LTE (6 RBs)	1.2 MHz	1.2 MHz	9 / 3 Mbps

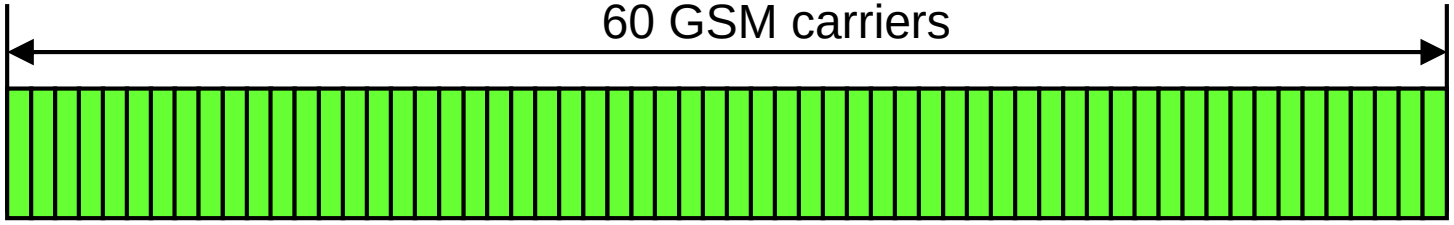
LTE refarming to 900/1800 MHz frequency bands

- Introduction of LTE services into frequency band that is already used for GSM
- In order to fit the LTE carriers into same bandwidth, typically spectrum efficiency needs to be improved

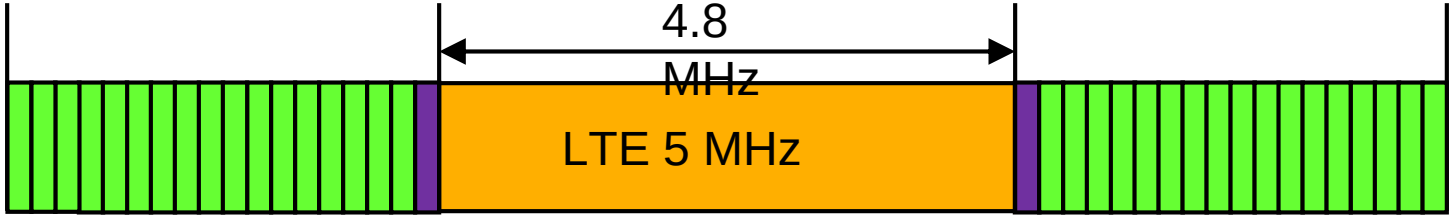


1800 MHz LTE - Refarming Evolution example

GSM only with 60 carriers

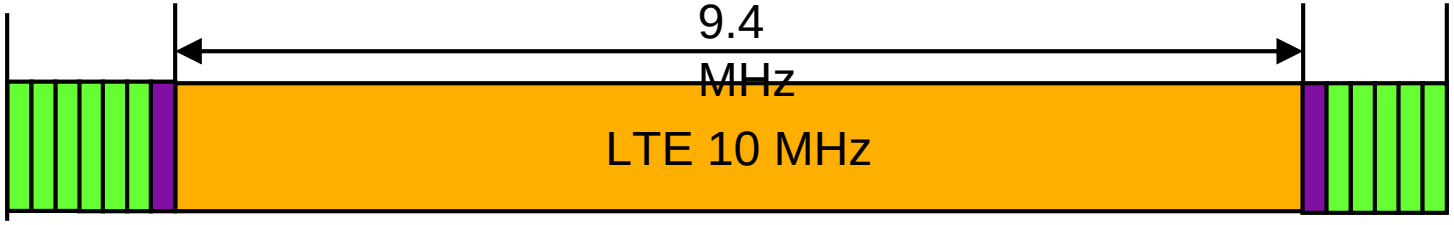


LTE5.0 MHz + 36 GSM carriers



37 Mbps

LTE 10MHz + 13 GSM carriers



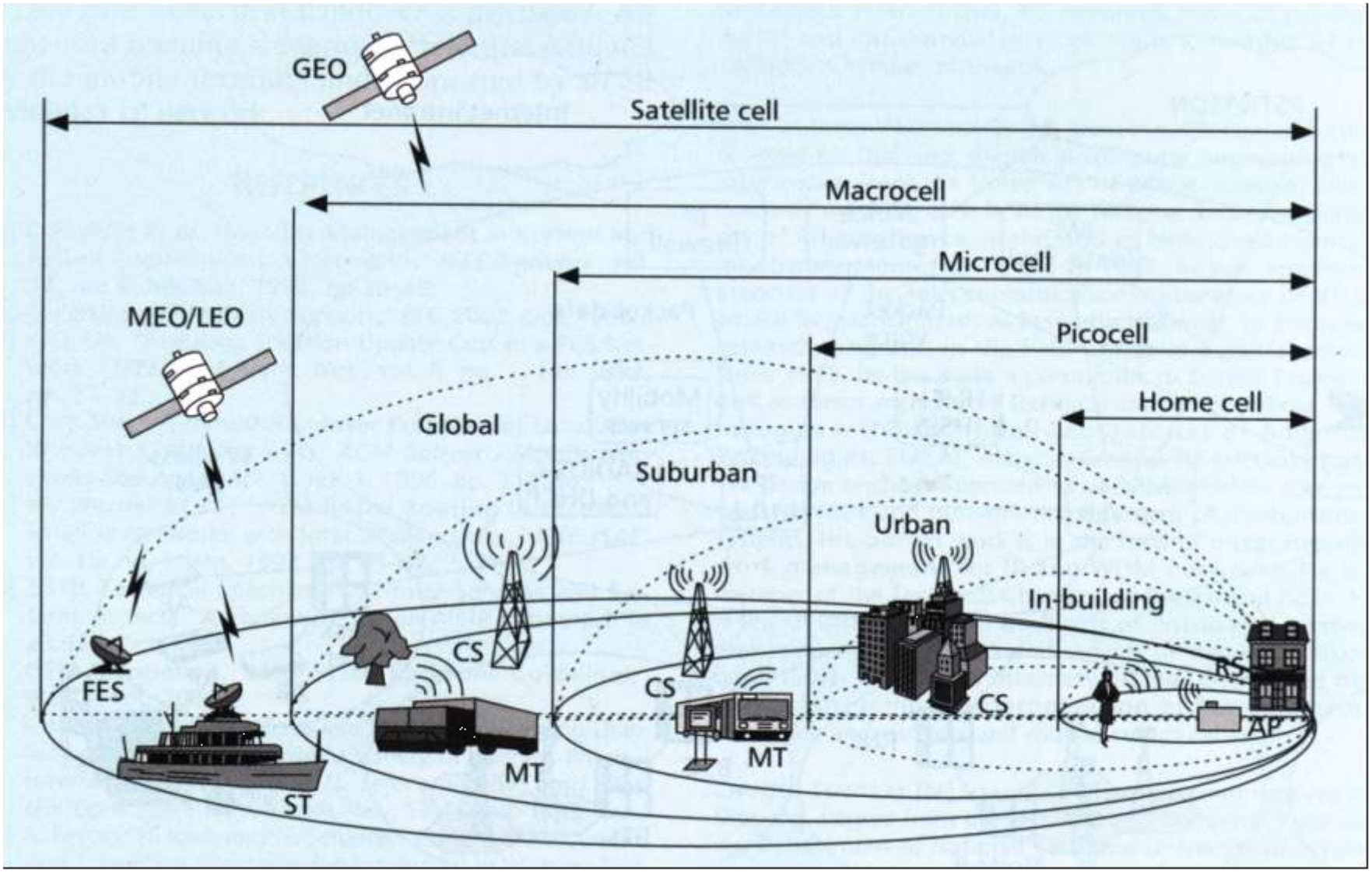
74 Mbps

Dimenzovanie a návrh mobilnej siete

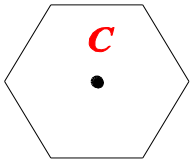
Základné údaje pri návrhu:

- Pokrytie územia
- Počet užívateľov v jednej bunke (kapacita a rýchlosť)
- Business case

Cellular Geometries



Frequency Reuse



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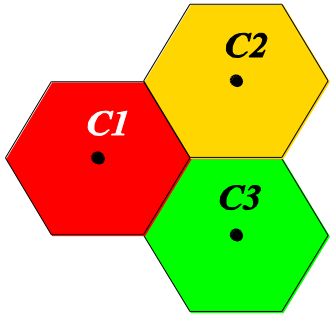

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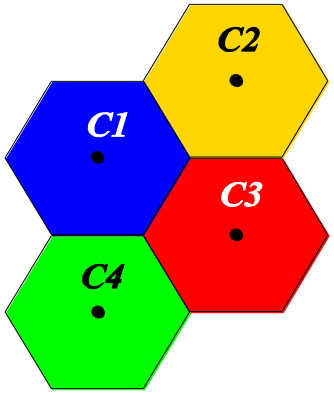

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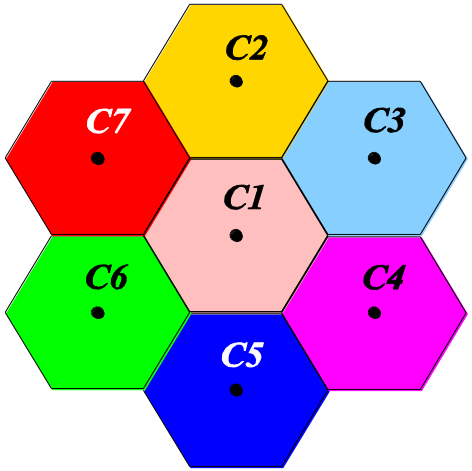
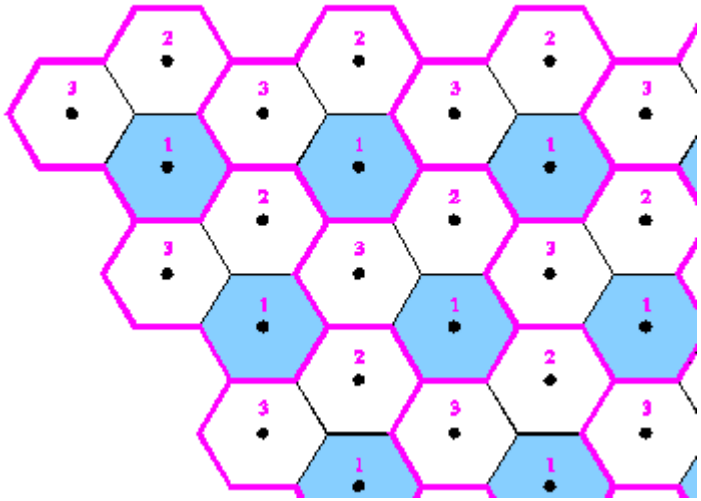
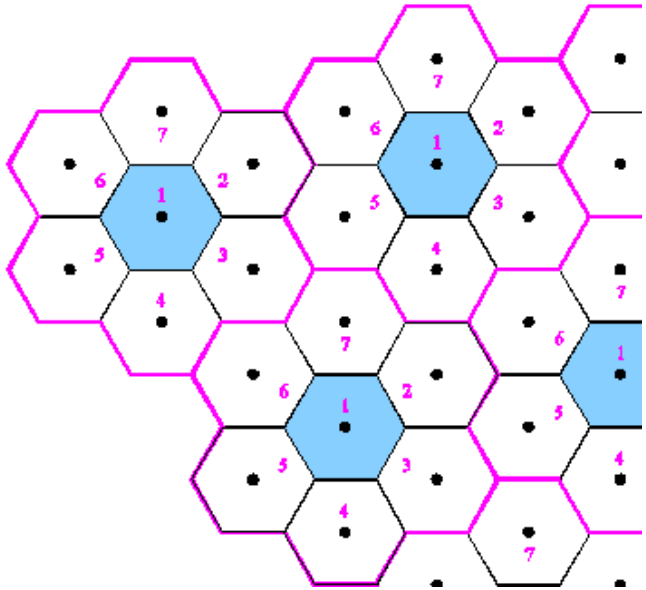


N = 7

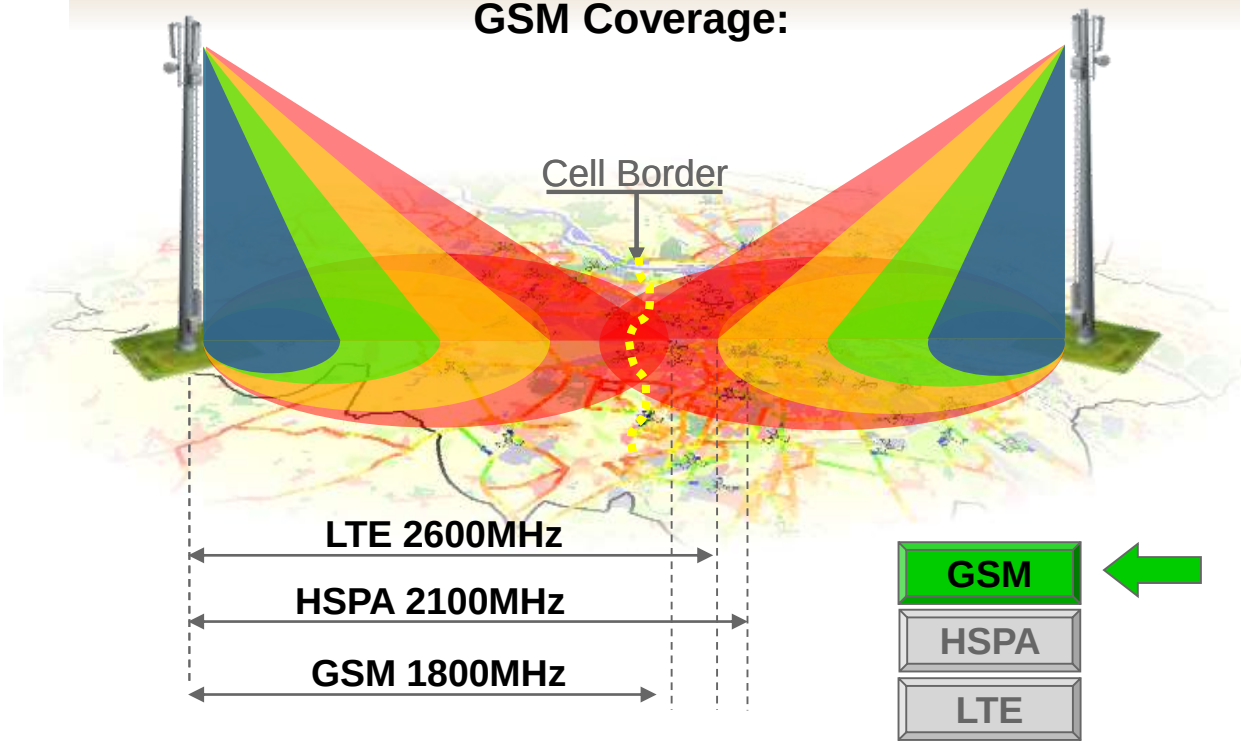




LTE introduction – reusing existing network grid
LTE 2600, UMTS 2100 on GSM 1800MHz grid (urban sites)

Exemplary cell ranges comparison for Urban Environment

GSM Coverage:



General Assumptions:
Urban Environment,
indoor coverage (15 dB)
WCDMA 5, LTE 10MHz bandwidth
Dedicated antennas for 2100, 2600

Cell range Link budget (MAPL)	**UL**	**DL**
GSM1800 - km	**0.97**	**1.34**
dB	**135.8**	**140.7**
WCDMA - km	1.17	1.22
dB	140.2	140.8
LTE2600 - km	1.08	1.09
dB	142.8	142.9

GSM – voice*
More advanced radio technology:
- higher allowable path loss
- minimal difference in cell range

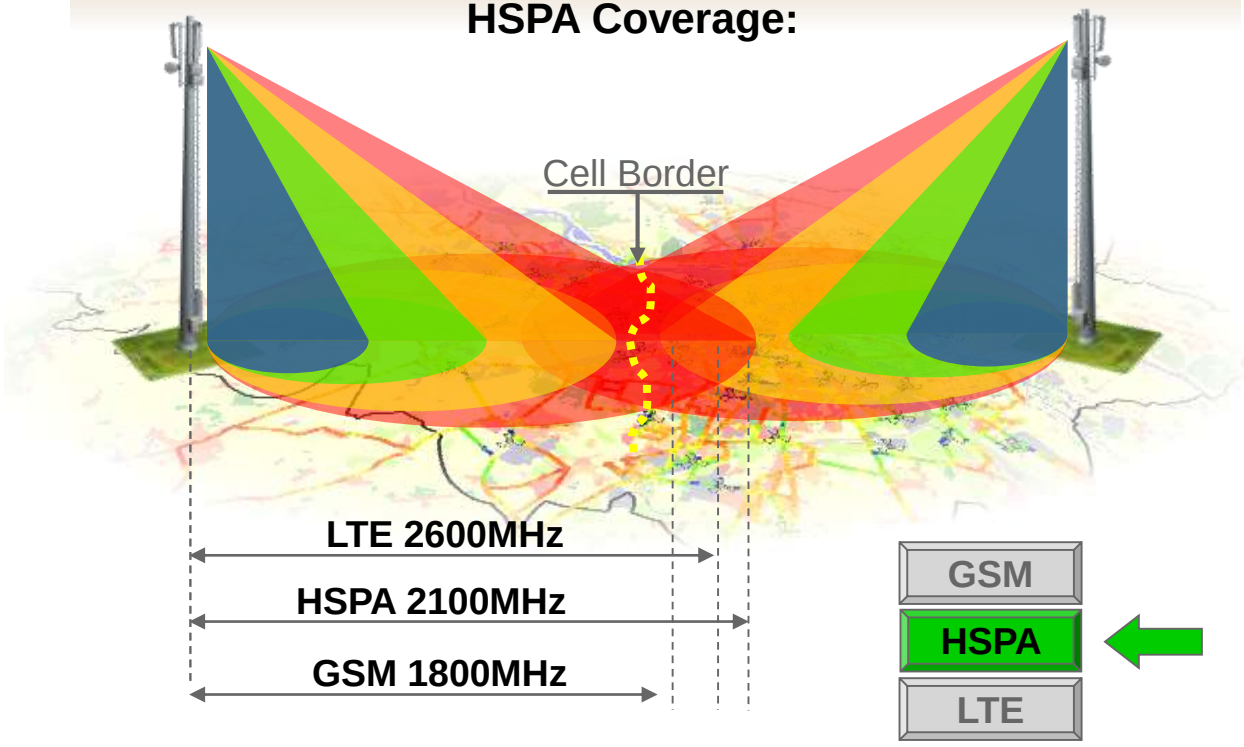
LTE-2600, UMTS-2100 and GSM-1800 can be deployed on same grid

* 3 dB body loss

LTE introduction – reusing existing network grid
LTE 2600, UMTS 2100 on GSM 1800MHz grid (urban sites)

Exemplary cell ranges comparison for Urban Environment

HSPA Coverage:



General Assumptions:
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WCDMA 5, LTE 10MHz bandwidth
Dedicated antennas for 2100, 2600

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dB	**140.2**	**140.8**
LTE2600 - km	1.08	1.09
dB	142.8	142.9

WCDMA – CS64, HSPA- 64/384 kbps*
More advanced radio technology:
- higher allowable path loss
- minimal difference in cell range

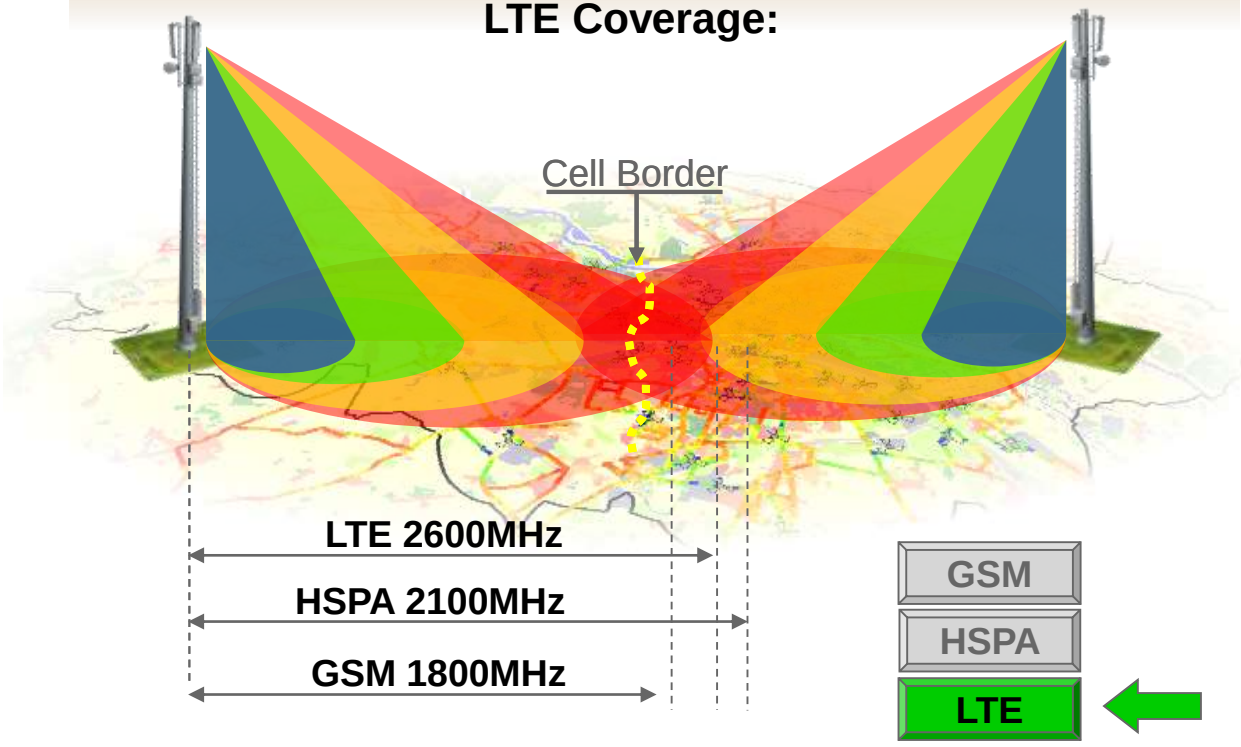
LTE-2600, UMTS-2100 and GSM-1800 can be deployed on same grid

* HSPA 64/512kbps for HSPA-only operation

LTE introduction – reusing existing network grid
LTE 2600, UMTS 2100 on GSM 1800MHz grid (urban sites)

Exemplary cell ranges comparison for Urban Environment

LTE Coverage:



General Assumptions:
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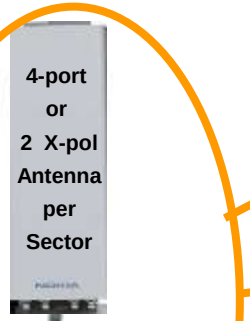
dB	140.2	140.8
LTE2600 - km	**1.08**	**1.09**
dB	**142.8**	**142.9**

LTE – 64/1024 kbps
More advanced radio technology:
- higher allowable path loss
- minimal difference in cell range

LTE-2600, UMTS-2100 and GSM-1800 can be deployed on same grid

GSM/LTE – site solution

- one RF Module per sector
- 60 + 60 W per cell with 2TX MIMO
- Sectorization by High Gain Antennas (e.g. 6 sector / 30 deg)



Flexi RF Module
60 + 60 W

Sector 5

Sector 4

Sector 3

Sector 2

Sector with extended coverage (~3…6 dB)

Coverage maps

http://www.which.co.uk/technology/phones/reviews-ns/best-mobile-phone-networks/mobile-phone-coverage-map/

http://opencellid.org/#action=filters.GPSPositions&mcc=231&mnc=01

Each Base station is identified by

MCC — a Mobile Country Code. This code identifies the country (Slovensko 231)

MNC - a Mobile Network Code. This code identifies the mobile operator (01 Orange, 02+04 Telekom, 06 O2, 03 SWAN)

LAC - Location Area Code is a unique number of current location area. A location area is a set of base stations that are grouped together to optimize signalling.

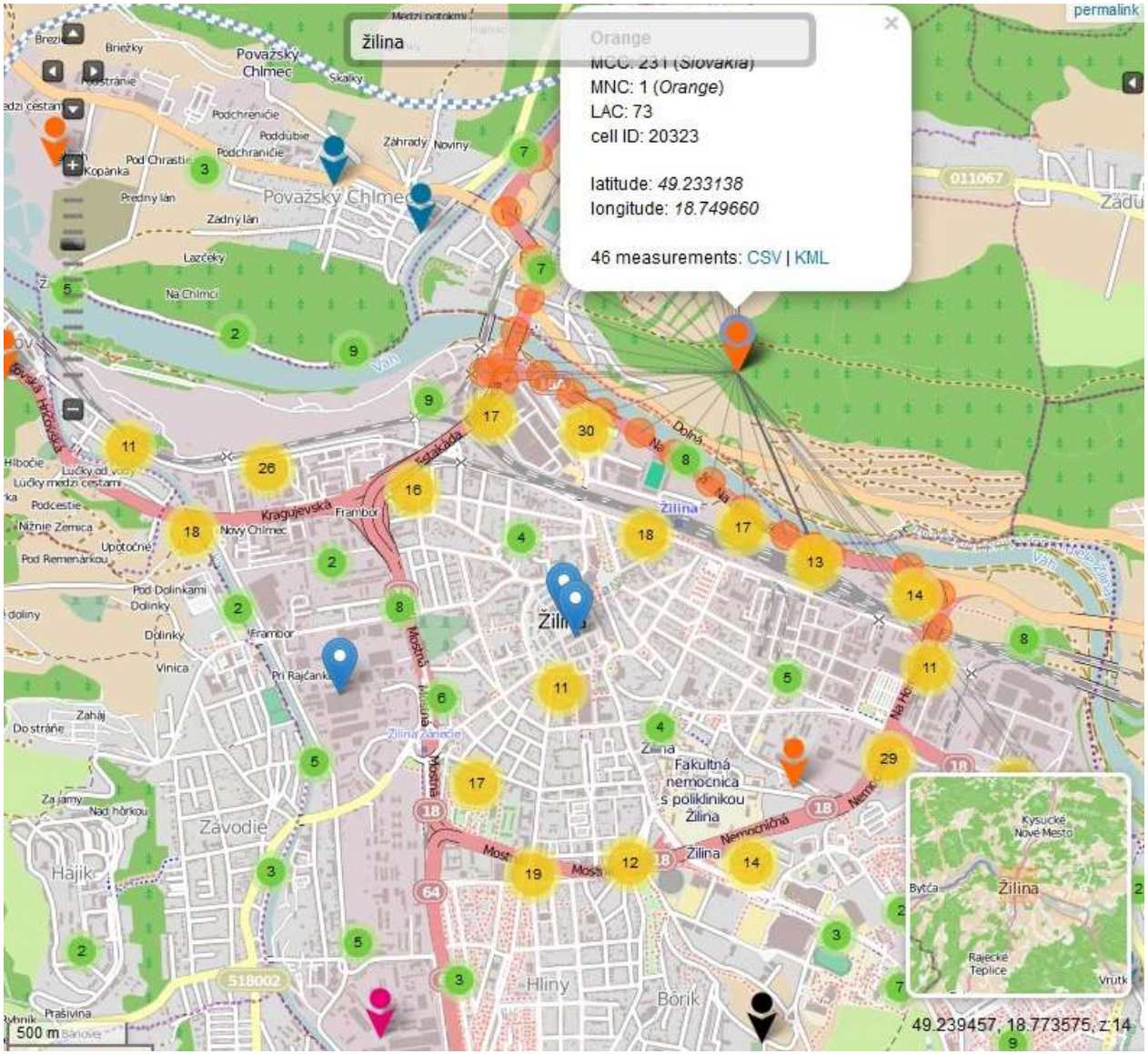
CellID (CID) — is a generally unique number used to identify each Base transceiver station (BTS) or sector of a BTS within a Location area code.

2G

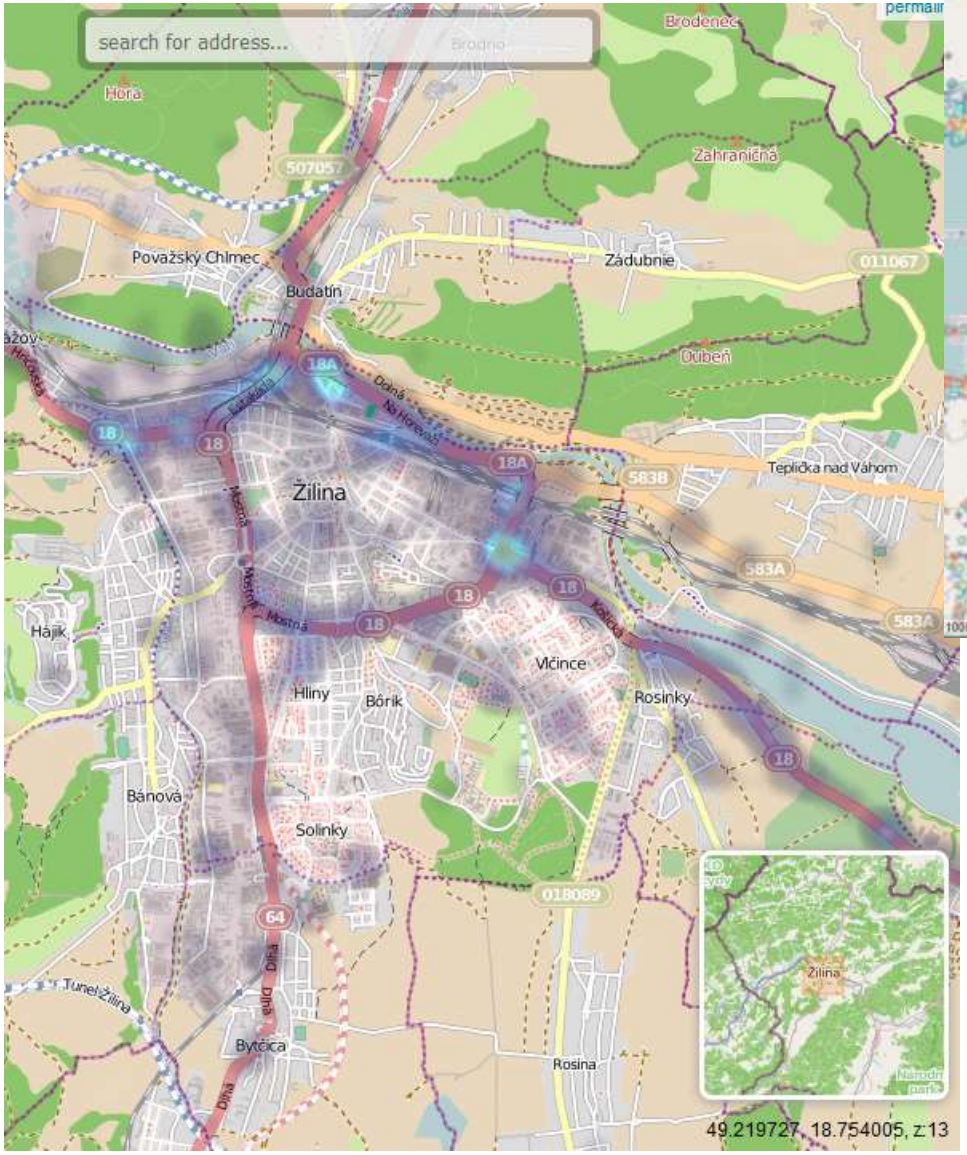
3G

4G coverage

Base stations approximate coordinates



Heat maps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Brodenec
Záhraničná
Považský Chlmec
Budatín
Zádubnie
Dubeň
Teplička nad Váhom
Žilina
Hájik
Vlčince
Hliny
Bórik
Rosinky
Bánová
Solinky
Bytčica
Rosina
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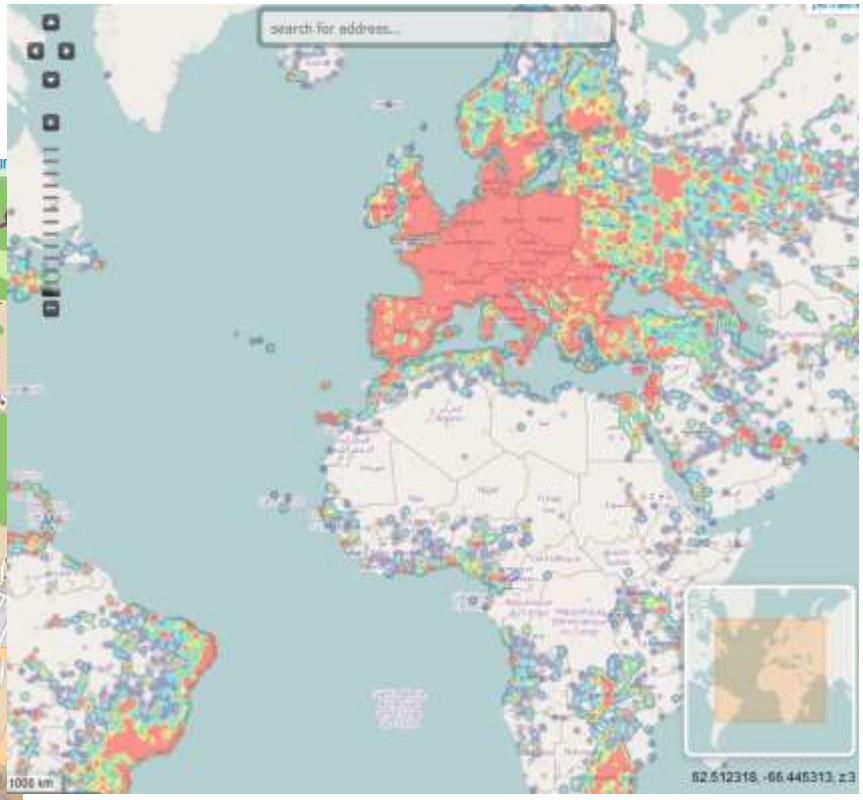
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