INF-111

Redes Sem Fio

Aula 06
Tecnologias para WMAN

Prof. João Henrique Kleinschmidt

Santo André, março de 2016

Roteiro

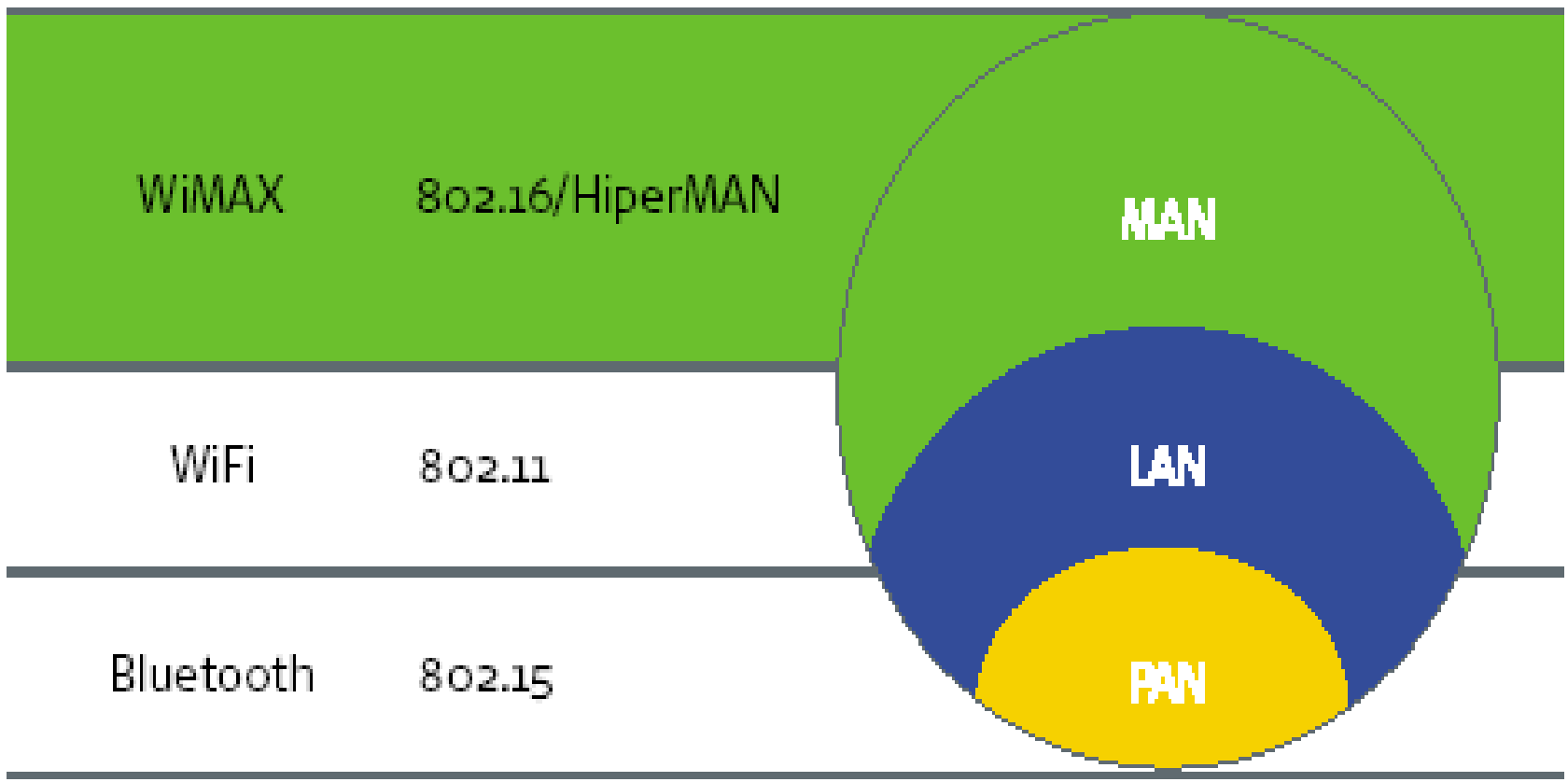
- **WMAN – WiMAX – Arquitetura**
- **Sistemas de Telefonia Celular**
- **Evolução dos Sistemas Celulares**
- **Futuro – 5G**

WMAN

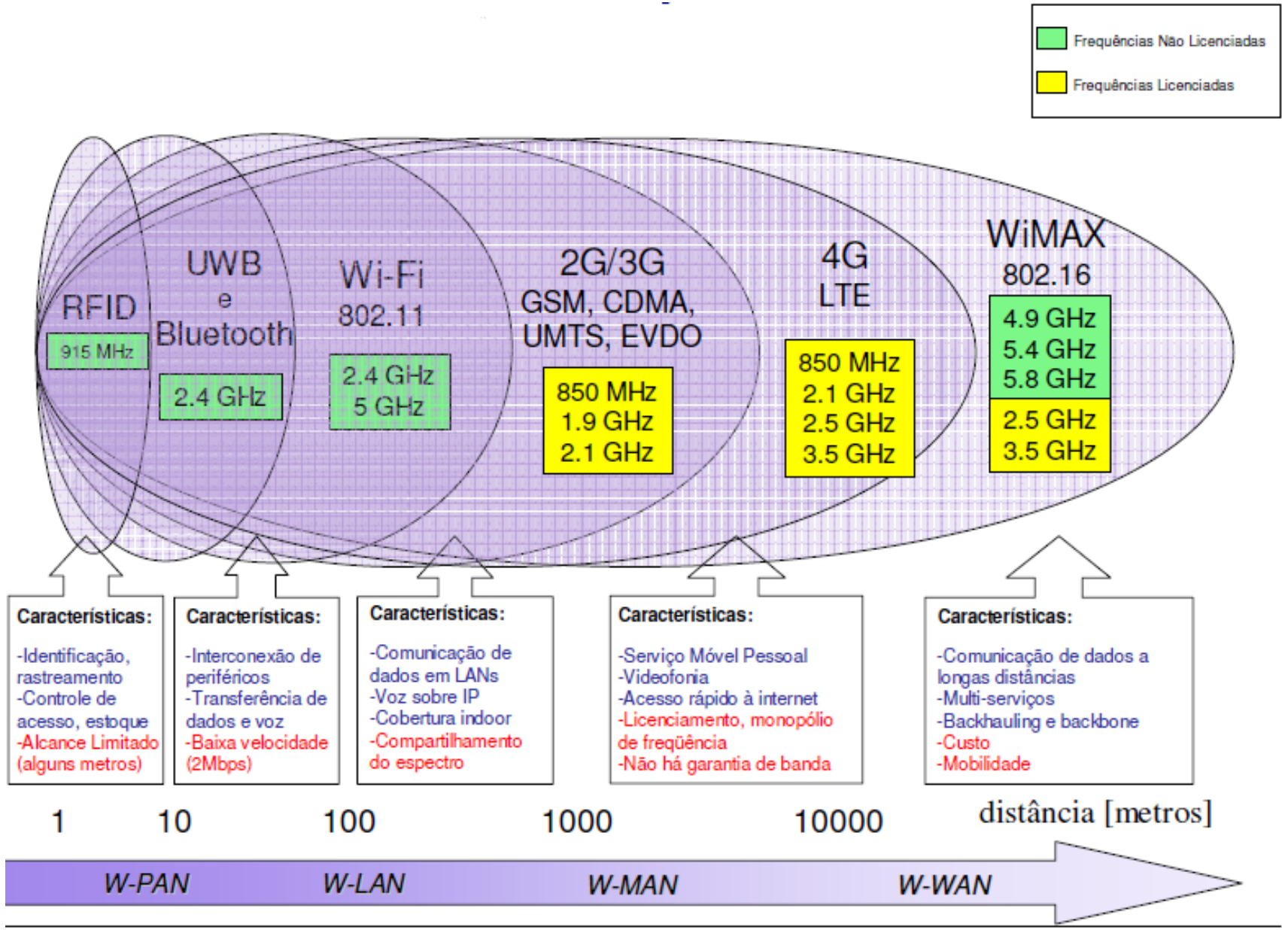
IEEE 802.16

WiMAX

Redes Sem Fio



Wireless standards and their networking environments



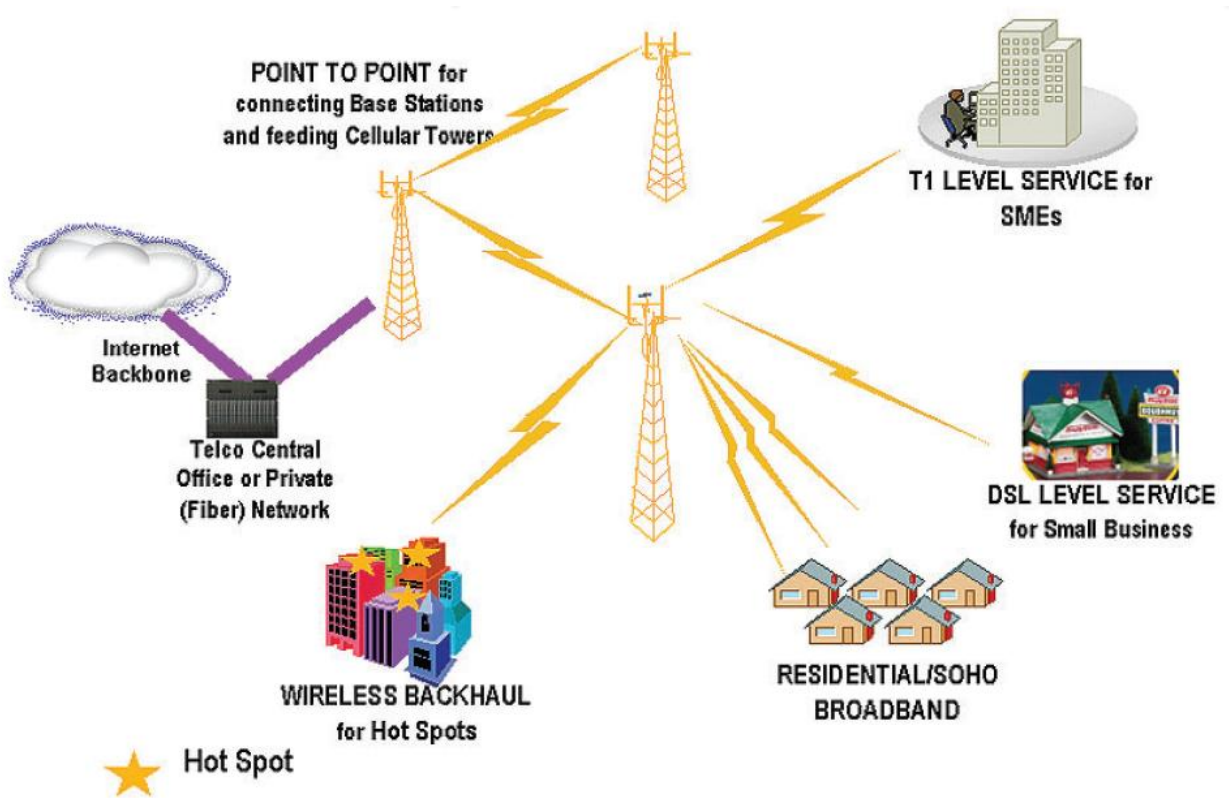
- O WiMAX pode operar na W-LAN (como hotspot), na W-MAN (como backhaul-interconexão de redes) ou na W-WAN (como backbone).

WiMAX

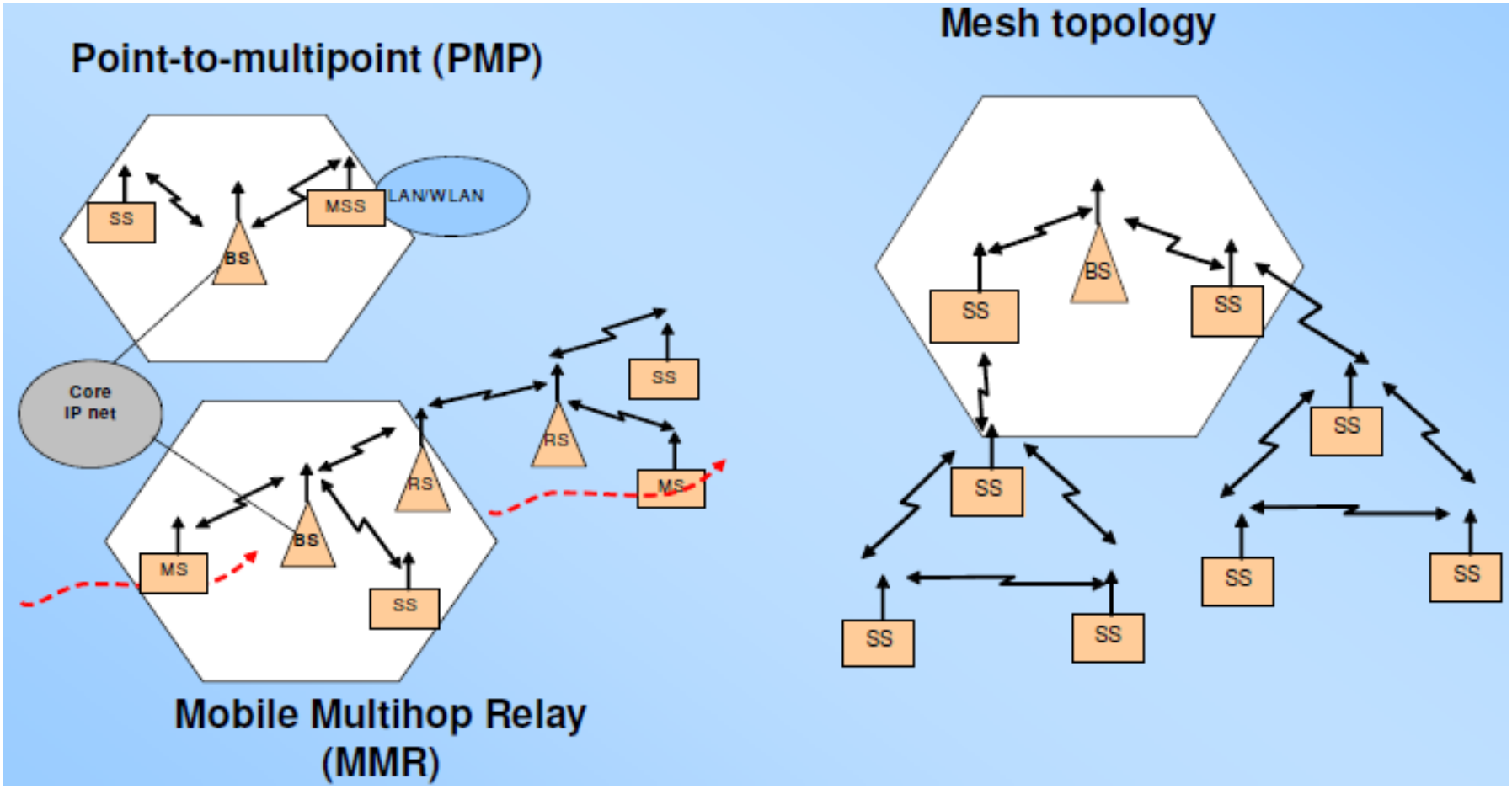
- *Worldwide Interoperability for Microwave Access*.
- Baseada em padrão global, o IEEE 802.16.
- Visa solucionar o problema da última milha.
- Diminui o investimento em infraestrutura de alto custo, comparada com a telefonia.
- Espectro: de 2 a 11 GHz ou de 10 – 66 GHz.
- Modulação dinâmica adaptativa (QPSK e QAM), baseada na qualidade do enlace.
- Topologia: *Point-to-Multipoint* (PMP) e Mesh.
- Alcance: vários quilômetros

O padrão IEEE 802.16

- Define a comunicação sem fio entre a BS (estação base) e uma ou mais SSs (estações de assinantes) servindo a usuários domésticos ou comerciais.
- Estação base controla transmissões
- Alternativa às tecnologias tradicionais como DSL e cabo:



Topologias


Point-to-multipoint (PMP)
SS
BS
MSS
LAN/WLAN
Core
IP net
SS
RS
RS
MS
BS
MS
SS
Mobile Multihop Relay
(MMR)
Mesh topology
BS
SS
SS
SS
SS
SS
SS
SS
SS

Padrões IEEE 802.16

- 802.16a (2-11 Ghz, sem linha de visão) – WiMAX fixo - obsoleto
- 802.16b - obsoleto
- 802.16c - (*detailed system profiles*) - perfis
- 802.16d – revisão integrando os padrões a,b, c
- 802.16e (Mobile Wireless MAN) – WiMAX móvel
- 802.16f – redes mesh

Visão Geral

TABLE 1—SUMMARY OF 802.16 STANDARDS

	802.16	802.16a/802.16REVd	802.16e
Completion date	Dec 2001	802.16a: Jan 2003; 802.16REVd: Q3 2004	Q3 2004
Spectrum	10 to 66 GHz	<11 GHz	<6 GHz
Channel conditions	Line of sight only	Non line of sight	Non line of sight
Bit rate	32 to 134 Mbps (28-MHz channelization)	75 Mbps max (20-MHz channelization)	15 Mbps max (5-MHz channelization)
Modulation	QPSK, 16QAM, 64QAM	OFDM 256 subcarriers, QPSK, 16QAM, 64QAM	Same as 802.16a
Mobility	Fixed	Fixed	Pedestrian mobility, regional roaming
Channel bandwidths	20, 25, and 28 MHz	Selectable between 1.25 and 20 MHz	Same as 802.16a with uplink subchannels
Typical cell radius	1 to 3 miles	3 to 5 miles (30 miles max based on tower height, antenna gain, and power transmit)	1 to 3 miles

Courtesy of the WiMax Forum
Notes:
QPSK = Quadrature phase shift keying;
QAM = Quadrature amplitude modulation;
OFDM = Orthogonal frequency division multiplexing

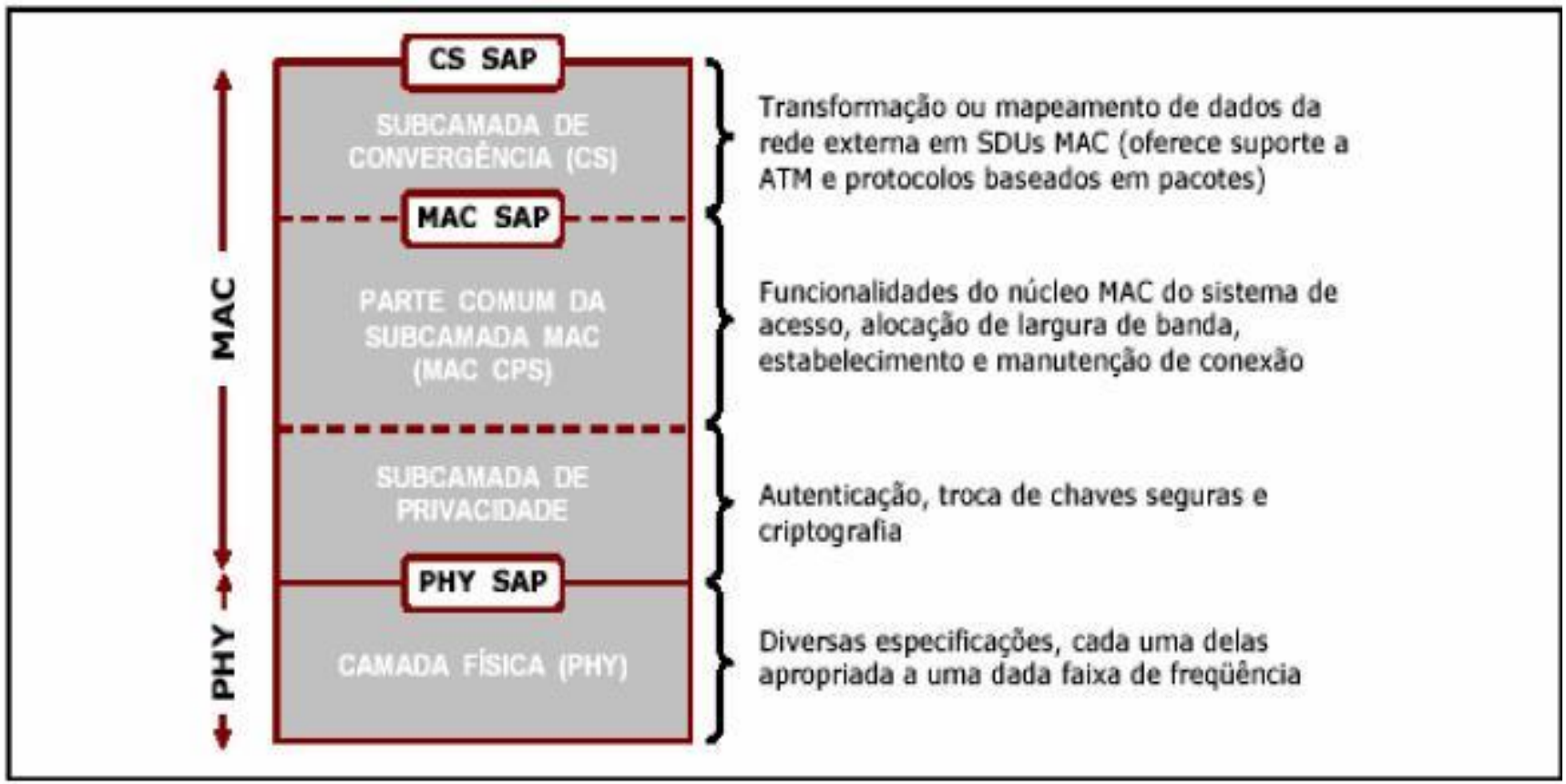
O padrão IEEE 802.16e WiMAX Móvel

- O WiMAX Móvel é uma solução de banda larga para a convergência das redes fixas e móveis, oferecendo:
  - Altas taxas de transmissão;
  - Escalabilidade;
  - Qualidade de Serviço;
  - Segurança;
  - Mobilidade.
- Tem como principais características técnicas:
  - Usa OFDMA
  - MIMO (***M****ultiple* ***I****nput* ***M****ultiple* ***O****utput*)
  - Tamanho de canal escalável.

Arquitetura do WiMAX

- Camada física (PHY).
- Camada de acesso ao meio (MAC).
- A subcamada MAC encontra-se dividida em três subcamadas:
  - subcamada de Convergência de Serviços (CS),
  - subcamada de Parte Comum (CPS)
  - subcamada de Privacidade (*PS*).

Camadas


CS SAP
SUBCAMADA DE CONVERGÊNCIA (CS)
MAC SAP
PARTE COMUM DA SUBCAMADA MAC (MAC CPS)
SUBCAMADA DE PRIVACIDADE
PHY SAP
CAMADA FÍSICA (PHY)
MAC
PHY
Transformação ou mapeamento de dados da rede externa em SDUs MAC (oferece suporte a ATM e protocolos baseados em pacotes)
Funcionalidades do núcleo MAC do sistema de acesso, alocação de largura de banda, estabelecimento e manutenção de conexão
Autenticação, troca de chaves seguras e criptografia
Diversas especificações, cada uma delas apropriada a uma dada faixa de freqüência

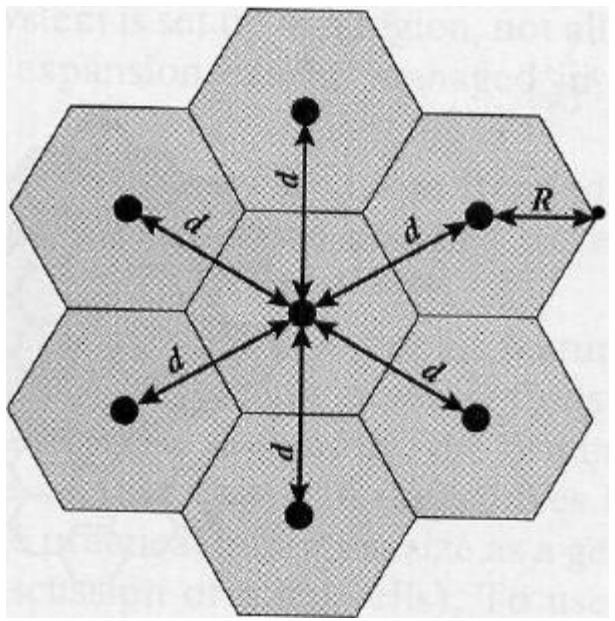
Sistemas de Telefonia Celular

Sistemas de Telefonia Celular

- Comunicação sem fio a longas distâncias
- Oferece uma conexão sem fio à PSTN (*Public Switched Telephone Network – Rede Telefônica Pública Comutada)*
- Permite mobilidade contínua dos usuários
- Acomodam um grande número de usuários em uma grande área geográfica e dentro de um espectro de frequência limitado
- Alta capacidade é alcançada limitando-se a cobertura dos transmissores a sub-regiões geográficas: **células**
- Cada célula é servida por uma estação rádio base (ERB), composta por: transmissor, receptor e unidade de controle

Sistemas de Telefonia Celular

- A cada célula são atribuídas faixas de frequência
  - Reuso de frequências – uso da mesma frequência (canal) na cobertura de diferentes áreas
- Células são organizadas de forma que todas as antenas vizinhas sejam equidistantes (padrão hexagonal)
  - Interferência co-canal – interferência entre células que usam a mesma frequência (limites toleráveis)



Organização das Células

Modelo de propagação teórico

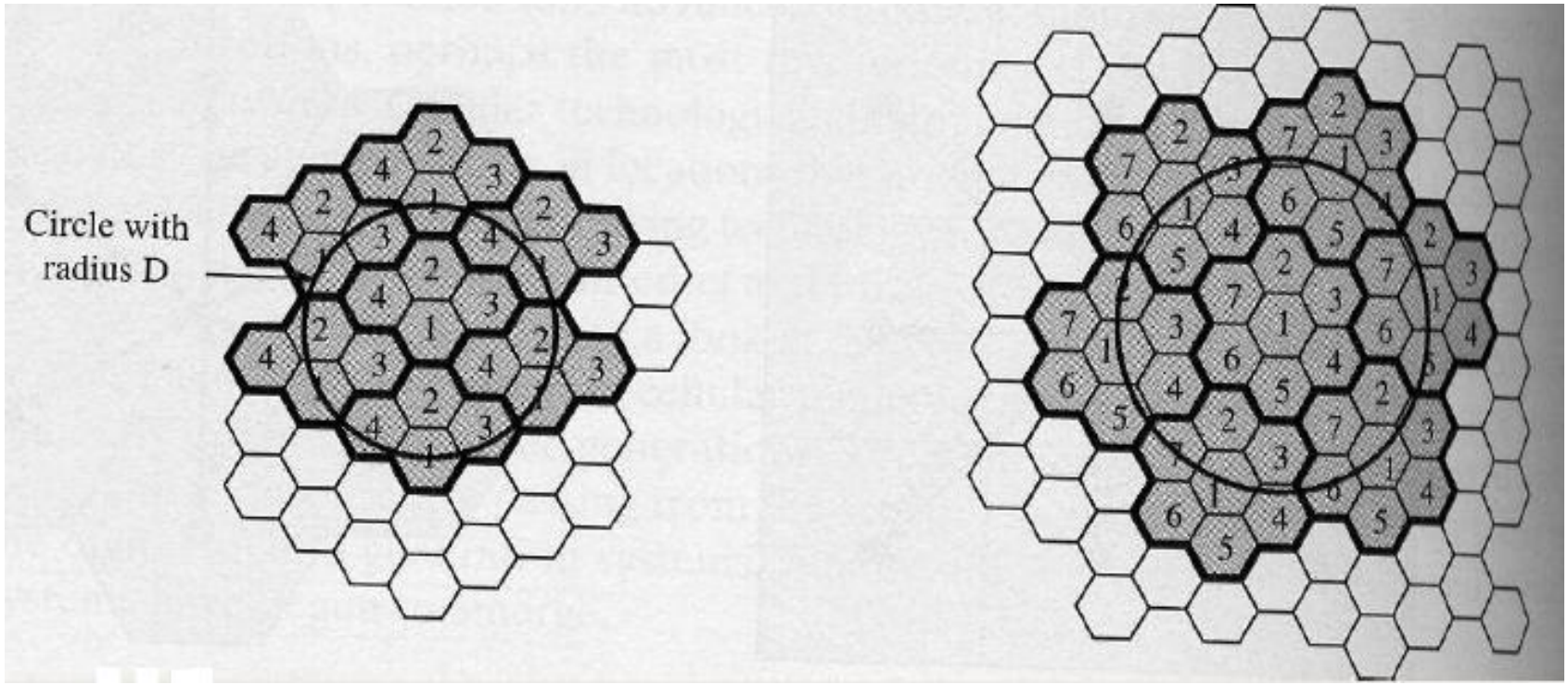
Projeto de grade celular

Layout real

Telefonia celular - Conceitos

- Por que não usar uma grande torre de rádio e uma grande área de serviço?
- Número de usuários simultâneos seria bastante limitado
- Relacionado ao número de canais disponíveis
- Terminal móvel teria um grande requisito de potência de transmissão
- Conceito de telefonia celular – pequenas células com reuso de frequência
- Vantagens : Baixa potência de transmissão dos dispositivos
- Aumento da capacidade do sistema com reuso de frequências
- Desvantagens: Custo das células
- *Handoff (ou handover) entre as células deve ser suportado*
- Necessário rastrear o usuário móvel para rotear mensagens e chamadas

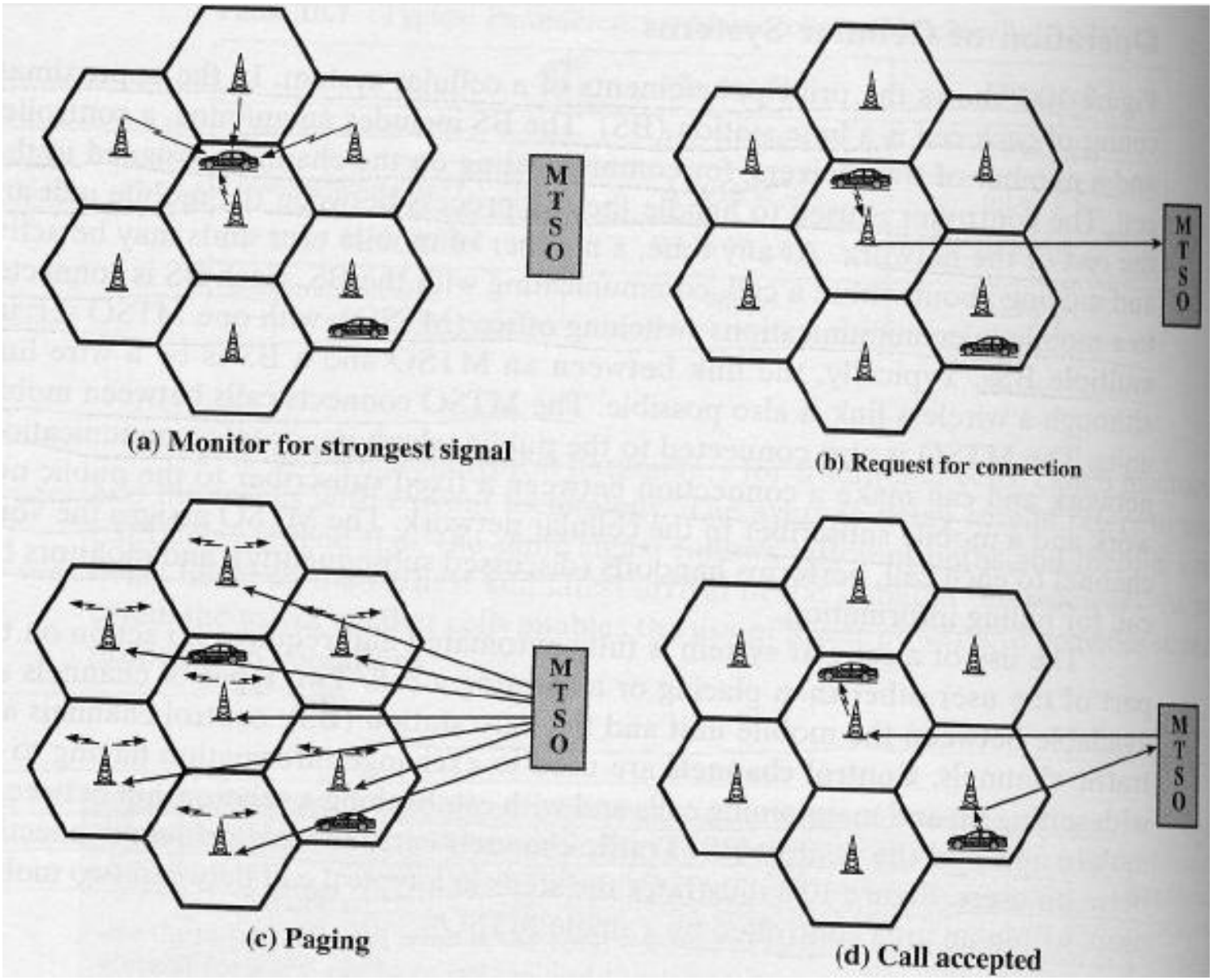
Reuso de Frequências



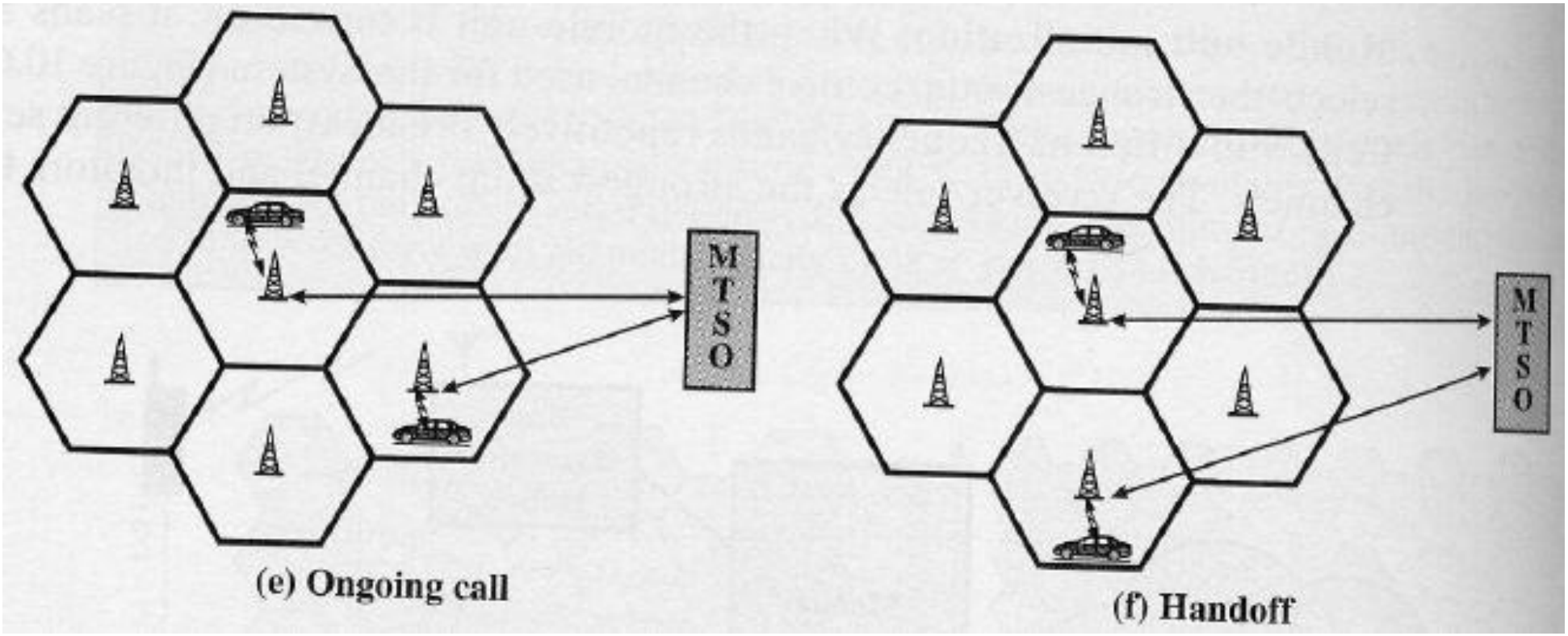
Cluster — conjunto de células em que não há reutilização de frequências

Estruturas mais empregadas (antenas omnidirecionais — células hexagonais)

Processo de Chamada Celular



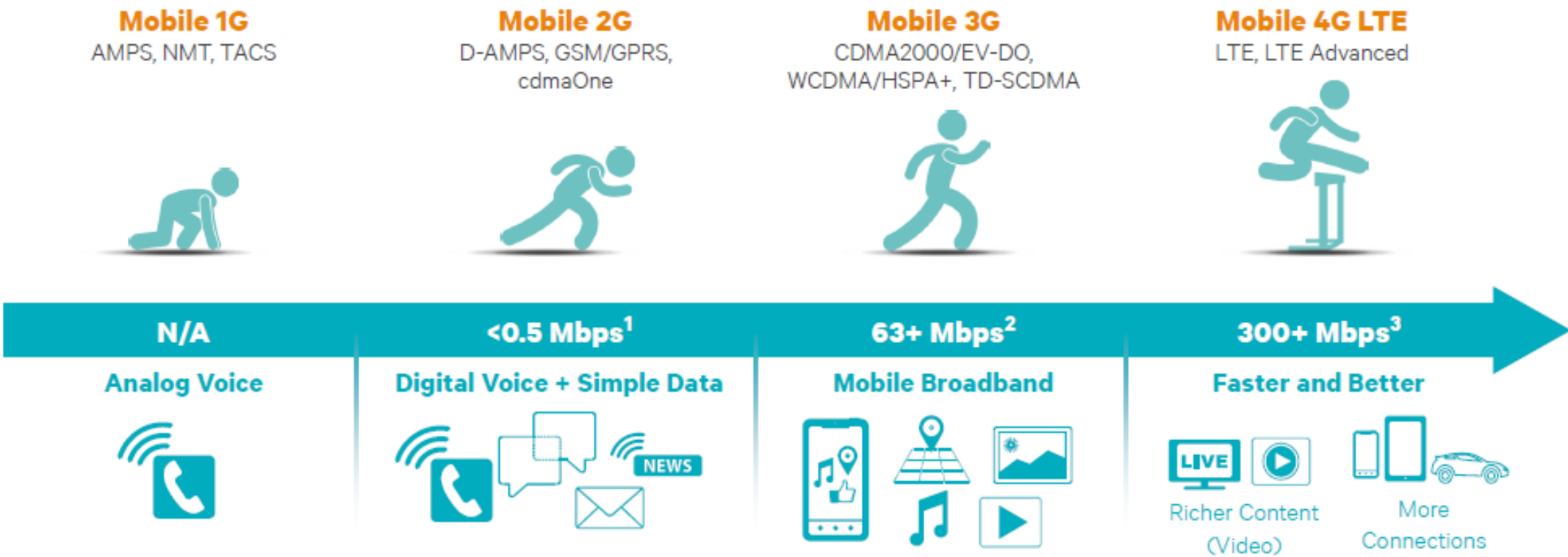
Handoff



- Função que permite manter a continuidade de uma conversação quando o usuário passa de uma célula para outra
- O handoff pode causar uma (pequena) interrupção na comunicação

Evolução da Telefonia Móvel

Evolução da Telefonia Móvel



Mobile 1G established the foundation of mobile

1

Licensed Spectrum

Cleared spectrum for exclusive use by mobile technologies

Operator-deployed **base stations** provide access for subscribers

2

Frequency Reuse

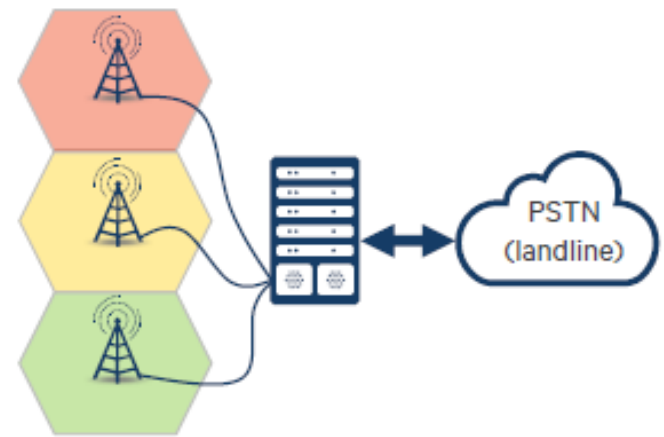
Reusing frequencies without interference through geographical separation

Neighboring **cells** operate on different frequencies to avoid interference

3

Mobile Network

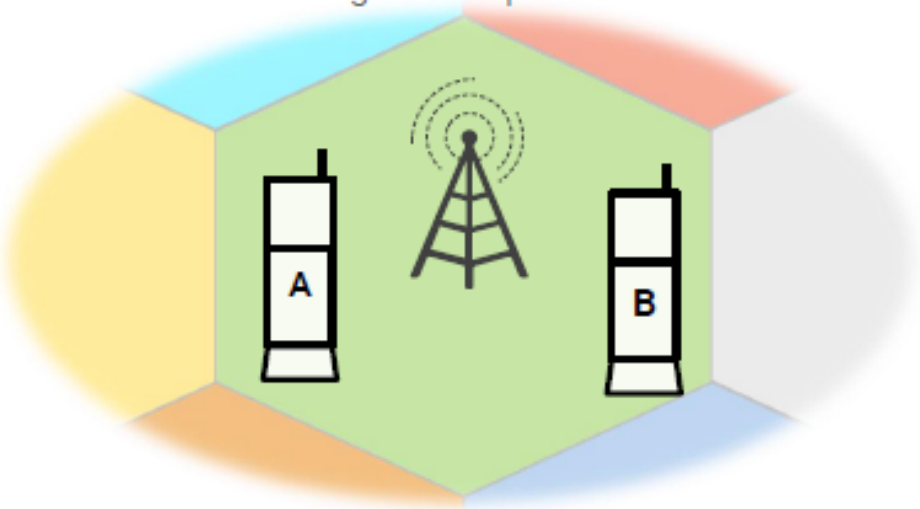
Coordinated network for seamless access and seamless mobility



Integrated, transparent **backhaul network** provides seamless access

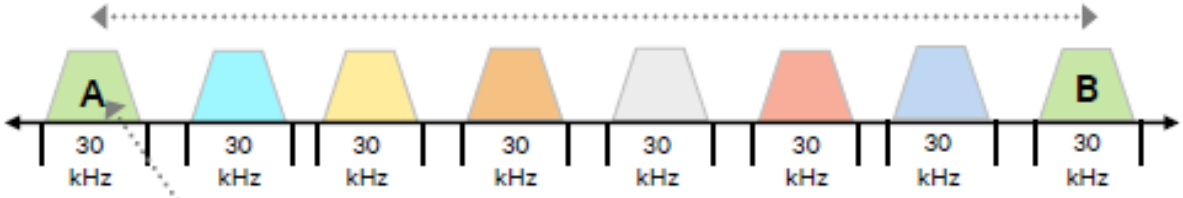
Limited Capacity

Analog transmissions are inefficient at using limited spectrum



Frequency Division Multiple Access (FDMA)*

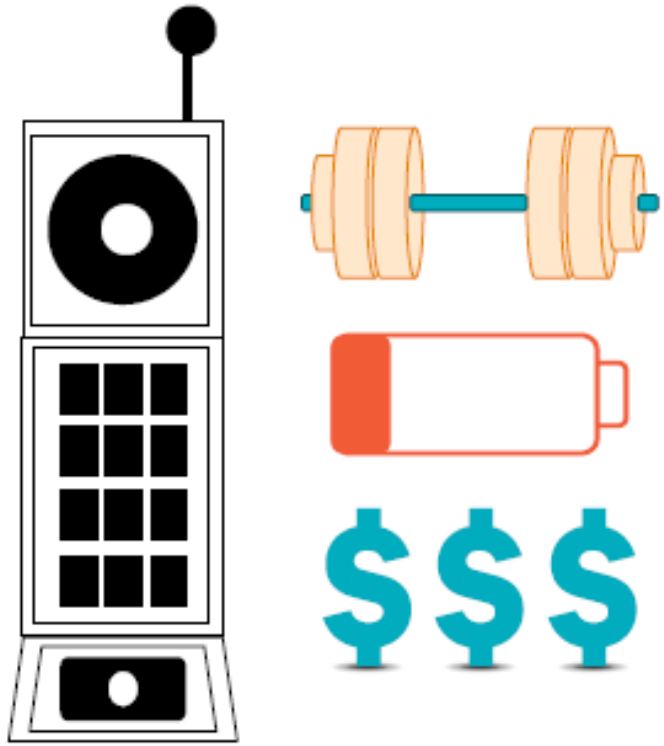
Large frequency gap required between users to avoid interference



Support for only 1 user (analog phone call) per channel

Limited Scalability

Analog devices are large/heavy, power inefficient, and high cost

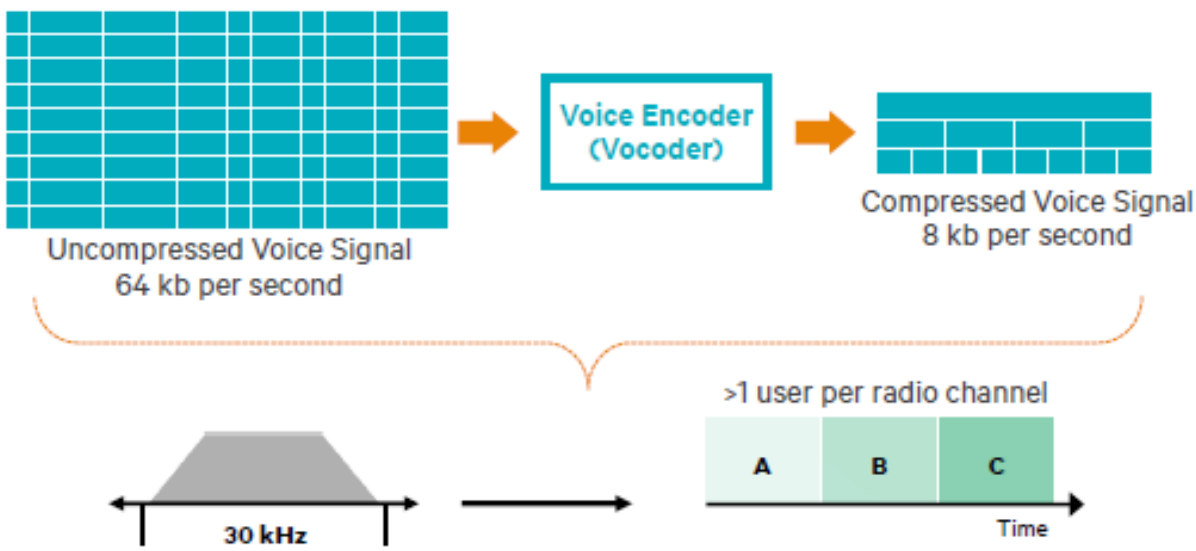


Mobile 2G digital wireless technologies enabled more users

Initial 2G technologies (D-AMPS, GSM) based on TDMA

More Voice Capacity

Digital transmissions enable compressed voice and multiplexing multiple users per channel

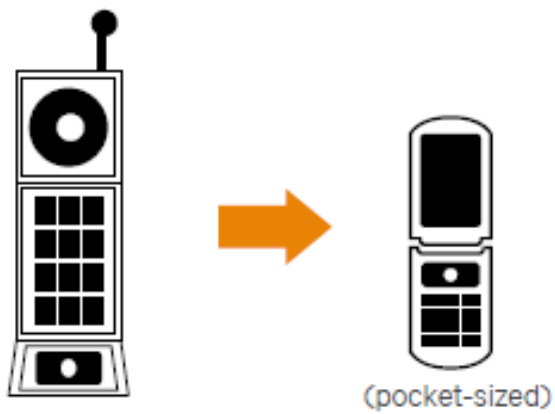


Time Division Multiple Access (TDMA)

Allows multiple users per radio channel with each user talking one at a time

Scalable Technology

Digital components cost/weight far less plus deliver more secure signal

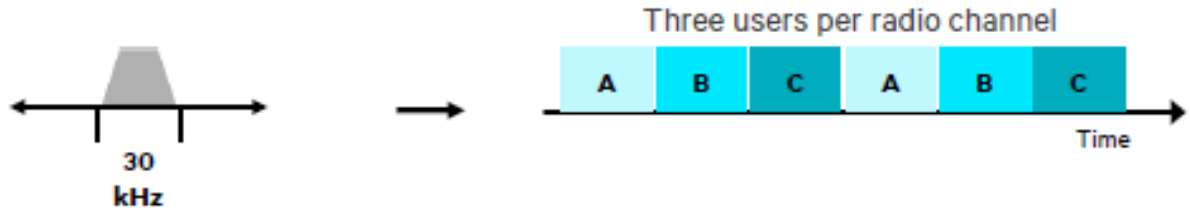


Different Mobile 2G TDMA techniques were standardized

Mobile 1G (Analog)
AMPS, NMT, TACS

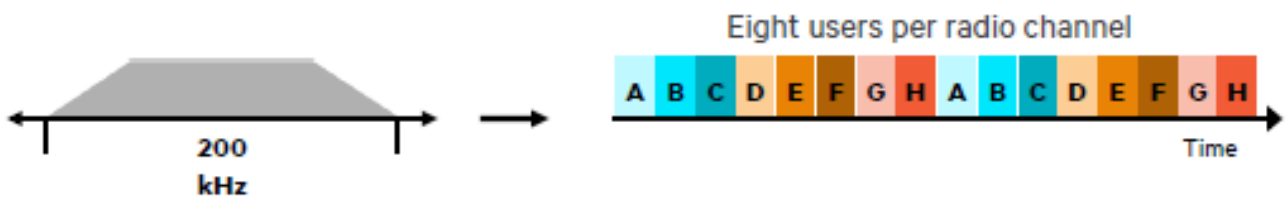
Mobile 2G (Digital)
D-AMPS

Standardized as IS-54 by TIA in 1992
Mainly in North America
No longer utilized

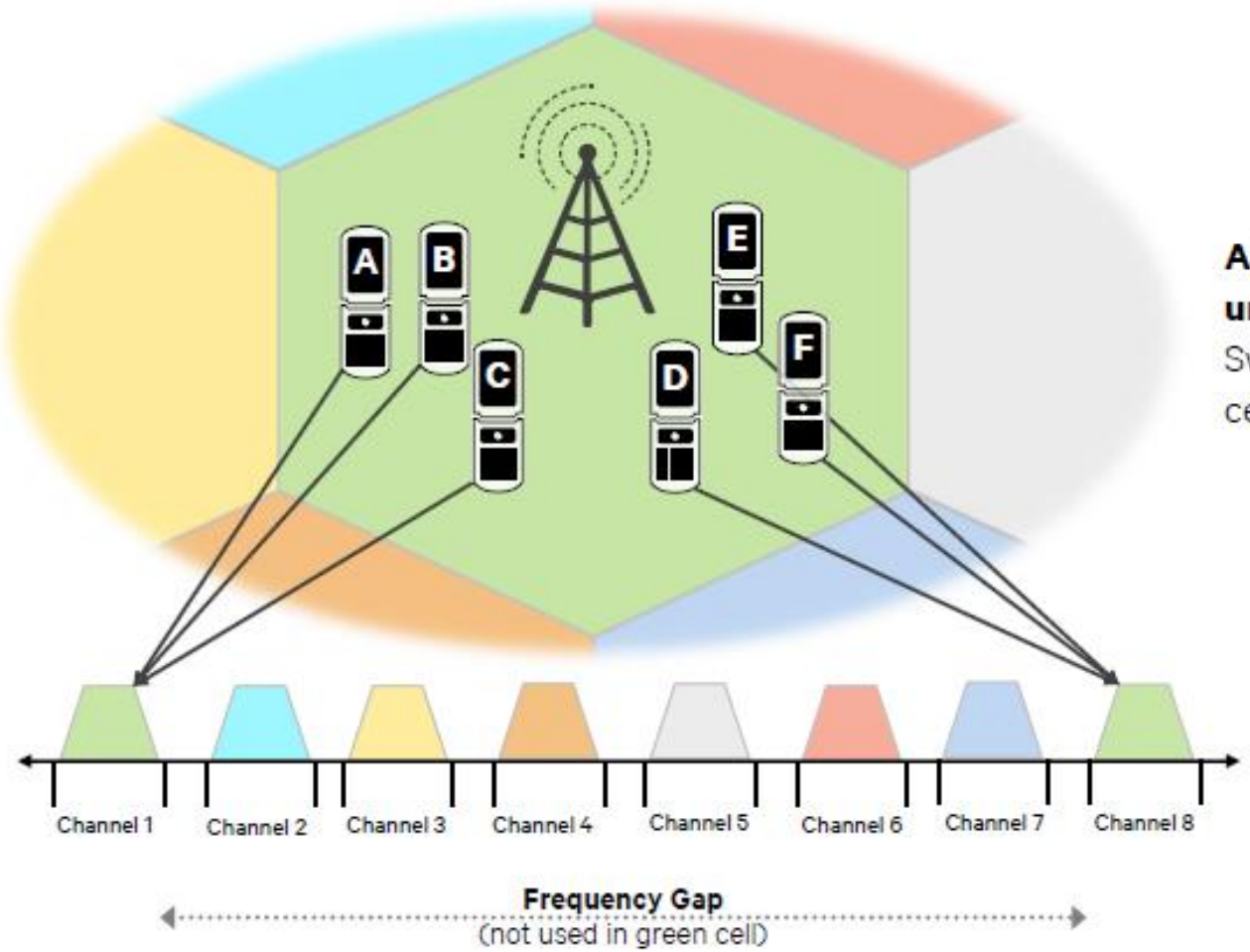


Mobile 2G (Digital)
GSM

Standardized by ETSI in 1990 (phase 1)
Initiated in Europe
Still widely used today (>4B connections WW[1])
Simple data services with GPRS



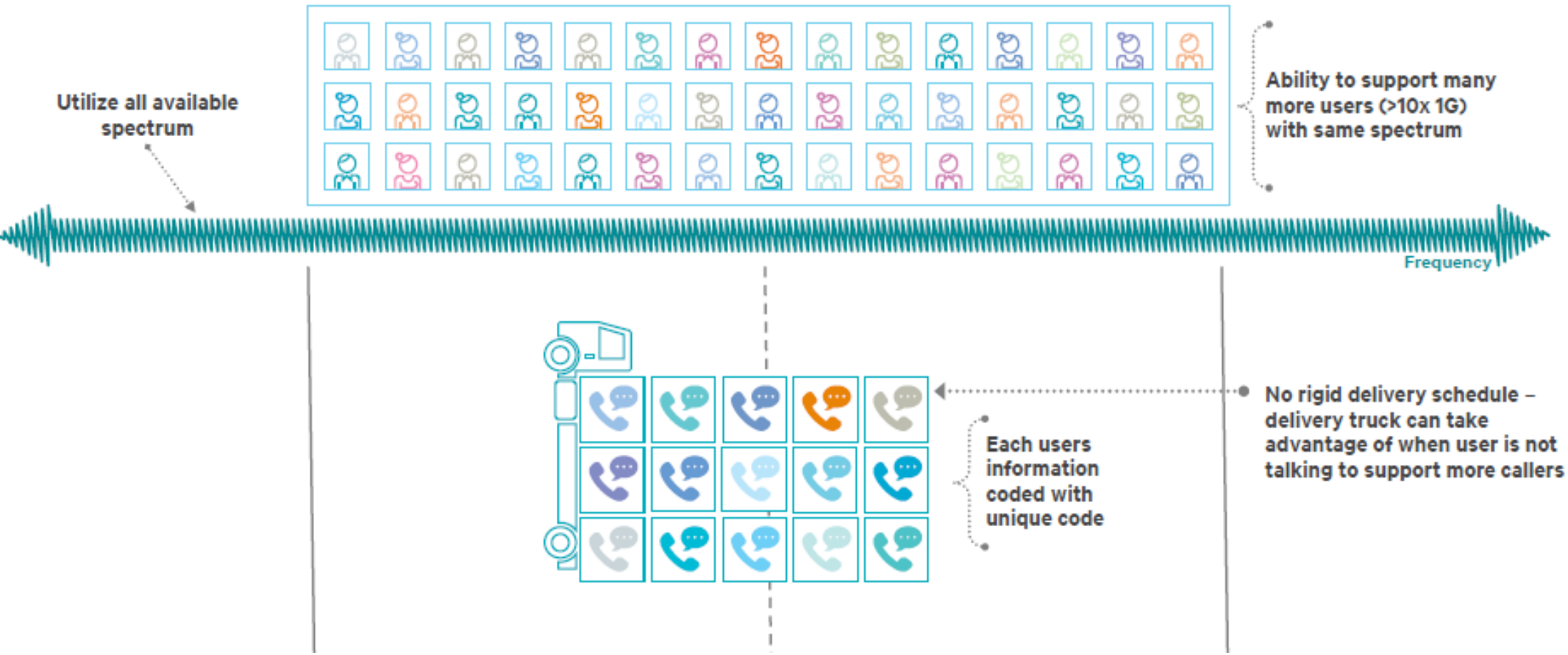
TDMA still required large frequency gaps to reduce interference



Also required potentially unreliable "hard" handoffs

Switch channels between adjacent cells – potential for dropped calls

CDMA utilizes all the available spectrum to support more users

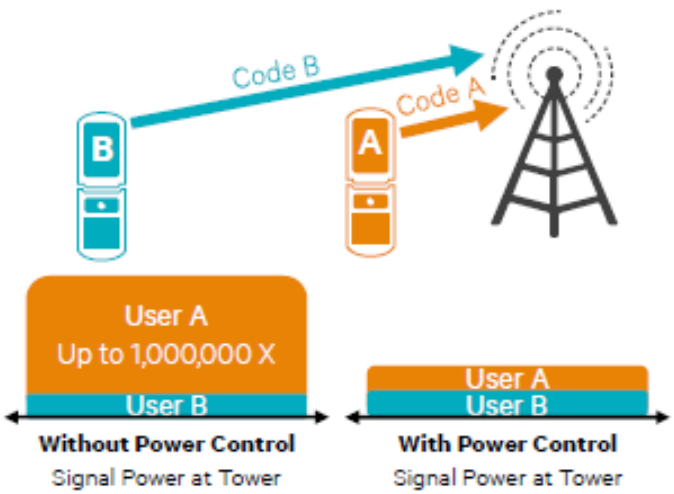


1 Near-Far Power Challenge

Users close to the tower overpower the uplink signal minimizing capacity on the shared channel

Solution:

Continuous control of transmit power based on signal strength



2 Cell-Edge Challenge

Interference caused by users in close proximity, on the same frequency, and communicating with different towers

Solution:

Users simultaneously communicate with multiple towers at cell edge

+ Soft (vs. Hard) Handoffs

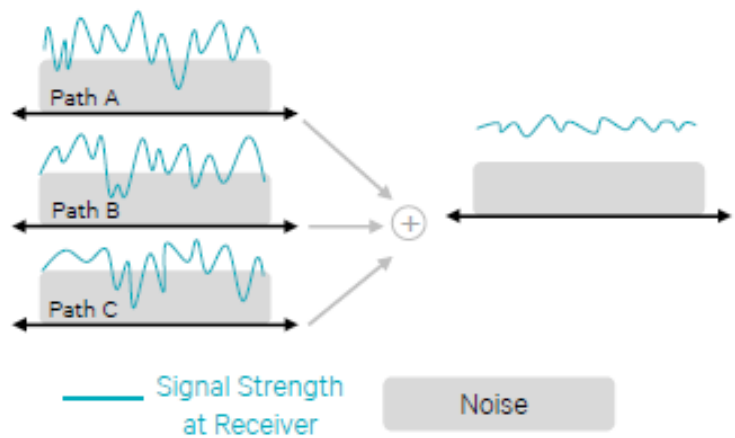
Additional benefit of simultaneous connections – more reliable handoffs

3 Multipath Fading Challenge

Interference caused by the reception of the same signal over multiple paths resulting in poor signal-to-noise ratio

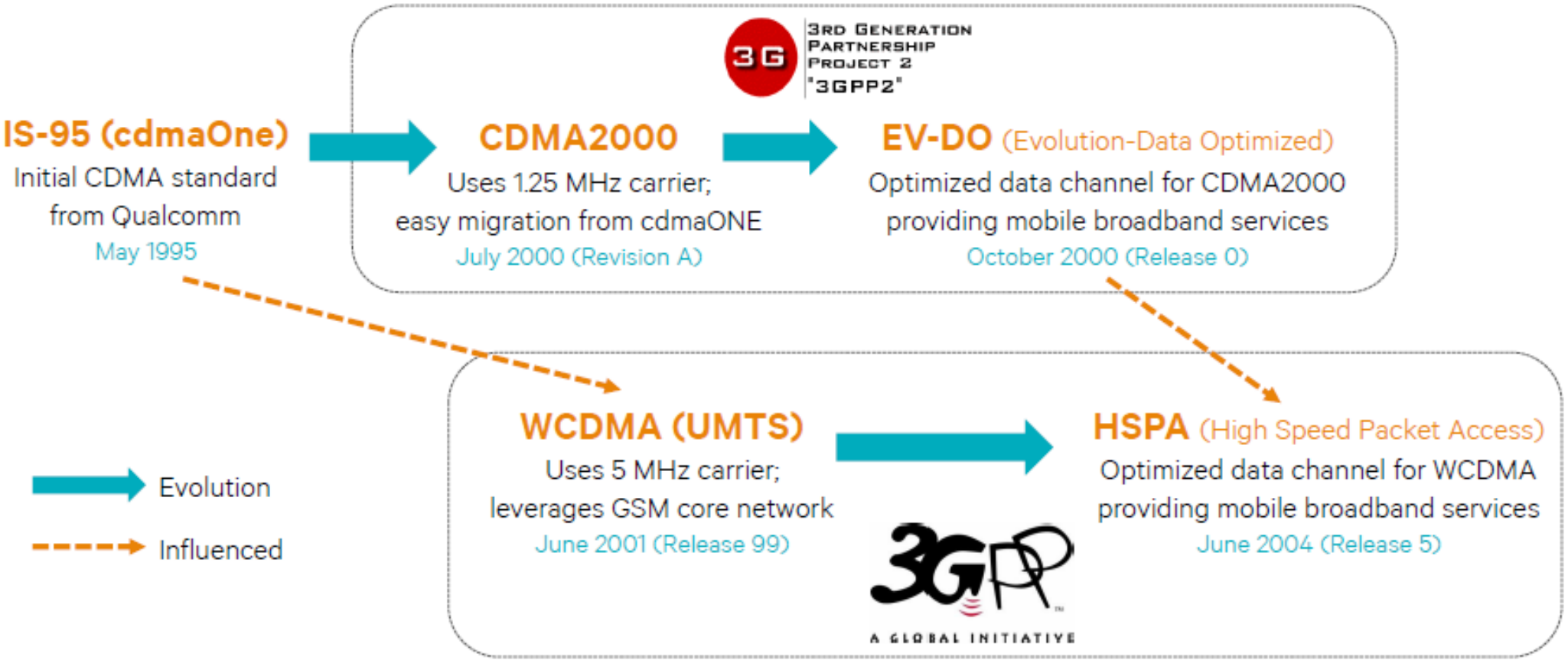
Solution:

Advanced ("rake") receivers combine energy of multiple signal paths



CDMA established the foundation for 3G technologies

Mobile 3G evolved into two competing standards both based on CDMA



EV-DO optimized 3G for data enabling mobile broadband

Data Enabled
Simple Data Services

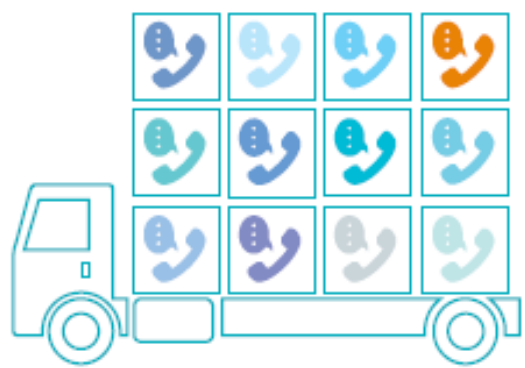
Mobile 2G
<0.5 Mbps[1]

Text Email

Capable of efficiently supporting small data files

Data Optimized
Mobile Broadband

CDMA2000/EV-DO
14.7 Mbps[2]



CDMA2000
Voice Services

EV-DO
Data optimized channel with support for larger package sizes

EV-DO inventions are the foundation to mobile broadband

1 Data Optimized Channel

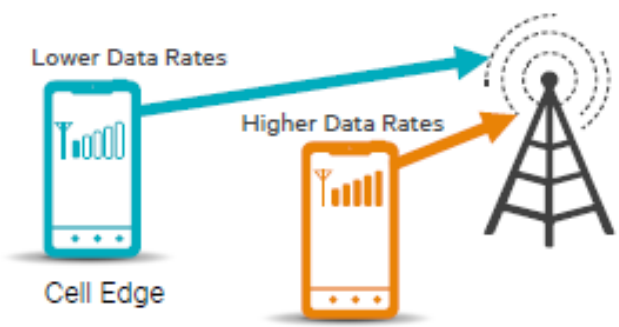
Splits channel into time intervals enabling a single user to get all the resources at once

Enables richer content

2 Adaptive Modulation

Uses higher order modulation to get more bps per Hz for users with good signal quality

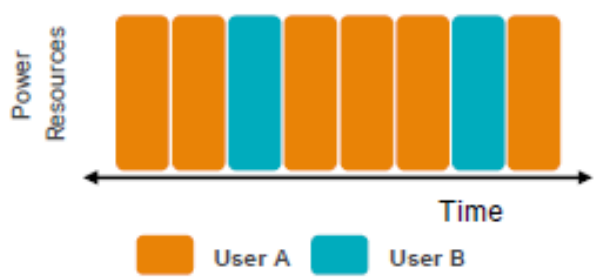
Increases peak data rates



3 Opportunistic Scheduling

Optimizes channel by scheduling users at the time instances when users have good radio signal conditions (with fairness)

Increases overall capacity

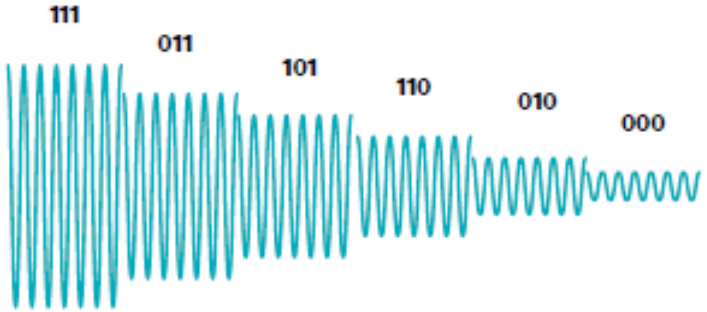


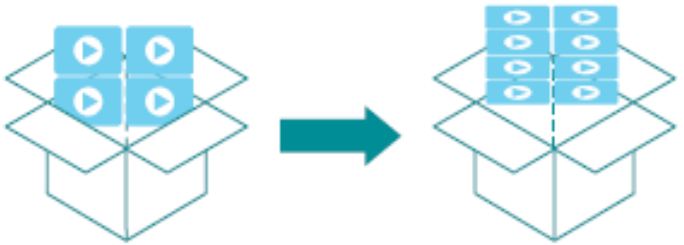
Mobile 3G evolved to HSPA+ and EV-DO Rev. B

Delivering higher data rates, more capacity, and enhanced mobile broadband experiences

Higher Order Modulation (HOM)

Introduces 64-QAM enabling 50% more bits per second per Hz (bps/Hz)

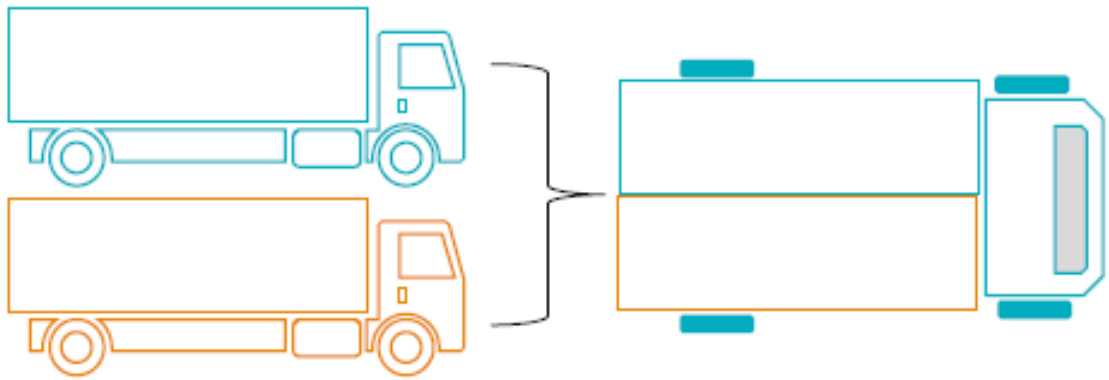




Enabling packing 50% more data into packages

Carrier Aggregation

Aggregating spectrum enabling increased user and peak data rates

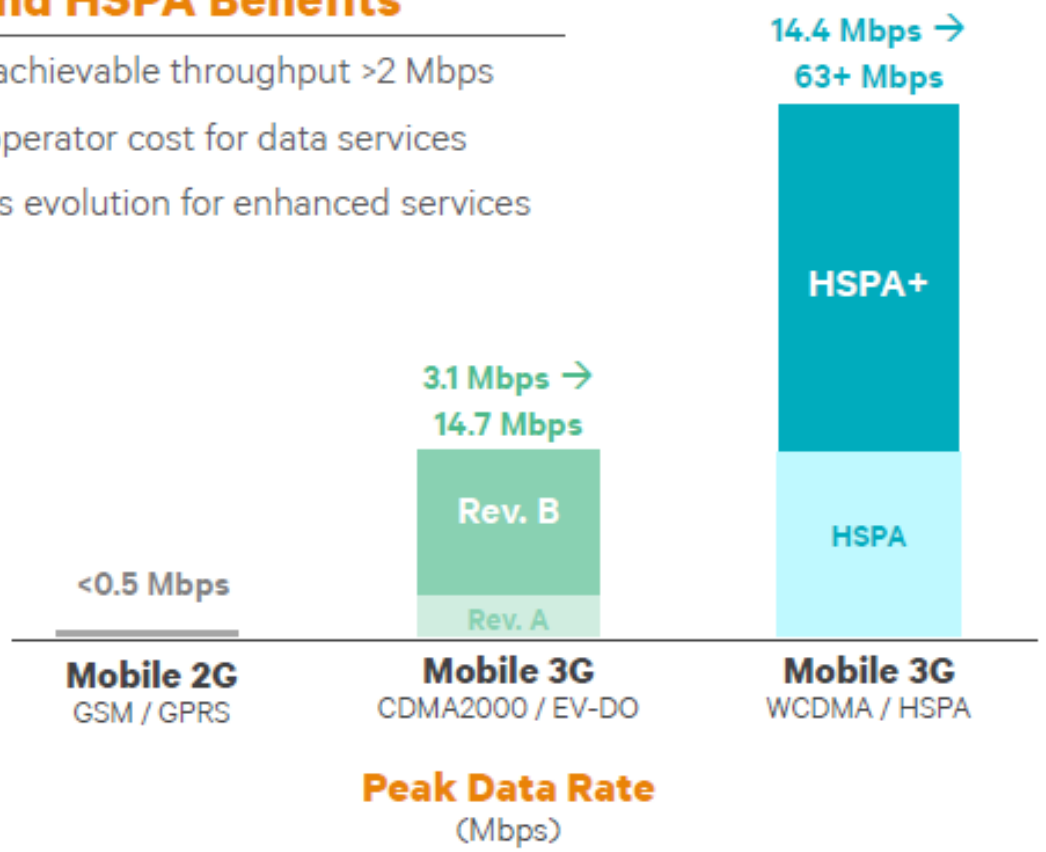


Aggregate channels for higher data rates

3G technologies optimized mobile for data

EV-DO and HSPA Benefits

- Delivered achievable throughput >2 Mbps
- Reduced operator cost for data services
- Continuous evolution for enhanced services



Mobile Broadband Timeline[1]

1999
Qualcomm introduces EV-DO

January 2002
First EV-DO commercial launch

Q4 2004
3GPP release 6 with HSPA is published based on WCDMA technology

Q1 2007
EV-DO passes 50 million connections

Q108
HSPA passes 50 million connections

June 2008
First HSPA+ (21 Mbps) commercial launch

September 2010
First DC-HSPA+ (42 Mbps) commercial launch

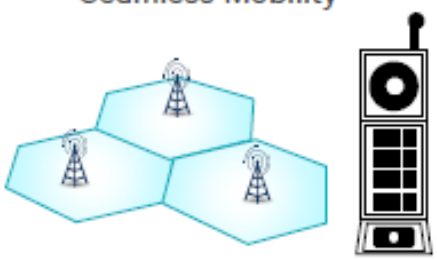
3G technologies continue to evolve
Surpassed 2B connections in 2013[2]

Mobile 4G LTE is evolving to provide more data capacity

Delivering faster and better mobile broadband experiences

Mobile 1G
AMPS, NMT, TACS

Foundation of Mobile
Seamless Mobility



Mobile 2G
D-AMPS, GSM/GPRS, cdmaOne

Mobile for the Masses
More Voice Capacity

Mobile 3G
CDMA2000/EV-DO, WCDMA/HSPA+, TD-SCDMA

Mobile Broadband
Data Optimized

Mobile 4G LTE
LTE, LTE Advanced

Faster and Better Mobile Broadband
More Data Capacity

1980s 1990s 2000s 2010s

Mobile 4G LTE delivers more data capacity

Download, browse, stream, and game faster than ever with faster and better connectivity

Connect Faster

Wider Channels

Flexible support for channels up to 20 MHz enabled with OFDMA

More Antennas

Advanced MIMO techniques to create spatially separated paths; 2x2 MIMO mainstream

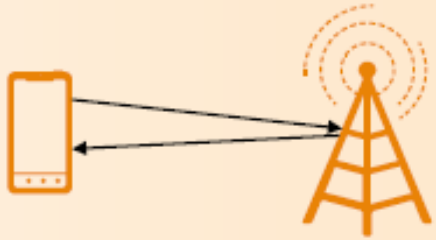
Carrier Aggregation

Aggregate up to 100 MHz for higher data rates – 2 carrier (2C) commercial; 3C announced[1]

Connect Real-time

Simplified Core Network

All IP network with flattened architecture resulting in less equipment per transmission



Low Latencies

Optimized response times for both user and control plane improves user experience

Mobile 4G LTE is the first global standard for mobile broadband

Global LTE network launches

279 Launches

101 Countries

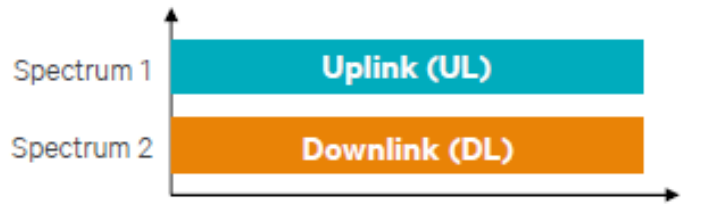
Large device ecosystem

1,563 Devices

>100 Vendors

LTE FDD & LTE TDD

Two modes, common standard, same ecosystem



Frequency Division Duplex (FDD)
Paired spectrum enables better coverage

Time Division Duplex (TDD)
Unpaired spectrum enables asymmetrical DL/UL for more DL capacity

Mobile 3G and 4G LTE continue to evolve

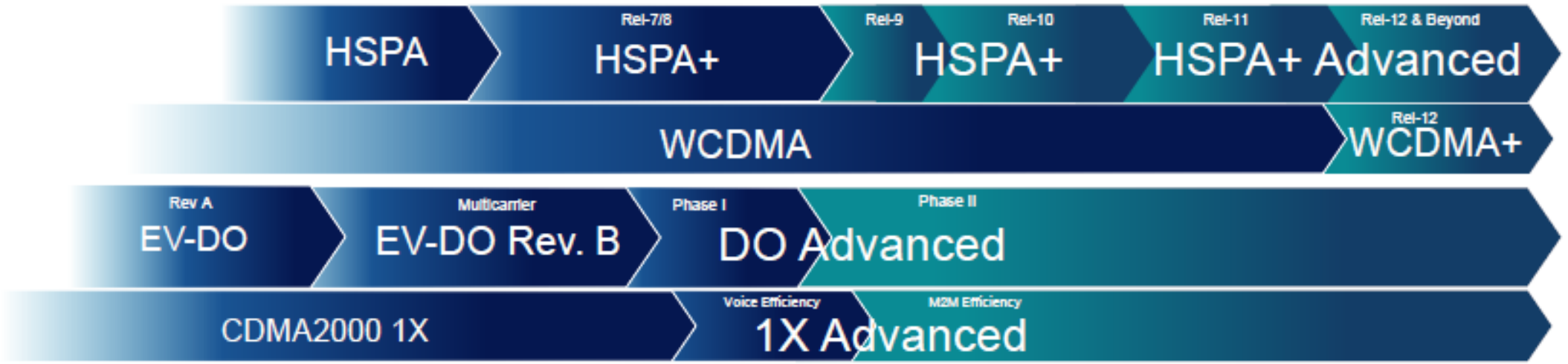
Delivering a faster and better mobile broadband experiences

4G LTE has evolved to LTE Advanced

Providing more data capacity and expanding into new frontiers

3G networks have continued to evolve and improve—so much so some call it 4G

Providing a consistent broadband experience outside LTE coverage



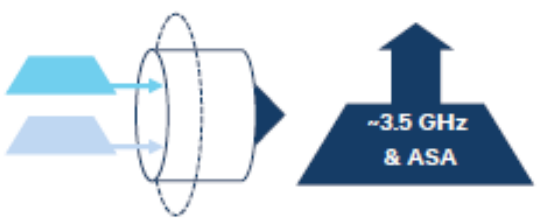
Mobile 3G/4G technologies are evolving for more data capacity

Shannon's Law

$$C \approx W \cdot n \cdot \log_2(1 + SNR)$$

Capacity | Spectrum | Antennas | Signal Quality

More Spectrum



Making the best use of all spectrum types with more licensed spectrum as the top priority, e.g., ASA, ~3.5 GHz, unlicensed spectrum

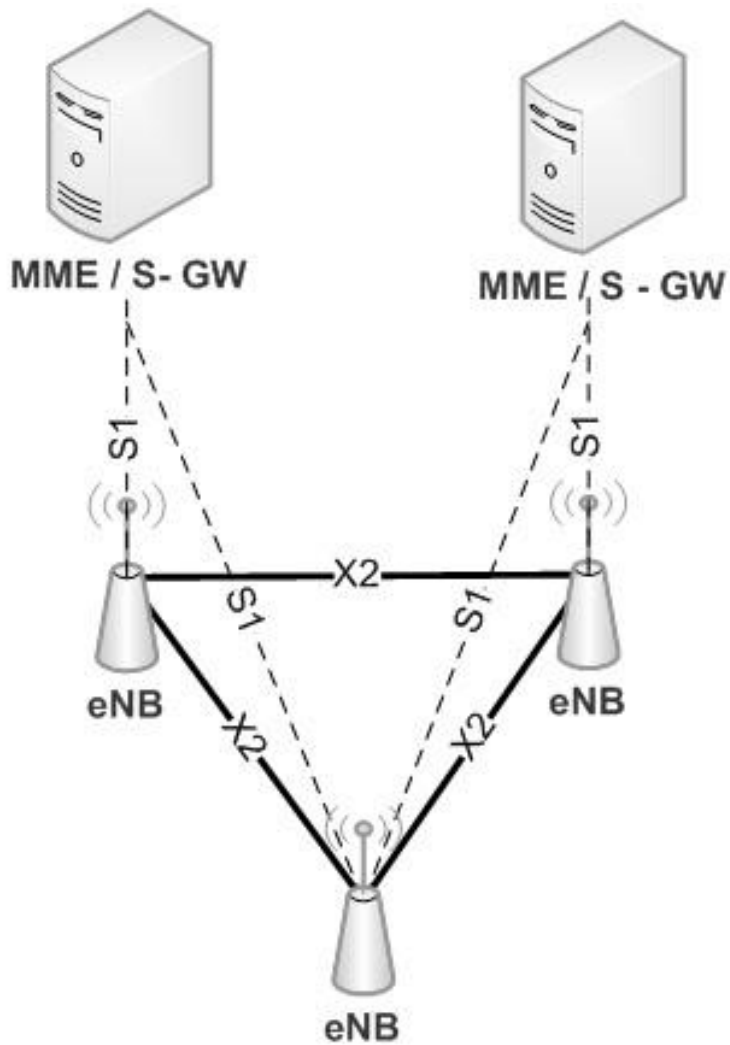
More Antennas

Advanced multiple antenna techniques to create spatially separated data paths, e.g., 4 way receive diversity, 4x4 MIMO

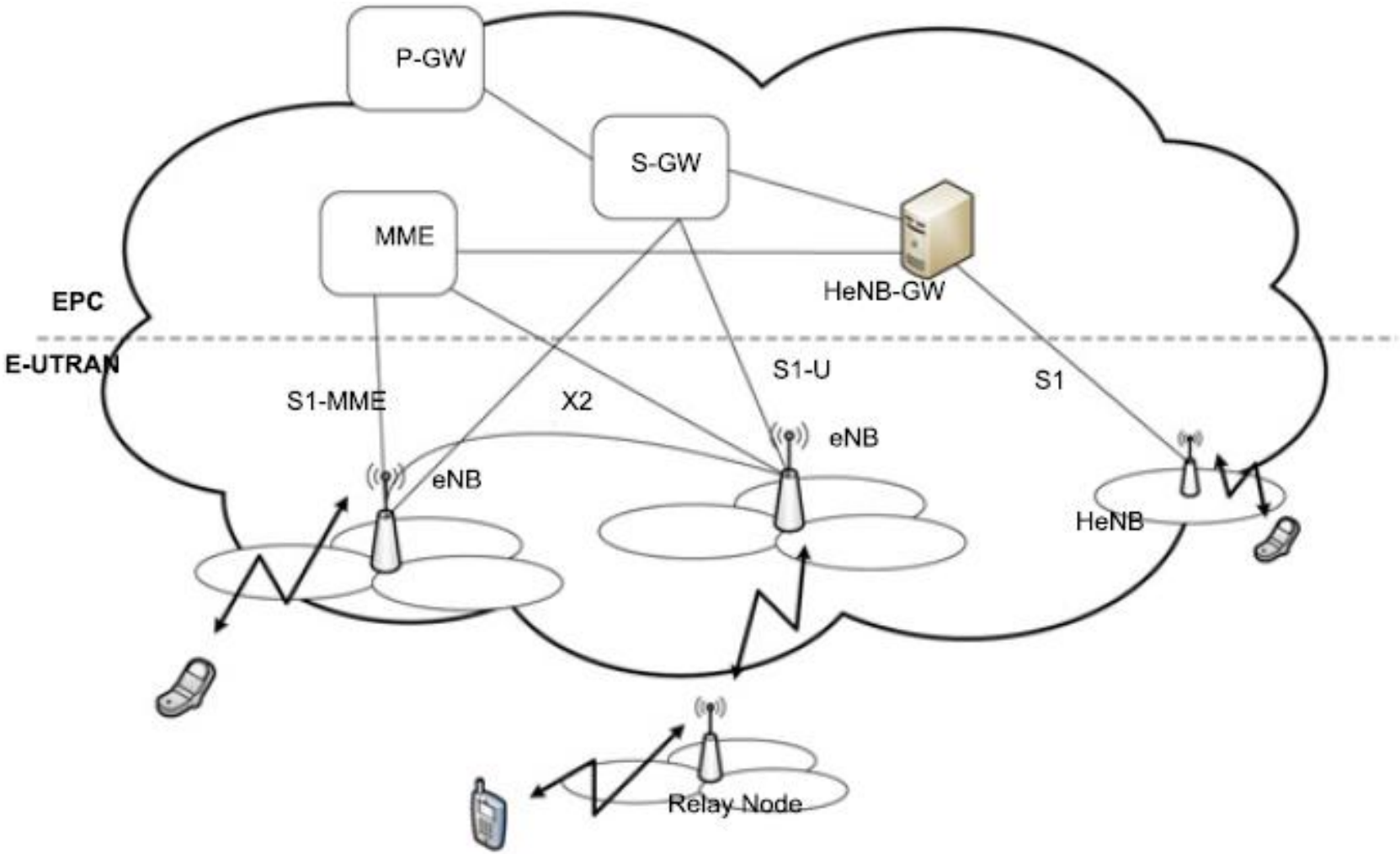
Interference Mitigation

Advanced receivers and antenna techniques, e.g., LTE FeICIC/IC, HSPA+ advanced device receiver

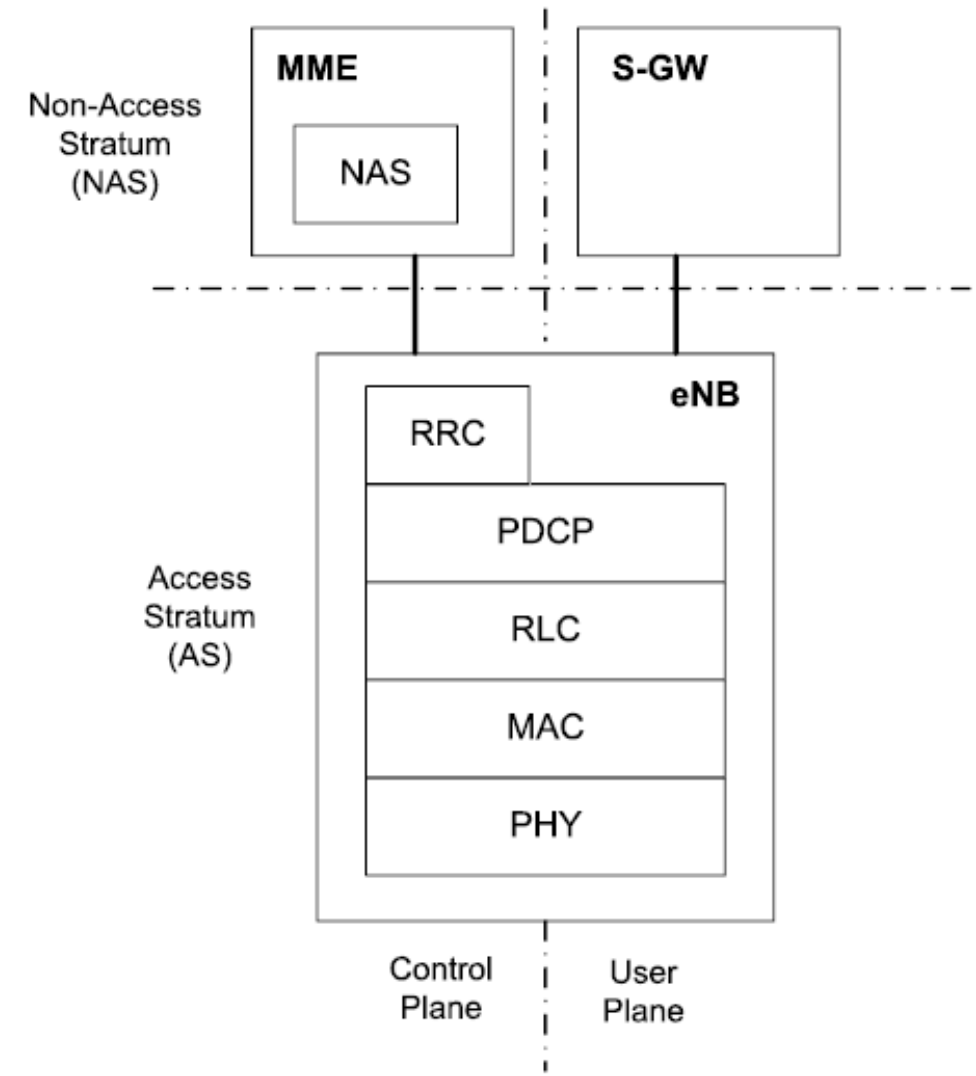
Arquitetura LTE



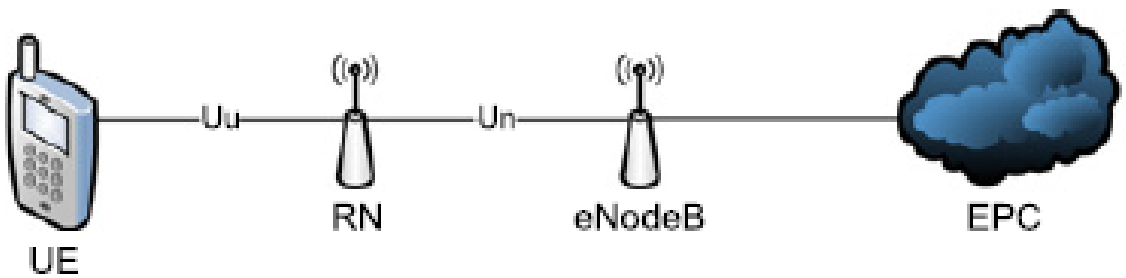
Arquitetura LTE-advanced

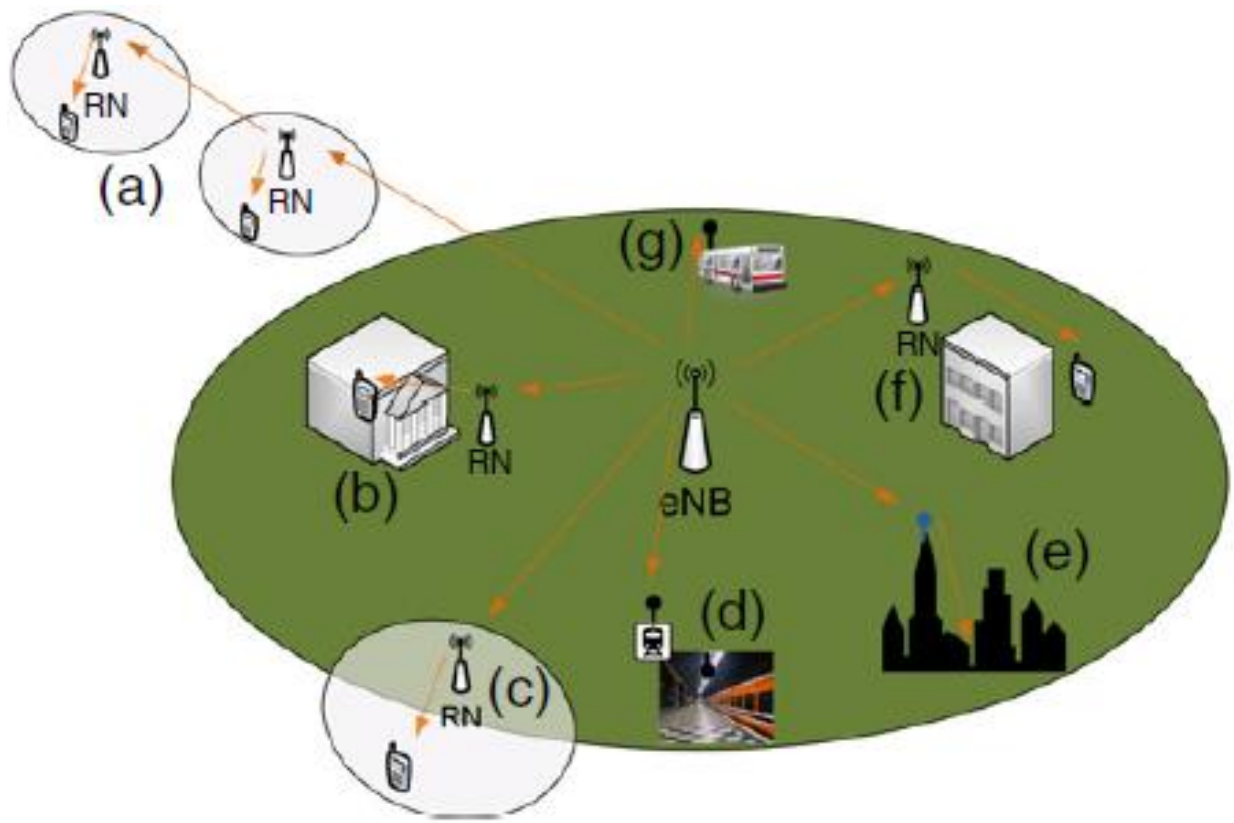


Camada de protocolos



Relays

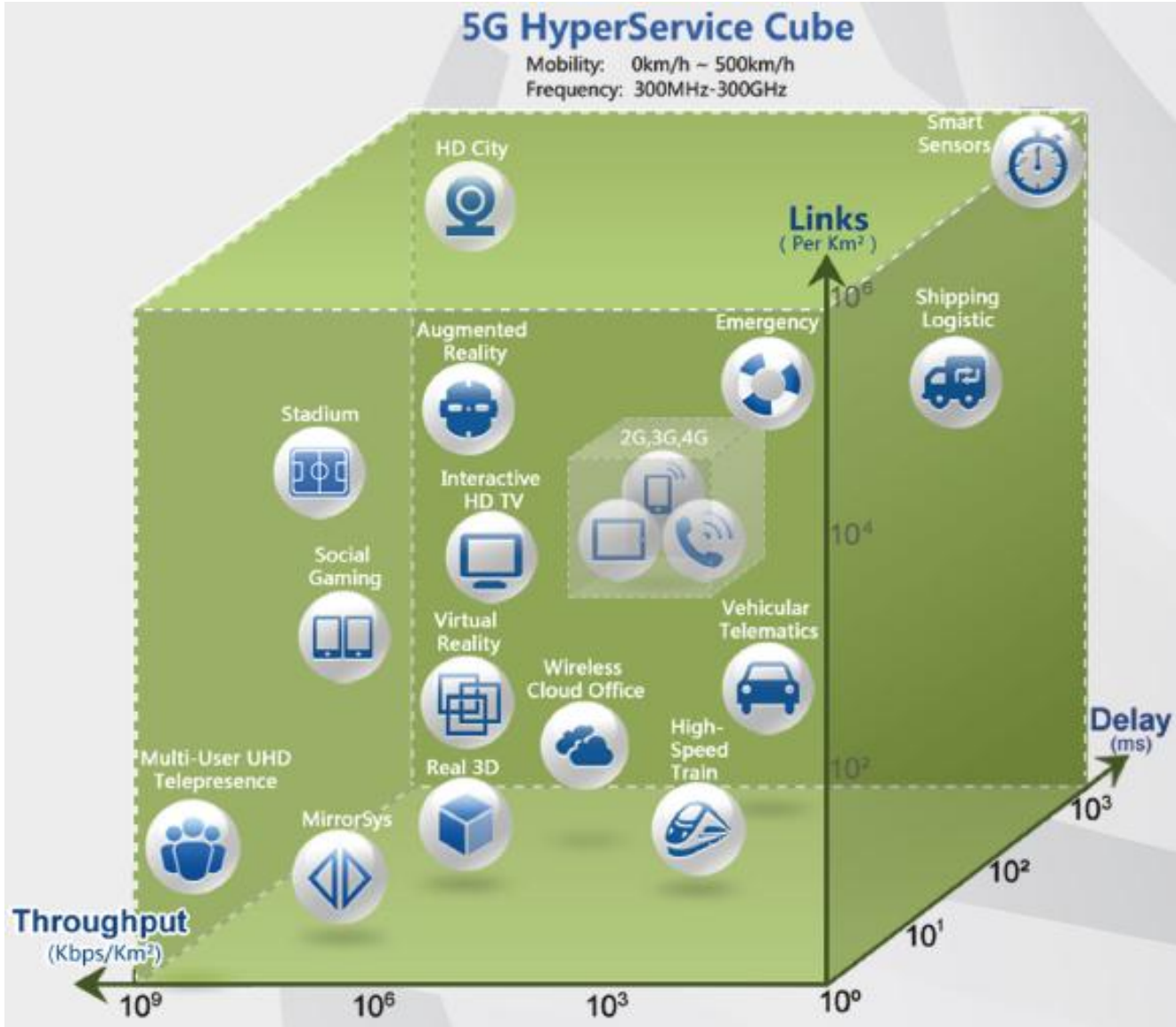




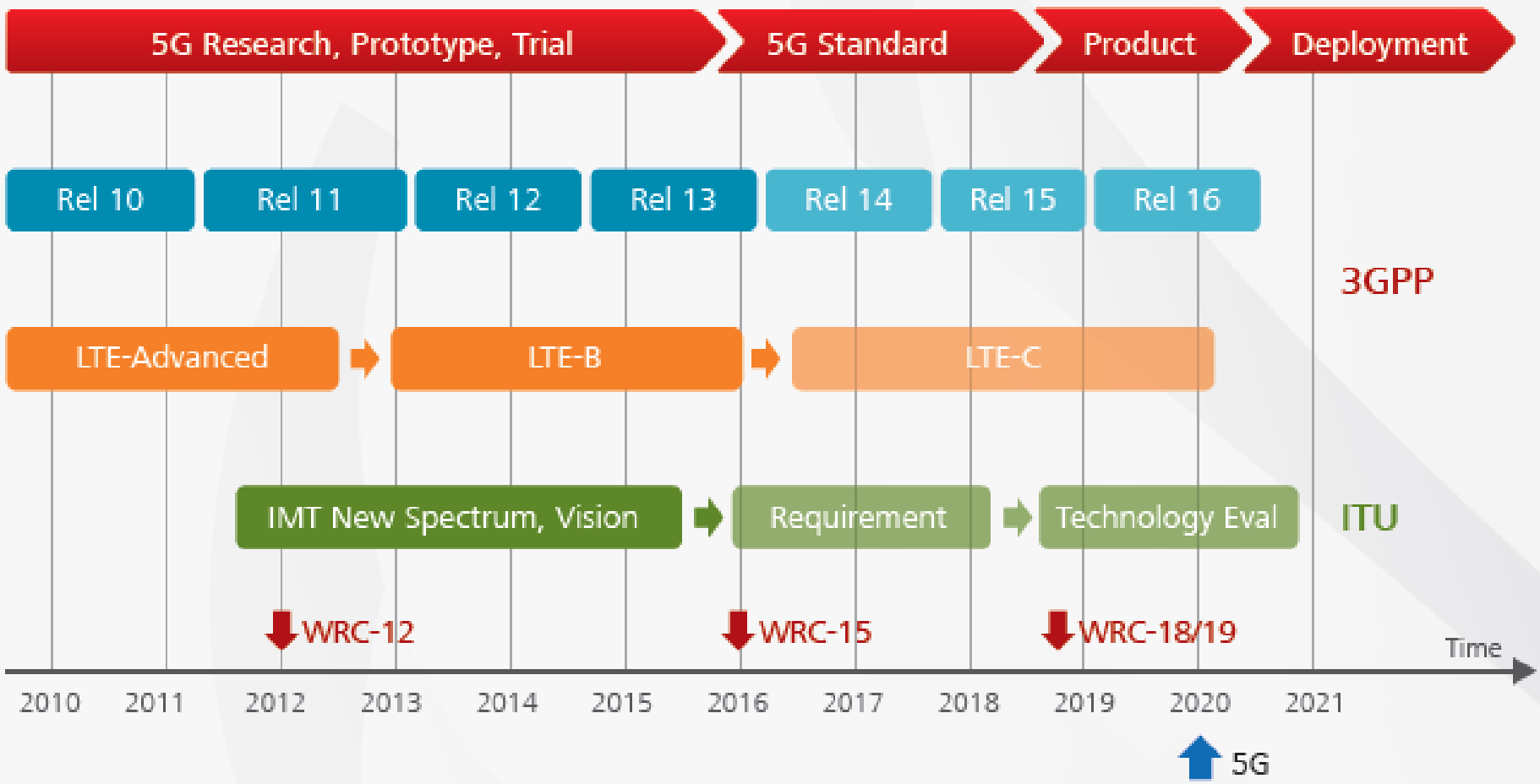
Futuro

- LTE
- Convergência
- 5G
  - 100 bilhões de dispositivos
  - +10 Gbps
  - Novas tecnologias de acesso de rádio e evolução da atuais
  - A partir de 2020?

5G – Requisitos de serviços e cenários




50 Gb/s
Macro
100 Gb/s
Micro
80 Gb/s
E-Band Link
100 Tb/s
Tera-Cell
10 Gb/s
Device
100 Billion Things
300MHz
3GHz
30GHz
300GHz
5G All-spectrum access RAN



5G roadmap and timeline