

CS 621

Mobile Computing

<https://www.qualcomm.com/media/documents/files/the-evolution-of-mobile-technologies-1g-to-2g-to-3g-to-4g-lte.pdf>

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The Evolution of Mobile Technologies:

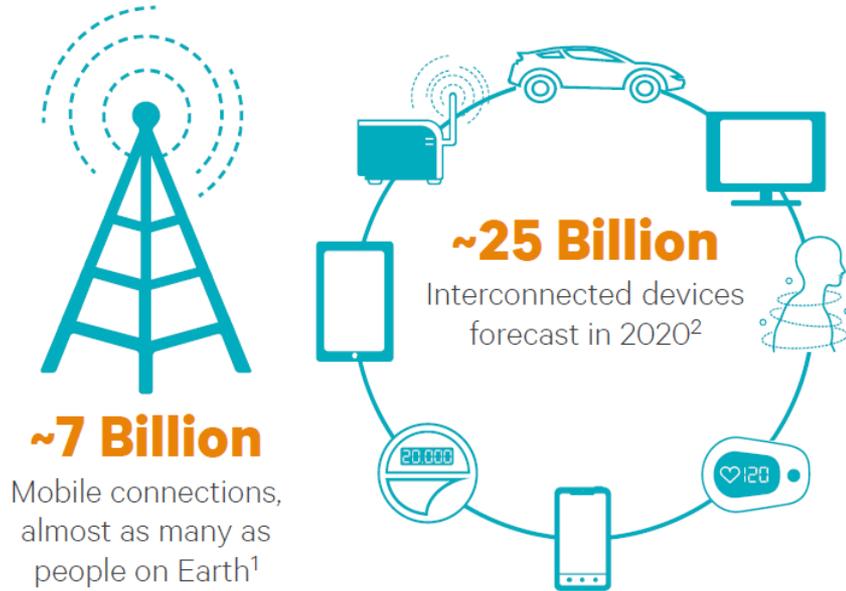
1G ⇔ 2G ⇔ 3G ⇔ 4G LTE

QUALCOMM®

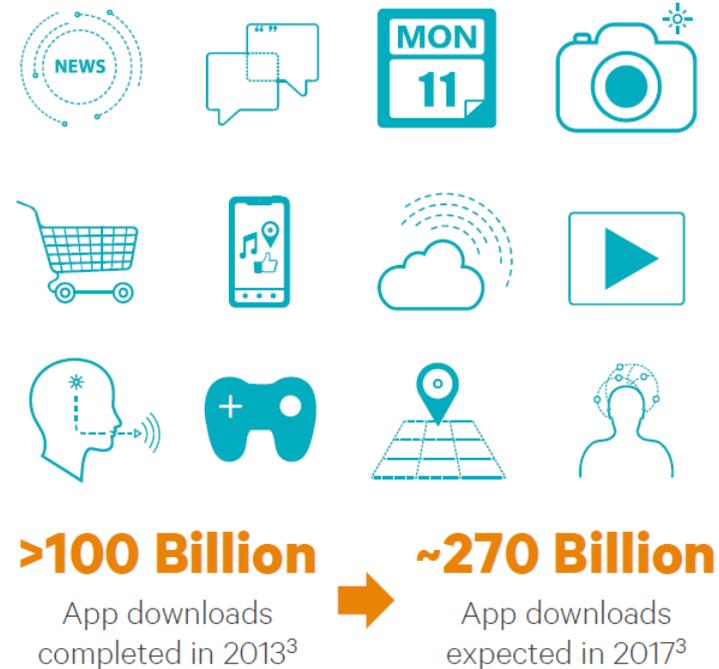


The mobile experience is expanding everywhere

Billions of Mobile Connections



Billions of Mobile Experiences



Mobile is an amazing technical achievement



Mind-blowing Performance

with processing power greater than the most advanced super computers of the early 1990s¹



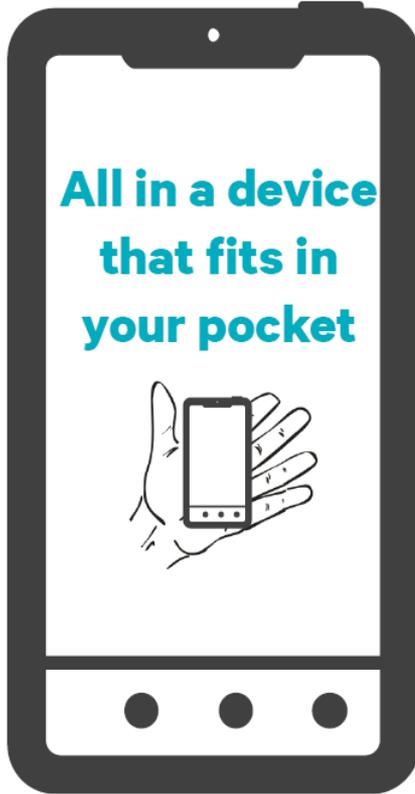
Jaw-dropping Graphics

with capability to process several thousand megapixels per second²



High Quality Multimedia²

4K UltraHD video player/recorder
HD gaming console
5.1/7.1 surround sound system
High resolution digital camera



Reliable Connectivity

overcoming signal loss resulting in receiving signal 100 trillion times weaker than when it originated³



Broadband Speeds

with blazing fast data rates capable of 300+ Mbps⁴



Long Battery Life

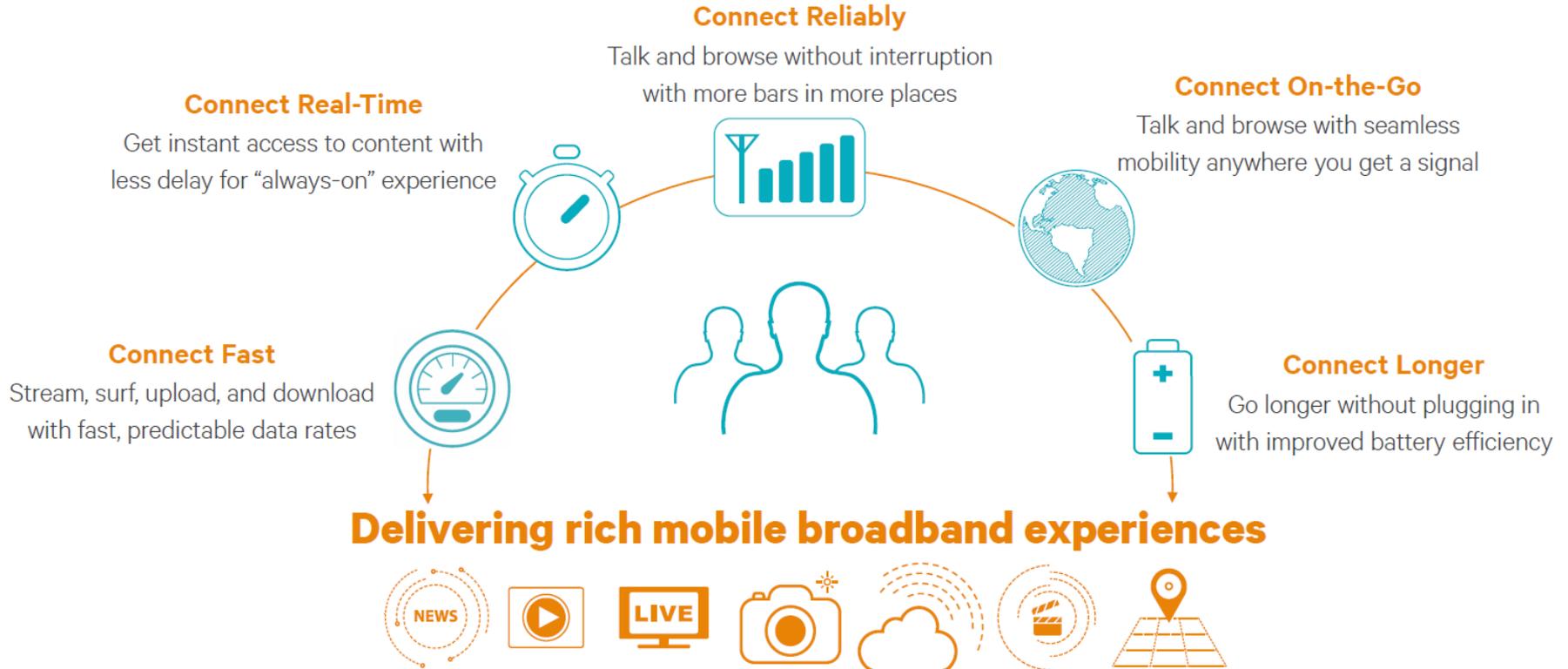
with ability to power all these amazing experiences with less energy than it takes to power a light bulb for 15 minutes⁵



¹ Source: Charlie White, Sep. '13 & giffgaff.com, Sep'13; ² Based on latest Qualcomm® Snapdragon™ 800 series processors; ³ Based on >140 dB path loss typical in mobile;

⁴ Based on peak data rates for LTE Advanced; ⁵ Based on >2,000 mAh smartphone battery and >60W light-bulb

Connectivity is the foundation of a great mobile experience



Powered by evolving mobile technologies for better experiences

Mobile 1G

AMPS, NMT, TACS



Mobile 2G

D-AMPS, GSM/GPRS,
cdmaOne



Mobile 3G

CDMA2000/EV-DO,
WCDMA/HSPA+, TD-SCDMA



Mobile 4G LTE

LTE, LTE Advanced



N/A

Analog Voice



<0.5 Mbps¹

Digital Voice + Simple Data



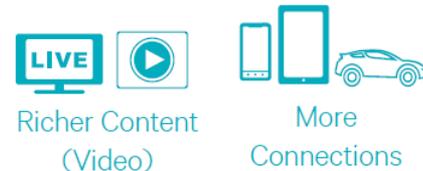
63+ Mbps²

Mobile Broadband



300+ Mbps³

Faster and Better



Evolving mobile technologies deliver great mobile experiences

Appreciating the magic of mobile requires understanding the evolution from 1G to 4G LTE

1



1G established seamless mobile connectivity introducing mobile voice services

2



2G digital wireless technologies increased voice capacity delivering mobile to the masses

3



3G optimized mobile for data enabling mobile broadband services, and is evolving for faster and better connectivity

4



4G LTE delivers more capacity for faster and better mobile broadband experiences, and is also expanding in to new frontiers

Mobile 1G established the foundation of mobile

1

Licensed Spectrum

Cleared spectrum for exclusive use by mobile technologies

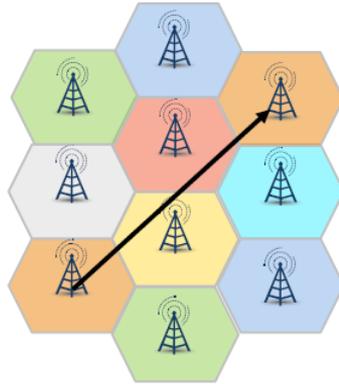


Operator-deployed **base stations** provide access for subscribers

2

Frequency Reuse

Reusing frequencies without interference through geographical separation

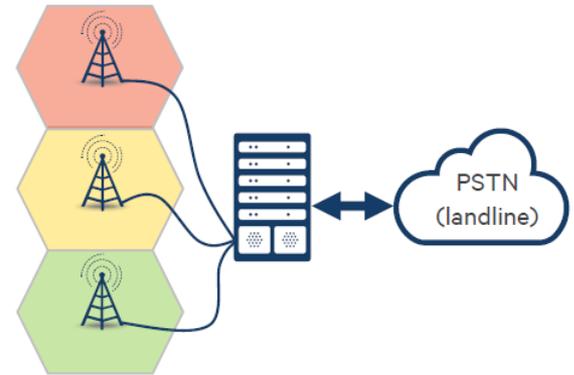


Neighboring **cells** operate on different frequencies to avoid interference

3

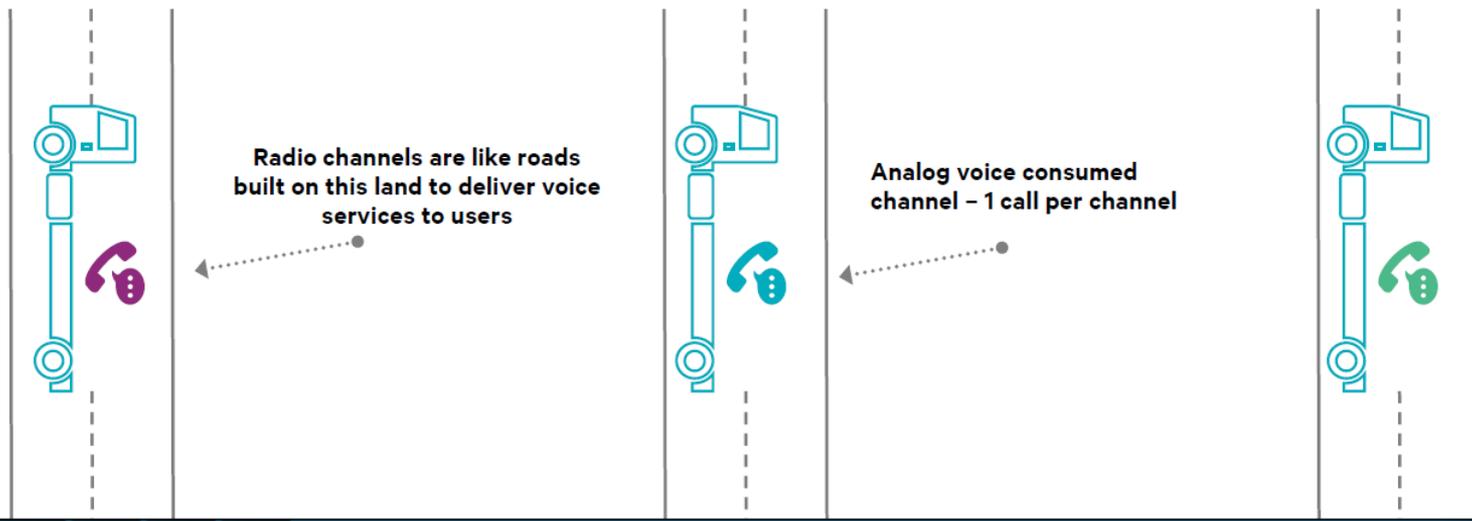
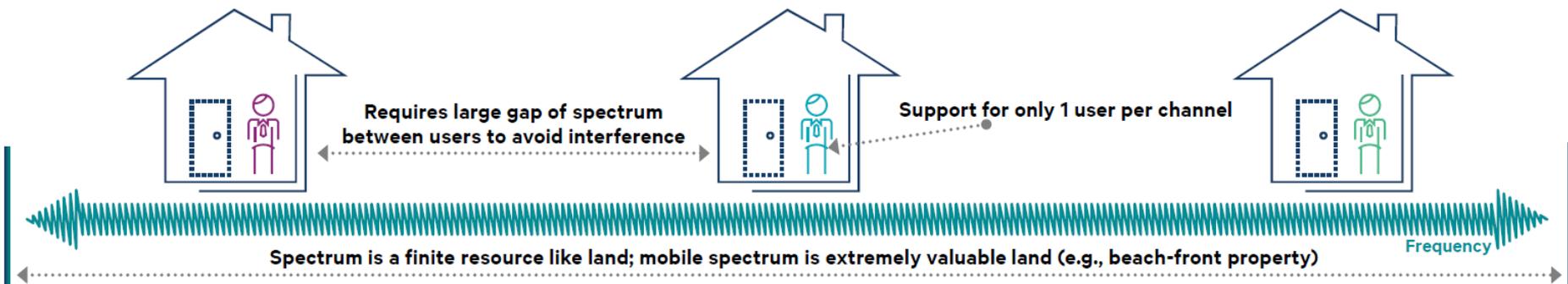
Mobile Network

Coordinated network for seamless access and seamless mobility



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

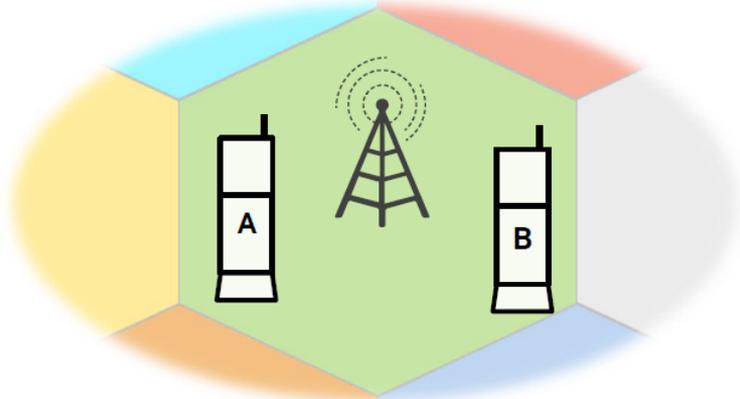
Mobile 1G was amazing, but limited



1G analog voice was amazing, but limited

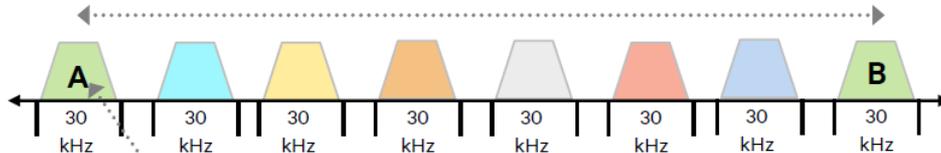
Limited Capacity

Analog transmissions are inefficient at using limited spectrum



Frequency Division Multiple Access (FDMA)*

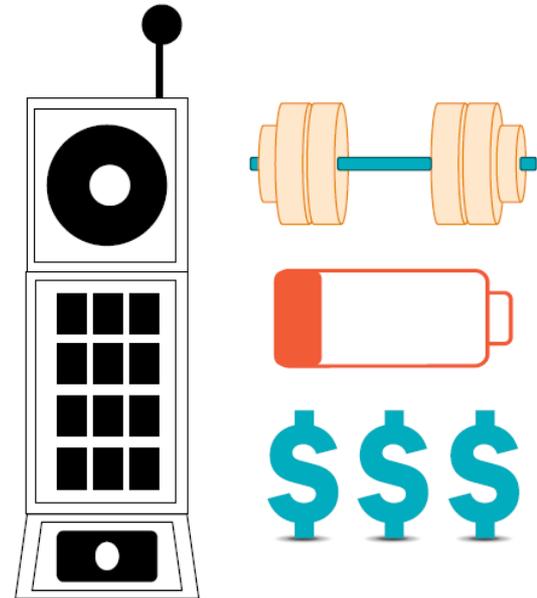
Large frequency gap required between users to avoid interference



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

Limited Scalability

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



* Example shown based on AMPS 1G technology

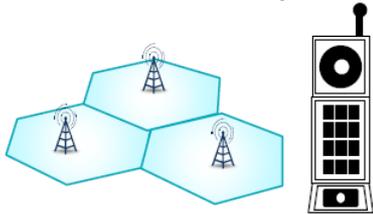
Mobile 2G digital technologies increased voice capacity

Delivering mobile voice services to the masses – more people, in more places

Mobile 1G

AMPS, NMT, TACS

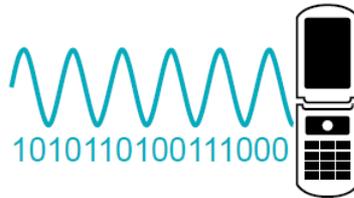
Foundation of Mobile
Seamless Mobility



Mobile 2G

D-AMPS, GSM/GPRS,
cdmaOne

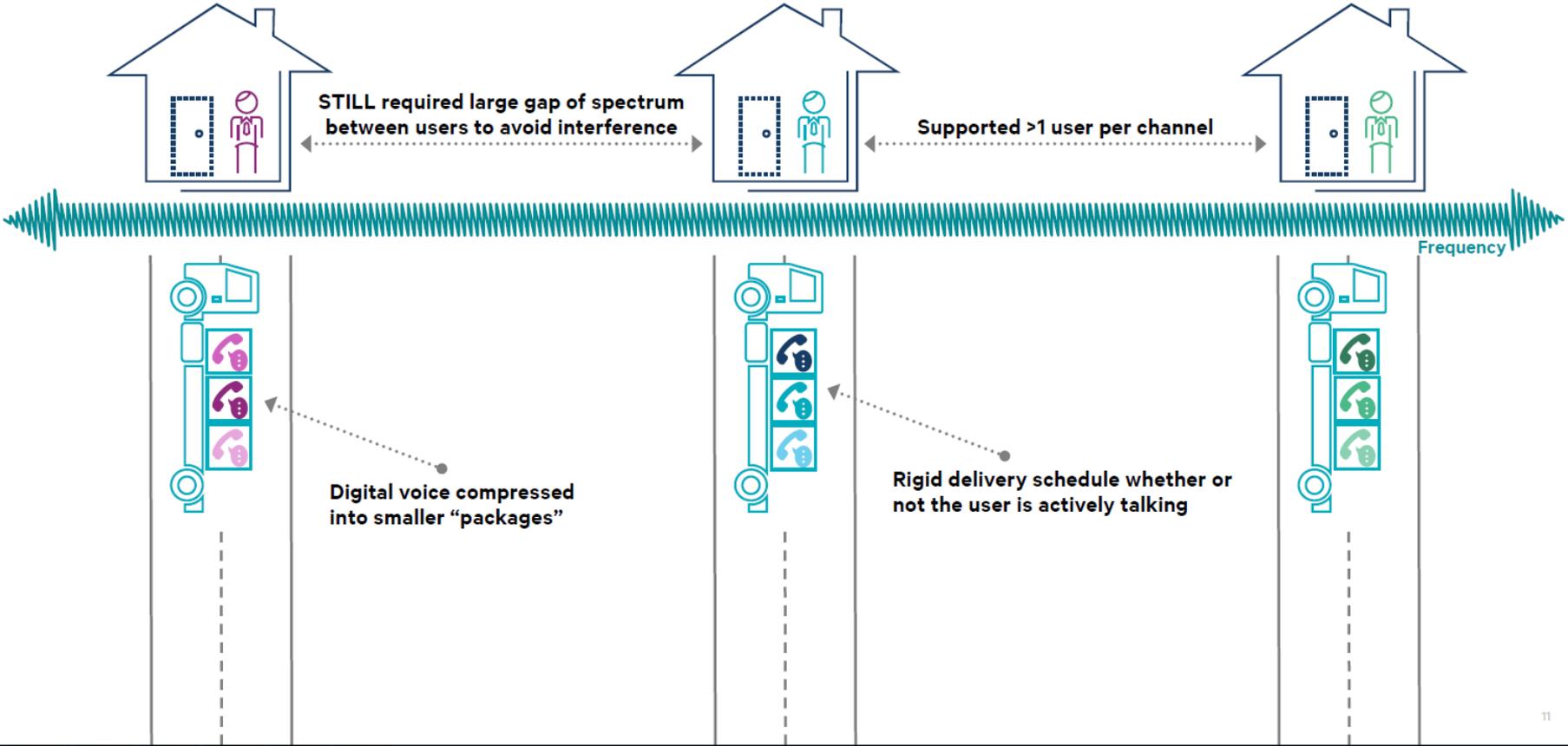
Mobile for the Masses
More Voice Capacity



1980s

1990s

Early Mobile 2G technologies enabled more users per channel

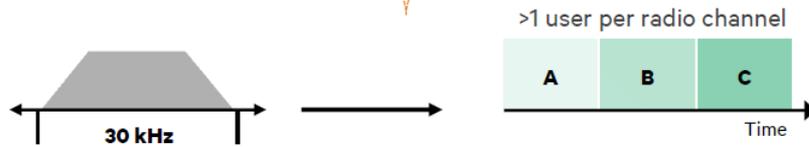
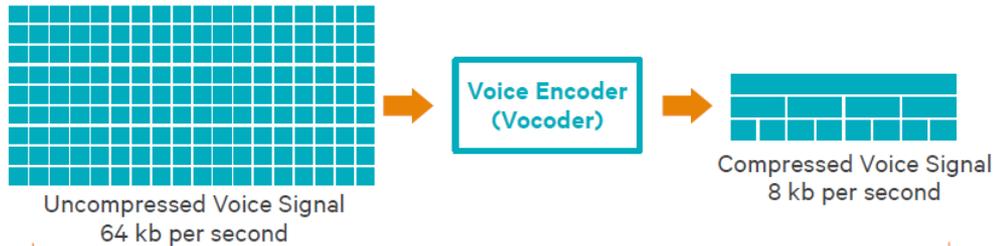


Mobile 2G digital wireless technologies enabled more users

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

More Voice Capacity

Digital transmissions enable compressed voice and multiplexing multiple users per channel

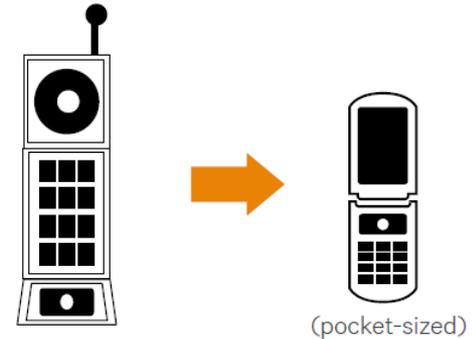


Time Division Multiple Access (TDMA)

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

Scalable Technology

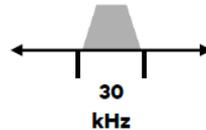
Digital components cost/weight far less plus deliver more secure signal



Different Mobile 2G TDMA techniques were standardized

Mobile 1G (Analog)

AMPS, NMT, TACS



Only one user per radio channel



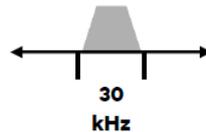
Mobile 2G (Digital)

D-AMPS

Standardized as IS-54 by TIA in 1992

Mainly in North America

No longer utilized



Three users per radio channel



Mobile 2G (Digital)

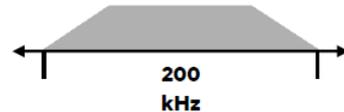
GSM

Standardized by ETSI in 1990 (phase 1)

Initiated in Europe

Still widely used today (>4B connections WW¹)

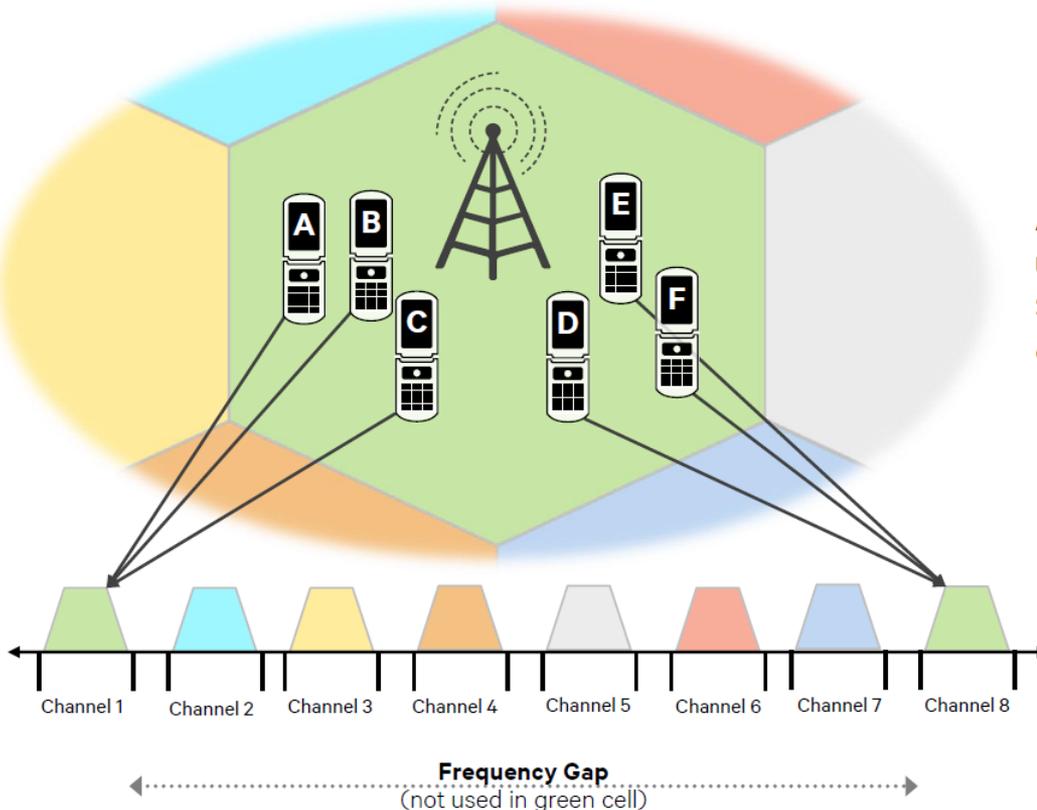
Simple data services with GPRS



Eight users per radio channel



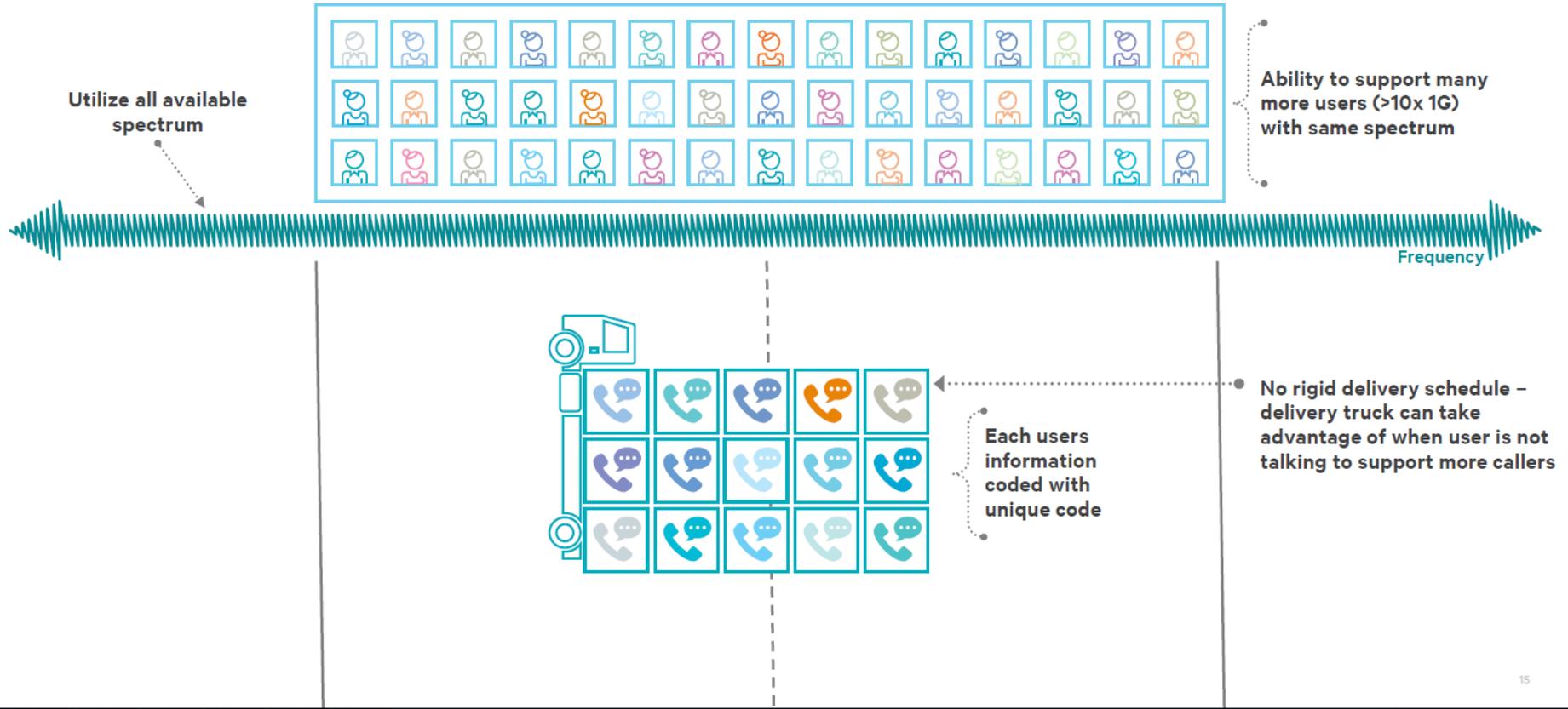
TDMA still required large frequency gaps to reduce interference



Also required potentially unreliable “hard” handoffs

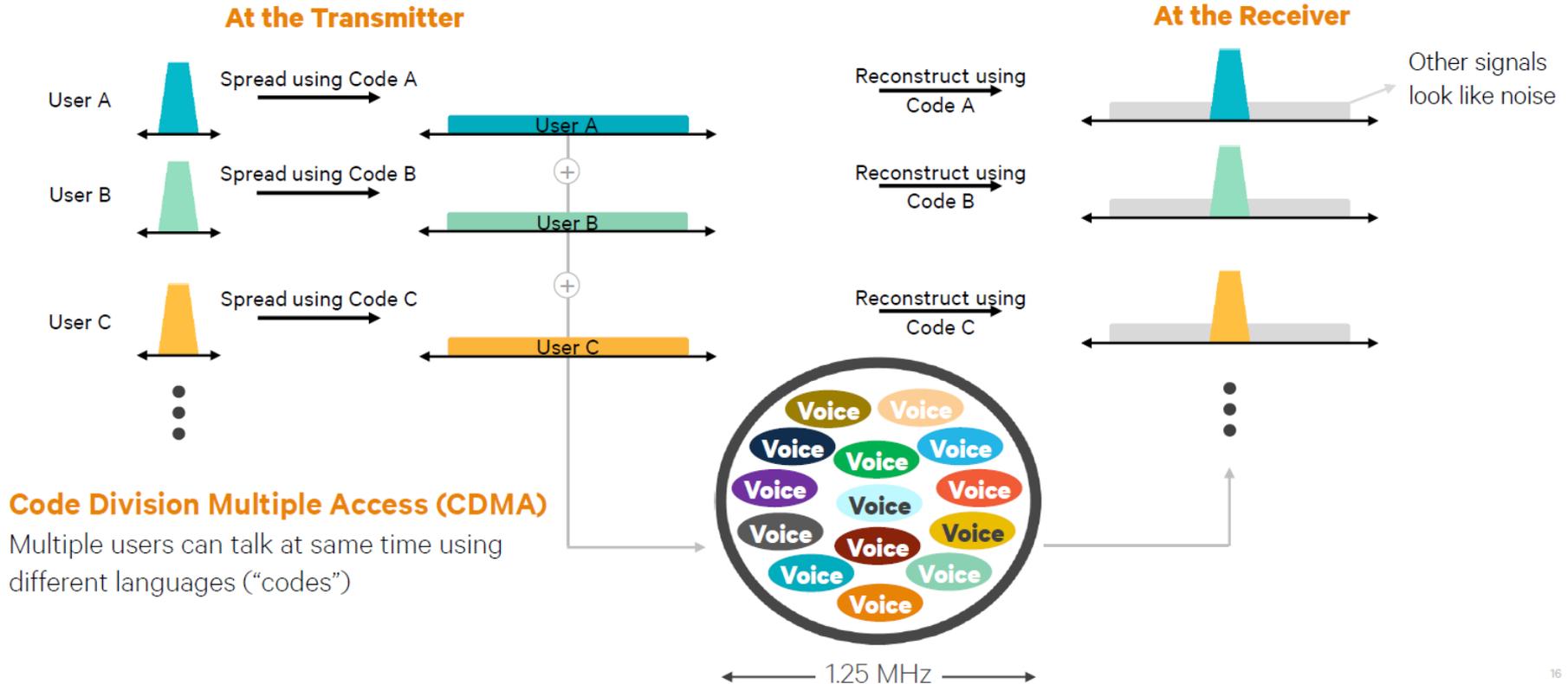
Switch channels between adjacent cells – potential for dropped calls

CDMA utilizes all the available spectrum to support more users



Qualcomm solved the seemingly impossible wireless challenge

CDMA enables users to share the same frequency and communicate at the same time



Qualcomm solved complex challenges to commercialize CDMA

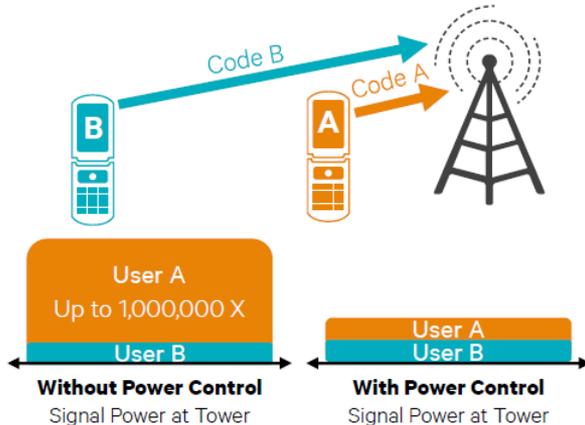
1

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



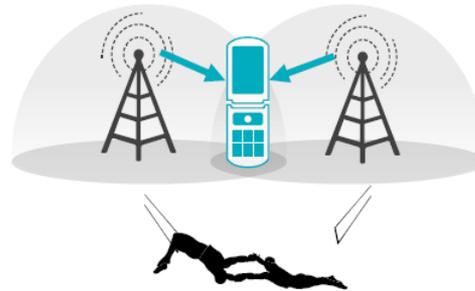
2

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

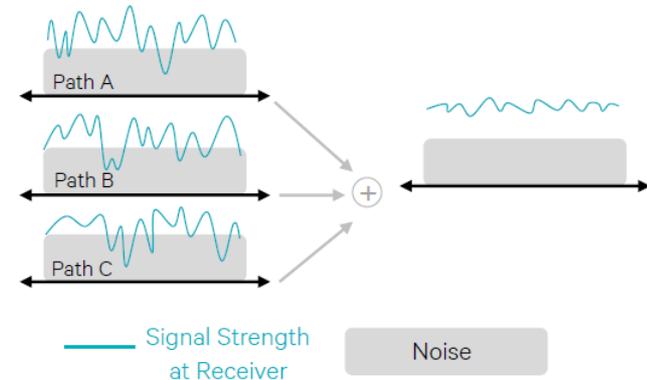
3

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

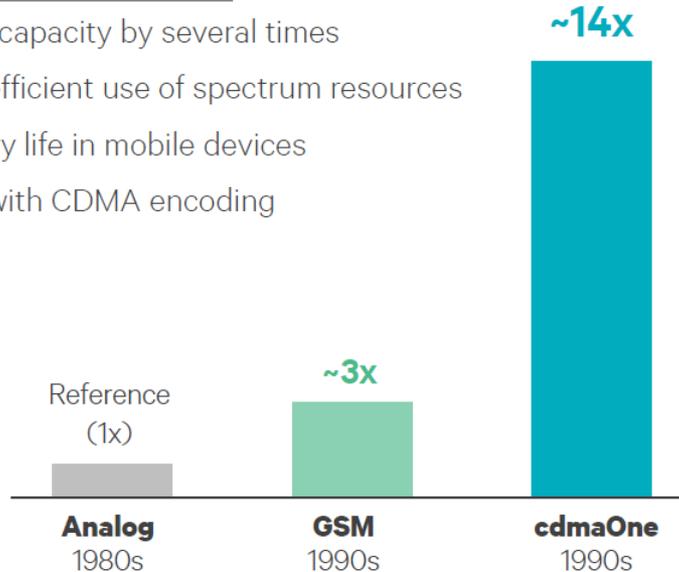


CDMA delivered unprecedented voice capacity and much more

Qualcomm efforts lead to new CDMA standard (IS-95) referred to as cdmaOne

CDMA Benefits

- Increased voice capacity by several times
- Provided more efficient use of spectrum resources
- Increased battery life in mobile devices
- Better security with CDMA encoding



Potential Voice Capacity Improvements¹

CDMA Timeline²

February 1990

First CDMA field trial completed by Qualcomm and NYNEX

March 1992

Standards committee formed in Telecommunications Industry Association

May 1995

IS-95 revision A (cdmaOne) released

December 1995

First commercial deployment

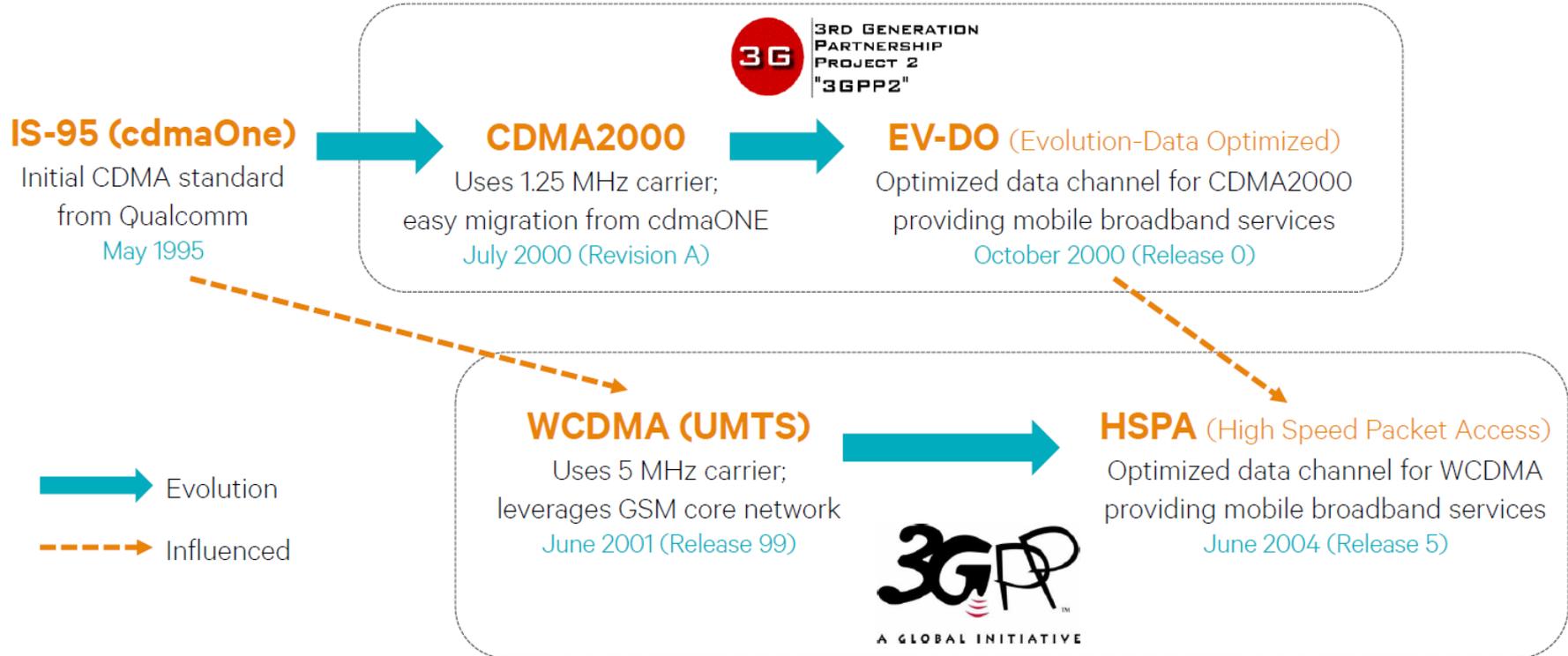
December 1999

cdmaOne subscribers pass 50 million worldwide (>80 operators in >30 countries)

CDMA is the foundation for Mobile 3G technologies

CDMA established the foundation for 3G technologies

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



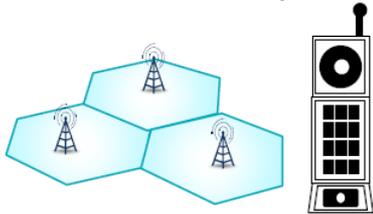
Mobile 3G evolved mobile for data

Introducing high-speed internet access for the first time

Mobile 1G

AMPS, NMT, TACS

Foundation of Mobile
Seamless Mobility

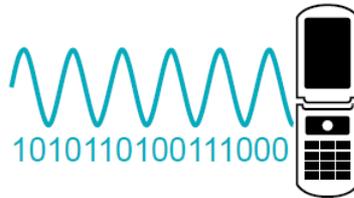


1980s

Mobile 2G

D-AMPS, GSM/GPRS,
cdmaOne

Mobile for the Masses
More Voice Capacity



1990s

Mobile 3G

CDMA2000/EV-DO,
WCDMA/HSPA+, TD-SCDMA

Mobile Broadband
Data Optimized



2000s

Mobile voice was amazing, but consumers wanted more

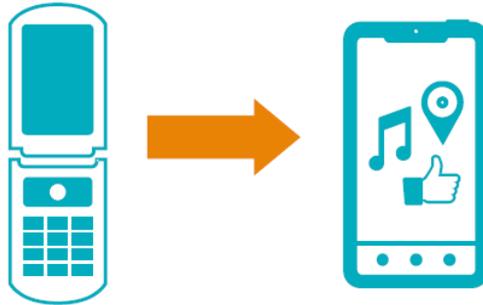
A new, insatiable demand for internet access and data services emerges

Broadband Internet



Consumers introduced to broadband internet access in the home/office

The Smartphone



Amazing innovations in device technology resulted in the era of the smartphone

Mobile Everywhere

2 → **39** → **92**
1990 2000 2010

Average mobile subscriptions per 100 people¹

Thanks to 2G technologies, more and more people had a mobile subscription

¹Source: Worldbank.org for United States

- To be continued in next class...

THANKS!