mmWave Technology Evolution From WiGig to 5G Small Cells

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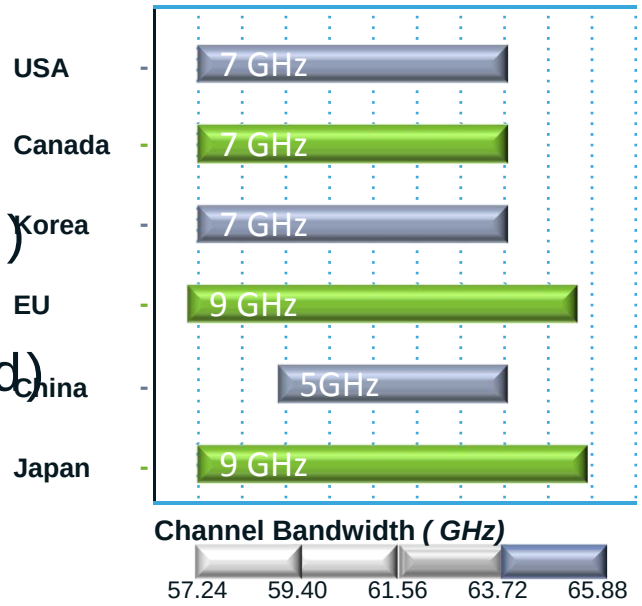
Wireless Connectivity in Our Lives

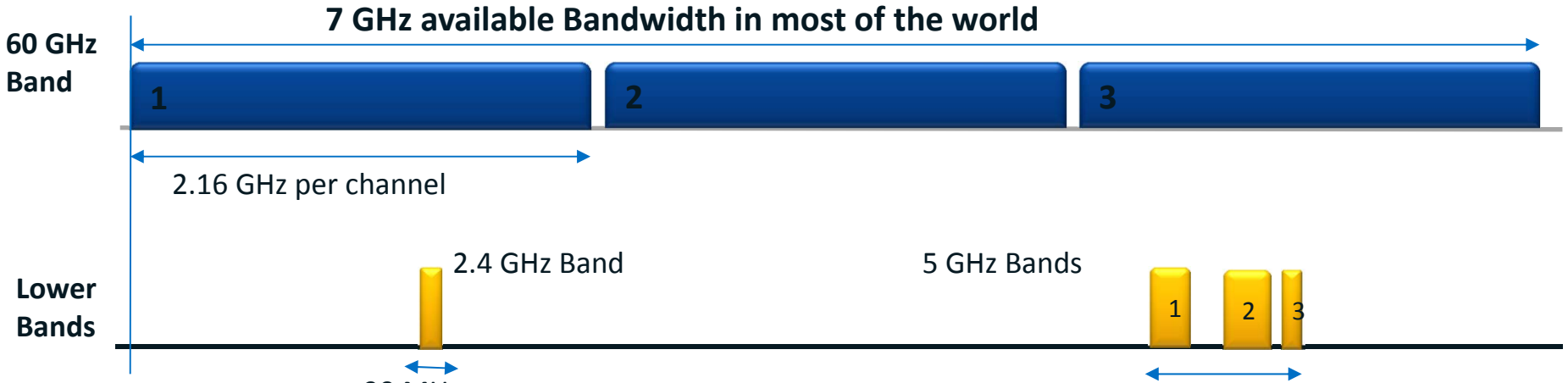
What Do We Have in Common?

- Smaller Form Factor!
- Limited Connectors!
- Limited Data Storage!
- Larger Media Contents!
- Fast Upload / Download!
- Always Connected!

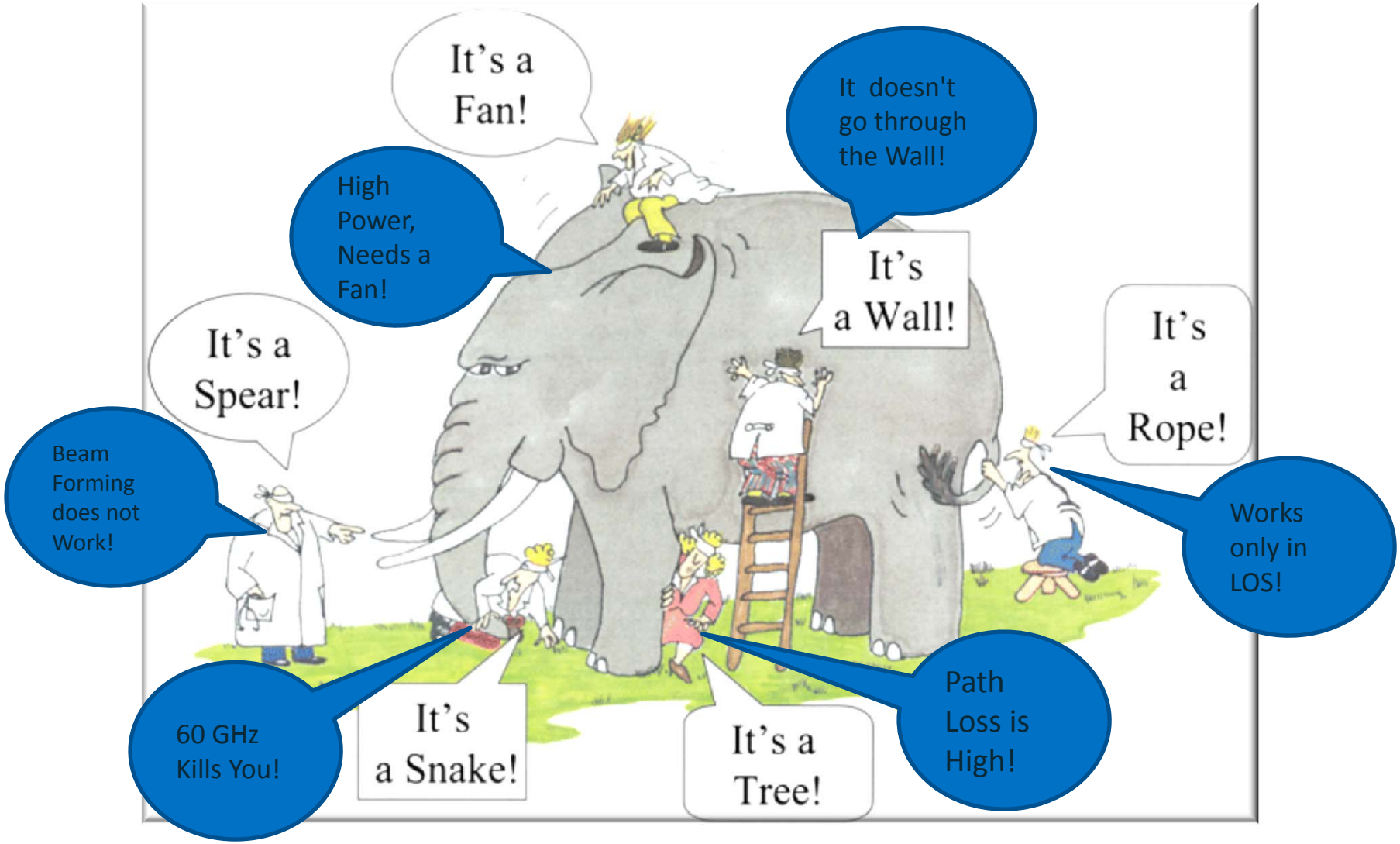
Available Unlicensed Frequency Bands

- The 60GHz band offers 5 – 9 GHz of unlicensed bandwidth across most Geographies.
  - 2.16GHz Bandwidth per channel
- Compared with:
  - ~90 MHz in ISM band (2.4GHz band)
    - 20Mhz – 40MHz per channel
  - ~500 MHz in UNII band (5 GHz band)
    - 20Mhz – 160MHz per channel





mmWave Challenges



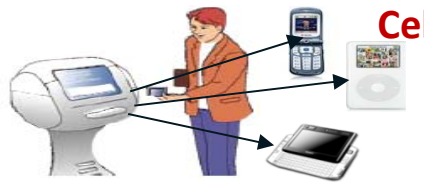
mmWave Challenges

WiGig Usage Models

Instant Wireless Sync
- IP based P2P applications
- Wireless I/O
- Media HotSpot

Peer to peer

Kiosk Sync & Nano small Cell



Wireless Display
-HD streams over HDMI or DP
-CE & PC & HH usages
-Hulu, IPTV, YouTube

Wireless Display

Wireless Docking
- Combination of Wireless display, sync and I/O

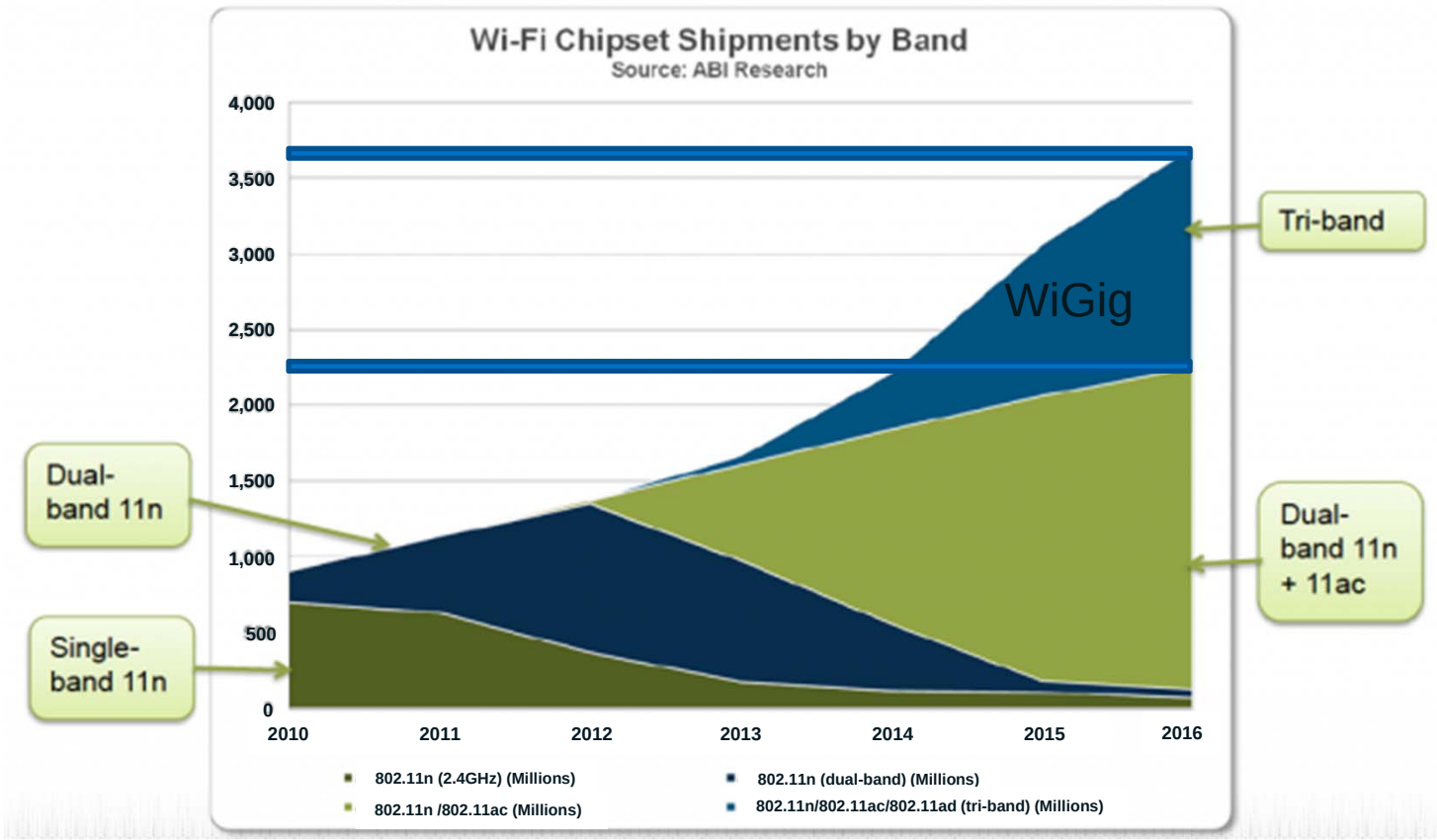
Cordless IO

Distributed peripherals

Access
- WiFi, IEEE TGad
- 3G/4G, Offload
- Small Cell Access & Backhaul

Access, Offload, Backhaul

ABI Projection for WiGig Market



WiGig enabled chipsets will be over a BILLION units; almost 40% of all multiband chipset

WiGig Alliance Members

Board of Directors

AMD
Broadcom — Connecting everything
Cisco
Huawei
Intel
Marvell
MediaTek
Microsoft
NEC
Panasonic
Qualcomm Atheros
Samsung
Toshiba
Wilocity — truly wireless

Contributors

Agilent Technologies
Alereon
Allegro — Digital Video Technology
Beam Networks
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Hittite Microwave Corporation
A*STAR — Institute for Infocomm Research
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NXP — founded by Philips
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SRTC — The State Radio_monitoring_center Testing Center 国家无线电监测中心检测中心
ST
Texas Instruments
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TÜVRheinland® — Precisely Right.
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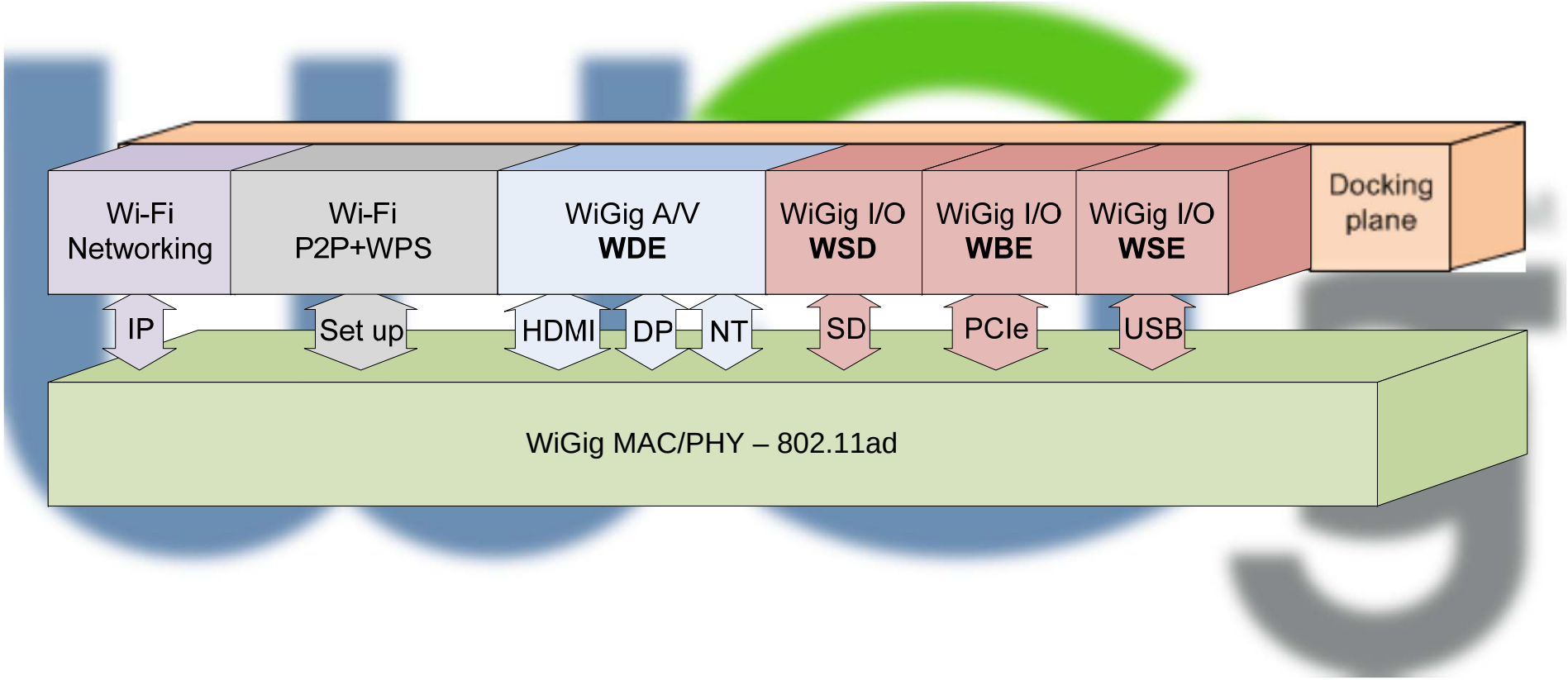
What is WiGig?



WiGig System Attributes

MAC
- Compatible with legacy 802.11
- Includes new PBSS mode (point to point)
- Includes new channel access (TDMA)

PHY
- Includes Single Carrier rates up to 4.62Gbps
- Includes OFDM rates up to 6.756Gbps

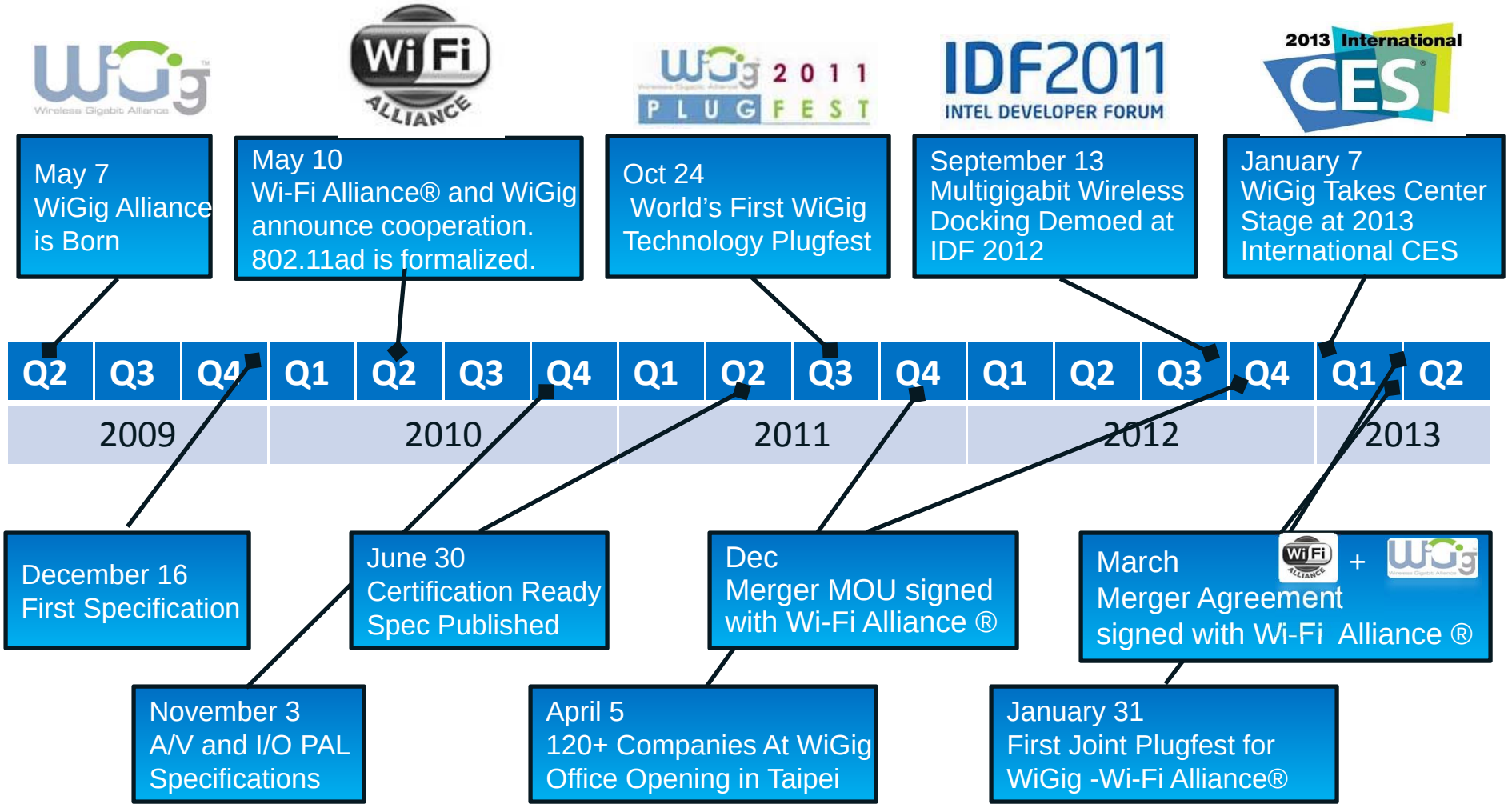
PAL
- WiGig Serial Extension(WSE) , USB payload over WiGig link
- WiGig Bus Extension(WBE), PCIe over WiGig link
- WiGig SDIO Extension(WSD), SDIO payload over WiGig link
- WiGig Display Extention(WDE), HDMI and DP over WiGig link

Industry Support
- Royalty free 60GHz standard with wide industry support
- IEEE 802.11ad publication by EOY 2012

Interoperability
- Wi-Fi certified, Merged with WiFi Alliance

Regulatory
- Harmonized around the world
- ITU-R recommended

WiGig: Evolution of a mmWave Technology



WGA Merging with WFA

- Prevent ecosystem fragmentation, duplication and thus accelerate development & adoption
- Prevent confusion by delivering a high-impact integrated branding & communication
- Leverage existing brand recognition of WFA for MAC/PHY cert, USB for WSE cert and VESA for WDE cert
- Make efficient use of resources (people, travel, fees, certification, etc.)

WiGig Usage Models

Instant wireless sync
- IP based P2P applications
- Wireless I/O
- Media HotSpot

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Access
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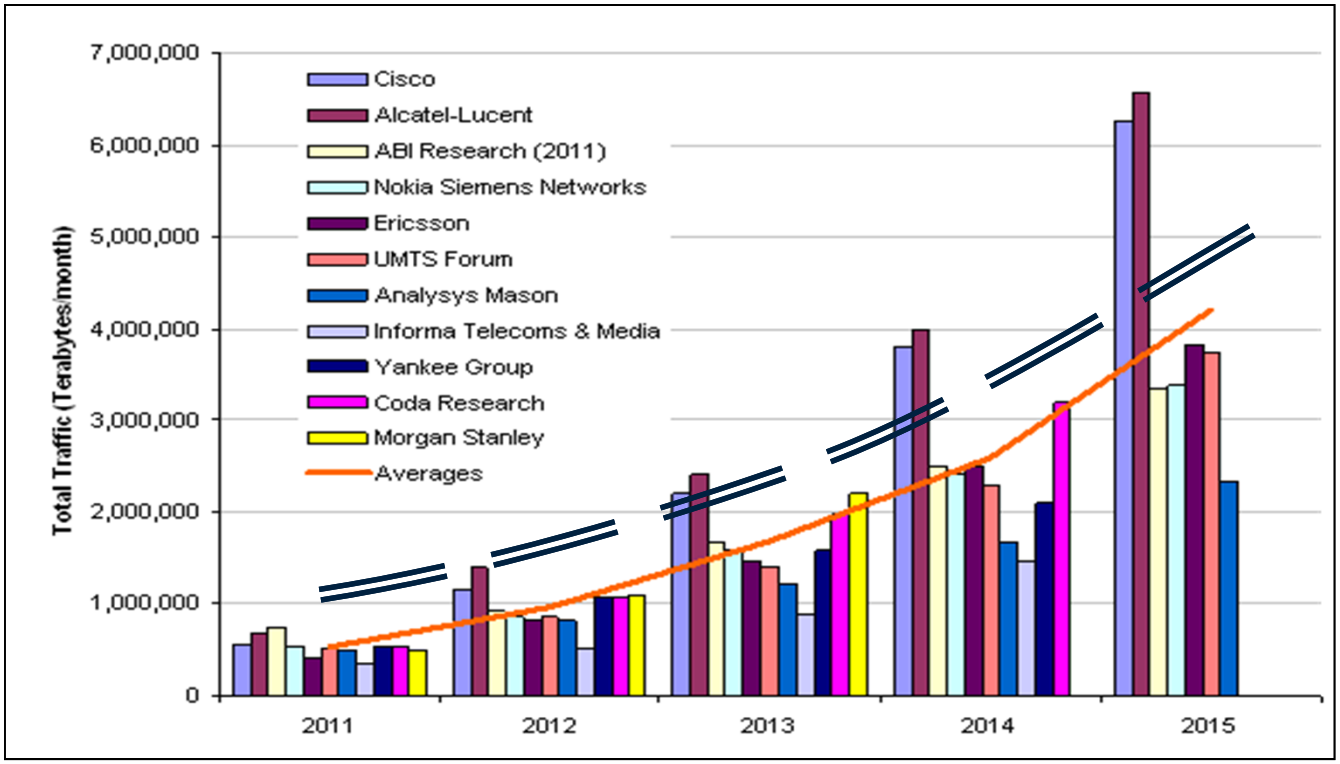
- Small Cell Access & Backhaul

Exponentially Increasing Capacity

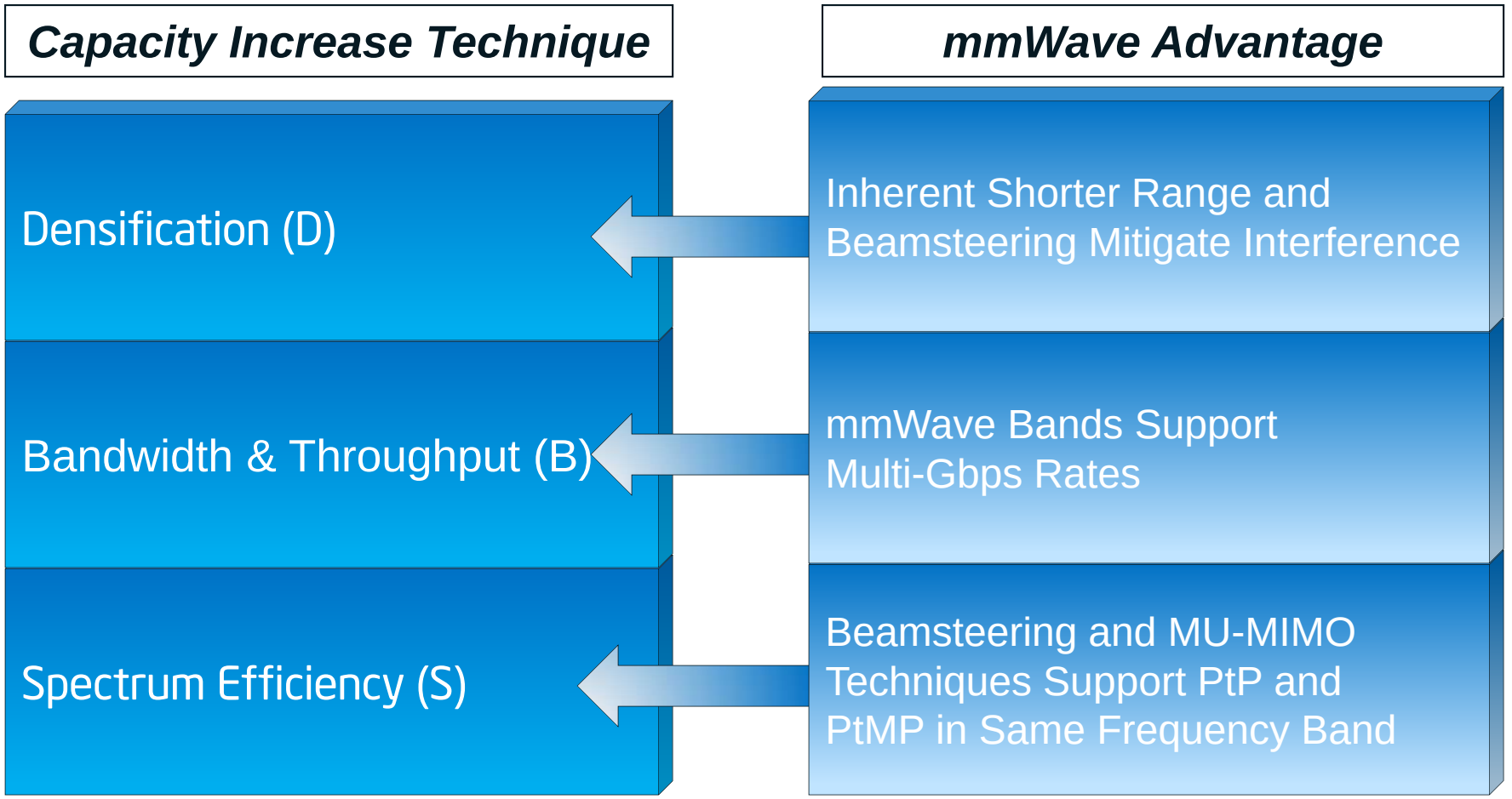
•Multi-company forecast of rapid growth of total traffic[1]:



•By 2016: Over 10B connected devices and
Global mobile data traffic will reach 10.8 exabytes/month. [2]

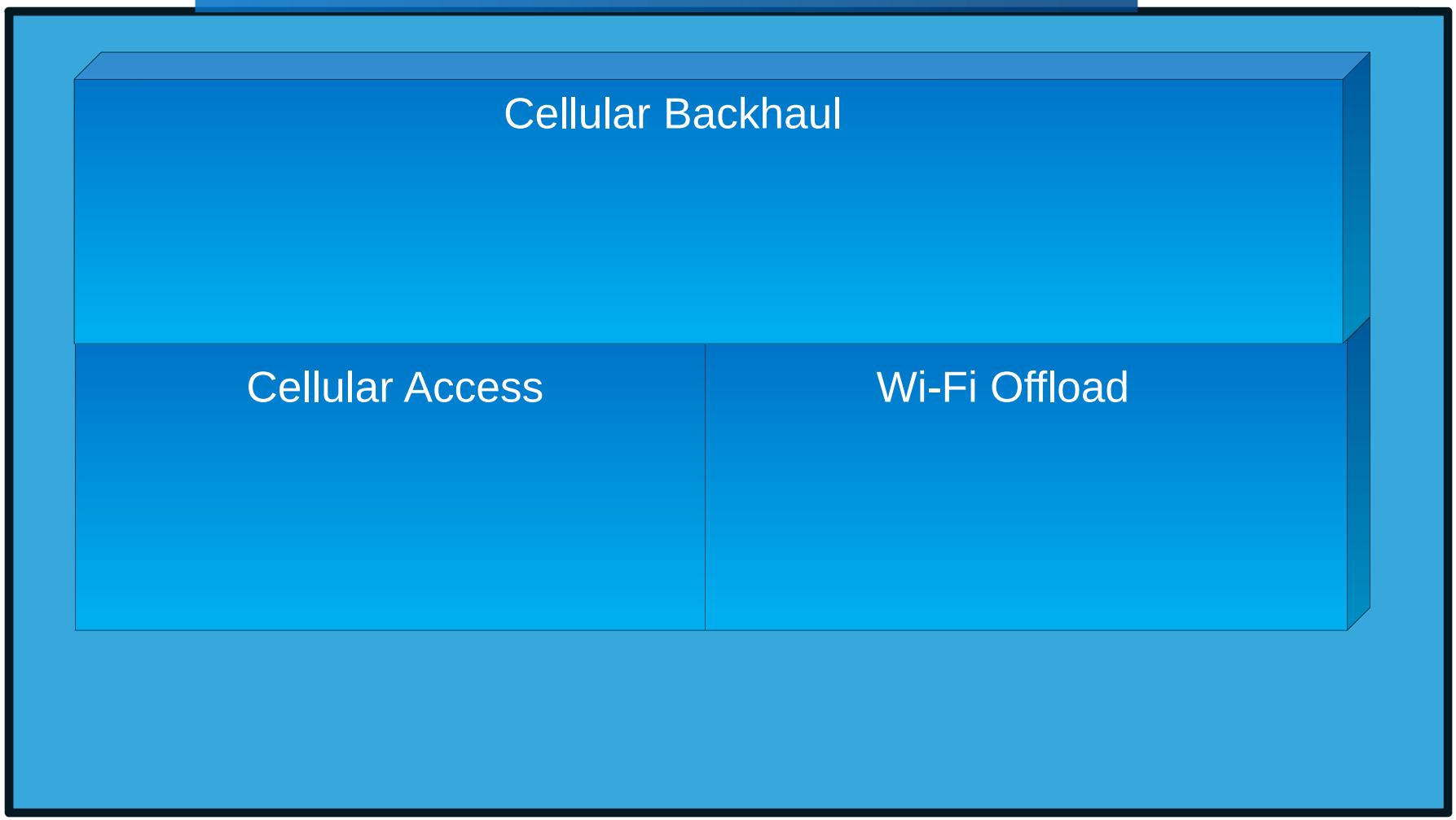
1. ITU-R Report M.2243:
2. Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2011–2016

mmWave Advantage

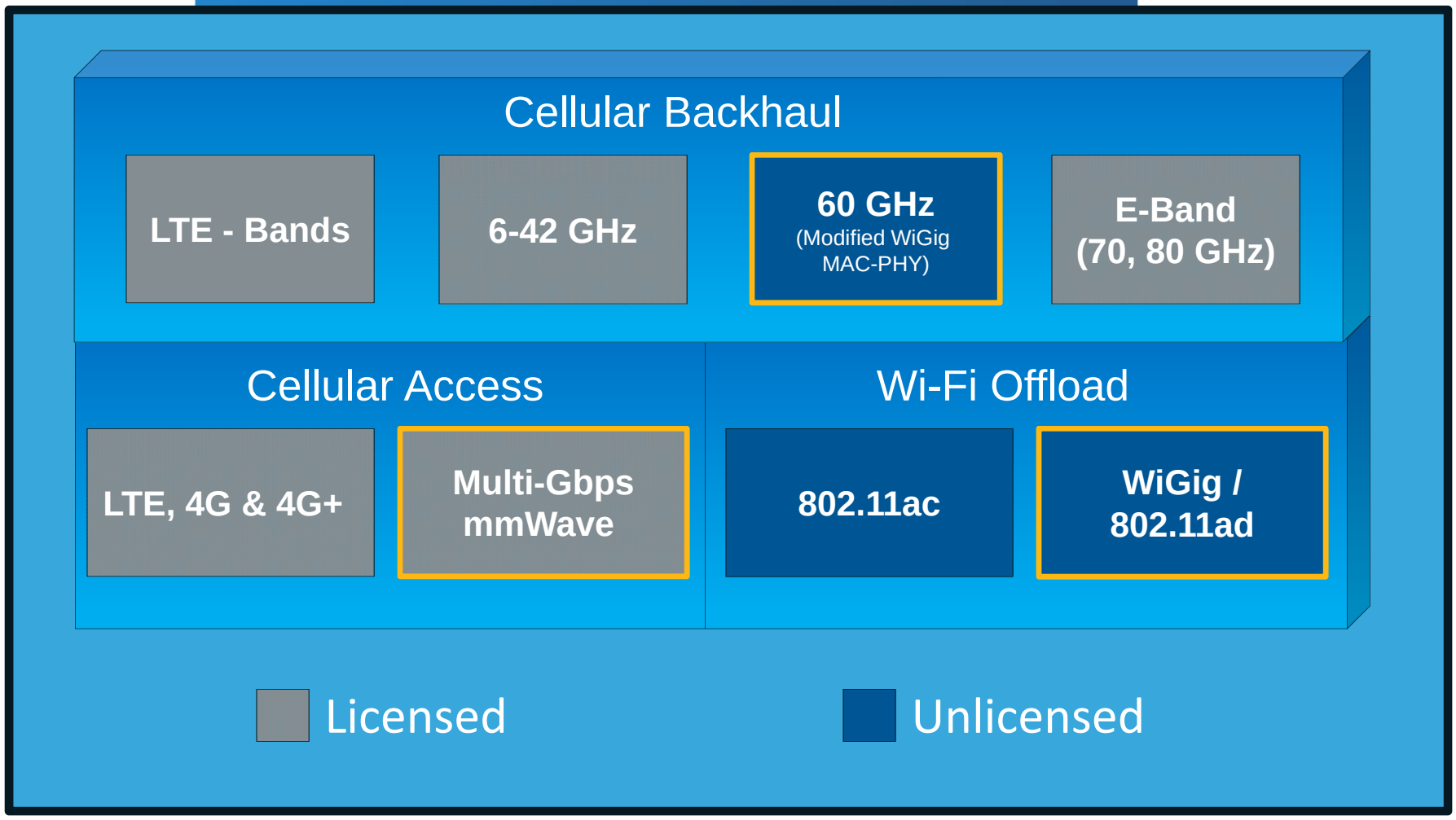


Capacity Increase = D x B x S > 1000

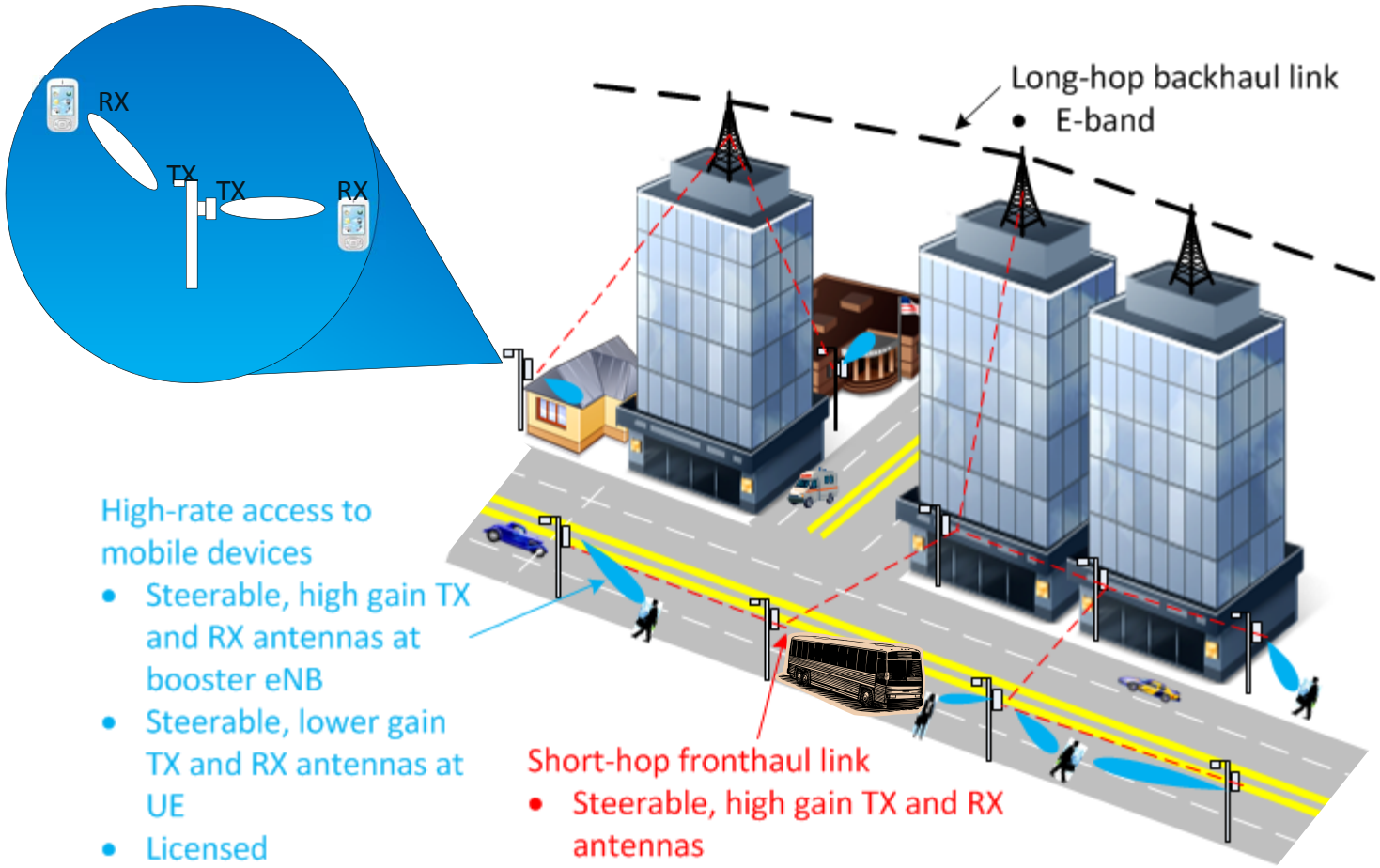
Small Cell Components



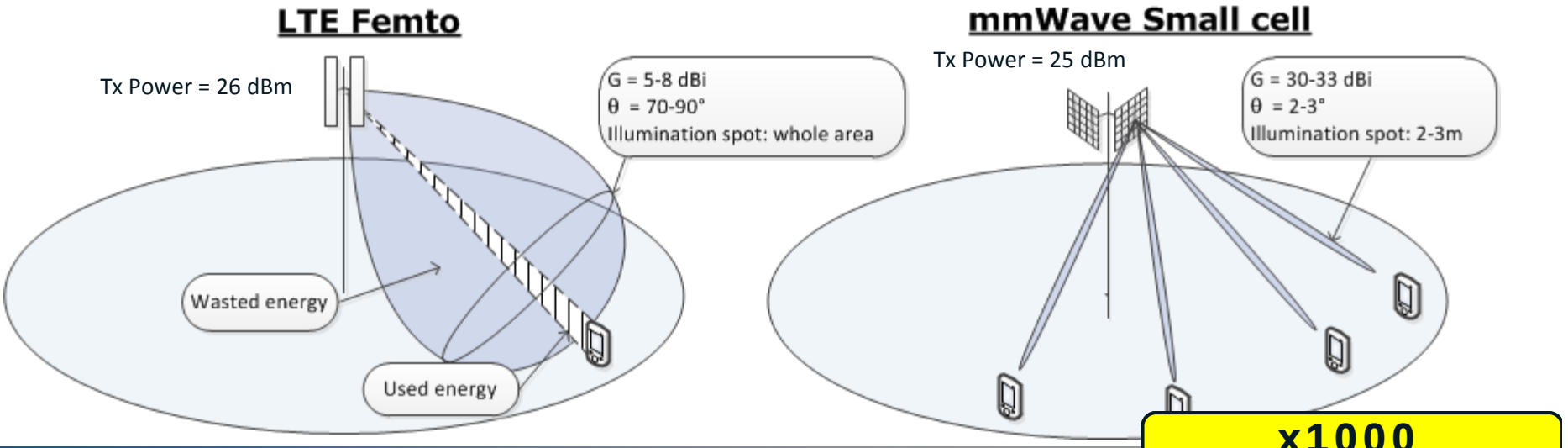
mmWave Capable Small Cells (MCSCs)



The mmWave Enabled HetNet



mmWave Small Cell vs. Modern LTE Femto



Cell throughput comparison

x1000
throughput increase

LTE average : **50 Mbps/cell** MU

mmWave Small Cell: Up to **4 Gbps** SU, **50 Gbps** MU

Energy efficiency / beamwidth comparison (green radio)

LTE Femto antenna HPBW: **70-90°**

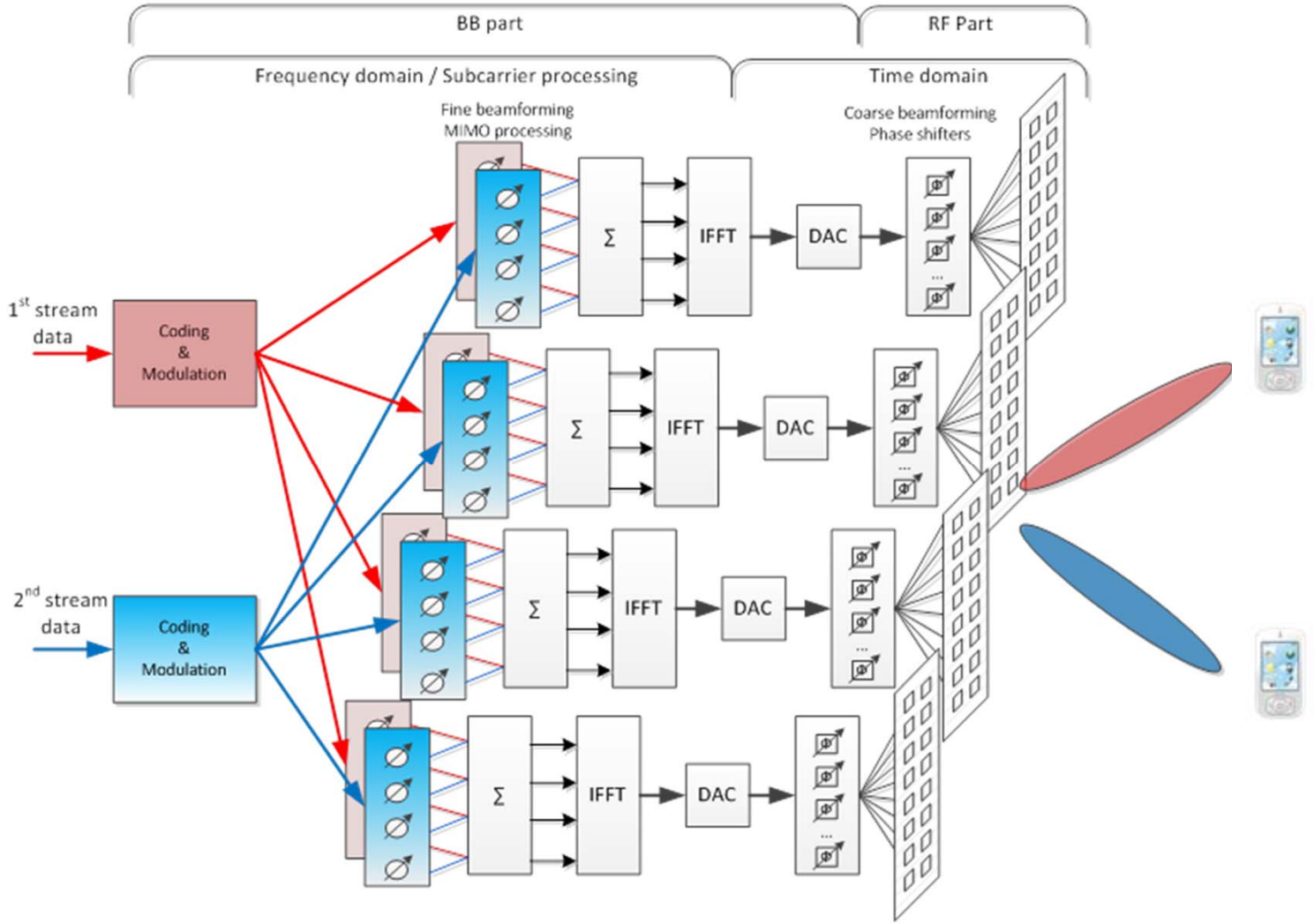
mmWave Small Cell antenna HPBW: **2-3°**

New feature: Intelligent beam control

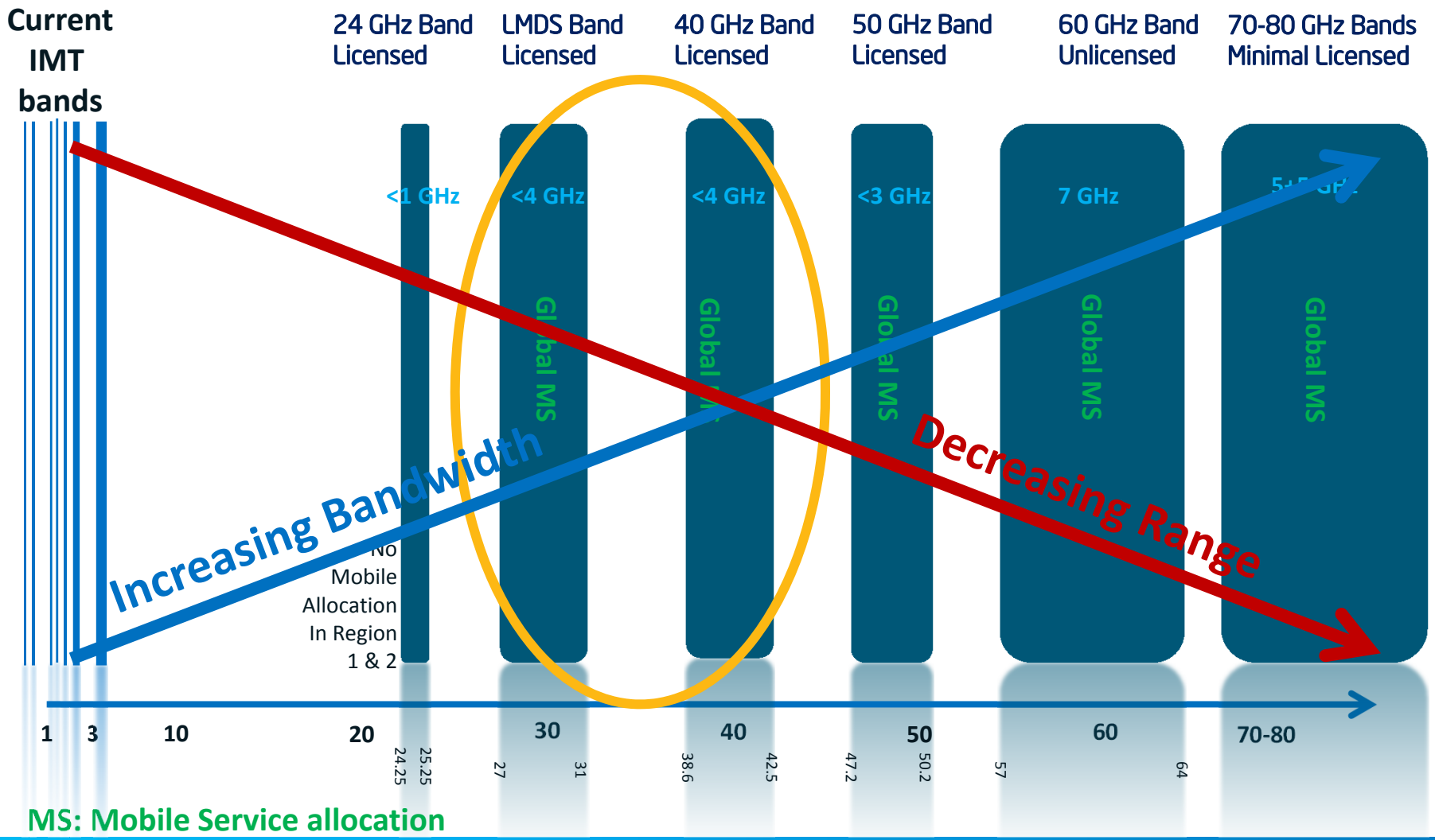
x30
Energy efficiency increase

- Per-beam power control to meet QoS and FCC requirements
- Beam steering / Beam tracking and Precise user positioning

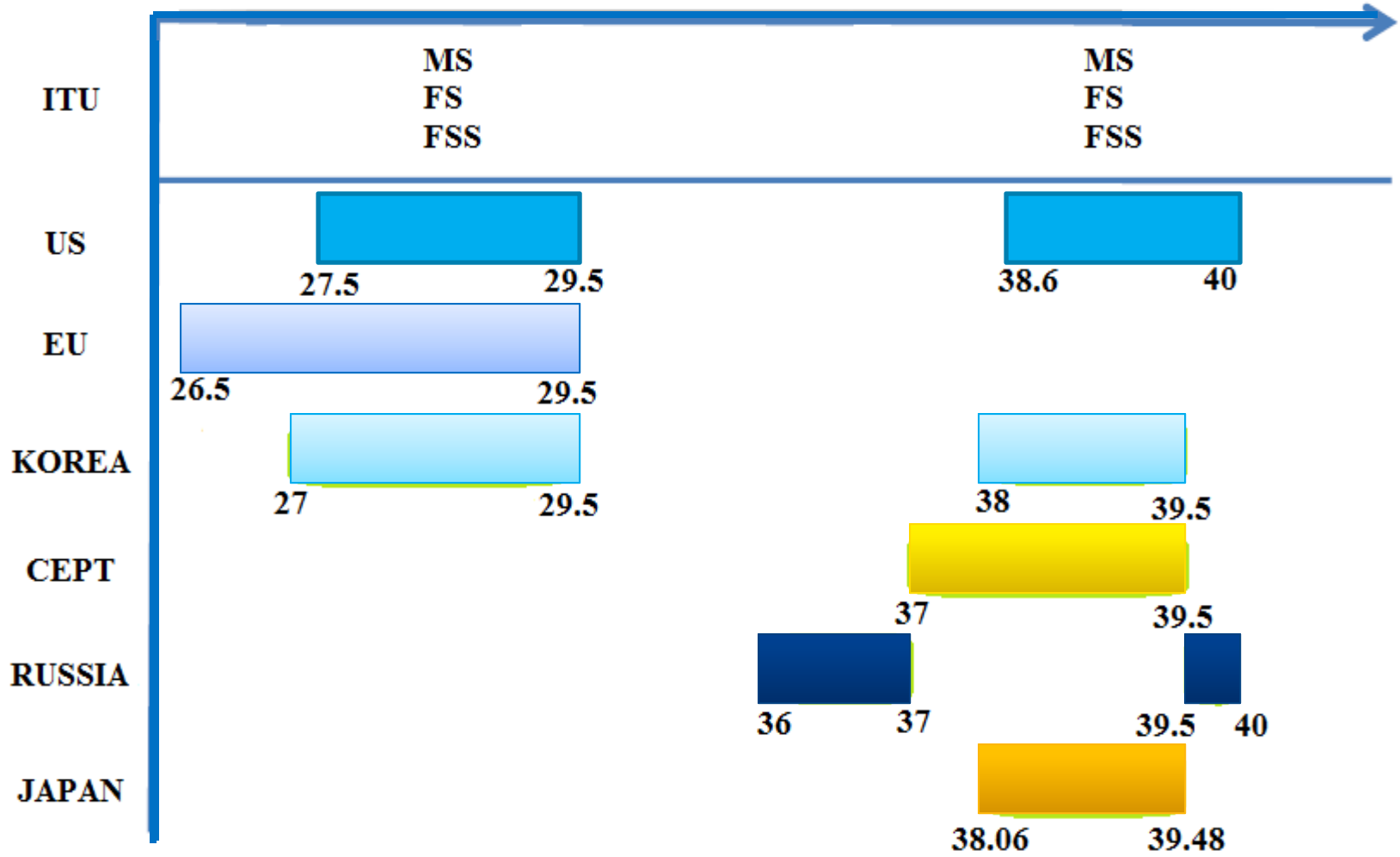
Long Term Goal, MU-MIMO



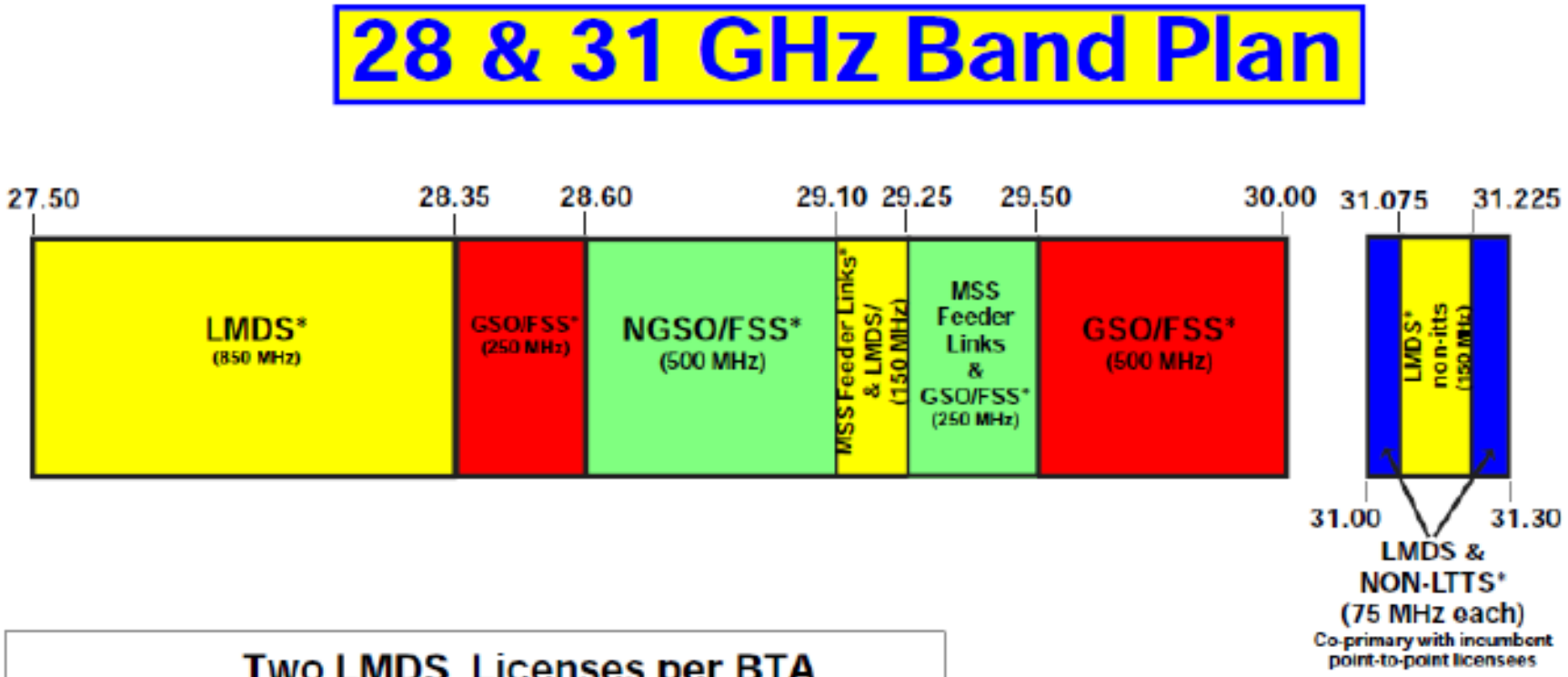
The Search for Alternate Spectrum



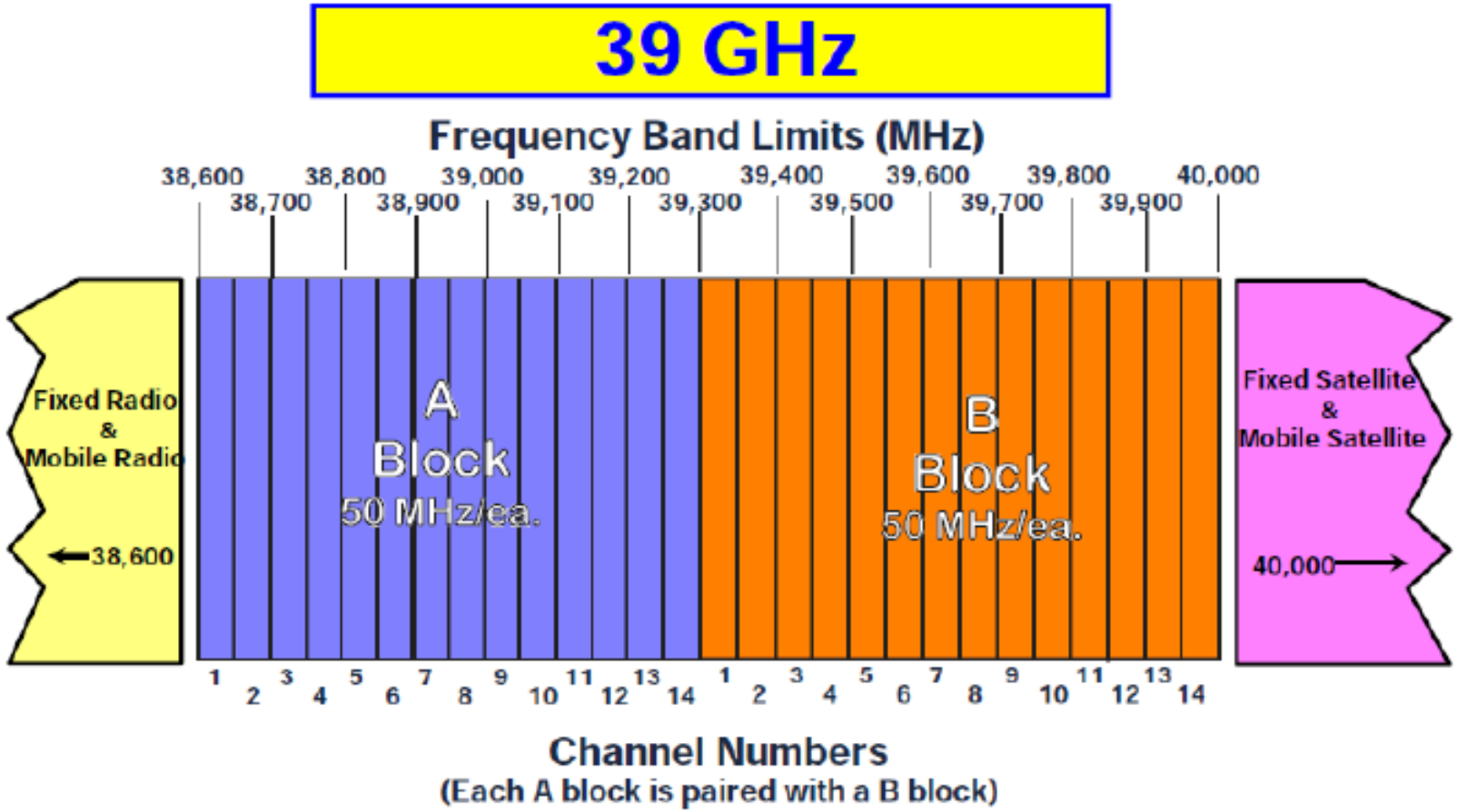
Possible Frequency bands for mmWave Access



LMDS band plan in the US

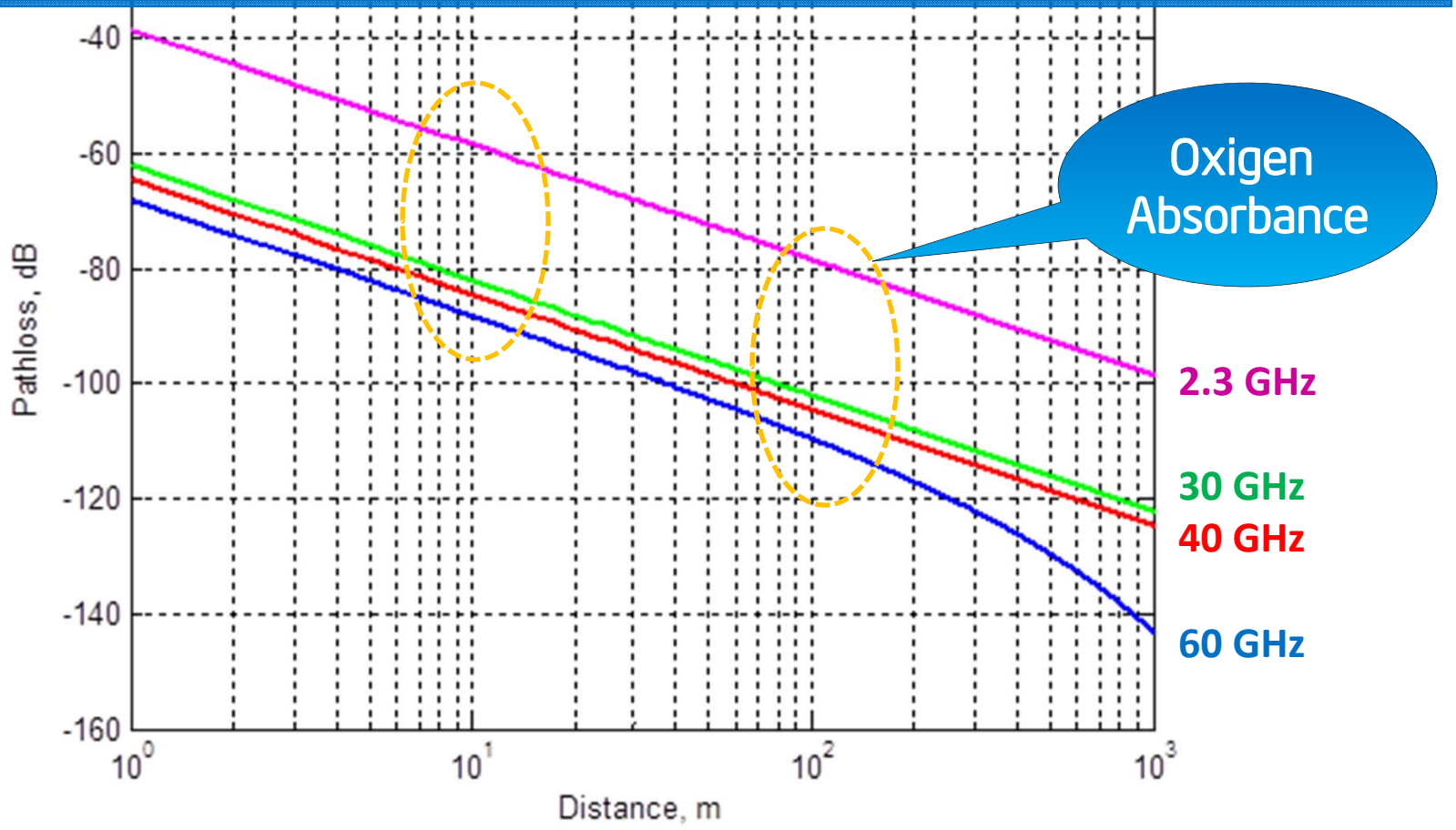


39 GHz band plan in the US

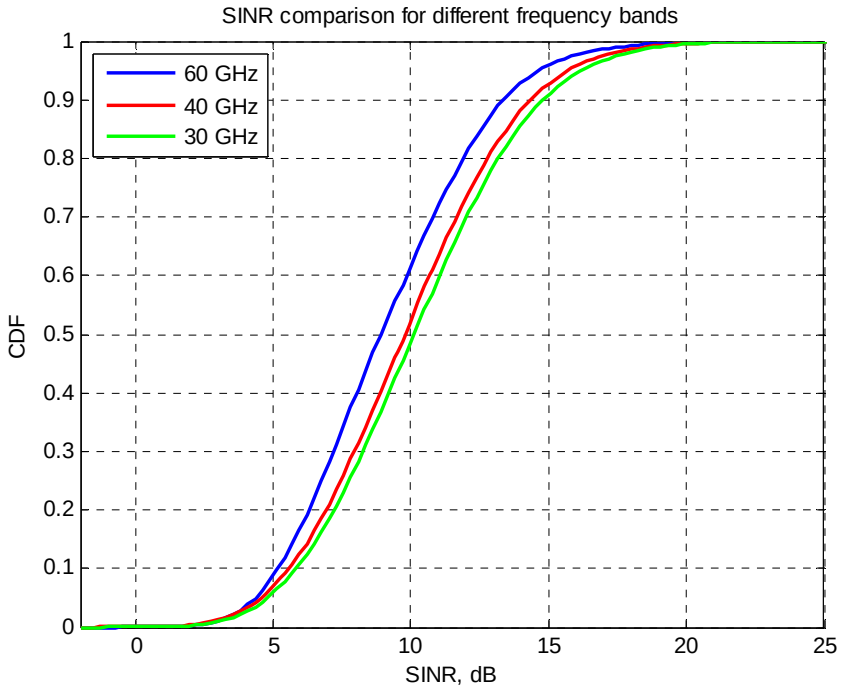


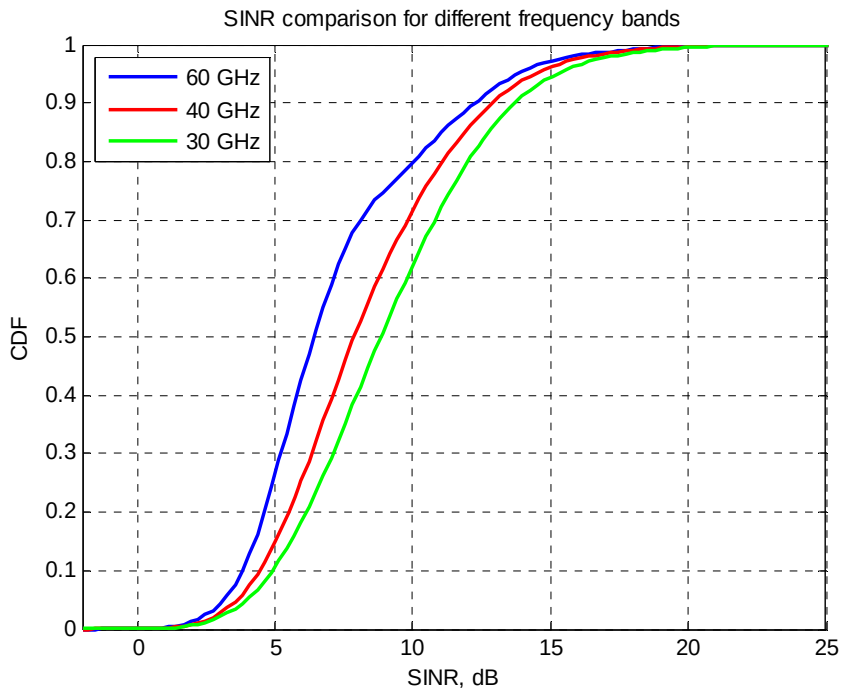
mmWave Path loss Comparisons

Note: Assumption is that we are using the same TX/RX antennas **gain for all bands.** But it means that antenna size for 30GHz will be two times larger than for 60GHz (aperture size by 4 times bigger!). In the case of hard limitations on antenna size additional **6dB** advantage will be lost for low frequency bands.



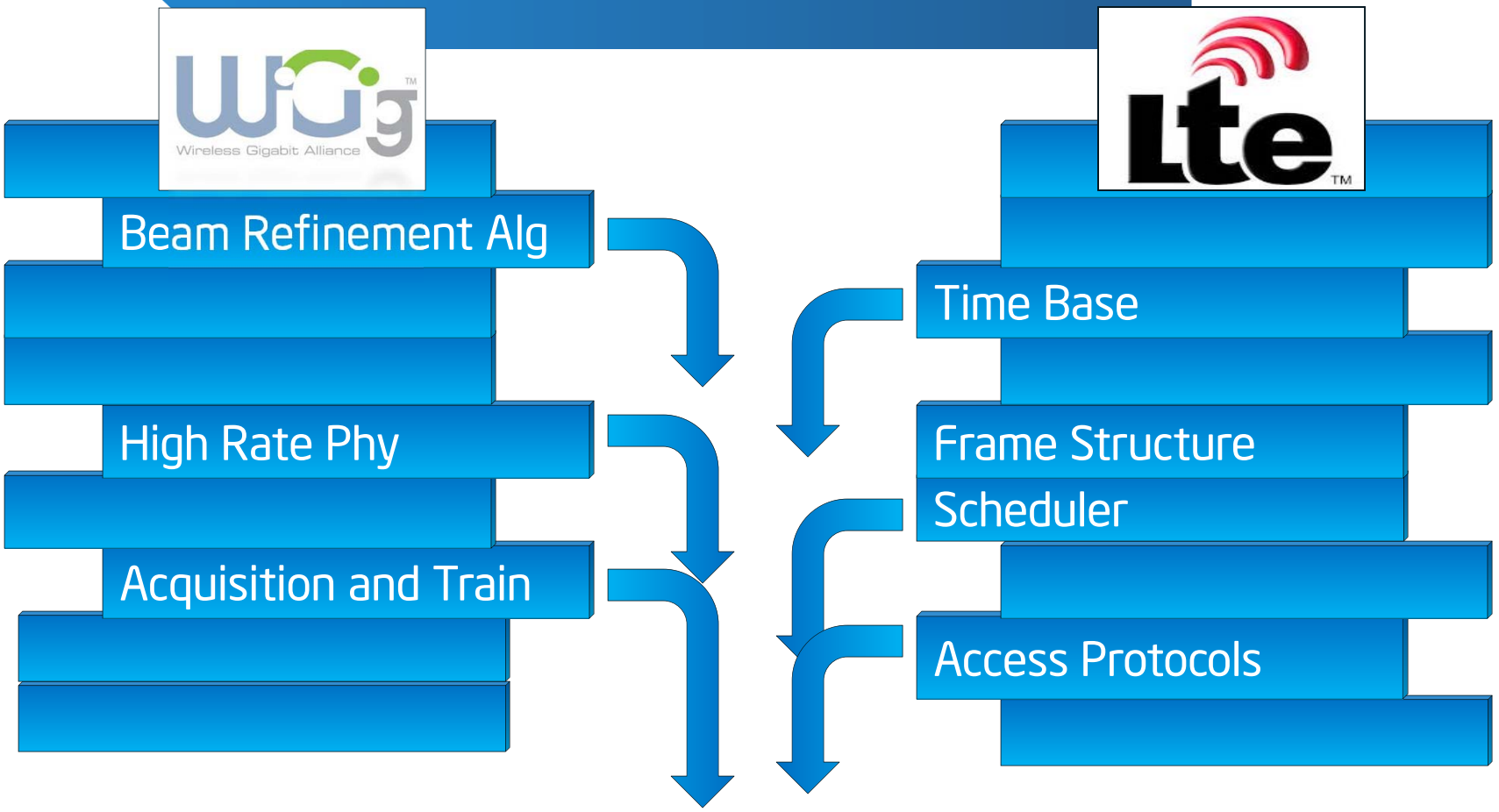
CDF Vs SNR Comparison





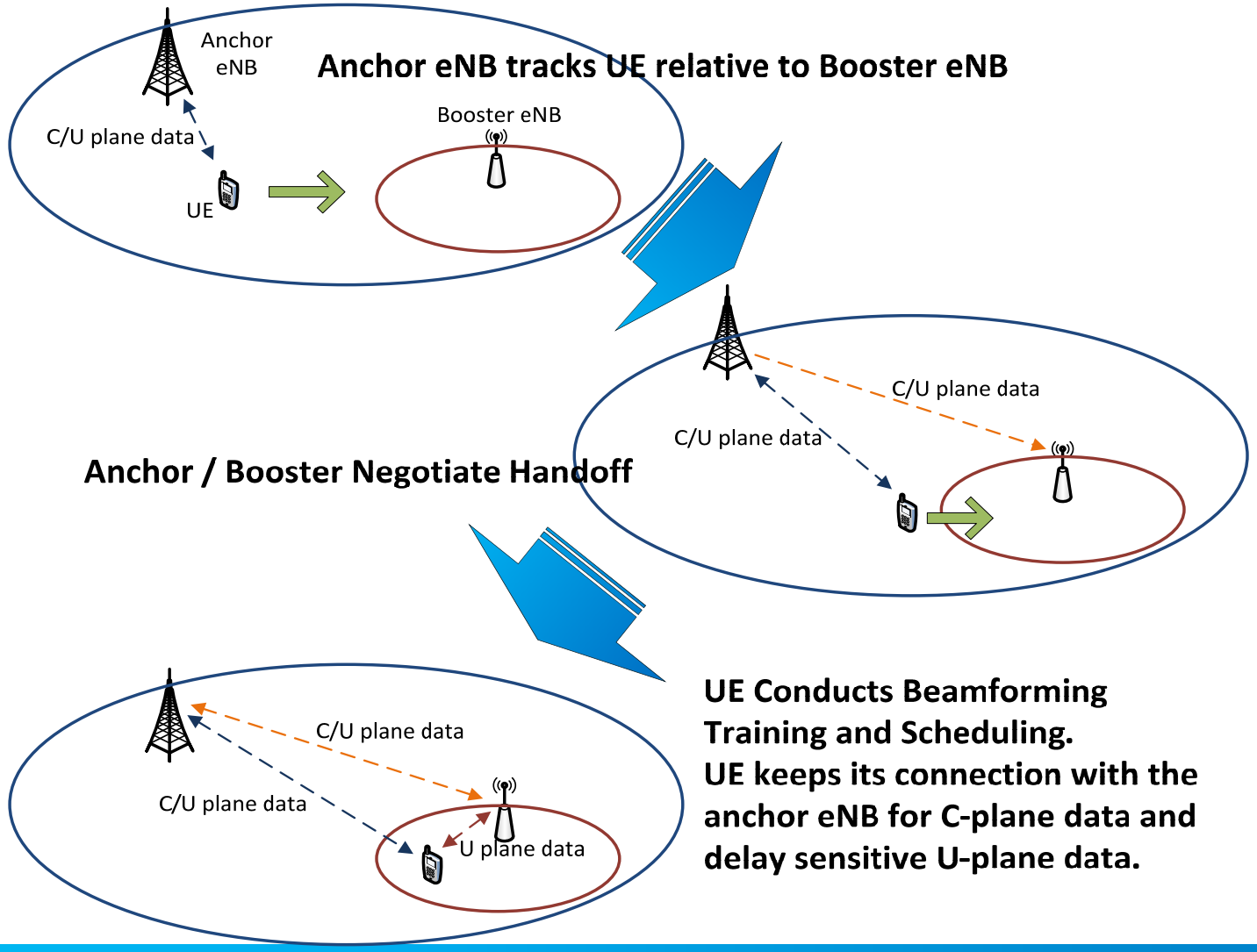
For 100 meters deployment 30 GHz outperform 60GHz on median level **by 1.2 dB.**
For 200 meters deployment 30 GHz outperform 60GHz on median level **by 2.4 dB.**

Achieving Compatibility with Legacy Systems



mmWave Enabled 5G

Possible LTE-Assisted Handoff

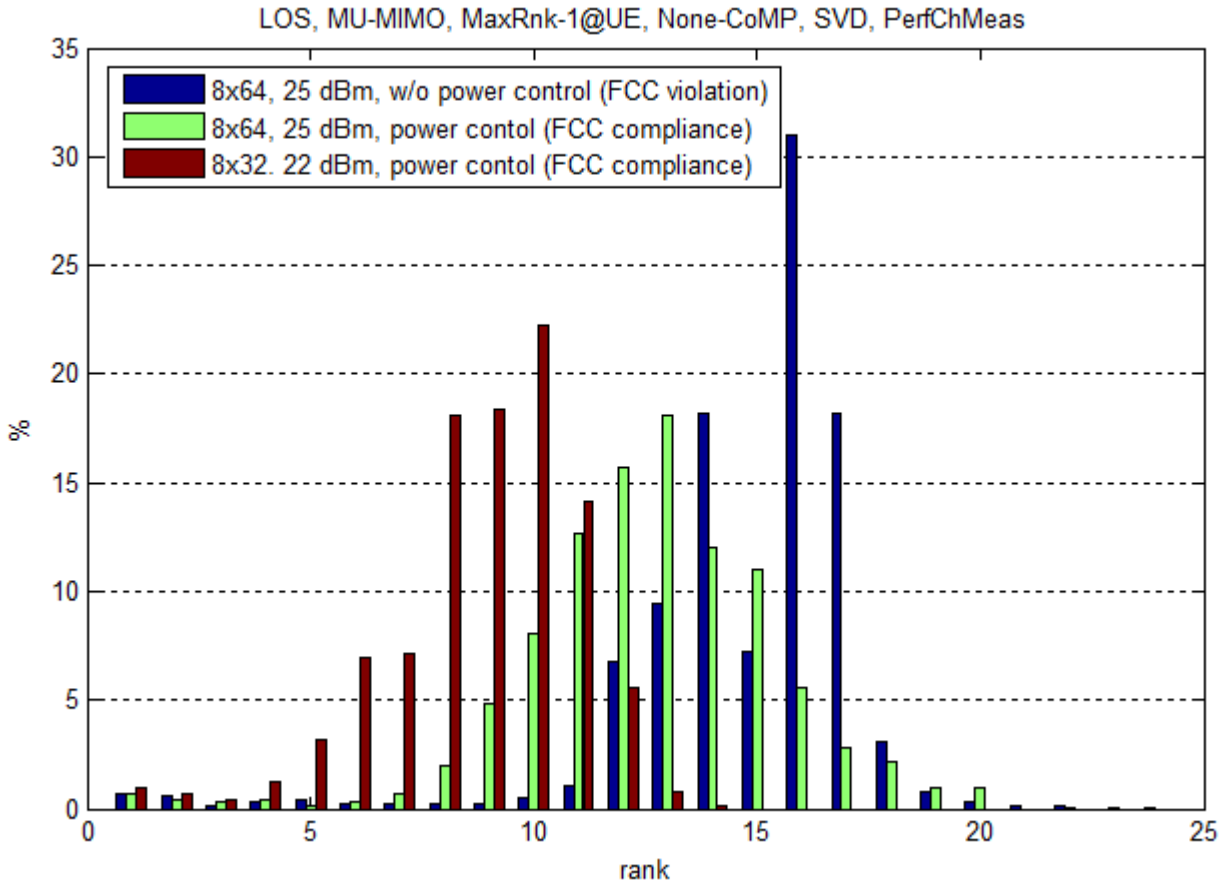


UE Conducts Beamforming Training and Scheduling.
UE keeps its connection with the anchor eNB for C-plane data and delay sensitive U-plane data.

Early Simulation result

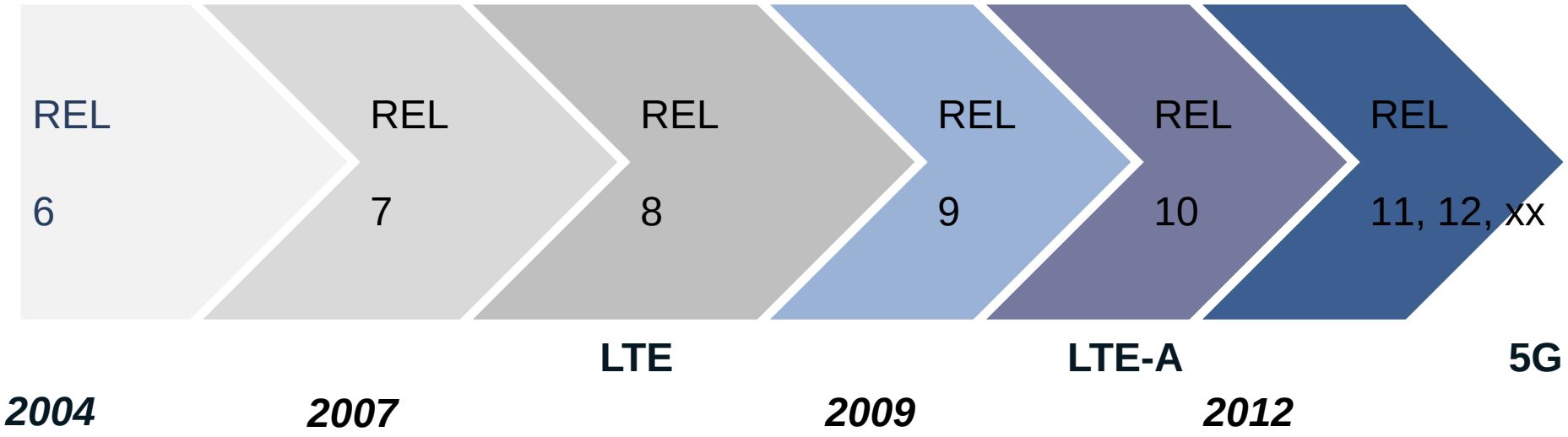
- For SU-MIMO mode mmWave communication system has shown 5.4 Gbps/cell throughput (90 Mbps/UE for 60 UE/cell) for 50 m Small cell size. (No overhead assumed)
- For MU-MIMO mode simulations, under reasonable assumptions, mmWave Small cell demonstrates 59 Gbps/cell throughput (about 1 Gbps/UE for 60 UE/cell) for 50 m Small cell size. *(matching analytical results previously presented)*
- The system without intelligent power transmit power control may violate FCC requirements on signal power density. ITPC scheme prevents this violation without substantial system performance metrics degradation (SW controlled EIRP/UE)

Simulation results: MU ranks for MU-MIMO modes



Cellular Systems Evolution

A new generation of cellular systems evolves every 5-7 years



Beyond 4G technology research and development begins now!

Summary

- WiGig is a multi Gigabit wireless standards and technology that enhances the usability of WiFi beyond connectivity and networking
- Multi Gigabit connectivity imposes higher capacity to the existing Cellular systems
- To increase capacity, increased small cell density, higher throughput and spectral efficiency systems are required
- mmWave enabled HetNet can significantly increase the system capacity
- WiGig as a proven mmWave technology can be extended to mmWave cellular systems.
- New generations of cellular systems evolve every 5-7 years, mmWave technology is a great candidate for beyond 4G systems