mmWave Spectrum and Deployment

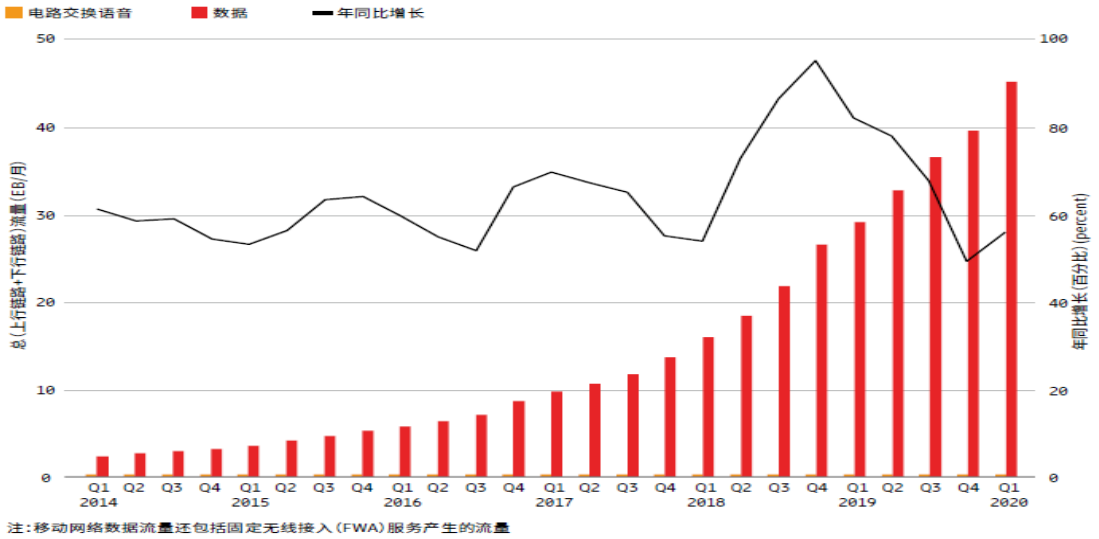
毫米波频谱和部署

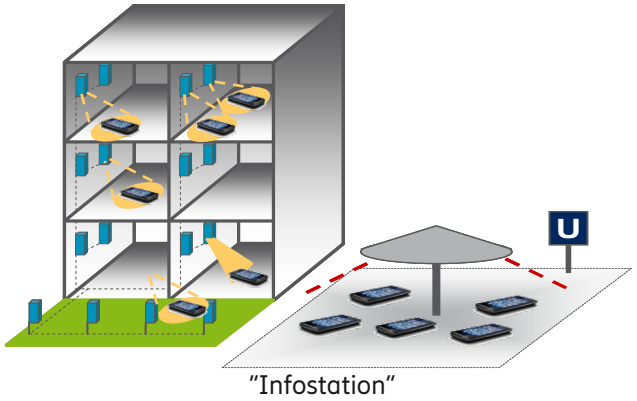
- Market Requirement and Technology Push for mmWave 毫米波市场需求和技术驱动
- mmWave Spectrum Deployment 毫米波频谱部署
- mmWave Characteristics and Technology 毫米波特性和技术特点
- mmWave Network Deployment and Use Cases 毫米波的网络部署实践和应用

Victoria Wang Wei Ericsson Aug,27, 2020

We are in a growth industry! 我们的产业依然处在增长阶段

Mobile data traffic grew 56 percent between Q1 2019 and Q1 2020 移动数据业务量在2019Q1到2020Q1的增长率达到56%



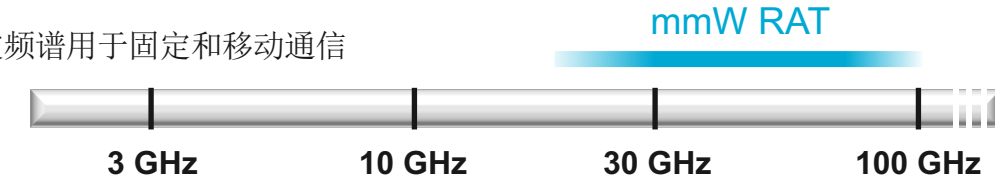


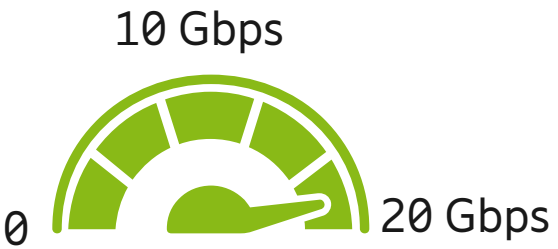
- Continued Growth in Traffic 业务量持续增长
  - Video, Voice and Data 视频、话音、数据
  - Increased in Resolution and Quality 高质量、高分辨率
  - Emerging of Data Intensive Applications 新兴的数据广泛应用
- Economic shift from built networks to exploitation of multi-purpose infrastructure 建设网络到探索多功能基础设施的经济转型

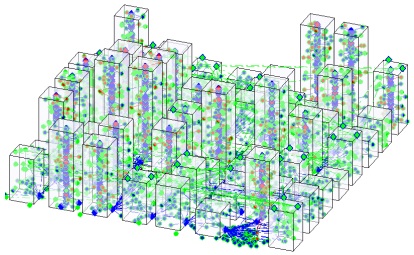
- Value of Mobility 移动性的价值
  - Wide Area 大覆盖
  - Nomadic 游牧式
  - Localized 本地移动
- Need for Ubiquity 无处不在的需求
- Speculative case of IoT 精彩的物联网应用

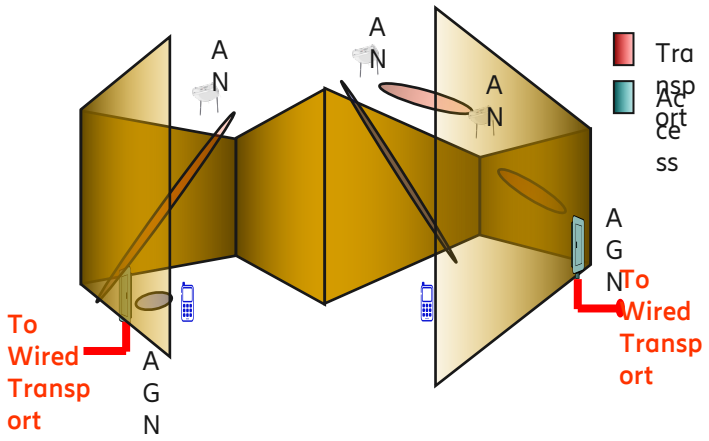
Technology Push 5G Radio Access Network 技术推动5G无线接入网

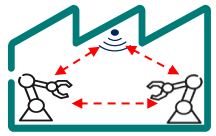
- Use of mmWave Spectrum– For Fixed and Mobile 毫米波频谱用于固定和移动通信
- Higher Bandwidth—Many Gbps Speeds 高带宽 Gbps 传输速率
- Very Dense Deployments 非常密集的部署
- Increases in Spectral Efficiency 提升频谱效率
  - Advanced Antennas System先进的天线系统
  - High Gain Beamforming 高增益的波束赋型
- Self-Backhauling 自回传
- Low Latency and Jitter 低时延和抖动



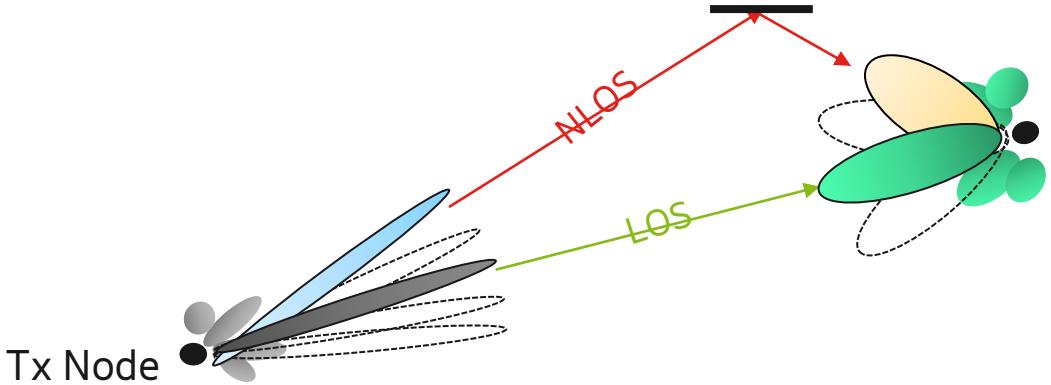






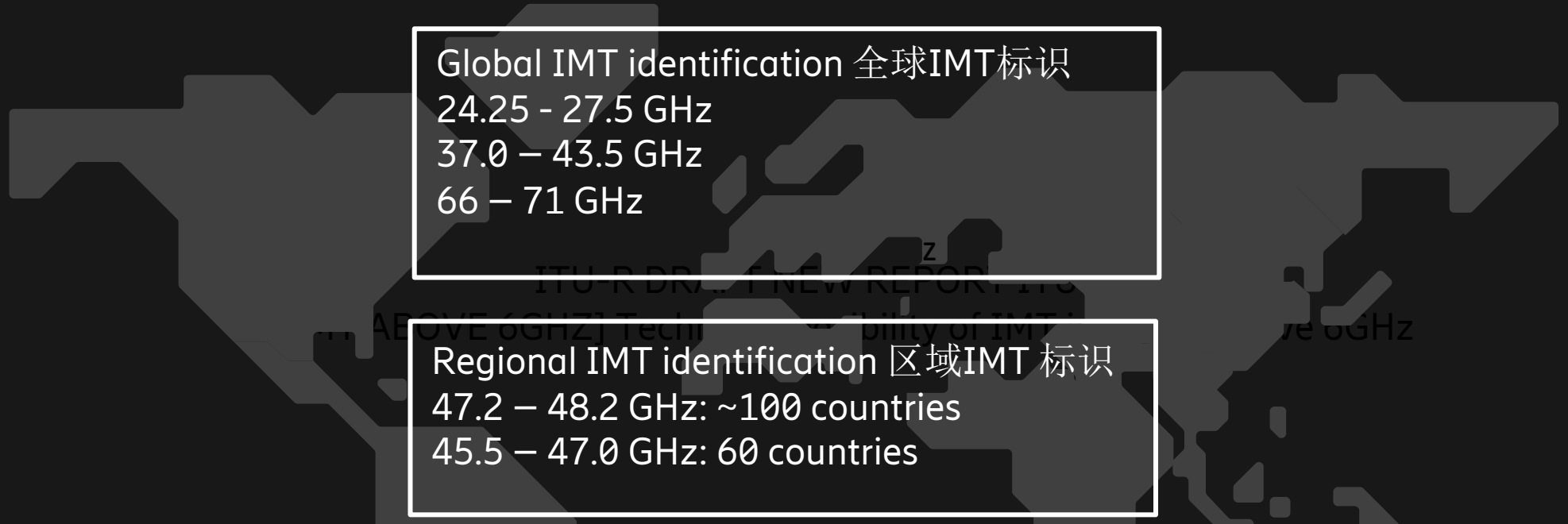


Industrial application



WRC-19 AI.13: IMT identification mmWave

WRC-19 AI1.13 标识用于IMT的毫米波频谱



Global IMT identification 全球IMT标识
24.25 - 27.5 GHz
37.0 – 43.5 GHz
66 – 71 GHz

Regional IMT identification 区域IMT 标识
47.2 – 48.2 GHz: ~100 countries
45.5 – 47.0 GHz: 60 countries

Notes: ITU-R WP5D made the DRAFT NEW REPORT ITU-R M. IMT.ABOVE 6GHZ for technical feasibility of IMT in bands above 6GHz before WRC-15

注：ITU-R WP5D早在2015年WRC-15研究周期就做了毫米波可行性技术研究报告

Technical conditions for mmWave in RR

世界无线电规则定义的毫米波技术要求

24.25 – 27.5 GHz

EESS protection 23.6-24 GHz 卫星地球探测业务保护

- Before September 1, 2027 2027，9月1号前
  -33 dBW/200MHz BS
  -29 dBW/200MHz UE
- After September 1, 2027 2027，9月1号后
  -39 dBW/200MHz BS
  -35 dBW/200 MHz UE

EESS protection @50.2-50.4 GHz and 52.6-54.25 GHz

- Encouragement to apply Cat B (SM.329) spurious limits

37 – 43.5 GHz

EESS protection 36-37 GHz

- -43 dBW/MHz and
  –23 dBW/GHz (obligatory)
- -30 dBW/GHz (recommended)

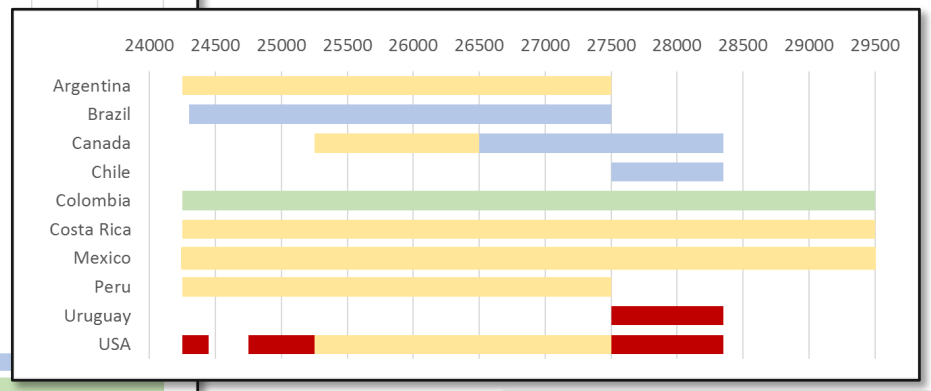
EESS (passive) protection 卫星地球探测业务(无源）保护

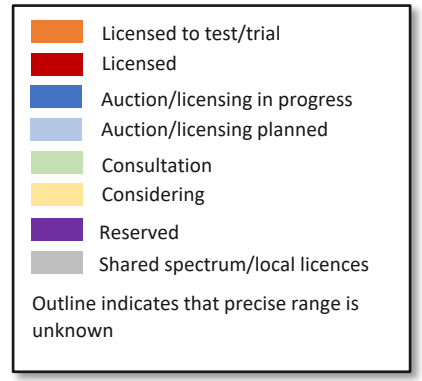
24.25 – 27.5 GHz; 42.5 – 43.5 GHz; 47.2 – 48.2 GHz

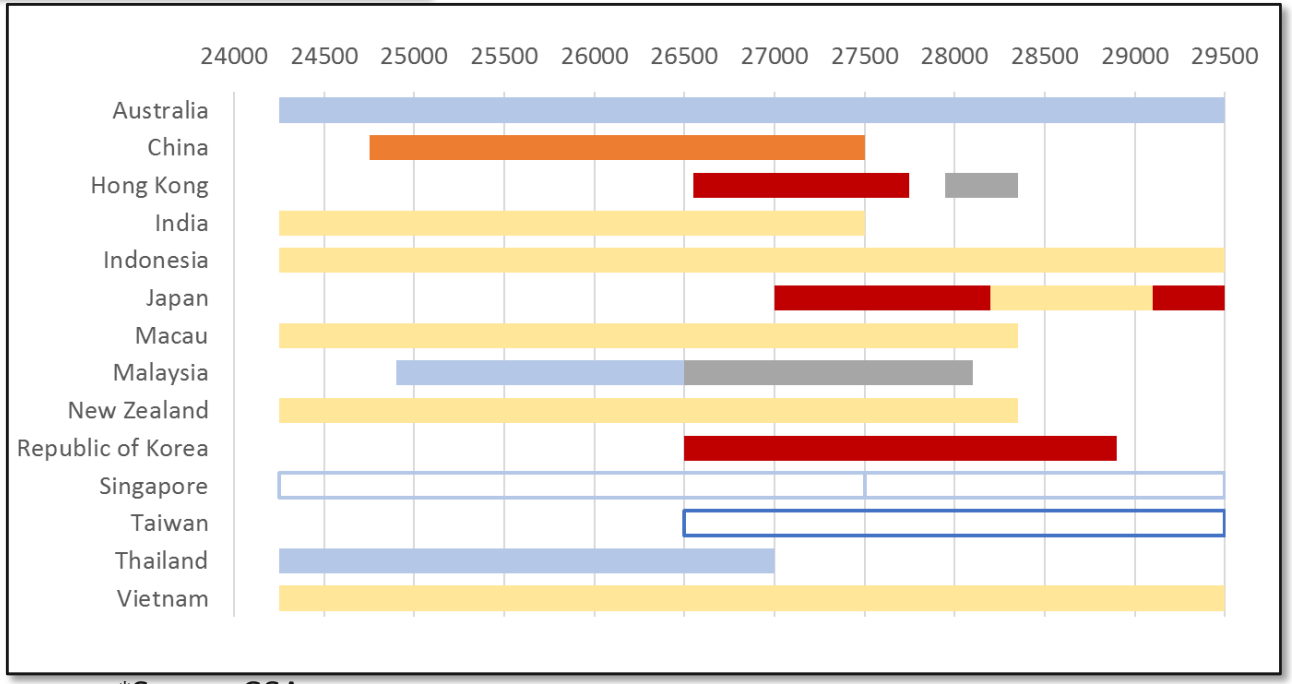
- Practical measure to ensure that Antennas pointing are below the horizon Mechanical is tilt below the horizon 天线指向水平面以下
- As far as practicable select sites for BSs with >30 dBW/200 MHz EIRP per beam so that direction of maximum radiation is separated from geostationary satellite orbit within line-of-sight by +/-7.5 degrees 对地静止卫星的轨道+/-7.5 度不能超过每波束30dBW/200MHz EIPR
- Encourages to keep base station antenna patterns within the limits of approximation envelope according to M.2101 鼓励保持基站天线发射在M.2101限制下

In band satellite protection 带内卫星保护

mmWave spectrum availability毫米波频谱的使用







26/28GHz (or parts of): pioneer 5G mmWAve bands globally

Large number of licenses to be issued during 2020-2021

26/28GHz（或其部分频谱）是5G毫米波频谱的先锋频段，2020-2021全球会有大量的频谱执照的发放

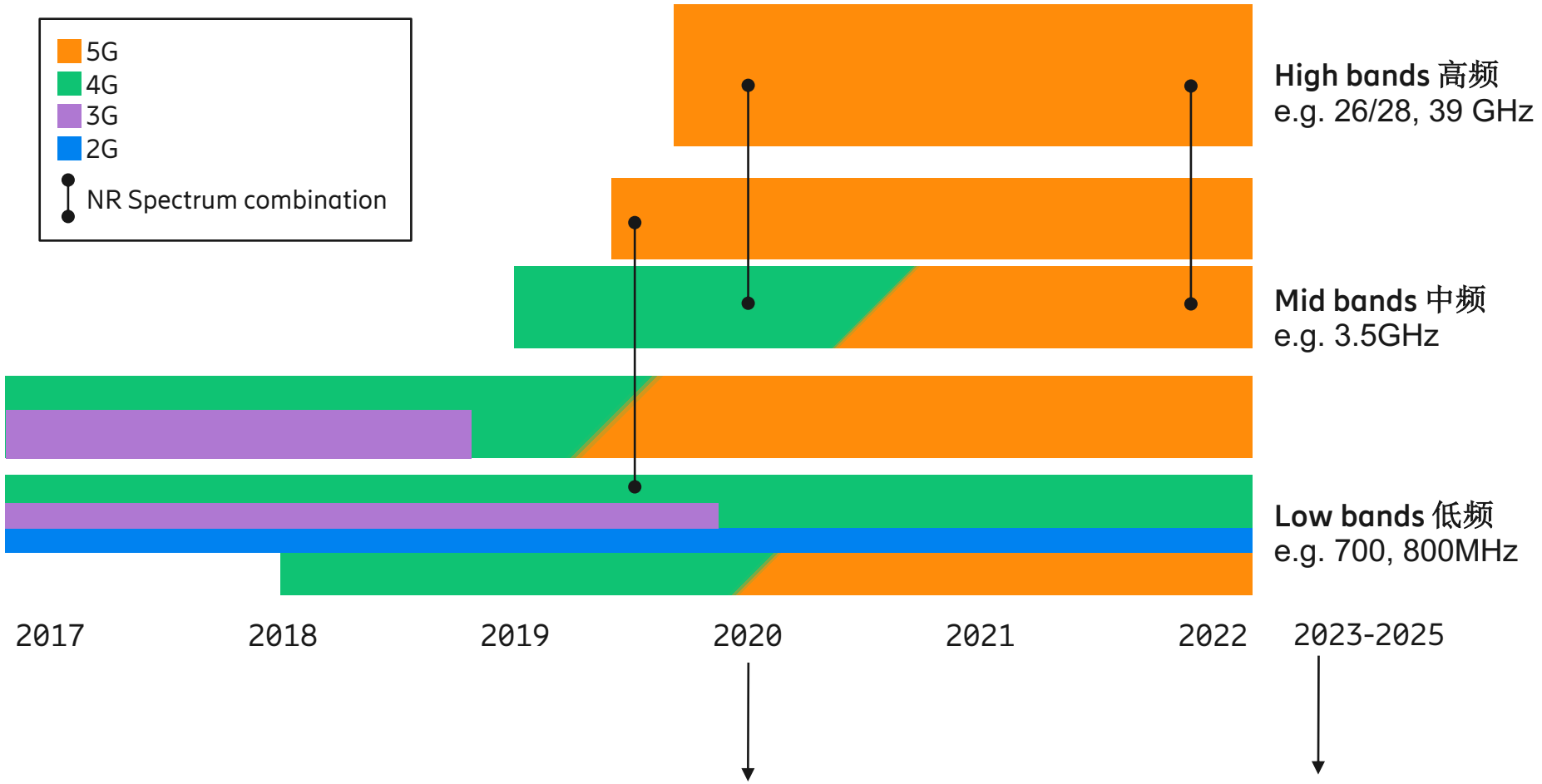
37-43.5GHz (or parts of) will come next globally, Auctioned in US

37-43.5GHz(或者部分频谱）将是接下来的全球频谱，目前在美国已经拍卖

Synchronization recommended, unless enough frequency/geographical separation 除非足够的频率/地理隔离，推荐同步使用

*Source: GSA

Spectrum usage overview 频谱使用概述



Deployment drivers 部署驱动

Localized Area
Very High Capacity
本地非常高容量

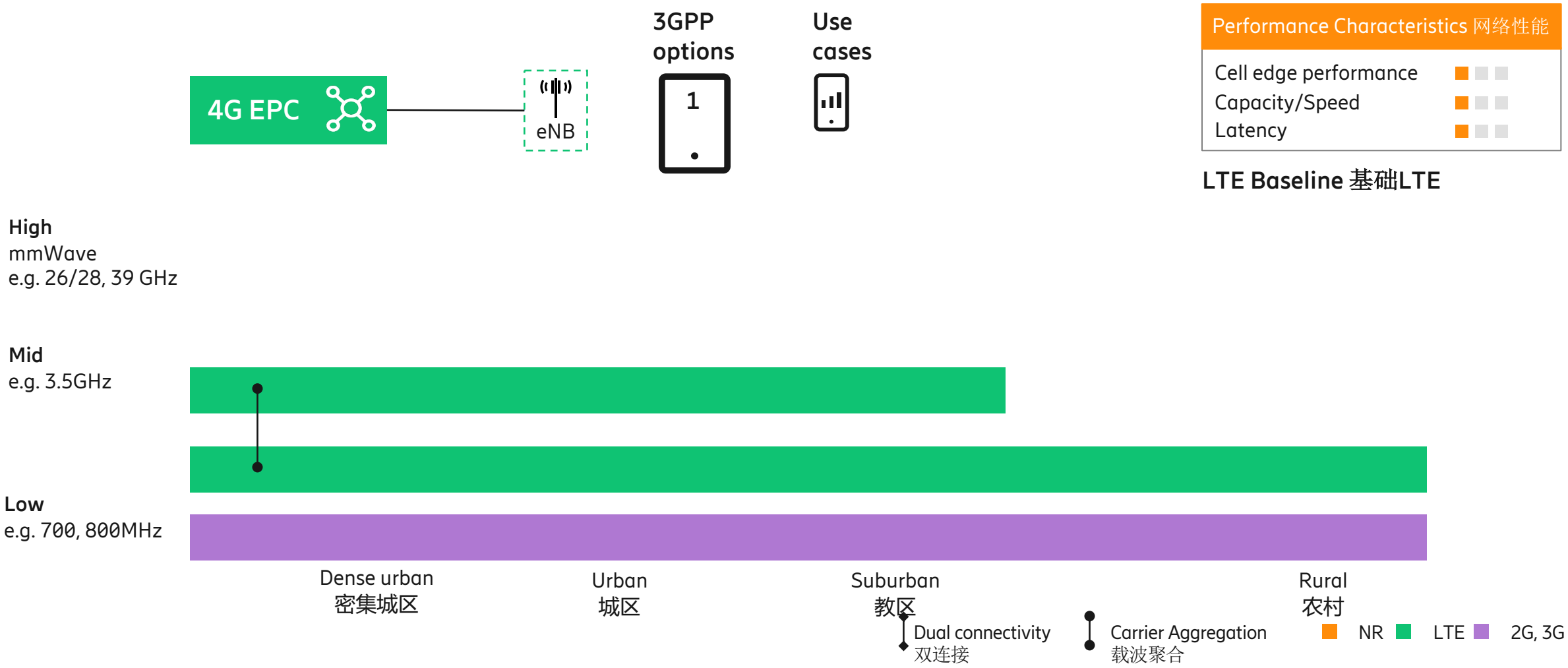
Wide Area High capacity
广域高容量

Coverage
覆盖

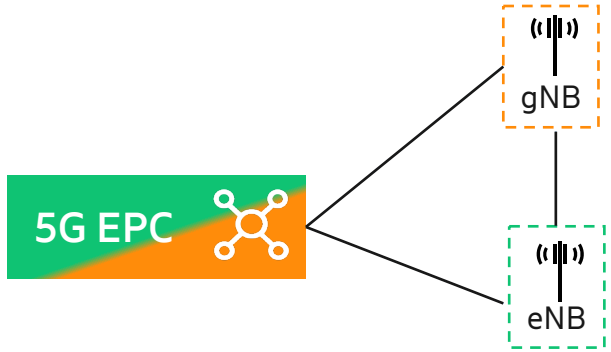
Mid-bands: At least 100 MHz contiguous spectrum per MNO 中频每个运营商连续100MHz
High bands: ~ 1 GHz contiguous spectrum per MNO 高频每个运营商连续1GHz

Additional Mid/High band spectrum required for MNOs 额外的中高频谱需要给运营商

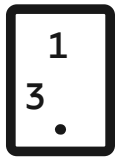
5G Deployment scenarios 5G 部署场景



5G Deployment scenarios 5G 部署场景



3GPP options



Use cases

Performance Characteristics	
Cell edge performance	■
Capacity/Speed	■ ■
Latency	■ ■

Add 5G on mid-band, 增加5G中频 **non-stand alone** NSA

High
mmWave
e.g. 26/28, 39 GHz

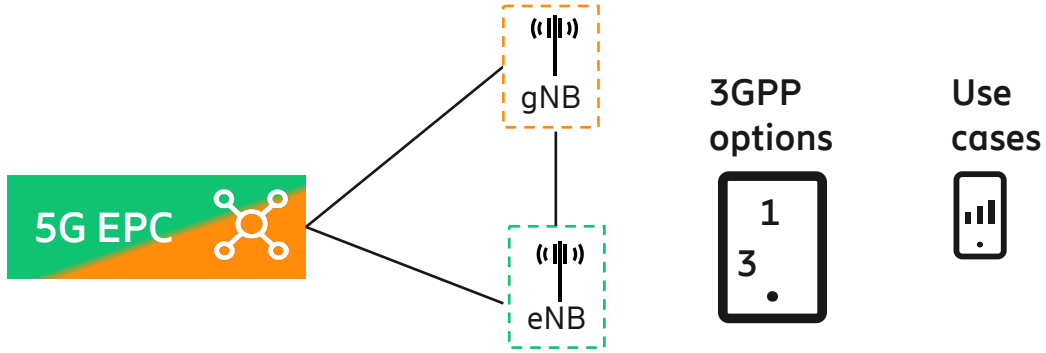
Mid
e.g. 3.5GHz

Low
e.g. 700, 800MHz

Dense urban 密集城区 | Urban 城区 | Suburban 郊区 | Rural 农村

Dual connectivity 双连接 | Carrier Aggregation 载波聚合 | NR | LTE | 2G, 3G

5G Deployment scenarios 5G 部署场景



3GPP options

1
3

Use cases

Performance Characteristics	
Cell edge performance	■■□
Capacity/Speed	■■□
Latency	■■□

Spectrum sharing on low band, non-stand alone 低频频谱共享 NSA

High
mmWave
e.g. 26/28, 39 GHz

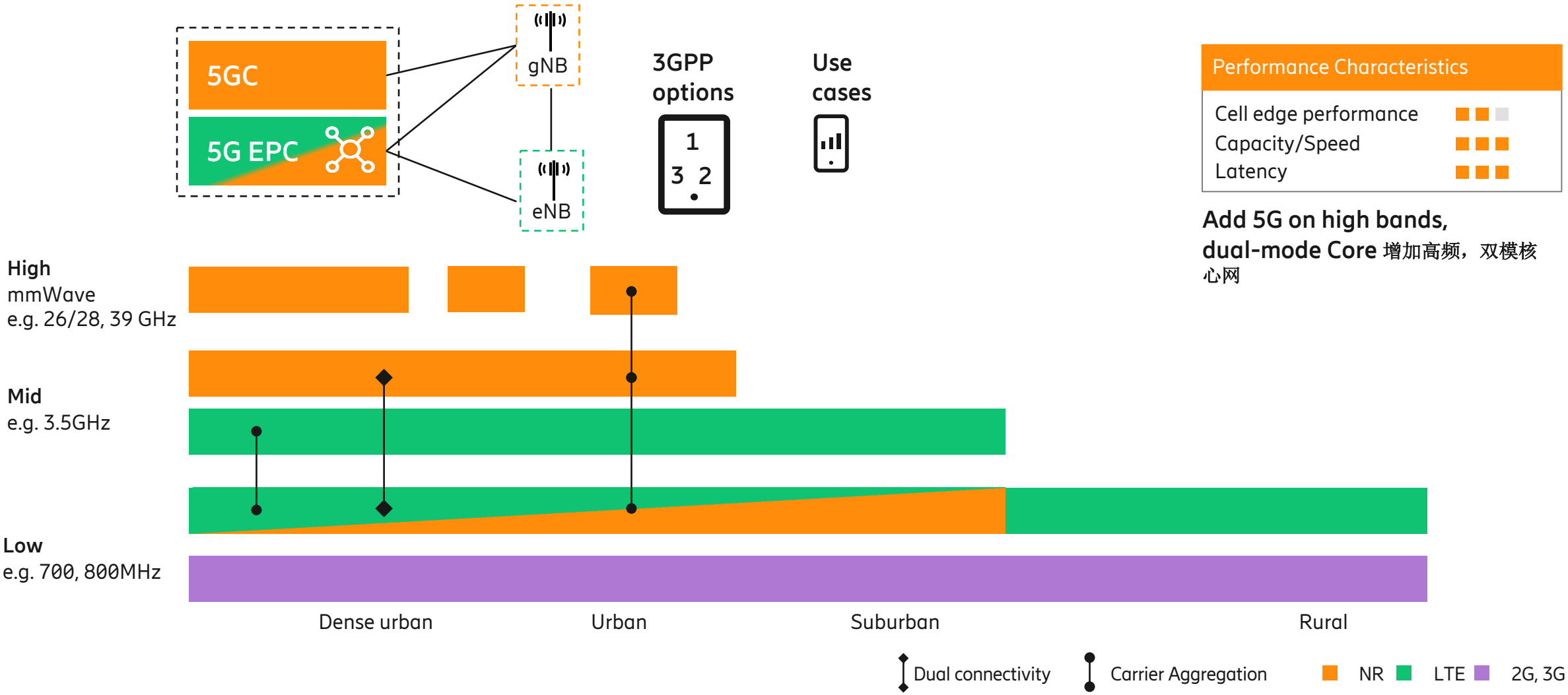
Mid
e.g. 3.5GHz

Low
e.g. 700, 800MHz

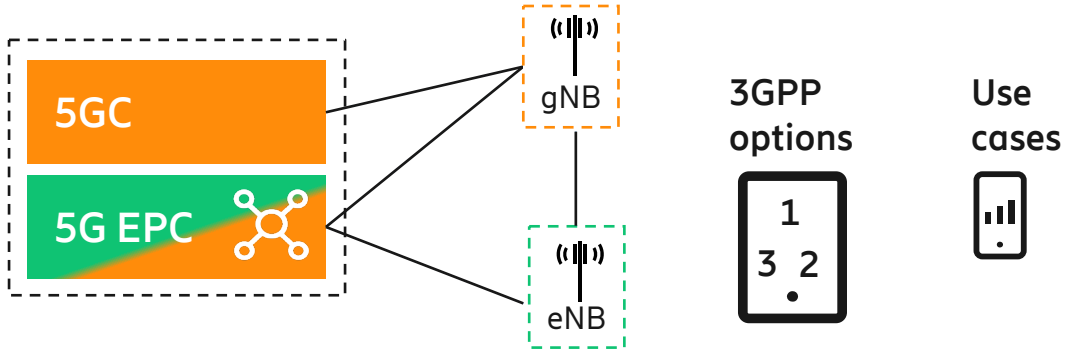
Dense urban | Urban | Suburban | Rural

Dual connectivity | Carrier Aggregation | NR | LTE | 2G, 3G

5G Deployment scenarios



5G Deployment scenarios



3GPP options

Use cases

Performance Characteristics	
Cell edge performance	■ ■ ■
Capacity/Speed	■ ■ ■
Latency	■ ■ ■

Spectrum sharing on mid-band, dual-mode Core 中频频谱共享

High
mmWave
e.g. 26/28, 39 GHz

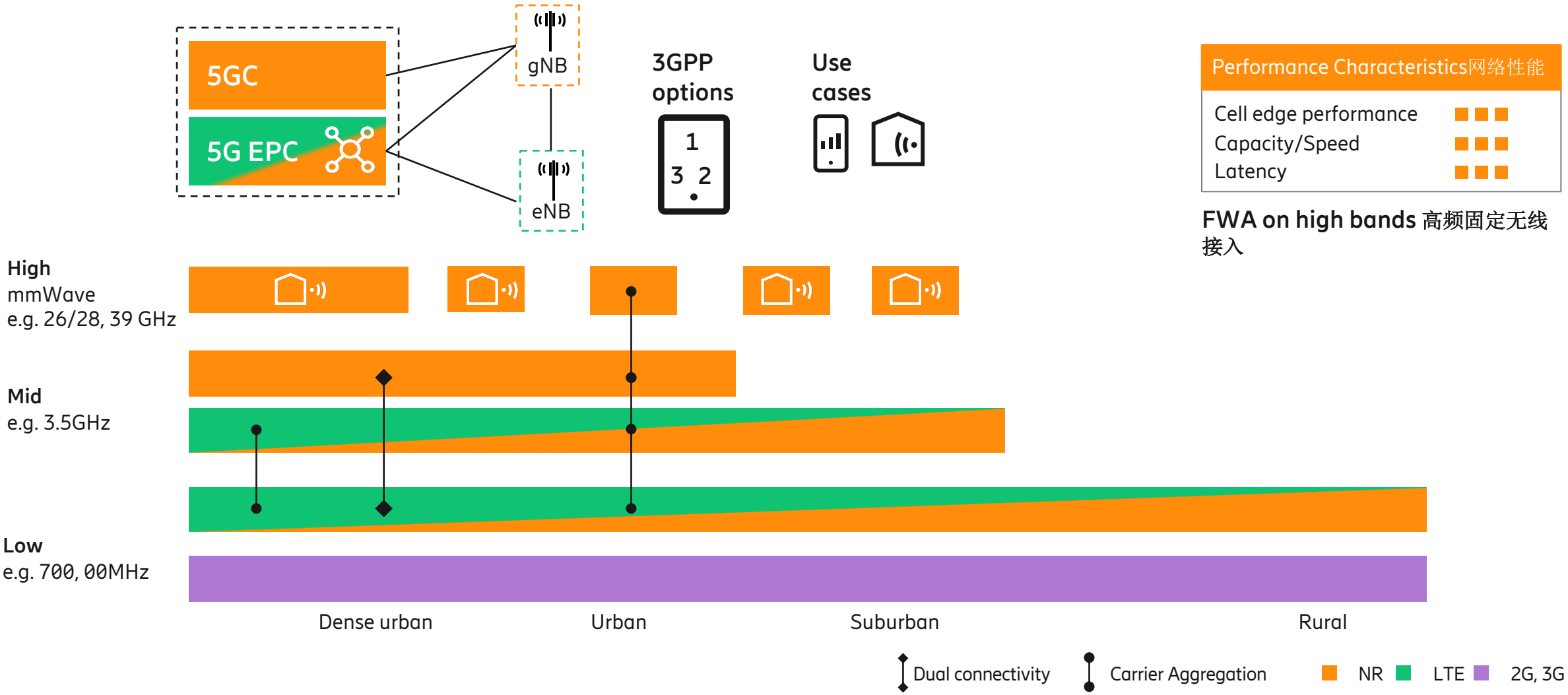
Mid
e.g. 3.5GHz

Low
e.g. 700, 800MHz

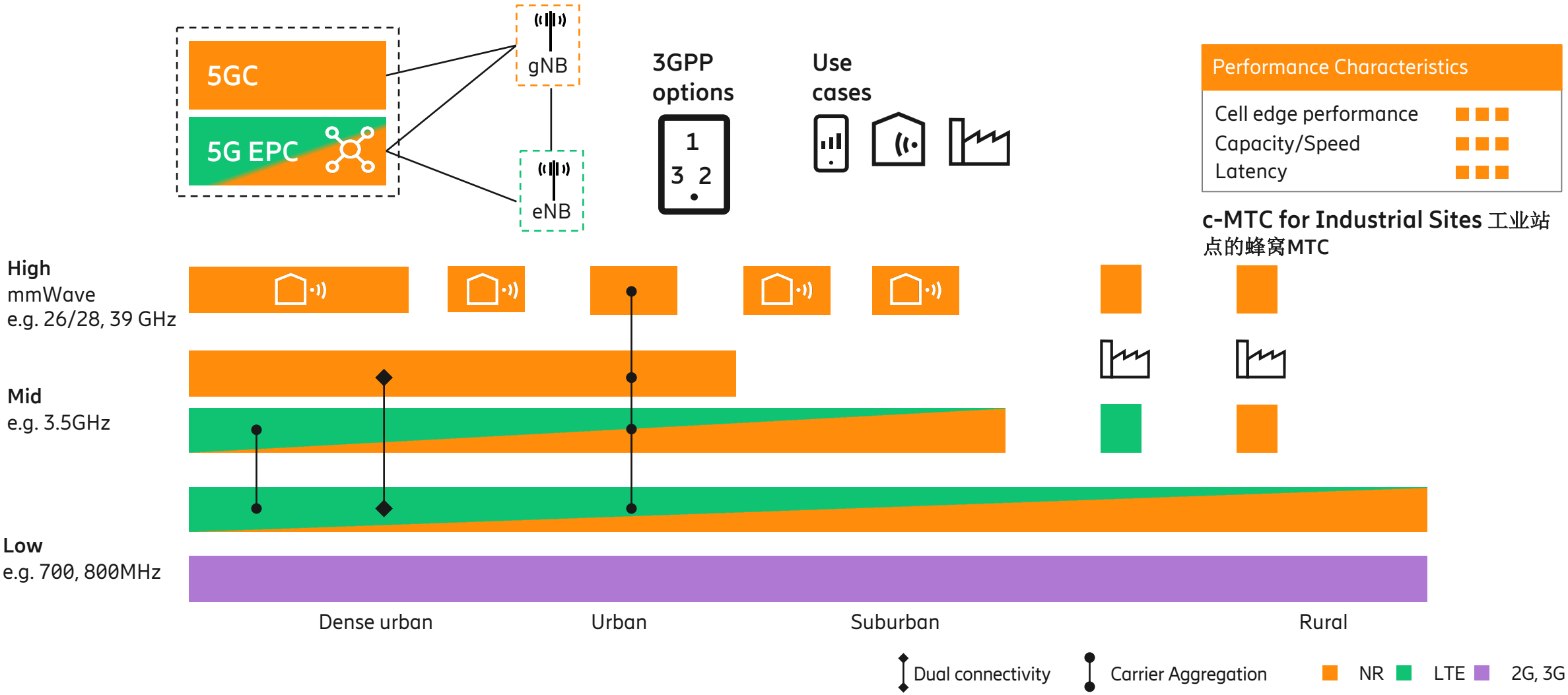
Dense urban | Urban | Suburban | Rural

Dual connectivity | Carrier Aggregation | NR | LTE | 2G, 3G

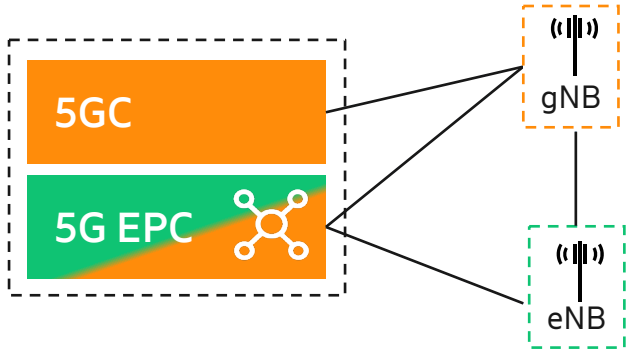
5G Deployment scenarios



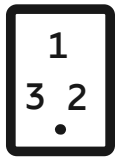
5G Deployment scenarios



5G Deployment scenarios



3GPP options



Use cases

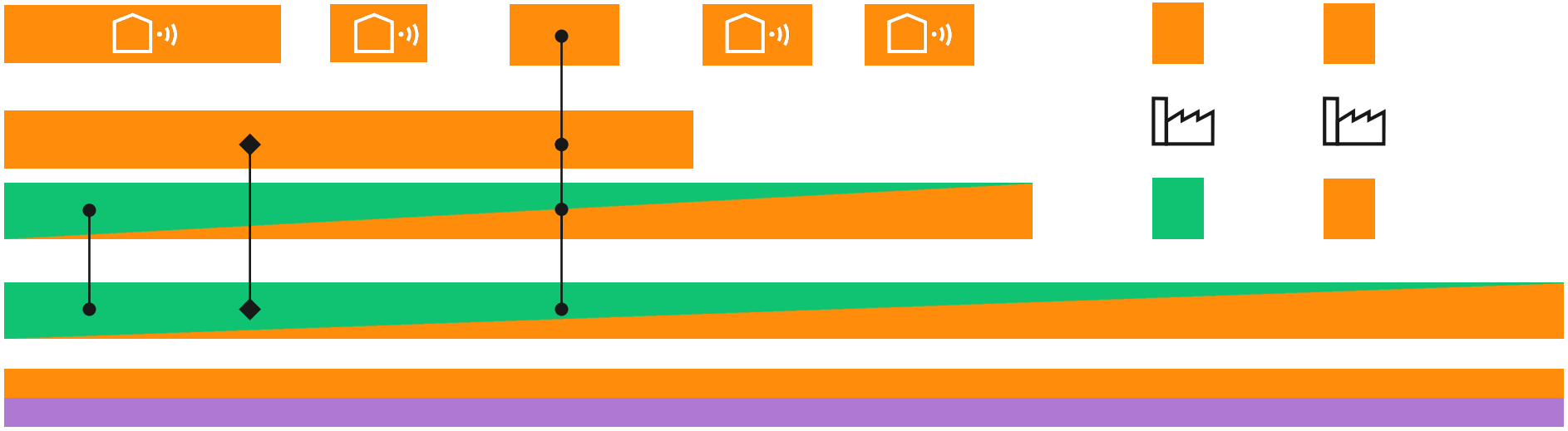
Performance Characteristics	
Cell edge performance	■ ■ ■
Capacity/Speed	■ ■ ■
Latency	■ ■ ■

Start reframing 2G/3G 2G/3G 重耕

High
mmWave
e.g. 26/28, 39 GHz

Mid
e.g. 3.5GHz

Low
e.g. 700, 800MHz

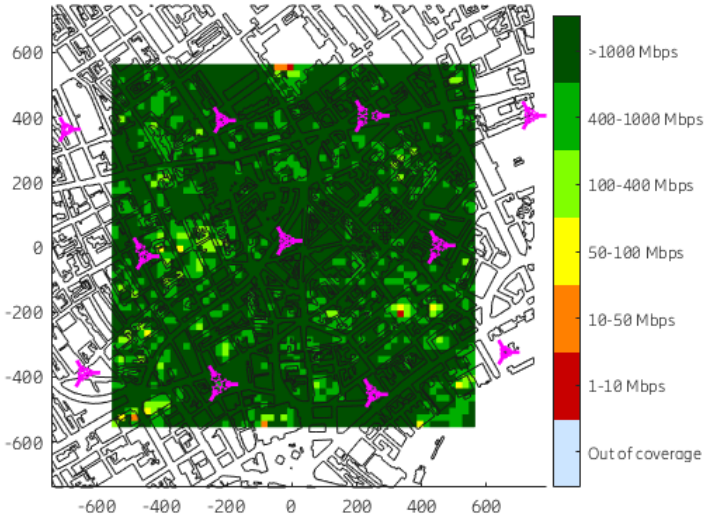


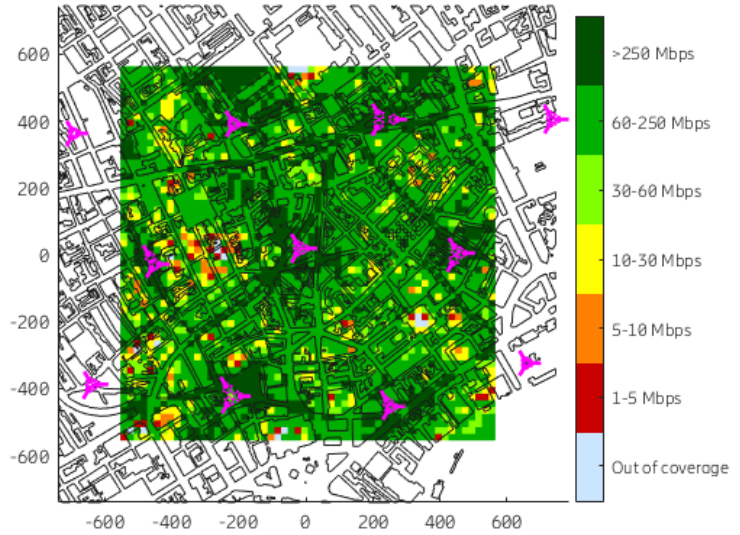
Dense urban | Urban | Suburban | Rural

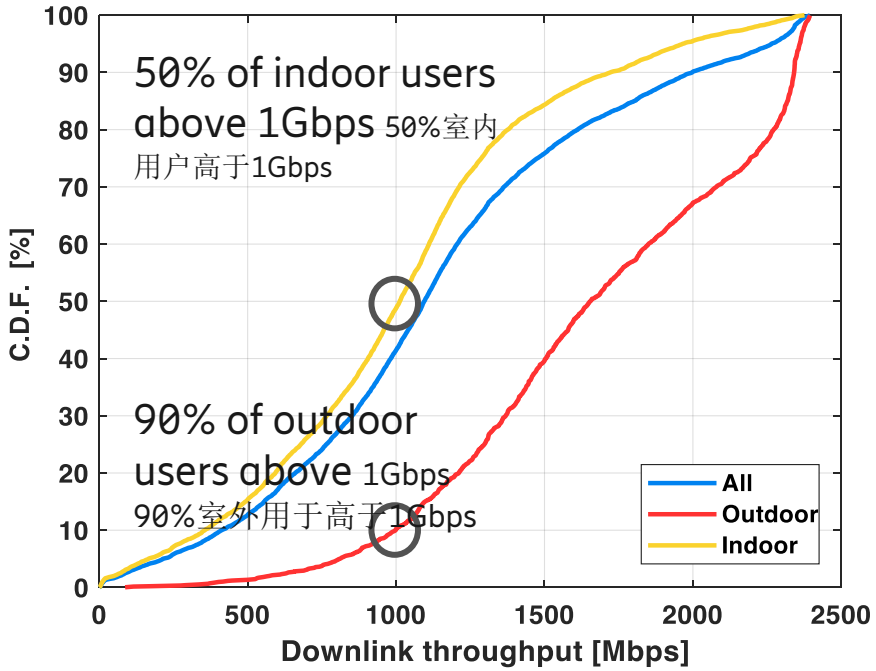
Dual connectivity | Carrier Aggregation | NR | LTE | 2G, 3G

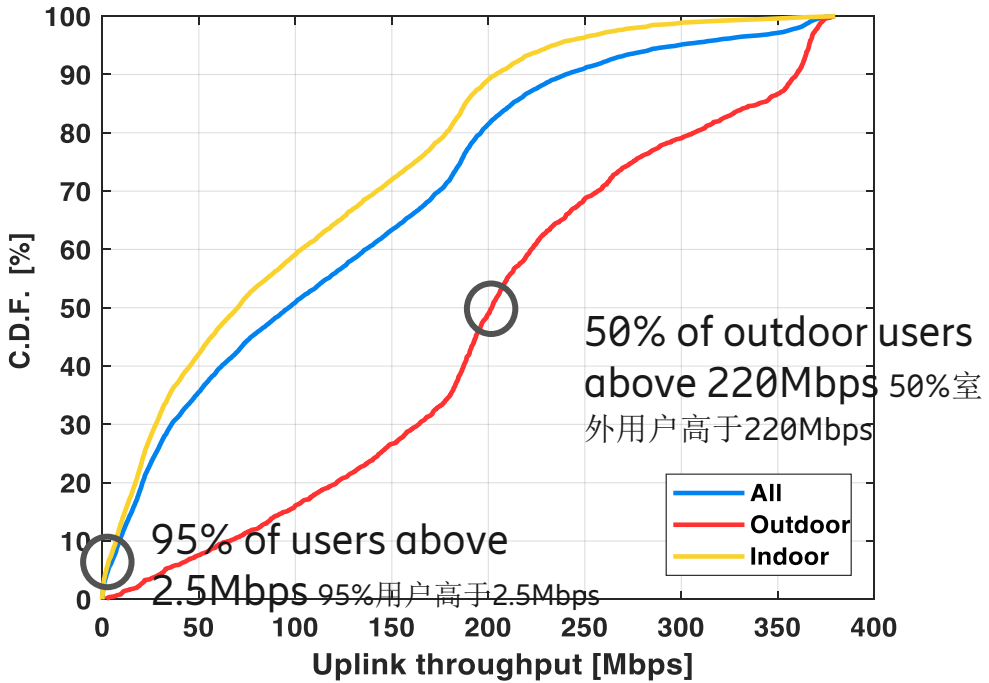
London LTE 0.8, 2.6 + NR 3.5GHz, 26GHz coverage

伦敦 800MHz+NR 3.5GHz+26GHz 覆盖

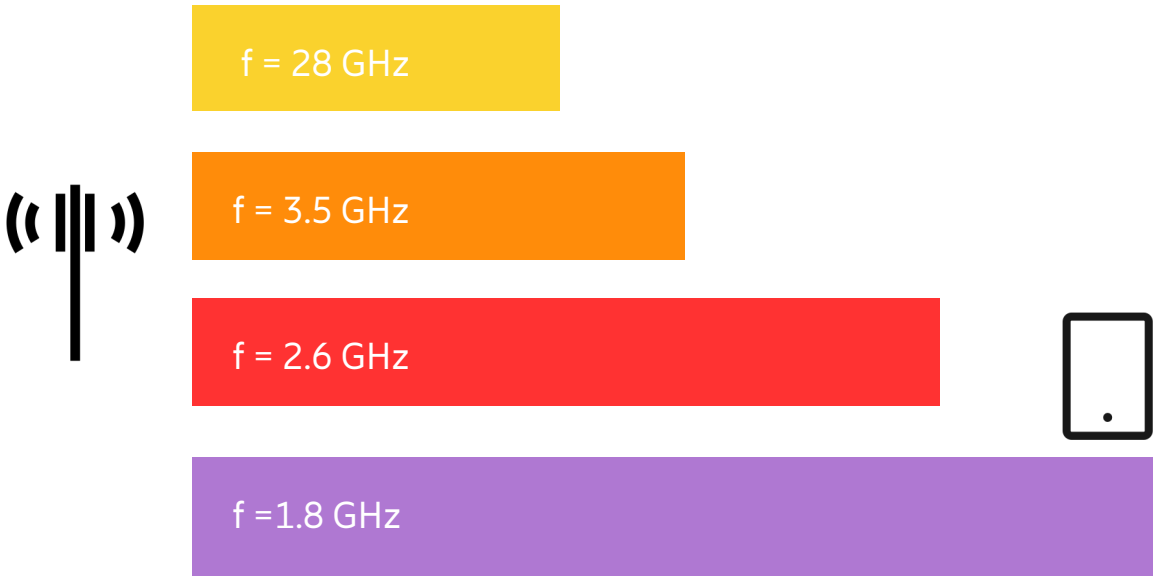


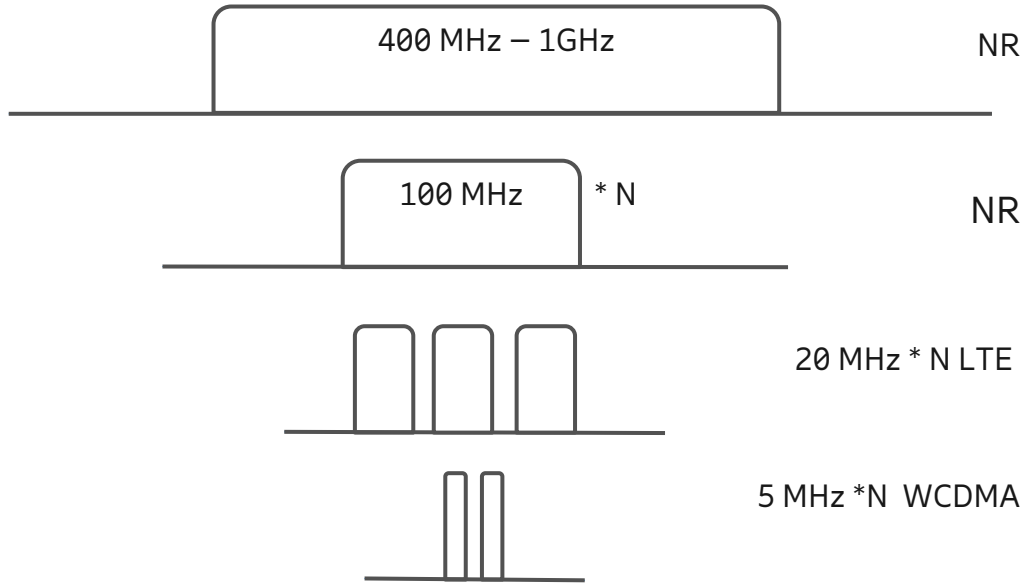






mmWave Technology Characteristics毫米波技术特性 –
High Bandwidth 高带宽





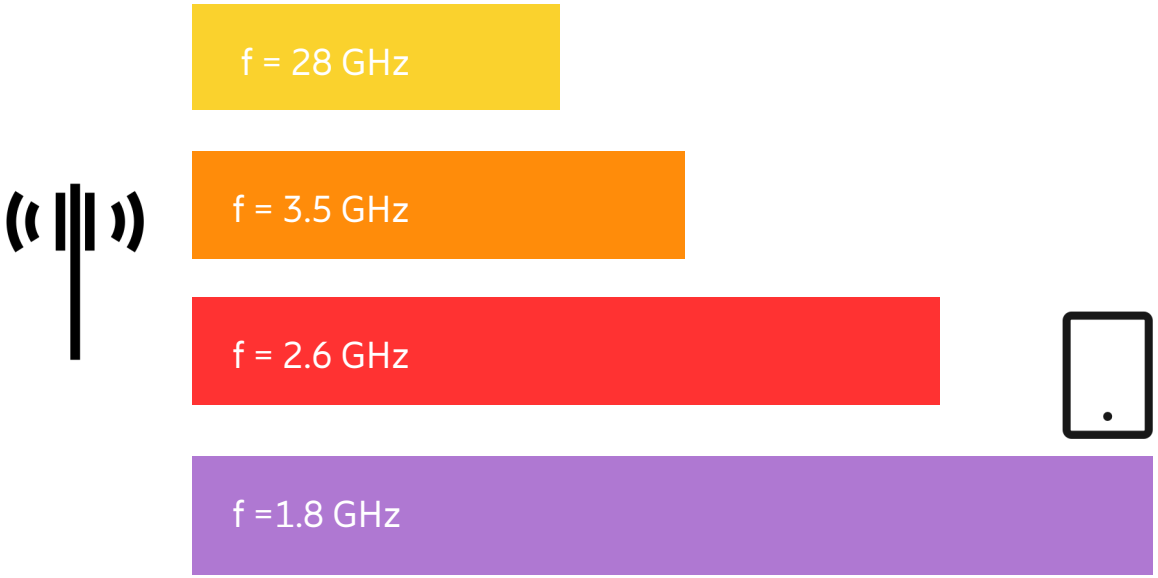
Capacity and Coverage are related to S/N ratio and available spectrum (BW) 容量和覆盖与信噪比和可用频谱有关

Max (Shannon) Capacity per communication channel: C= BW(Log_2(1+S/N))每通信信道的最大容量（香农公式）

Large capacity increase in NR from extra spectrum NR大容量增长来源于额外的频谱

mmWave Technology Characteristics—毫米波技术特性

Beamforming and AAS 波束赋形和先进的天线系统



S/N increases with 信噪比增加跟随

- Number of Tx/Rx Antennas 收发天线数
- Reduced Interference 降低干扰
  - **Beamform** towards wanted Transmitter / Receiver 发射接收方向的波束赋性
  - **Nullform** towards unwanted 无用方向产生无效型
- Antenna Gain 天线增益
- Transmit Power 发射功率

AAS

S/N decreases with: 信噪比降低跟随

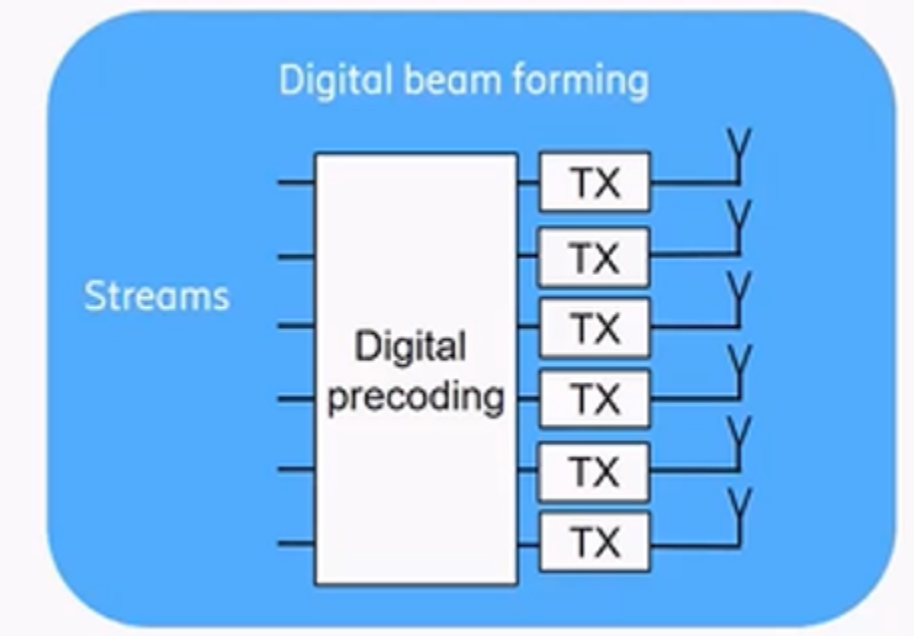
- Higher frequency 频率增高
- Greater Distance 距离增大
- Obstacles/Buildings 障碍物/建筑物
- Interfering users 干扰

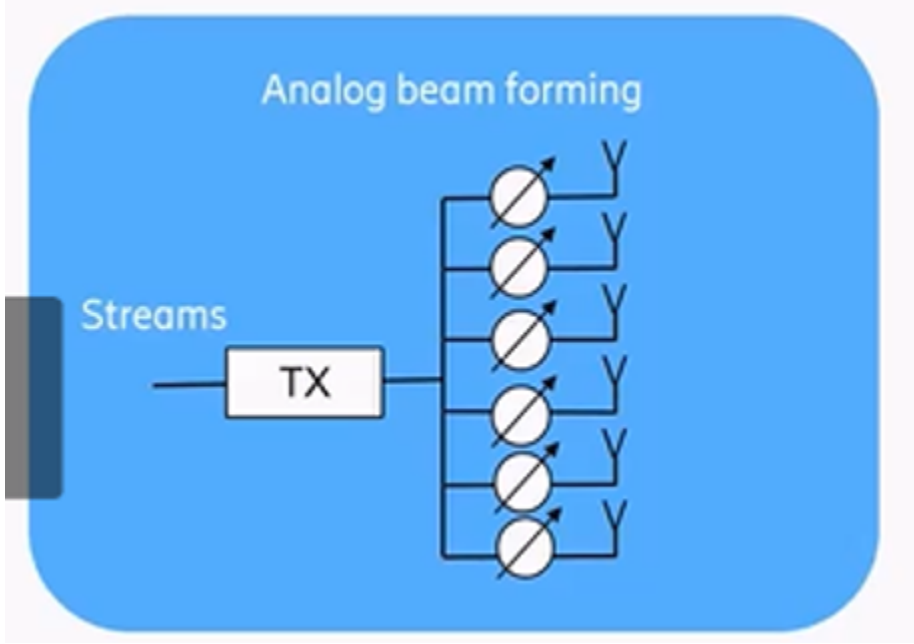
Physics

AAS improves S/N with beamforming. AAS also exploits improved S/N with MIMO techniques to increase capacity x
先进的天线系统通过波束赋形改善信噪比，同时通过MIMO技术来增加容量

AAS combats the physics, with coverage and capacity benefits AAS克服物理限制，带来覆盖和容量的好处

Digital vs Analogue Beamforming 数字和模拟波束赋形





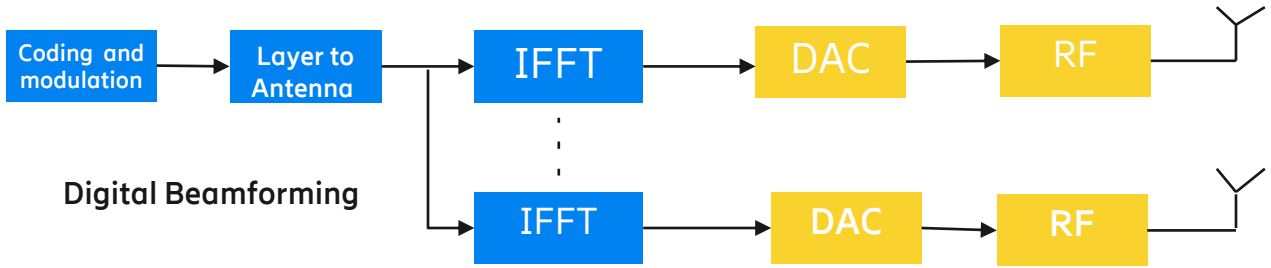
- One DAC/ADC per subarray 一个子阵一个模数转换
  - Baseband access to each individual antenna element
    每个基带接入对应一个天线单元
  - Allows different powers and phases to different antennas
    每根天线对应不同的功率和相位
- Different streams can get different beam weights 不同的流可以得到不同的波束权
- Flexible 灵活
- Multiple beams per antenna panel 每个天线板面产生多个波束

- One DAC/ADC per antenna panel 每个天线面板对应一个模数转换
  - The same signal is fed to each antenna and then analog phase-shifters are used to steer the signal in the time domain
    相同的信号发给每个天线，通过相位调节器来驱动信号在不同的时间发送
- One beam per time unit per polarization 每个时间单元每个极化方向对应一个波束
- One beam per antenna panel 每个天线面板对应一个波束

Why mmWave Using Analogue Beamforming毫米波用模拟波束赋型

Pros: 利

- One D/A and IFFT per beam instead of one per antenna
  每个波束一个D/A和IFFT,而不是每个天线
  - Lower cost and power dissipation 价格低和低功耗
  - Lower load and baseband processing 低负载和低基带处理



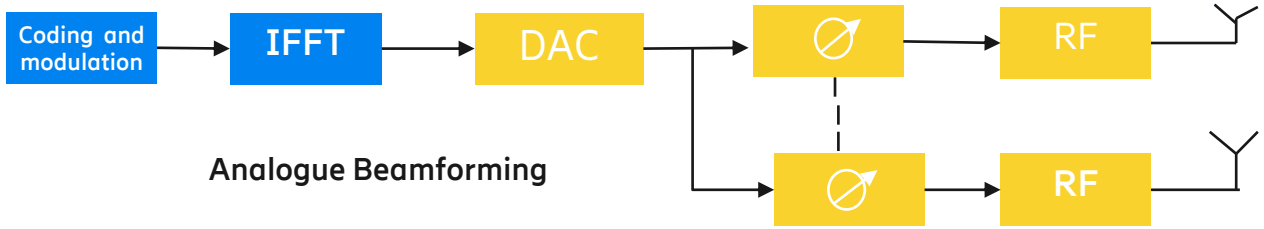
Digital Beamforming

Cons: 弊

- Not possible to do frequency selective scheduling(FSS) or Multiple beams (layers) per symbol (multi-user scheduling)
  不能做频率选择性调度或每个符号的多波束（多用户调度）

mmWave: 毫米波

- Large BW and many antennas 大带宽多天线
- Less multipath and lower delay spread, LoS propagation
  少的多径和较低时延扩展，视距传播
  - Lower probability for high channel rank 较低可能做多流
  - More important with polarization multiplexing 更重要的是极化复用
- Higher coherence bandwidth 高相干带宽
  - Less need for FSS, full BW can be allocated 不太需要频率选择性资源调度,整个带宽可以被调度

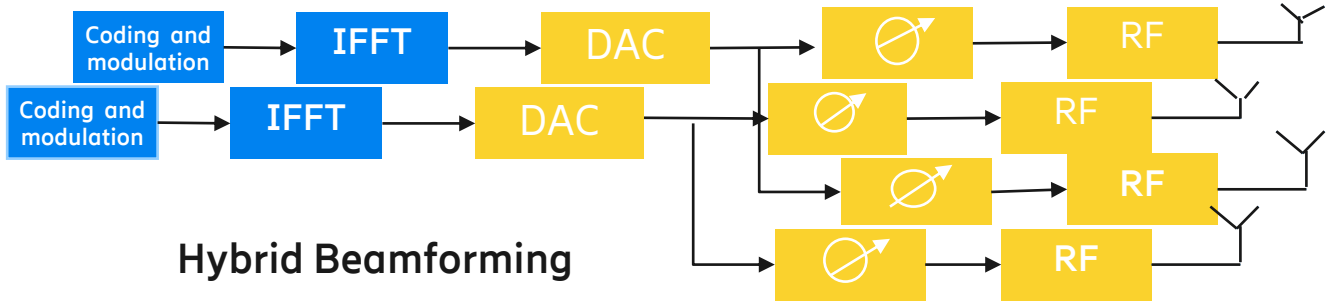


Analogue Beamforming

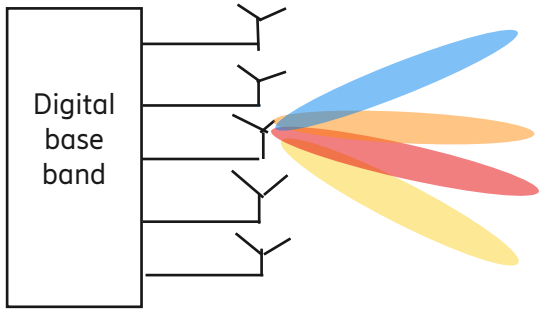
HybridBeam forming and comparison of different antenna architectures

毫米波混合波束赋型及几种天线架构的比较

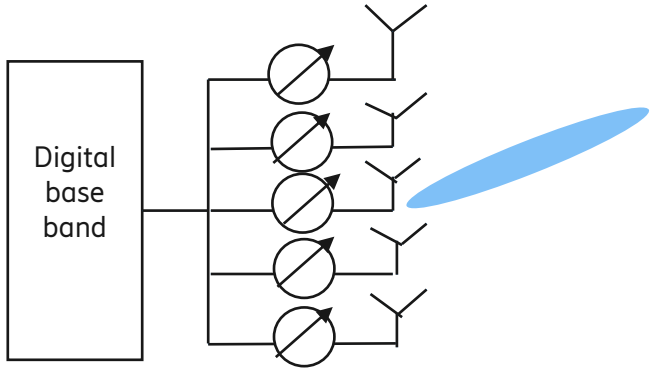
Hybrid Beamforming: Several parallel analog Networks that allow multiple beams/layers simultaneously



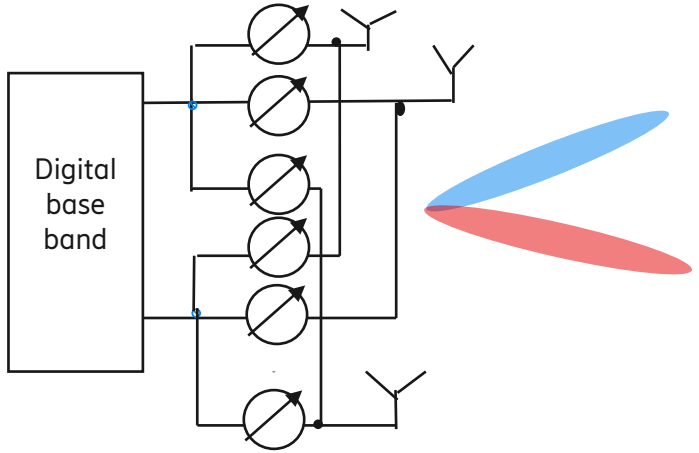
Hybrid Beamforming



Full flexibility, multiple beams per time unit
Adaptable to multi-path and frequency-selective fading
完全灵活，每个时间单元多波束
适应多径和频率选择衰落



One beam per time unit per polarization for the entire frequency band
One beam per antenna panel
全频带每个时间单元每个极化方向一个波束

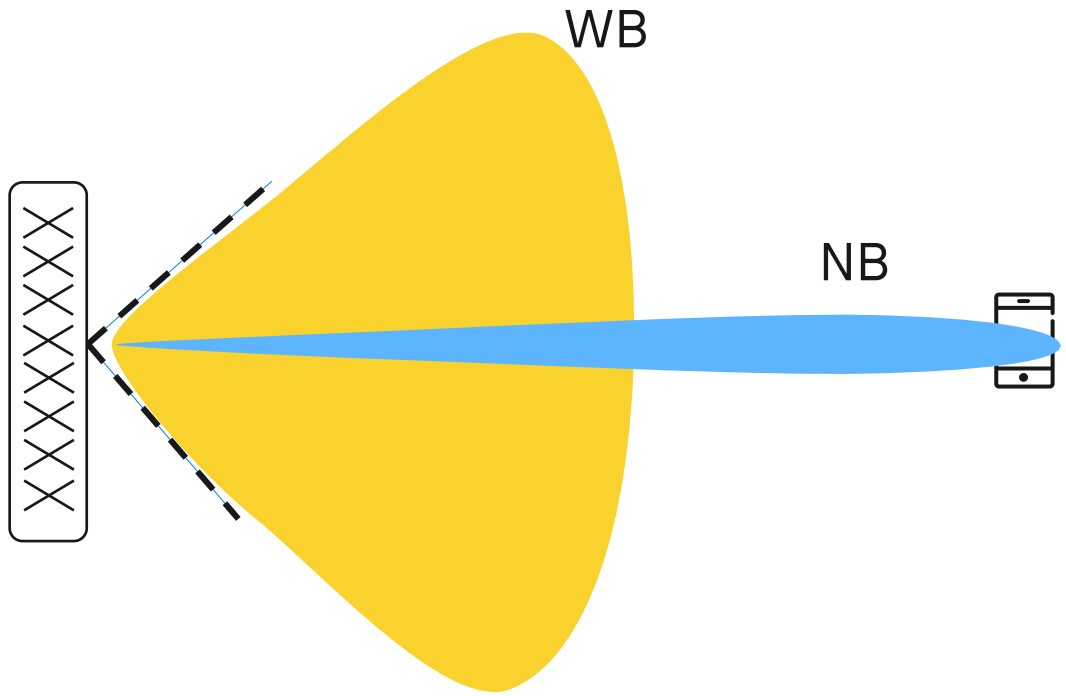


A few beams per time unit
Not adapted to multi-path or frequency selective fading
每个时间单元几个波束，不适应多径和频率选择性衰落

Why beam management? 波束管理

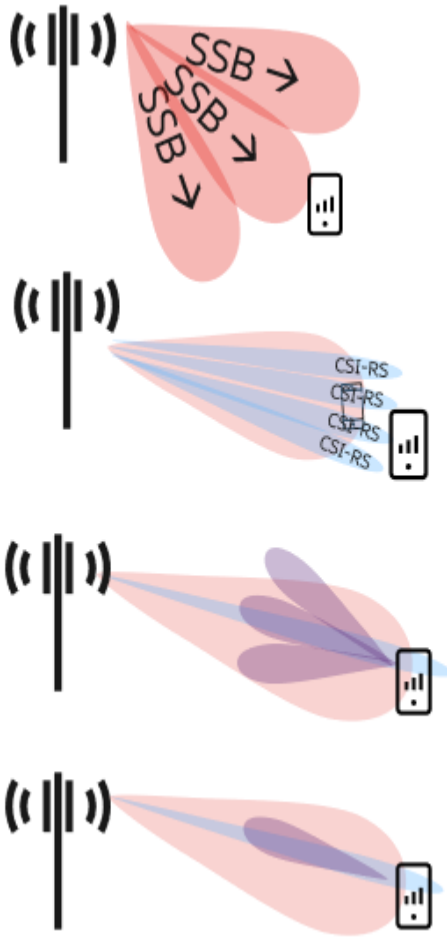
High band, analog beamforming 高频，模拟波束赋型

- Analog beamforming listens or sends in one direction at the time模拟波束赋形同时只能在一个方向上监听发送
- Wide beam that cover the whole cell will have too short reach宽波束可覆盖整个小区，但覆盖距离太短
- Narrow beam that reaches users will have too narrow coverage窄波束能覆盖更远的用户



Beam management波束管理

- Procedures for adding/updating a beam pair are supported 增加/修改波束配对
- A beam pair is updated by transmitting DL RSs
  - CSI-RS or SS block 通过发送DL RSs来进行波束配对更新
- The gNB and/or the UE updates its beams gNB 和UE更新他们的波束



"P1 procedure"

- gNB TX波束广播扫描
- UE 通过选定的宽波发起接入

"P2 procedure"

- gNB TX波束跟踪。CSI-RS窄波束扫描，用于TX优化
- UE 选定最好的接收波束方向进行发送

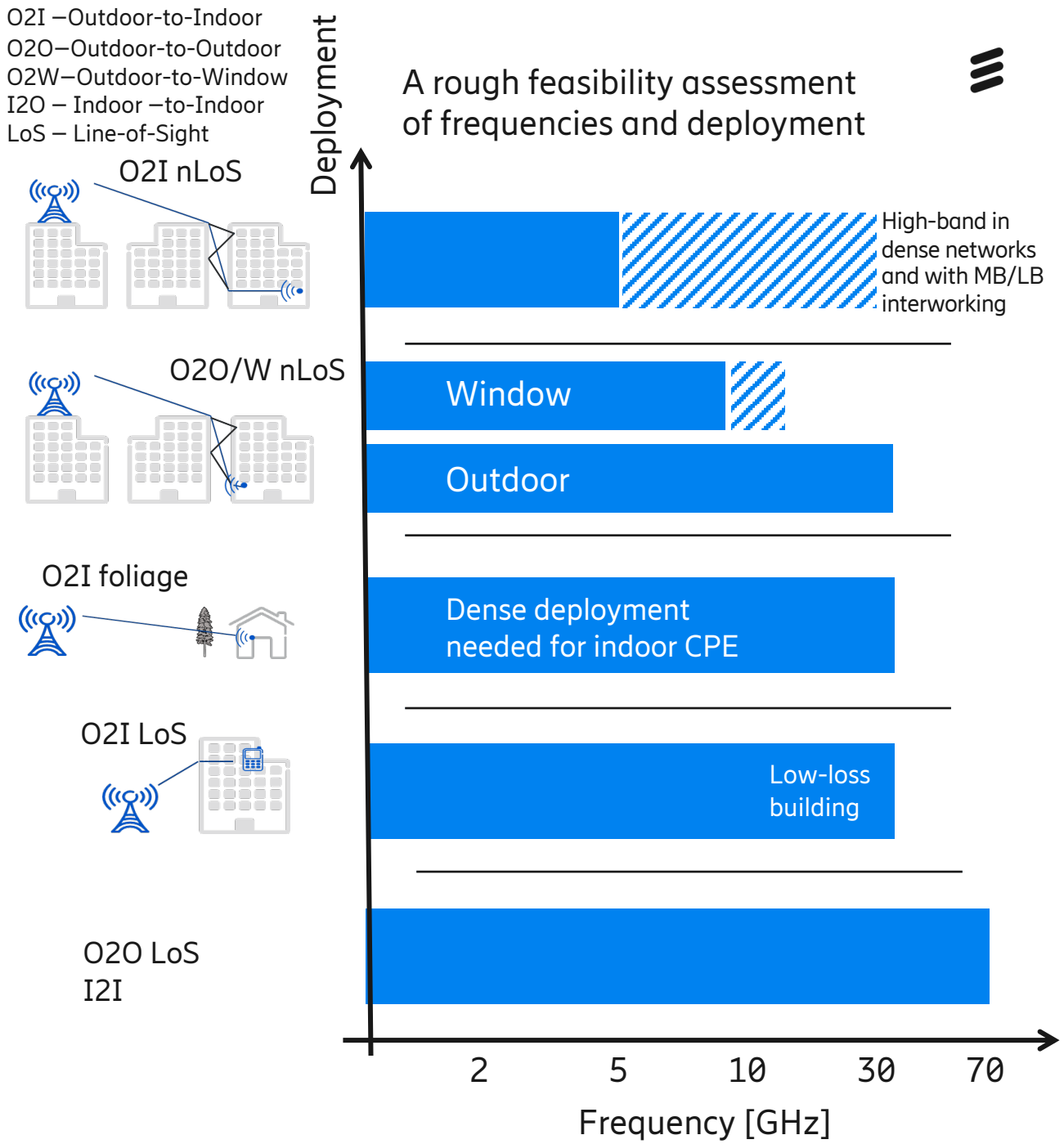
"P3 procedure"

- gNB RX波束配对

Frequencies & Deployments 频率和部署

- Usability depends on deployment and interworking with lower bands 毫米波的使用取决于与低频的共同作用
- Mid-bands are very valuable on existing grids when used together with lower bands 中频在现有网络布局里非常有价值当其与低频一起部署
- mmWave bands in deployments with good coverage 毫米波部署在覆盖比较好的情况
  - Examples: Line of sight to building, fixed wireless, outdoor-to-outdoor, indoor-to-indoor例如视距的楼宇、固定无线、室外到室外、室内到室内的传输

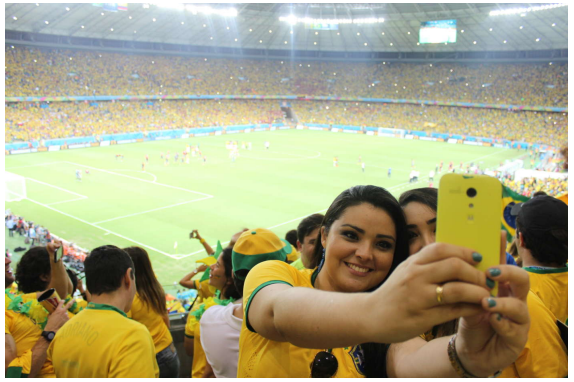
*Note: The figure is a rough summary of several simulation-based studies. Exact results depend on distances, building types, datarate requirements etc.



mmWave use cases 毫米波应用范例

- high throughput and capacity at low latency and small form factor 高吞吐量和容量、低时延和小的外型尺寸

Surveillance and video streaming / broadcast
监控和视频直播广播

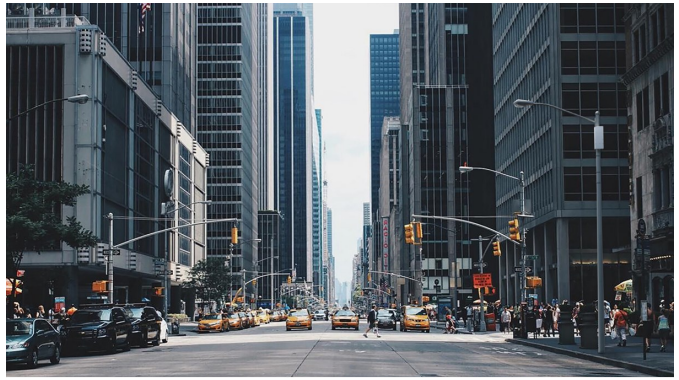


Crowded area capacity
密集区域的容量

Last-mile fiber/cupper complement
最后一公里/铜线替代

Everywhere AR/VR
各处的AR/VR

Smart Factory
Industry 4.0 智能工厂工业4.0



Street Macro applications
街区宏站应用

Live mmWave networks 毫米波现网的情况

AT&T achieves 1.3 Gbps @ 180m
AT&T获得1.3Gbps@180m

AT&T 5G live in 21 markets
AT&T 5G现网在21地区部署

- First commercial 5G launch Dec 21st 2018 2018年12月21号率先实现5G商用部署
- NETGEAR® Nighthawk 5G Mobile Hotspot & S10 5G
- Average speed record June/July tests (PCMag)

Gigabit speeds, Chicago, May 16th
Verizon 去年5月16号在芝加哥实现Gigabit 速率

Verizon 5G live in 15 markets
Verizon 5G 现网部署在15个市场

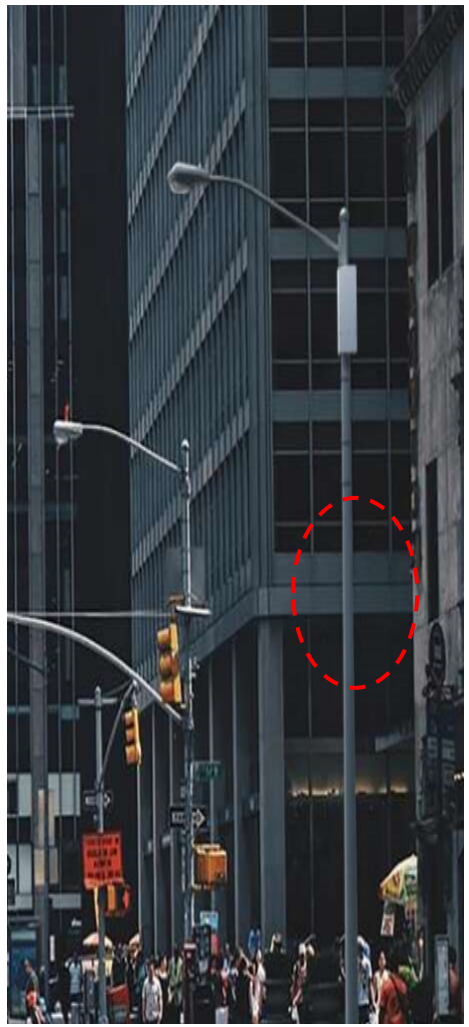
- Smartphone launch April 3rd 智能手机2019年4月3号上市
- Moto Z3, Z4, S10 5G, LG V50 & Inseego MiFi Hotspot
- NFL and NBA stadiums (NBA 场馆）

T-Mobile 5G coverage, New York City, June 28th 去年6月28日T-Mobile在纽约实现5G毫米波覆盖

T-Mobile 5G live in 6 cities
T-Moible 5G 现网部署在6个城市

- Launched June 2019 in 28 GHz 2019年6月部署的28GHz
- Samsung S10 5G
- Target to be 1st on nationwide coverage (600 MHz) 目标建设第一张600MHz的网络

mmWave live deployment measurements 毫米波商用网部署测试



Good outdoor/street coverage in live test 商用网测试中的较好的室外/街道覆盖

28G 400M带宽，12 站覆盖约1km²

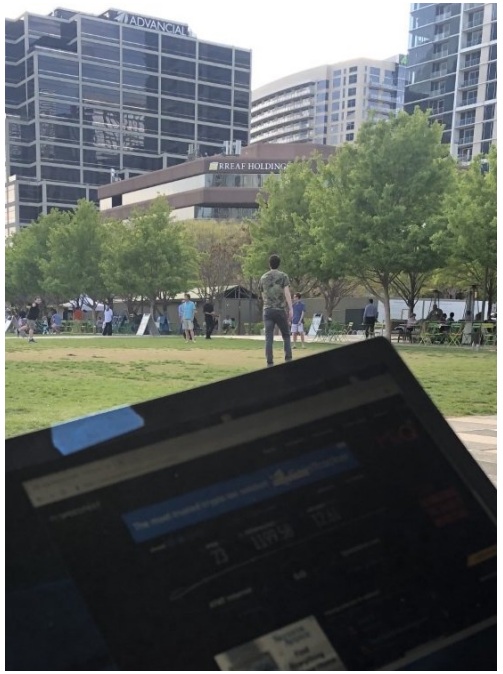
室外宏覆盖：

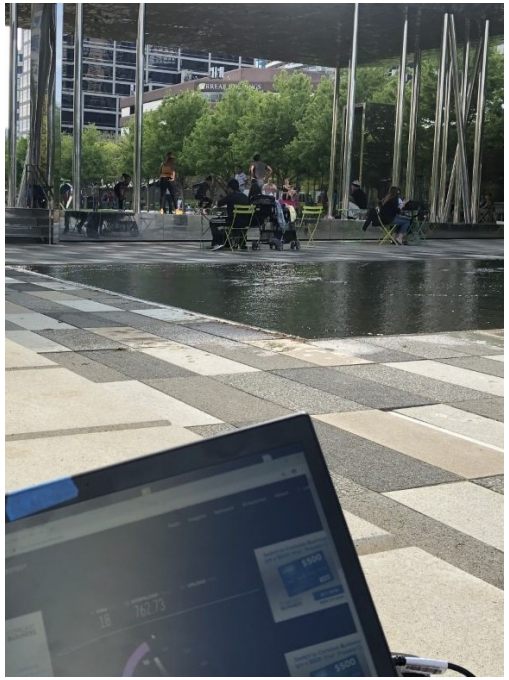
- RSRP < -80 dBm
- 好点速率约2Gbps

室内浅层穿透：

- DL speed ~ 400-500 Mbps
- UL speed ~ 24 Mbps

mmWave end-user experience 毫米波用户体验





	50m	100m	200m
Speed in mbit/s	1320	1199	762
Latency in ms	24	23	18

Moving in and out of some tree cover speeds varied between 687-763 Mbps
移动进出和树林覆盖物的速率在687-763 Mbps之间变化

mmWave deployment considerations 毫米波部署的一些考虑