

5G Priorities

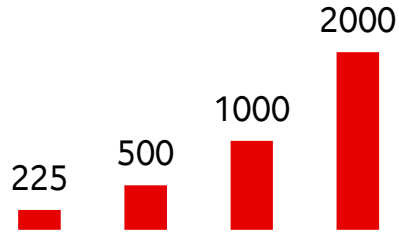


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Many factors will contribute to increased mobile usage

Network Evolution



- Higher speeds (Gbps+) drive higher usage
- Ubiquitous mobile data coverage still to come

Customer Evolution



- 20-40% customers still not using data today in many markets
- New generations will be “mobile native”

Device Evolution



- New device types
- New flexible form factors due to material evolution

Service Evolution



- New/evolved services (IoT, New “5G” services, everything in the Cloud)
- New commercial models drive usage

We are already starting to deliver new “5G” capabilities via LTE enhancements

Narrow Band IoT (NB-IoT)

Addresses immediate 5G use cases

- ✓ Massive connection density
- ✓ Power efficient, best coverage
- ✓ Standards completed in June 16
- ✓ Deployments in 2017



Vehicle to Vehicle based on LTE v2x

Addresses immediate vehicle safety use cases

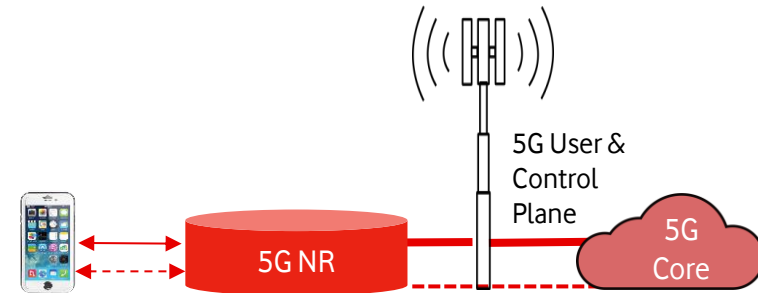
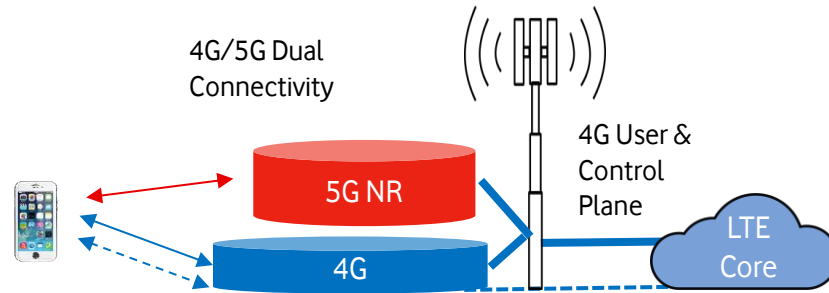
- ✓ Builds on existing LTE framework
- ✓ Offers a single family of technologies for ITS (Intelligent Transportation System)
- ✓ Standards completion due March 2017



Non Stand-alone operation enables early deployments reusing existing assets

Initial 5G deployment

Longer term 5G deployment



Timelines

Non-Standalone NR Spec (Dec 17), supporting commercial launches from H2 2019

Rel15 completion from June 2018

Benefits

Re-uses existing 4G assets and addresses eMBB

E2E 5G capabilities and cloud native applications

Deploying 5G in sub-6GHz is critical for commercial success

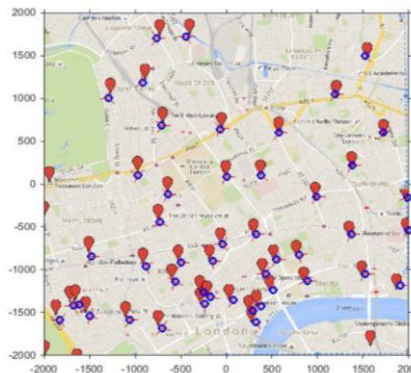
5G eMBB Features & Benefits

- ✓ Re-use of existing LTE Core Network
- ✓ LTE Anchor (Dual Connectivity) enabling seamless mobility & data aggregation
- ✓ New Massive MIMO technology maximising speed & capacity
- ✓ High Speed/Capacity Access in Single Band or in aggregation with other bands



Major City Performance (Simulations)

London City Area (ISD = 600m)



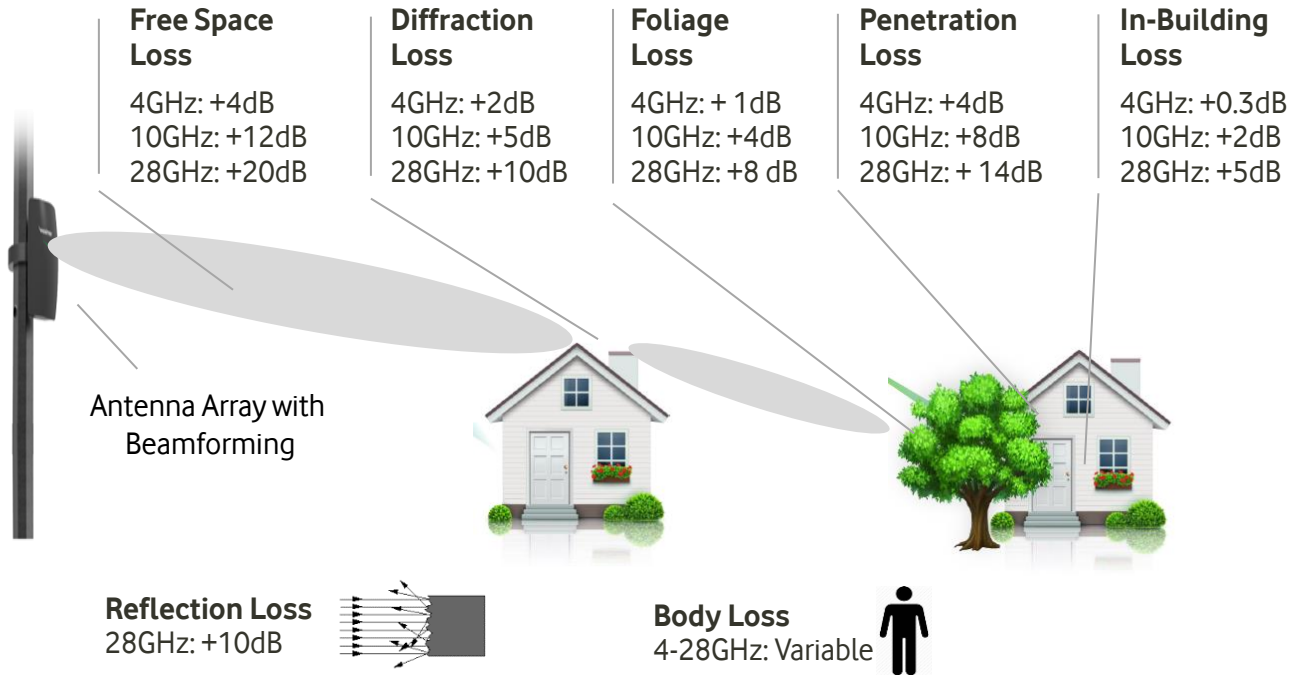
5G Capacity & Cell Edge Gains

Cell Edge Throughput	x 3
Capacity	x 4-5



Gains relative to LTE network with 10MHz @ 800 & 20MHz @ 2600

Buildings and vegetation limit coverage at 28GHz

Propagation Loss Relative to 2.6 GHz



Total Relative Loss

	4 GHz	+10 dB
cm Wave	10 GHz	+30 dB
	28 GHz	+57 dB

Excludes Body Loss

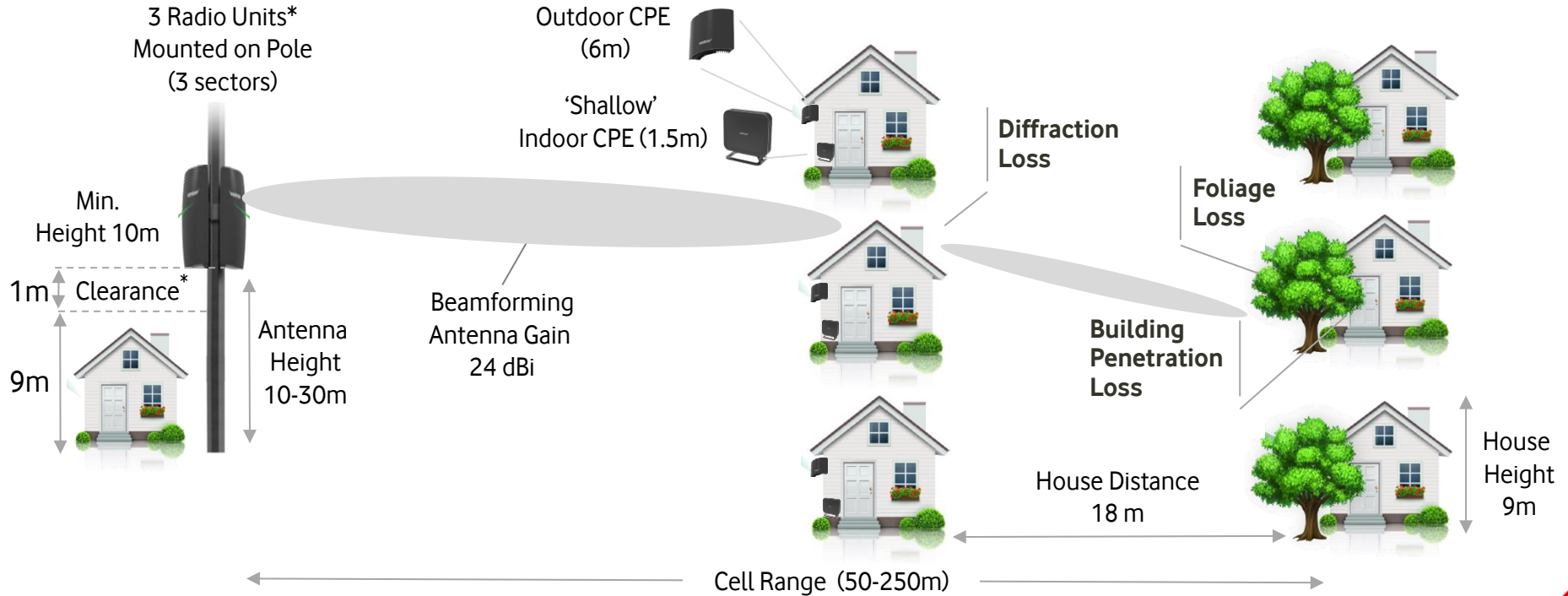
High frequency bands suitable only for outdoor near line-of-sight environments

Assumptions: Foliage depth of 3m, Indoor distance of 4m, Modern households with IRR glass



We have assessed performance at 28GHz

*Deploying antennas below or just above the average HH height will only provide suitable coverage in direct LoS conditions

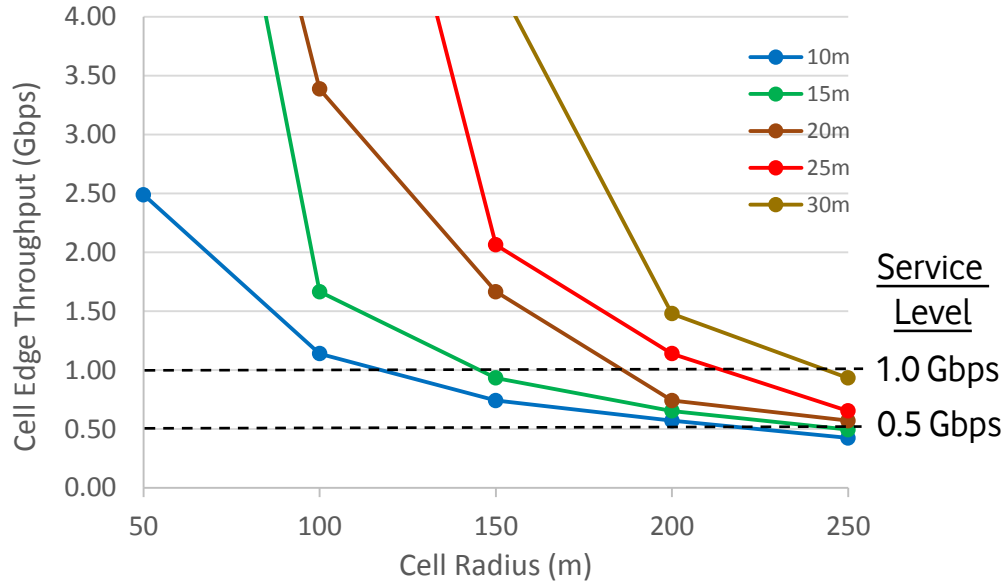


All cases assumes well positioned outdoor/indoor CPEs facing pole mounted Radio Units

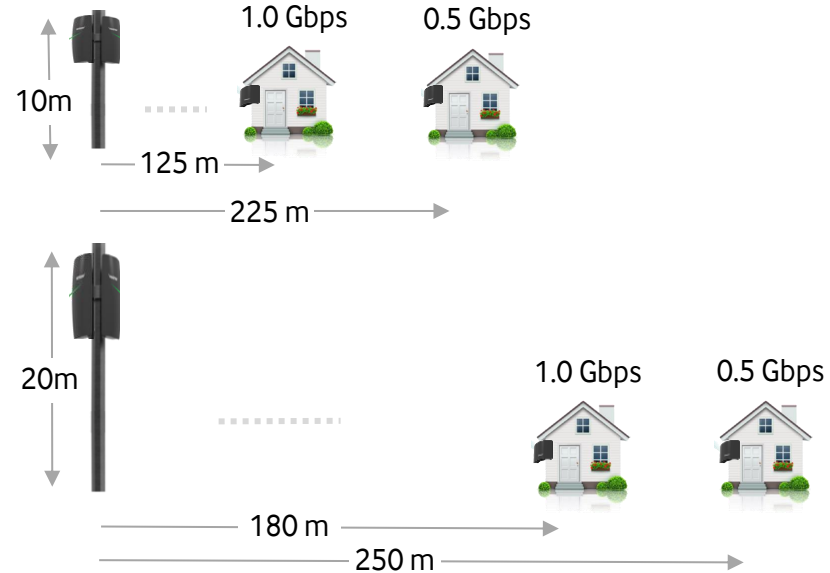


Range may be no more than 100-200 meters

Cell Edge Throughput vs Cell Radius & Pole Height *(Outdoor CPE)*



Maximum Supported Cell Range *(Outdoor CPE, No Foliage Loss)*



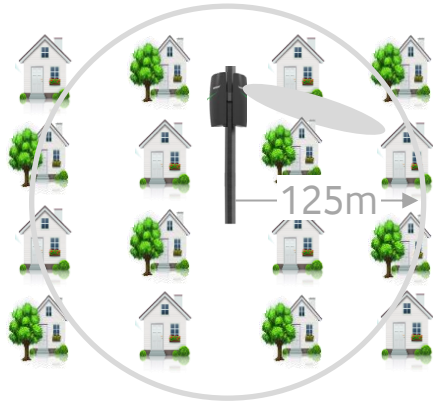
A minimum antenna height of 10m can provide 0.5 & 1 Gbps at a max range of 225 & 125m, respectively
Doubling the antenna height to 20m can provide 0.5 & 1 Gbps at a max range of 250 & 180m, respectively



European cost comparison for 1 Gbps Service Level

Max Cell Range (1 Gbps)

Frequency Band: 28MHz
Pole Height: 10m
Average Household Height: 9m
Bandwidth: **800MHz** (600 DL/200 UL)



Maximum Cell Range = 125m
Min. Required Sites/km² = 20

Household Density

Dense Sub-Urban
2000 Houses/km²



~100 houses per Site

Moderate Sub-Urban
1000 Houses/km²



~ 50 houses per Site

RAN Cost per Customer

excluding spectrum fees, IT systems, CPE costs & installation

50% Market Share

~ competitive to fixed

20% Market Share

~ 3x cost

50% Market Share

~ 2x cost

20% Market Share

~ 5x cost



Summary

- 5G is most commercially relevant for lower frequency bands supporting mobility and coverage based on existing macrocell assets
- Opportunity to use 5G to replace fibre to households is a niche use case with limited commercial impact
- Industry must focus on those bands which are most relevant to customers

