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# RF exposure impact on 5G rollout
# A technical overview

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# More spectrum with improved spectrum utilization

## To serve a broad range of 5G use cases

**< 3 GHz**
Wide & medium area coverage, existing grid, current radios

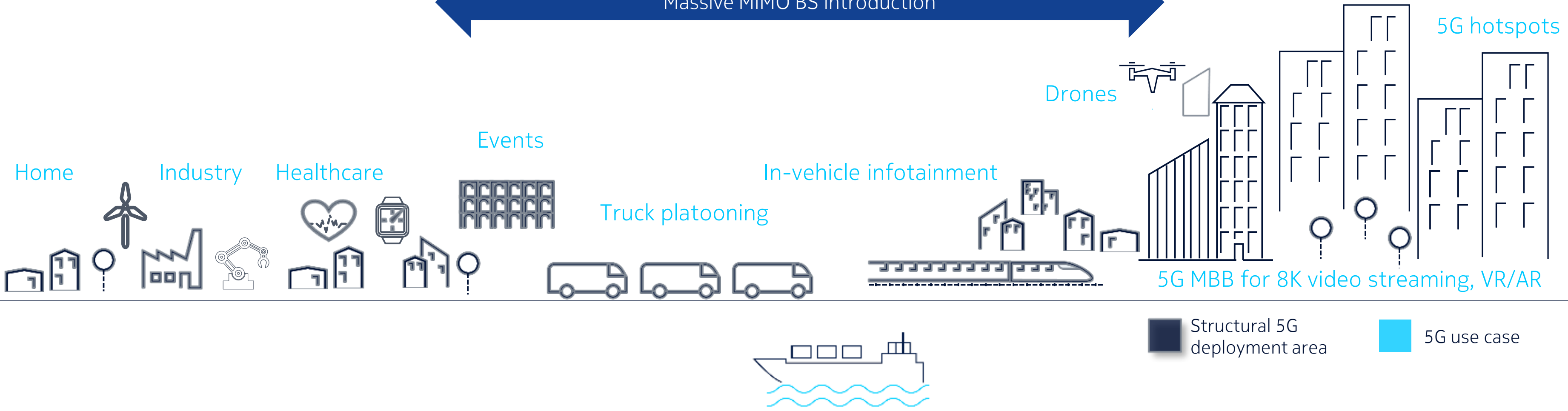
**3 GHz-6 GHz**
High capacity, existing grid, new radios

**mmWave (6 - 100 GHz)**
Ultra high capacity, denser grid, new radios

**Spectrum utilisation**
5G spectrum utilization is up to 98% of carrier bandwidth with 40-100 MHz bandwidth (vs. LTE up to 90%)

Macro BS & Small Cells

Massive MIMO BS introduction




Structural 5G deployment area

5G use case

# 5G Small Cell use cases

## Compounding factors will lead to Small Cells playing a key role in 5G

### 5G key characteristics pointing to SC

| | |
|---|---|
| High frequency bands | Lead to reduced ISD & poor indoor coverage |
| Unlicensed band aggregation | Unlicensed bands power limits lead to small aggregation zones |

### 5G key use cases pointing to SC

| | |
|---|---|
| Focus on Ultra broadband | 5G deployed where SC are today. Less UE/cell = ↗ spectral efficiency |
| Alternative use cases & IoT | Small Cells perfect fit for industry verticals, private networks & all indoor locations |

**5G small cells**

**Urban**

SC underlay utilising current 4G SC grid

**Mass events**

Small Cells for ultra broadband

**Indoor**

Dedicated indoor Small Cell solution

**Verticals**

Small Cells for Private networks

# Small Cells reduce RF exposure and improve performance

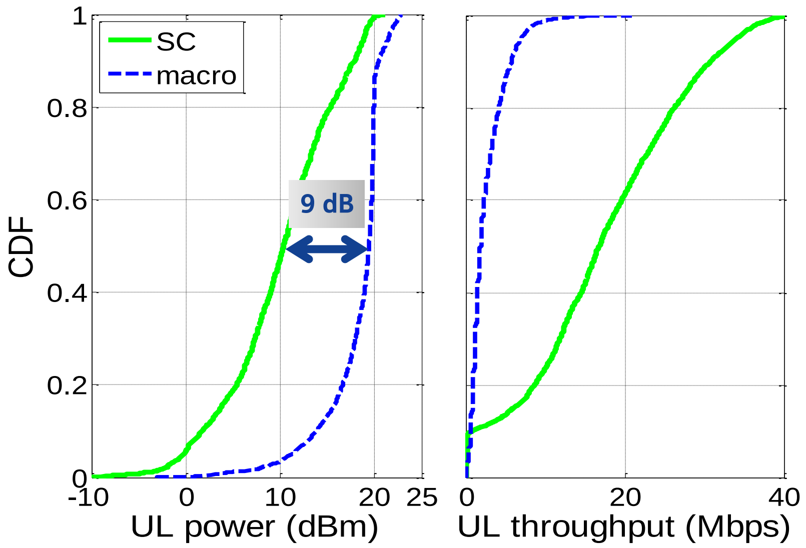
## Considering user equipment and system behavior

### Roles of Small Cells

- Low-powered base station (<6.3 W/port) installed close to users
- Indoor/outdoor coverage (10 to 100's meters)
- Improve capacity & coverage in localized areas

### When the Small Cell is "on"

- User equipment (UE) performance is increased
- UE power transmission is reduced by a factor 8 (9 dB) for a 50th percentile of points near the SC
- From field measurements using walk tests within 100 m around the small cells
  *(see T. Mazloum et al. "Assessment of RF Human Exposure to LTE Small-And Macro-Cells: UL Case, EuCAP'17, March 2017)*




| | UL power (dBm) | | | UL throughput (Mbps) | | |
|---|---|---|---|---|---|---|
| | mean | median | 95% | mean | median | 95% |
| SC | 13.2 | 10.4 | 18.9 | 17.1 | 16.8 | 34.1 |
| Macro | 19 | 19.5 | 21.5 | 2.6 | 1.9 | 6.9 |

# Impact of more restrictive limits on Small Cells with 4G (now) and 5G

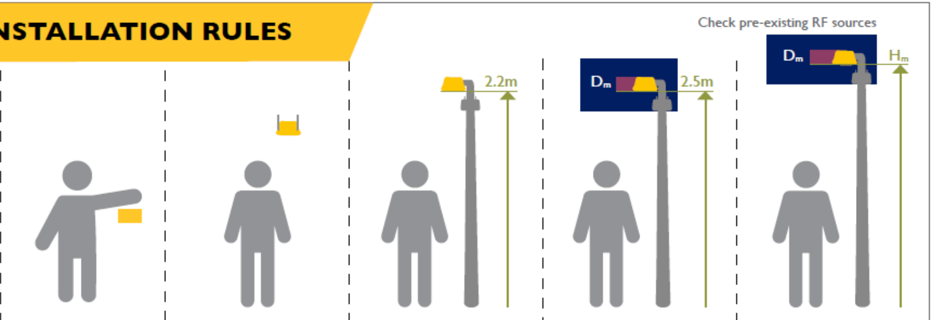
## Additional cost and delays

### Simplified installation criteria have been adopted globally (based on IEC 62232 & ITU-T K.100 using ICNIRP limits)

**SIMPLIFIED INSTALLATION RULES**

**From IEC 62232 Ed.2.0**

Installation must be done according to instructions from the manufacturer or entity putting into service




| | | | | | |
|---|---|---|---|---|---|
| Installation class | E0 | E2 | E10 | E100 | E+ |
| Total EIRP | N/A | ≤ 2 W | ≤ 10 W | ≤ 100 W | No limit |
| Minimum height above walkway | None | None | 2.2 m | 2.5 m | $H_m$ (calculation) |
| Exclusion zone | None, touch compliant | Provided in manufacturer's instructions Small $D_m$ not shown on the picture | | Provided in manufacturer's instructions $D_m$ in main lobe direction | |
| Check pre-existing RF sources | N/A | N/A | N/A | $5D_m$ in main lobe direction $D_m$ in other directions | |

Source: GSMA and Small Cell Forum SCF012 [http://scf.io/en/documents/012_IEC_equipment_classes_infographic.php]

## Consequences of restrictive limits

- Exposure limits reached with lower EIRP or less equipment per site
- Higher cost (more sites)
- Additional delays in providing broadband access to people

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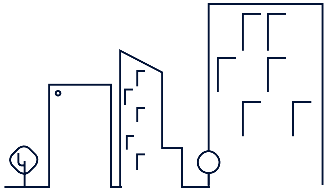
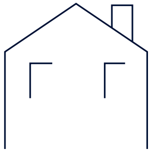
# Massive MIMO use cases in 5G

## Beneficial to end users with significant capacity and coverage gain

| Inside of buildings and towers | Stationary users | Dense Urban |
|---|---|---|
|  |  |  |
| Typical user throughput performance improvements:<br>• Uplink (UL): 5X to 8X<br>• Downlink (DL): 2X to 3X | Typical user throughput performance improvements:<br>• Uplink (UL): 2X to 5X<br>• Downlink (DL): 2X to 3X | Typical user throughput performance improvements:<br>• Uplink (UL): 2X to 3X<br>• Downlink (DL): 2X |

Assumptions: user throughput in 4.9G using B41 mMIMO 64T64R radio vs 8T8R radio
UL = transmission from the base station to the user equipment
DL = transmission from the user equipment to the base station

# Massive MIMO principles

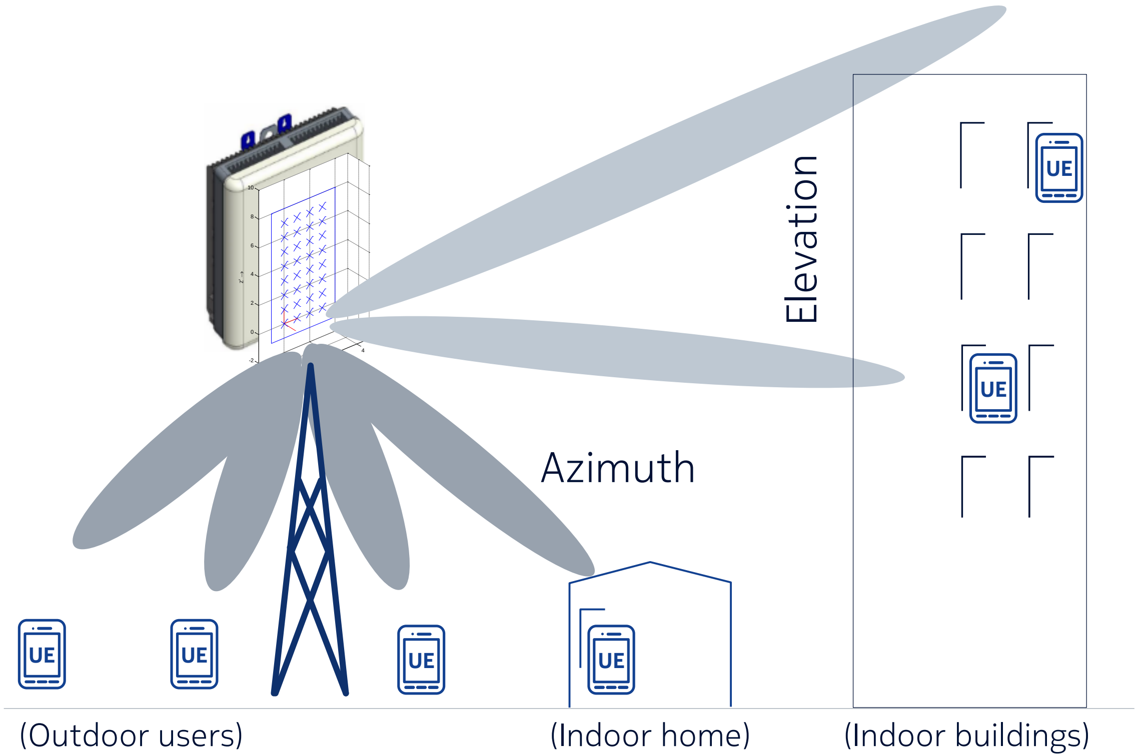
## To serve each active user with a dedicated beam for the duration of the call

### Roles of massive MIMO

- Coverage (high bands)
- Capacity and performance
- Spectrum efficiency

### Principle

- Active antenna system composed of many small active antenna elements
- Antenna beams are steerable in 2D or 3D directions
- Energy is mainly focused on active user equipment (UE)
- Lower amount of unwanted interference

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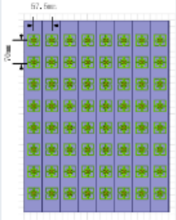
# 5G massive MIMO transmitted power statistics

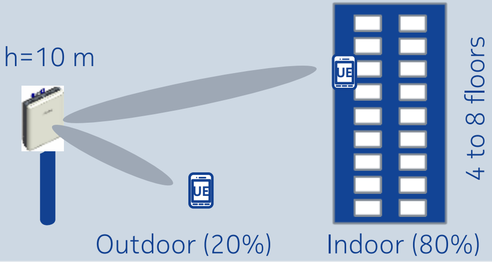
## Case study based on realistic scenarios defined in 3GPP TR 36.873

### Antenna array system

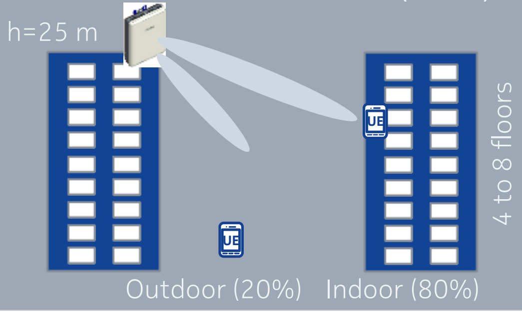
- 8x8 antenna elements
- 3.5 GHz
- 26 dBi gain
- Wideband eigenbeamforming
- Full buffer



### Urban Micro scenario (UMi)

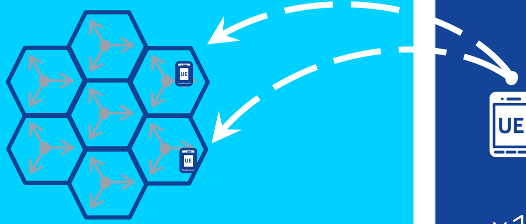



### Urban Macro scenario (UMa)

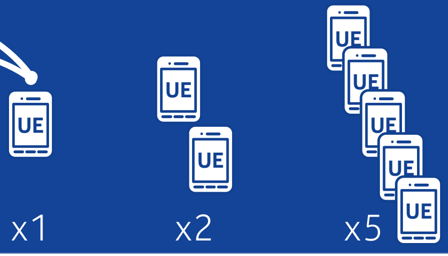



### Sub-network model

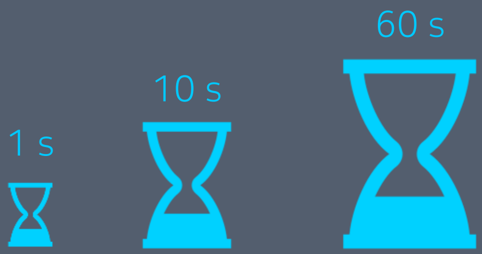
- 7 sites x 3 cells



### Number of UEs per cell (K)




### UE drop duration (D)




[from P. Baracca et al., “A Statistical Approach for RF Exposure Compliance Boundary Assessment in Massive MIMO Systems” submitted to WSA’18, Bochum.]



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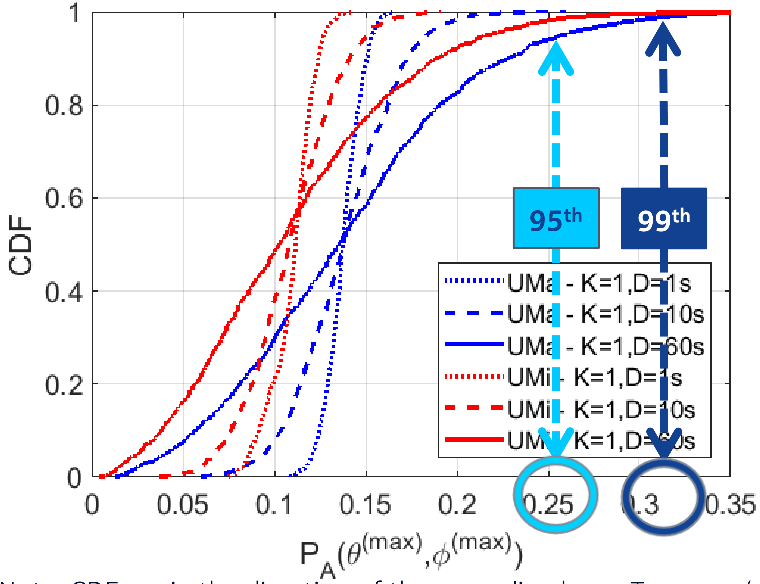
# Actual transmitted power with massive MIMO systems

## Normalized Tx power distribution: $95^{th}$ percentile < 26 % and $99^{th}$ percentile < 32 %

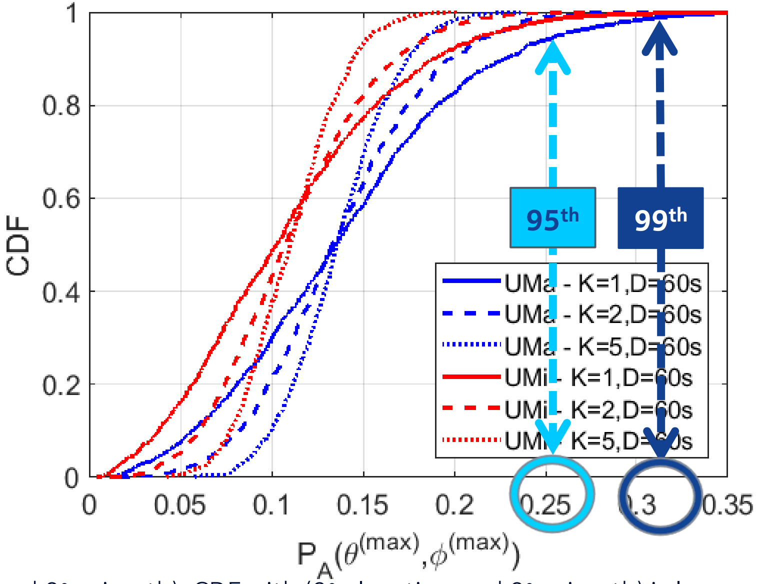
### Single UE served for 1 to 60 s

Lower Tx power for shorter active UE duration D




### Multiple UEs (1, 2 or 5) served for 60 s

Increasing the number of UEs K reduces the deviation of the Tx power around its average value




Note: CDF are in the direction of the normalized max Tx power (-5° elevation and 0° azimuth); CDF with (0° elevation and 0° azimuth) is lower
[from P. Baracca et al., "A Statistical Approach for RF Exposure Compliance Boundary Assessment in Massive MIMO Systems" submitted to WSA'18, Bochum.]

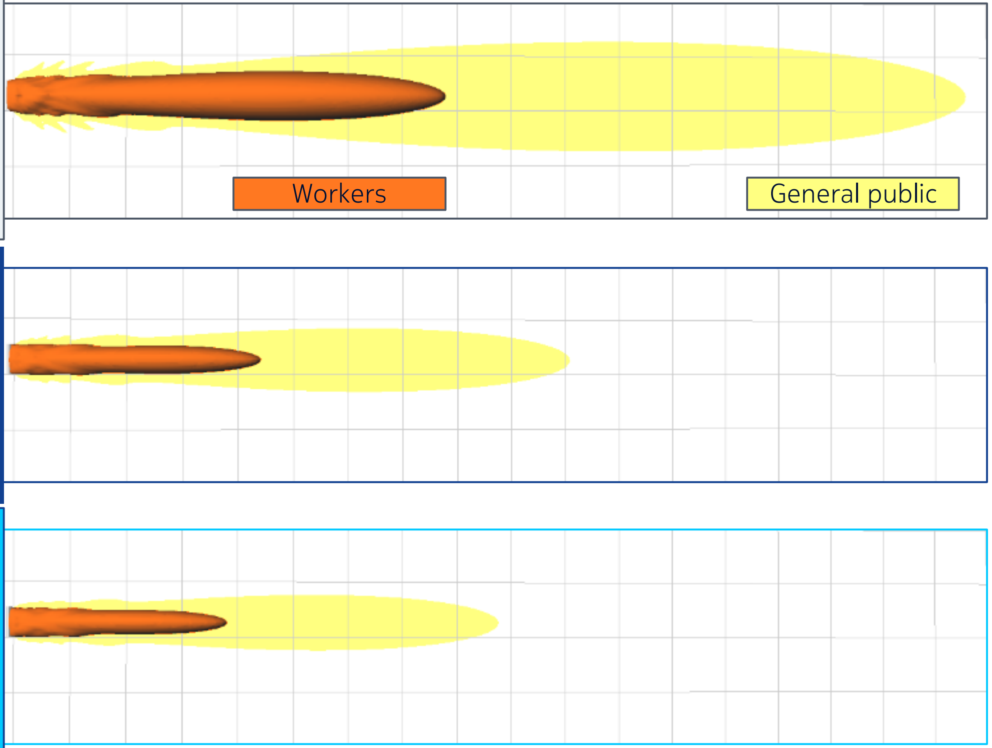
# Impact of more restrictive exposure limits on compliance distances

## Reduced Tx power → smaller cell range → increased nb of sites → increased costs & delays

**Full Tx power**

**99th percentile Tx power**

**95th percentile Tx power**




Assumptions:

- Synthetic method simulation (EMFVisual V.3.03c)
- TDD system with DL/UL ratio of 0.75

Derived from P. Baracca et al., “A Statistical Approach for RF Exposure Compliance Boundary Assessment in Massive MIMO Systems” submitted to WSA’18, Bochum

# RF exposure assessment impact on 5G rollout

## Key take-aways

- 5G is introducing new spectrum and improved spectrum utilization serving a broad range of use cases
- More restrictive exposure limits mean lower transmitted power per site and more sites to achieve the expected network performances, resulting in additional costs and delays to get access to 5G use cases
- RF exposure varies considerably in time and space depending on active users distribution and traffic conditions
- Statistical models provide a useful information to assess the actual RF exposure conditions for 5G systems
- Measurements and management systems (e.g. transmitted power analytics) provide complementary information to enforce statistical model based assessments

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