mmWaves
for future radio access
opportunities and challenges

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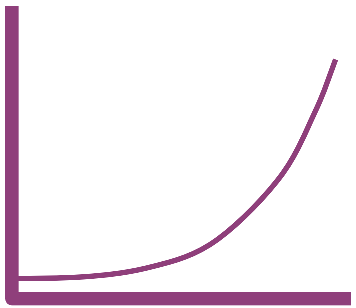
FUTURE RADIO ACCESS

KEY CHALLENGES

Massive growth in **Traffic Volume**

Expanding mobile broadband and communicating machines



"1000x and beyond"

Massive growth in **Connected Devices**

">50 billion devices"

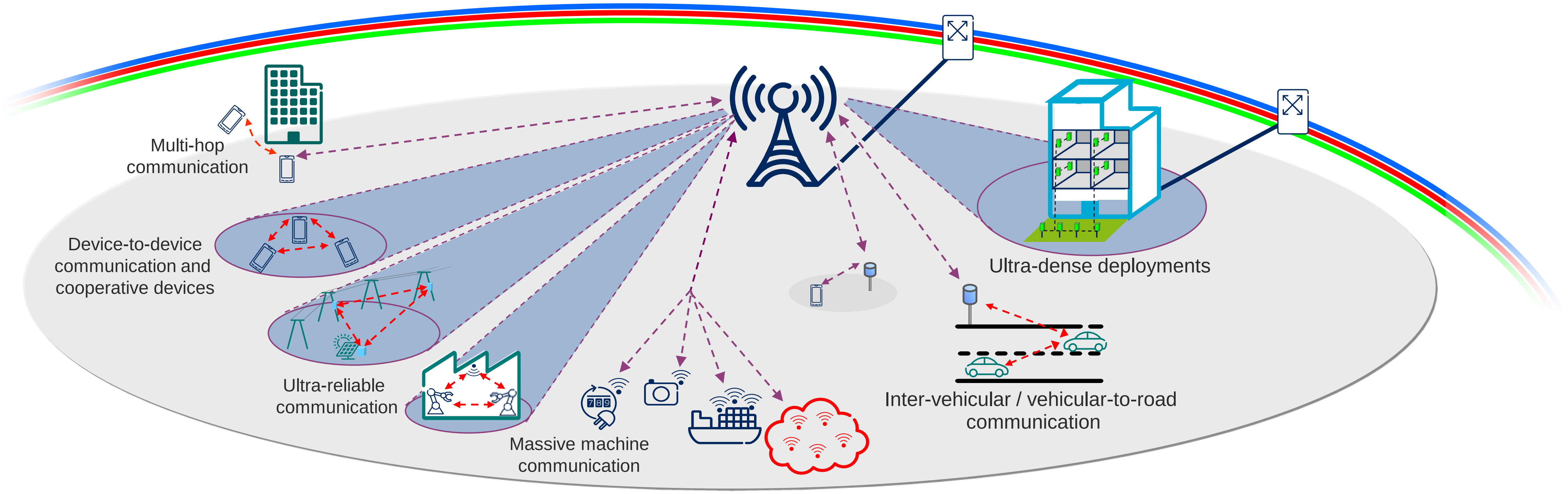
Wide range of **Requirements & Characteristics**

- **Data rates**
- **Latency**
- **Reliability**
- **Device energy consumption**
- **Device cost**
- **.....**

Affordable and sustainable

FUTURE RADIO ACCESS
NETWORKED SOCIETY VISION

Multiple Integrated Wireless/Access Solutions enabling the long-term Networked Society



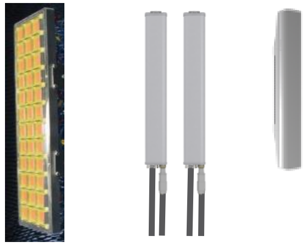
More than peak data rates and system capacity

DATA RATES AND CAPACITY

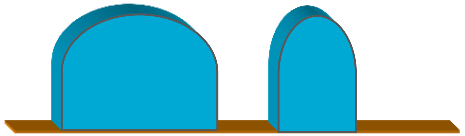
SOME TECHNOLOGY COMPONENTS

Further Densification

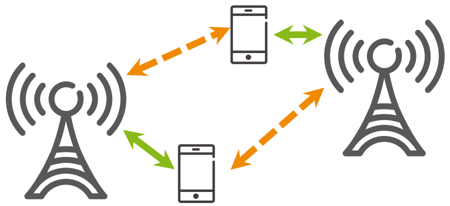
More Advanced Antennas

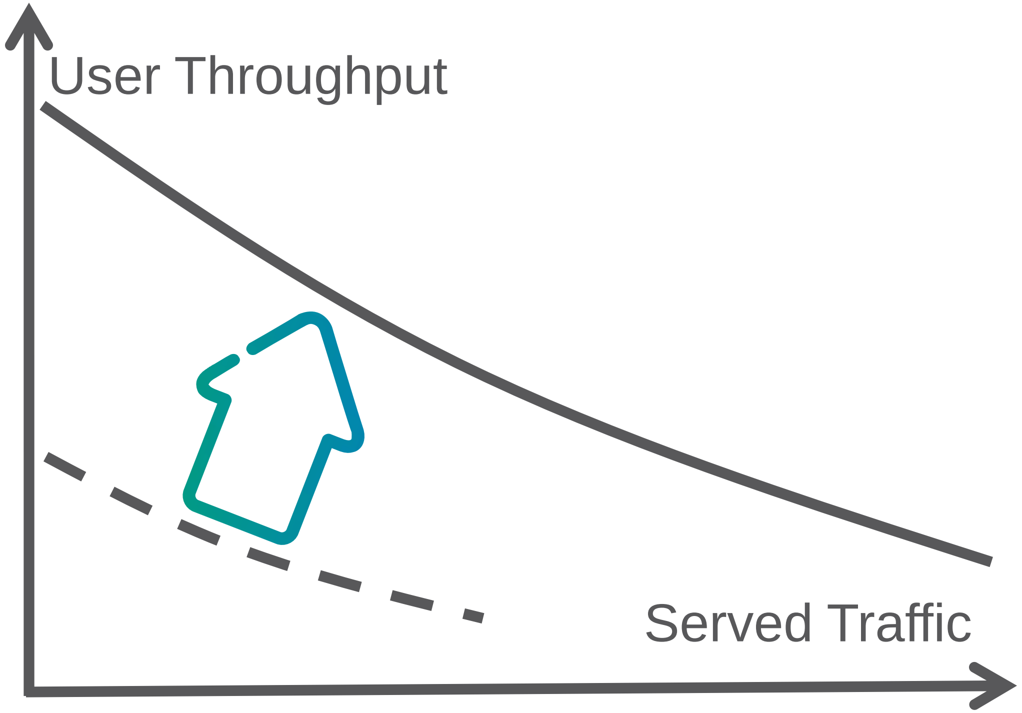


More Spectrum



Interference Management

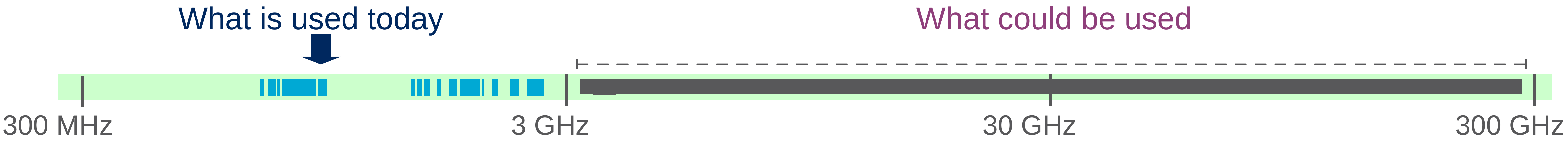




- Combine densification, antennas and spectrum for high data rates
  - Very high data rates pose basic link budget challenge,
  - Densification needs backhaul

"MMWAVE" FREQUENCIES
MORE SPECTRUM

- Potential for vast amount of spectrum



- Large bandwidths for high capacity and efficient provisioning of (very) high data rates
  - but not the only solution…

- But, spectrum is not un-used today
  - Wireless backhaul, an enabler for densification
  - … as well as satellite, military, short range communication, radar, sensing,…

MMWAVE PROPAGATION
LOS

- Path loss between *isotropic* antennas ~20log10(f)
  - Directivity for *fixed area antenna* ~20log10(f)
  - Fixed antenna area at one side ➡ frequency independency (ideally, perfect pointing)
  - Fixed antenna area both sides ➡ gain from increasing frequency (ideally, perfect pointing)

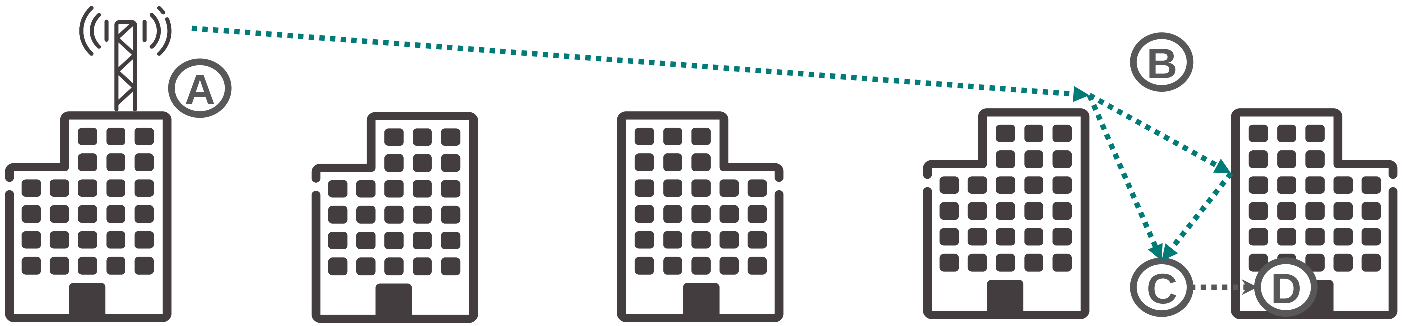
Example with parabolic antennas

- Atmospheric absorption*
- Rain attenuation*

Important for LOS wireless backhaul planning

**Sources: Rec ITU-R P.676-9 (02/2012) Attenuation by atmospheric gases and Rec ITU-R P.838-2 Specific attenuation model for rain for use in prediction methods*

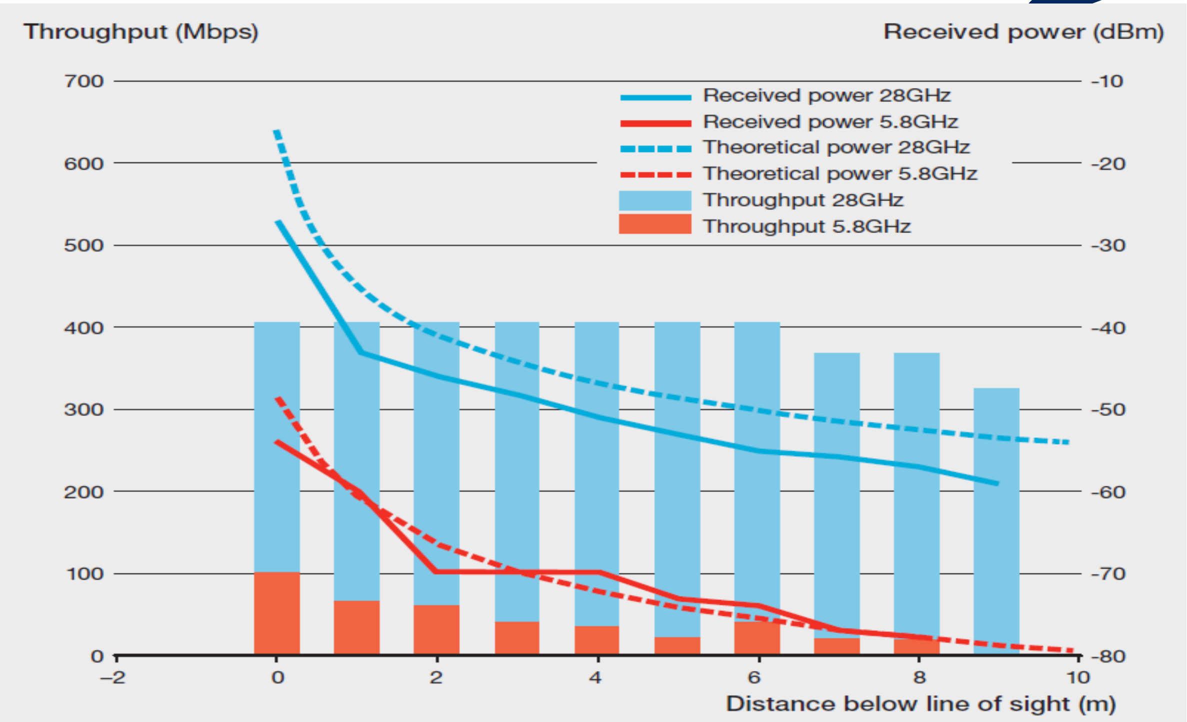
MMWAVE PROPAGATION
NLOS



- Diffraction loss
  - A ➡ B: possibly lower multi-screen diffraction losses
  - B ➡ C: ~10log10(f) additional loss (knife-edge diffraction based model)
- Reflection loss
  - Material dependent, frequency dependency?
- Outdoor-to-indoor penetration loss (C ➡ D)
  - Increasing with frequency for many materials ➡ loss likely increasing with frequency?

… there should be NLOS scenarios with “decent” additional loss…

NLOS BACKHAUL TRIAL
DIFFRACTION



- Comparison with similar antenna sizes at both ends
  - 5.8GHz: 1x40MHz TDD, 19dBm, 17dBi antennas
  - 28GHz: 2x56MHz FDD, 19dBm, 38dBi antennas (Ericsson MINILINK PT2010)

[Agreements for pathloss, antenna directivity and diffraction models,]

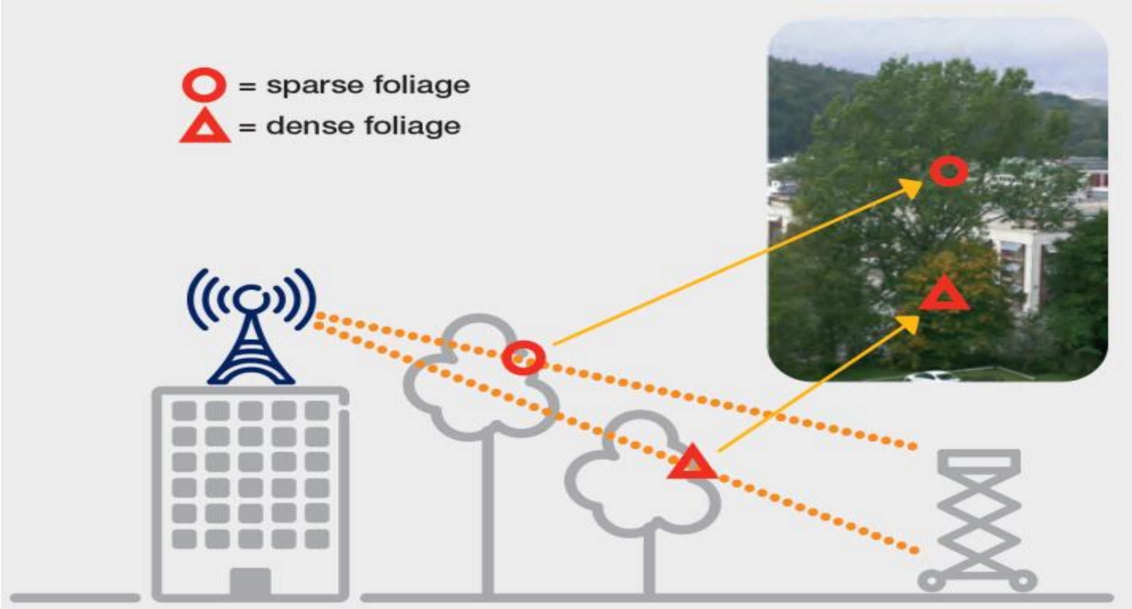
See further http://www.ericsson.com/news/130222-non-line-of-sight-microwave-backhaul-for-small-cells_244129229_c

NLOS BACKHAUL TRIAL
REFLECTION

- Reflections may be used
  - 5-25dB additional loss as compared to LOS expected in trial area
  - Multiple reflections may also be used

See further http://www.ericsson.com/news/130222-non-line-of-sight-microwave-backhaul-for-small-cells_244129229_c

NLOS BACKHAUL TRIAL
FOLIAGE PENETRATION



- Large signal power variations observed for dense foliage

- Communication through penetration through sparse foliage possible

See further *http://www.ericsson.com/news/130222-non-line-of-sight-microwave-backhaul-for-small-cells_244129229_c*

NLOS BACKHAUL TRIAL

SUMMARY

- Line of sight
- Single reflection
- Double reflection (not always possible)
- Diffraction

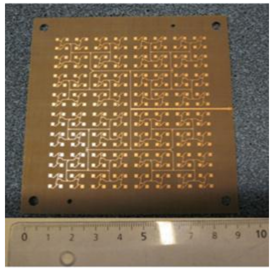
Distance	LOS	Single Reflection	Diffraction	Double Reflection
0-100m	400Mbps	400Mbps	400Mbps	280Mbps
100-250m	400Mbps	400Mbps	400Mbps	185Mbps
250-500m	400Mbps	400Mbps	280Mbps	185Mbps

› Rule-of-thumbs identified and verified

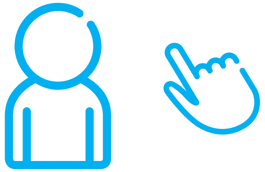
Directive high gain antennas key enabler for NLOS at 28GHz wireless backhaul

See further *http://www.ericsson.com/news/130222-non-line-of-sight-microwave-backhaul-for-small-cells_244129229_c*

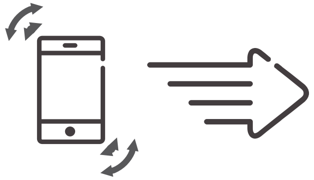
MMW FOR RADIO ACCESS
BEYOND WIRELESS BACKHAUL?



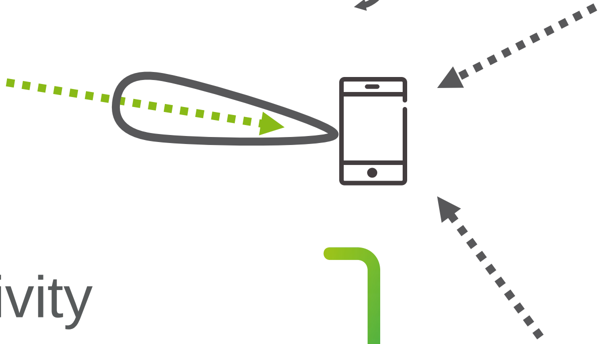
- Highly directive antennas to enhance data rate coverage
  - Antenna size need not prevent similar coverage as lower frequencies



- Impact of user?
  - Measured 40dB body loss at 60GHz, hand/head may shadow antennas, EIRP limitations



- Impact of mobility?
  - Larger channel variations due to larger diffraction loss, higher Doppler, more speculars?



- Impact of adaptive beam steering?
  - Degrees of freedom (analogue vs digital), higher Doppler, antenna design

[Access is different from backhaul, need adaptive directivity
possibly also multiple antenna arrays in terminal and macro diversity]

MMW FOR RADIO ACCESS
DEPLOYMENTS

› Indoor coverage from outdoor base stations?

› Link budget will depend on design choices such as
  - Antenna design, beam steering implementation, Rx vs Tx,…
  - RF parameters (power, noise figure, filters for co-ex, …)
  - Radio propagation
  - Data rate
  - …
  - *Challenging to exceed low frequency coverage in practice?*

Study indoor and outdoor (ultra) dense deployments for high data rates
- Heterogeneous deployment with lower frequency coverage layer?

CONCLUDING REMARKS

- mmWaves can be used for NLOS wireless backhaul
  - With stationary fixed-area directive high gain antennas, higher frequency may outperform lower
- Explore mmWaves for mobile radio access
  - To what extent can directivity be used in practice with mobile (handheld) devices to support deployments beyond (ultra) dense?
- Both use cases appear relevant options for future radio access

CONCLUDING REMARKS
SOME OPPORTUNITIES AND CHALLENGES

- Potentially vast amount of spectrum for high capacity
- Potentially large bandwidths for very high data rates
- Size does not prevent directive high gain antennas

- Better understanding of propagation including outdoor-to-indoor penetration
- (Terminal) antenna design and antenna steering for mobile terminals
- Efficient implementation based on relevant requirements and tradeoffs

- System design…

- Deployment/use case….

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