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

More than peak data rates and system capacity
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

What is used today
What could be used

300 MHz 3 GHz 30 GHz 300 GHz

› 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 \( \sim 20 \log_{10}(f) \)
  - Directivity for fixed area antenna \( \sim 20 \log_{10}(f) \)
  - Fixed antenna area at one side \( \Rightarrow \) frequency independency (ideally, perfect pointing)
  - Fixed antenna area both sides \( \Rightarrow \) gain from increasing frequency (ideally, perfect pointing)

\[
\sim 20 \log_{10}(d_1 f) \quad \sim 20 \log_{10}(f) \quad \sim 20 \log_{10}(d_2 f)
\]

› Atmospheric absorption*

› Rain attenuation*

Example with parabolic antennas

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…
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,

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

NLOS BACKHAUL TRIAL
FOLIAGE PENETRATION

- Large signal power variations observed for dense foliage
- Communication through penetration through sparse foliage possible

NLOS BACKHAUL TRIAL
SUMMARY

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

<table>
<thead>
<tr>
<th>Distance</th>
<th>LOS</th>
<th>Single Reflection</th>
<th>Diffraction</th>
<th>Double Reflection</th>
</tr>
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<tbody>
<tr>
<td>0-100m</td>
<td>400Mbps</td>
<td>400Mbps</td>
<td>400Mbps</td>
<td>280Mbps</td>
</tr>
<tr>
<td>100-250m</td>
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<td>400Mbps</td>
<td>400Mbps</td>
<td>185Mbps</td>
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<td>250-500m</td>
<td>400Mbps</td>
<td>400Mbps</td>
<td>280Mbps</td>
<td>185Mbps</td>
</tr>
</tbody>
</table>

› Rule-of-thumbs identified and verified

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

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?
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….