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mmWave for Ultra-Dense Networks (UDNs)

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Panel: 5G/mmWave Capacity Improvements: A Systems Perspective

Moderator: Chris Anderson, USNA/ITS

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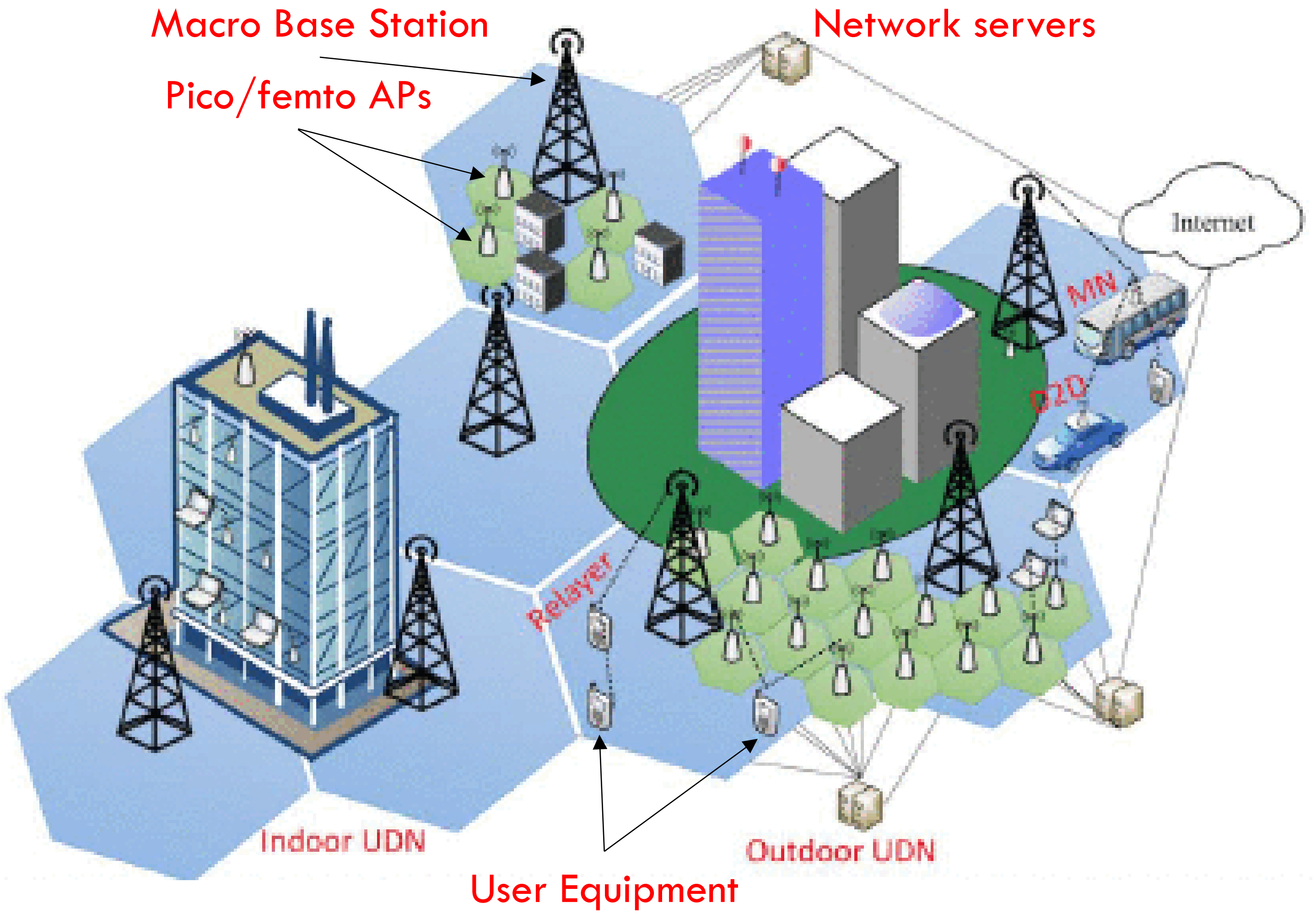
ISART
INTERNATIONAL SYMPOSIUM ON ADVANCED RADIO TECHNOLOGIES
CENTER FOR ADVANCED COMMUNICATIONS

“What *are* UDNs, anyway?”*

Three features of UDNs:

1. Large number of network access points (APs) (obviously…)
   a) More APs than devices (?)
   b) Offload macro traffic
   c) Extensive frequency reuse
2. Dense and heavily interconnected cross-tier network structure
3. Fast network access & flexible inter- and intra-tier switching (i.e., rapid, seamless handovers)



* These slides are based on the following paper: W. Yu, H. Xu, H. Zhang, D. Griffith and N. Golmie, “Ultra-Dense Networks: Survey of State of the Art and Future Directions,” *25th International Conference on Computer Communication and Networks (ICCCN)*, Waikoloa, HI, 2016.

Two Equations, Two Metrics

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- Hwang et al.[1]
  - Capacity density: $\delta_R \left[\frac{\text{bits/s}}{\text{km}^2}\right] = \delta_{\text{cell}} \left[\frac{\text{cells}}{\text{km}^2}\right] \times C \left[\frac{\text{bits/s/Hz}}{\text{cell}}\right] \times B\ [\text{Hz}]$
  - Increase cell density (UDN), bandwidth (spectrum migration), or spectral efficiency per cell (diminishing returns)
- Lopez-Perez et al.[2]
  - Total network capacity: $C\,[\text{bits/s}] = \sum_{m=1}^{M} \sum_{u=1}^{U_m} B_{m,u}[\text{Hz}] \log_2(1+\gamma_{m,u})$
  - Densification makes C increase linearly w.r.t. M
  - Densification reduces U_m but increases $B_{m,u}$ (fewer devices per cell)
  - Densification increases $\gamma_{m,u}$ (results in slower growth in C)

[1] D. López-Pérez, M. Ding, H. Claussen and A. H. Jafari, "Towards 1 Gbps/UE in Cellular Systems: Understanding Ultra-Dense Small Cell Deployments," in IEEE Communications Surveys & Tutorials, vol. 17, no. 4, pp. 2078-2101, Fourthquarter 2015.
[2] I. Hwang, B. Song, and S. Soliman, “A holistic view on hyper-dense heterogeneous and small cell networks,” IEEE Commun. Mag., vol. 51, no. 6, pp. 20–27, June 2013.

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Some Interference Management Techniques for sub-GHz UDNs

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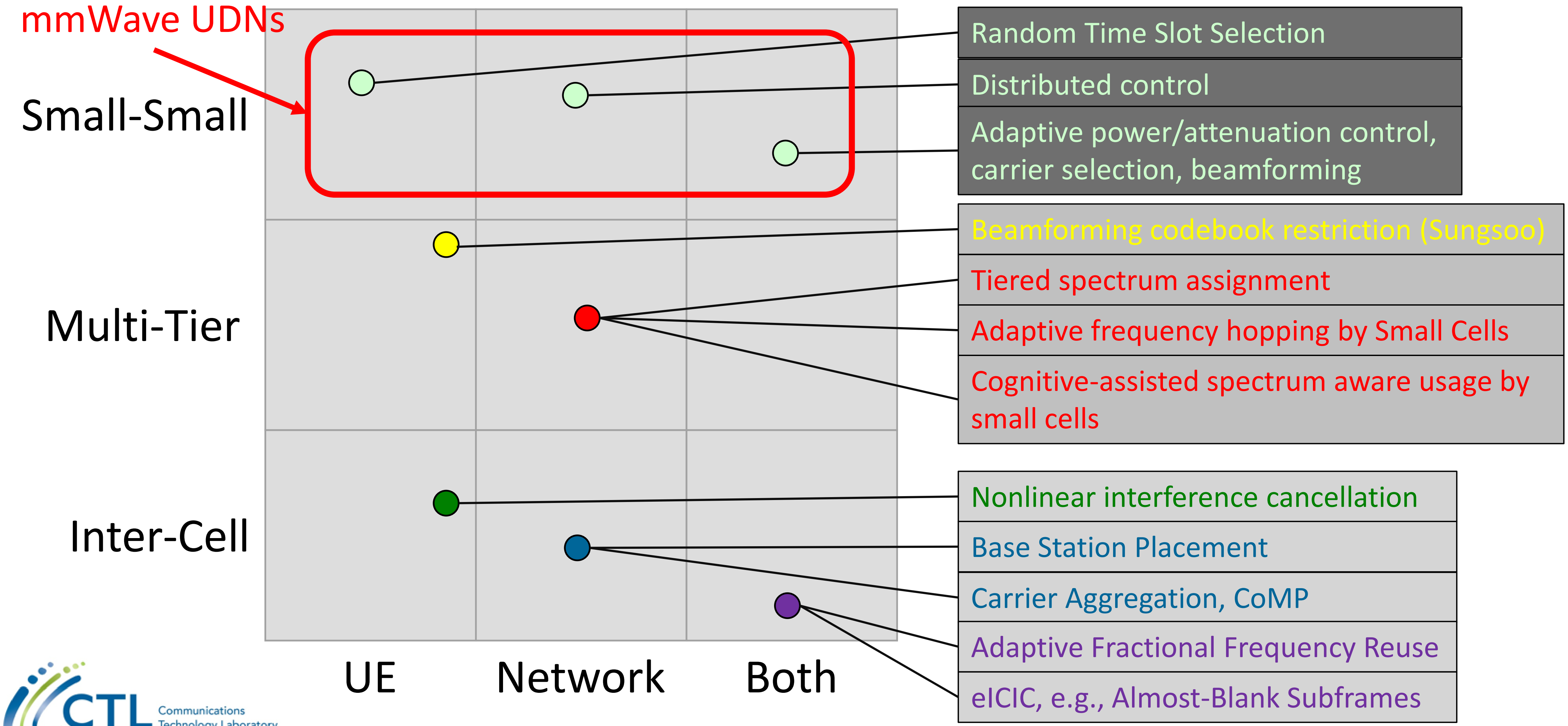

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UDNs Are a Natural Fit for mmWave

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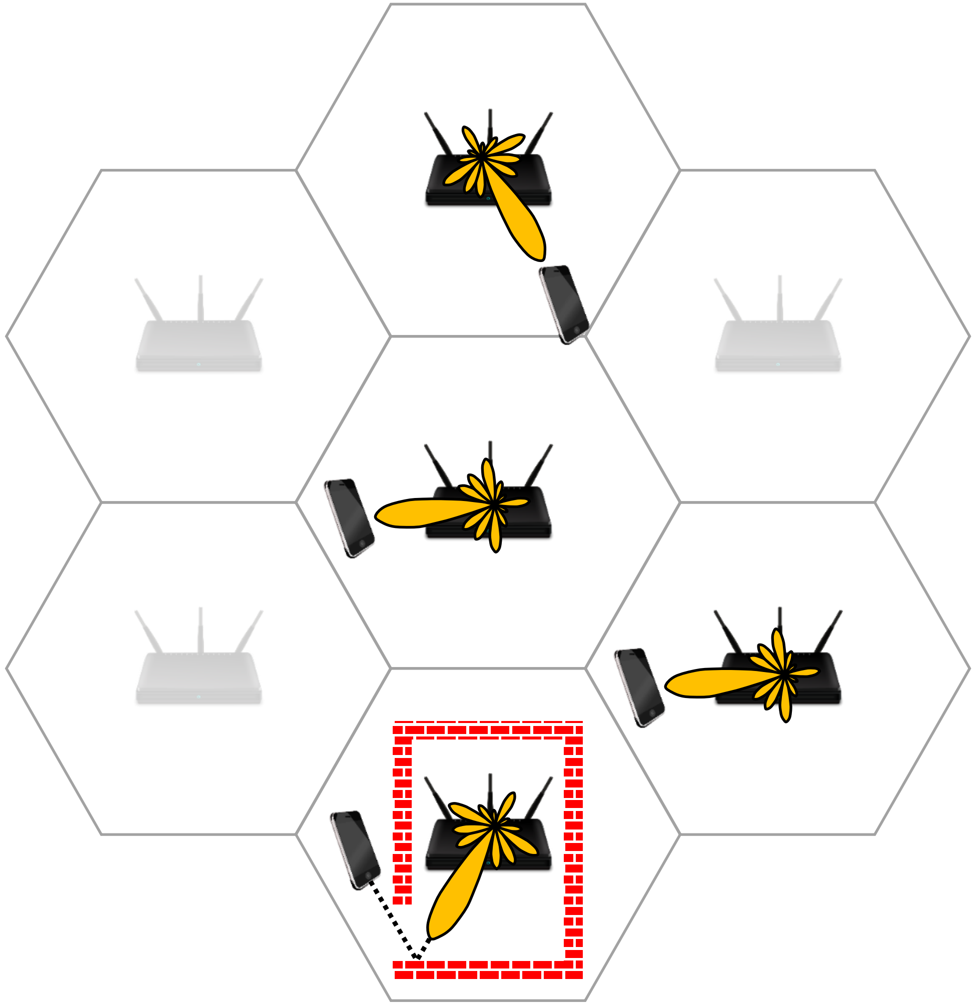
Benefits for UDNs:

- Short propagation distances decrease the interference "horizon"
- Short wavelengths allow massive MIMO or phased arrays to support high gain along LoS/dominant path, collection of signal energy from reflective paths, and adaptive nulling of nearby interferers
- No multi-tier interference

Some challenges:

- Tracking beams/devices/paths
- Energy conservation requirements
- Management requirements
- Effect of mmWave backhaul



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