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mmWave Distribution Networks - MDN

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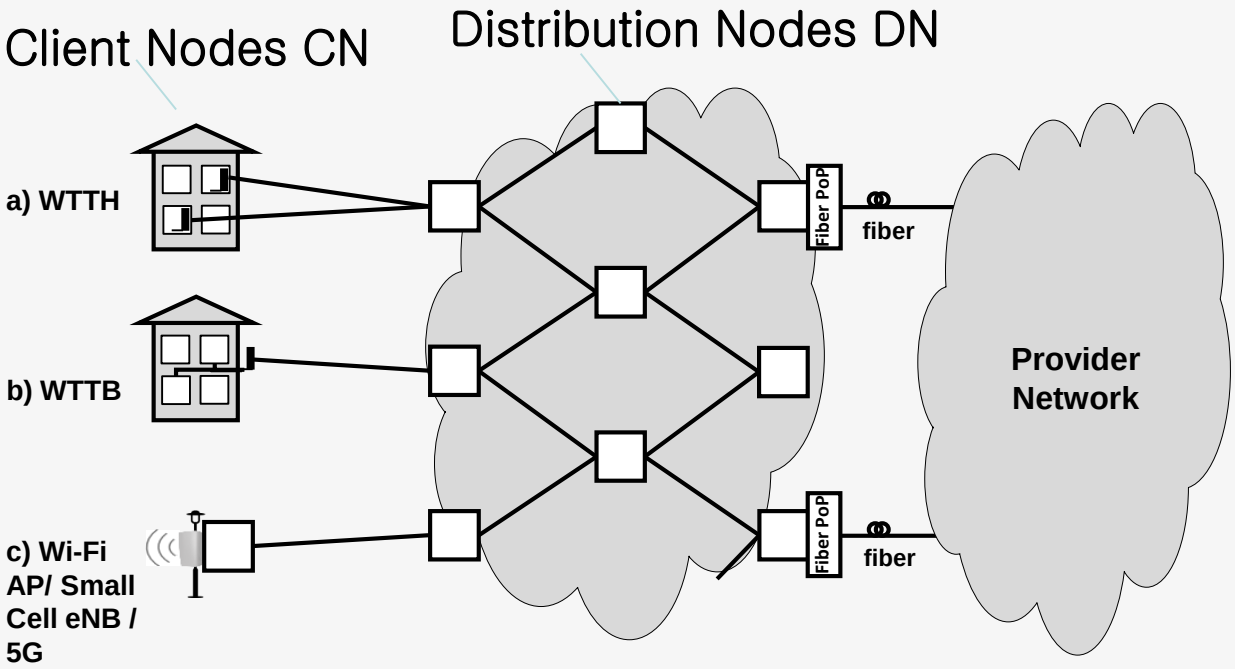
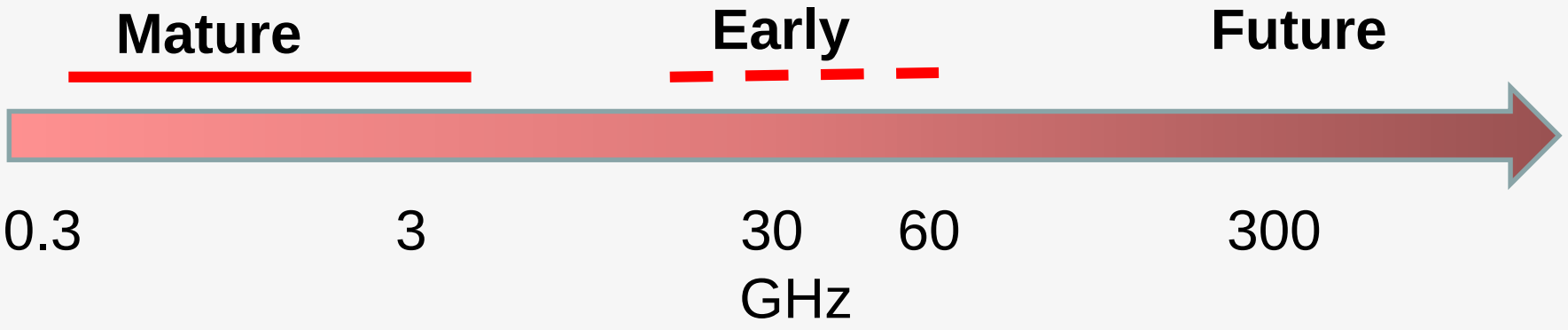
mmWave Distribution Networks - MDN



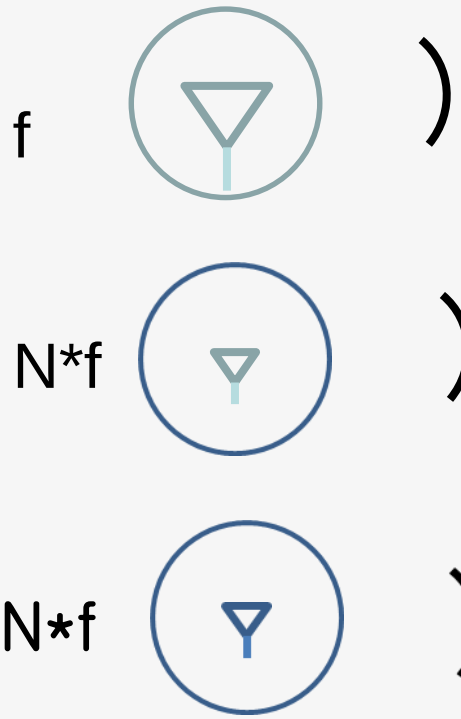
"Wireless Fiber"

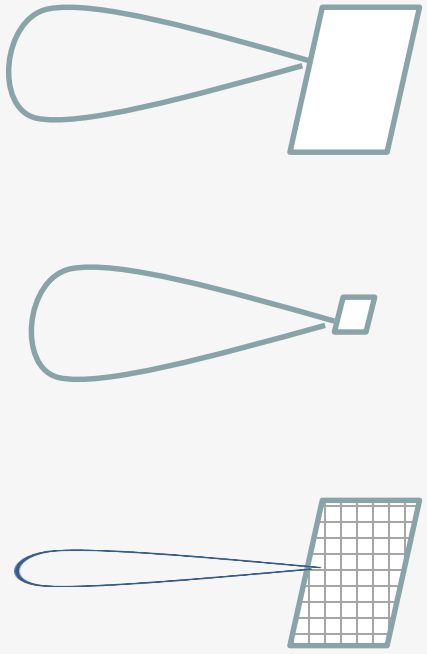
Source IEEE 802.11TGay

Access Networks – Frequency Bands



“Path Loss” Freq f to N * f

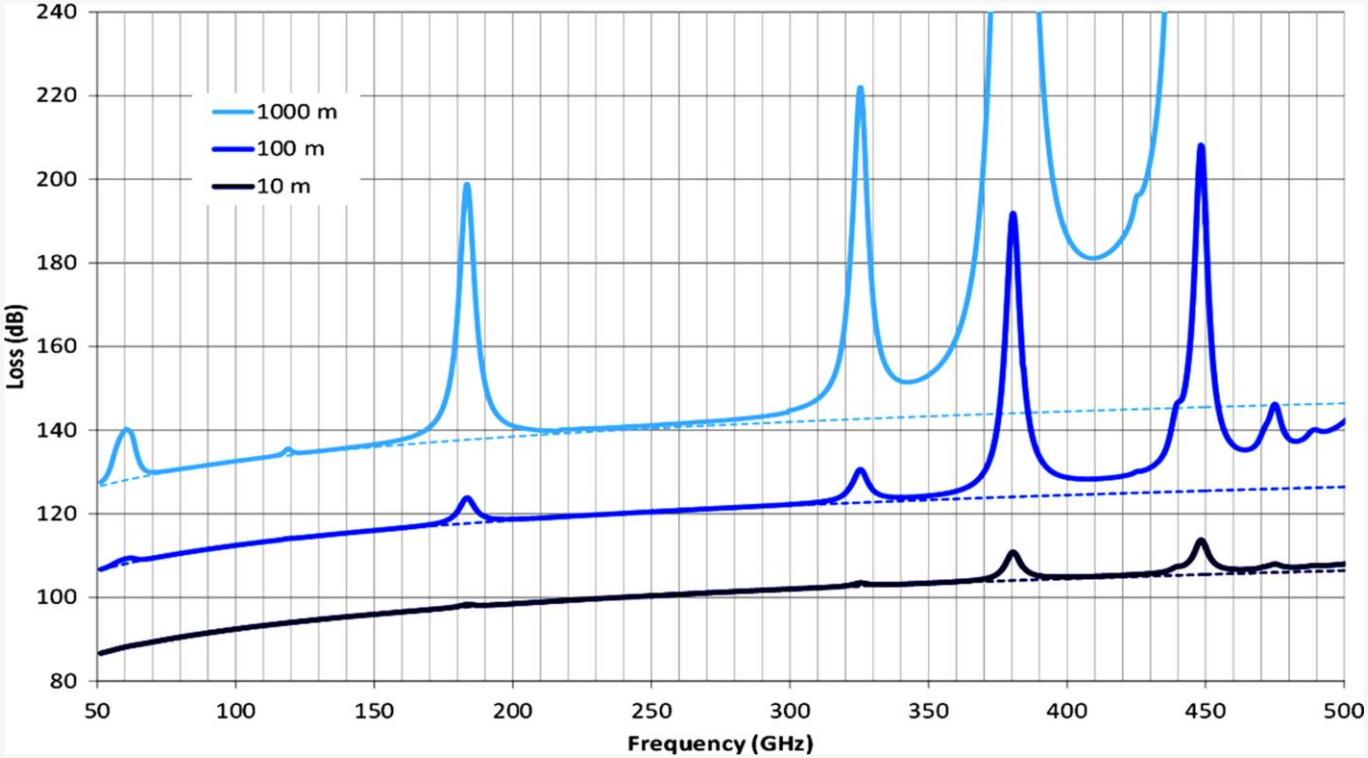




20 Log N
addl “path loss”

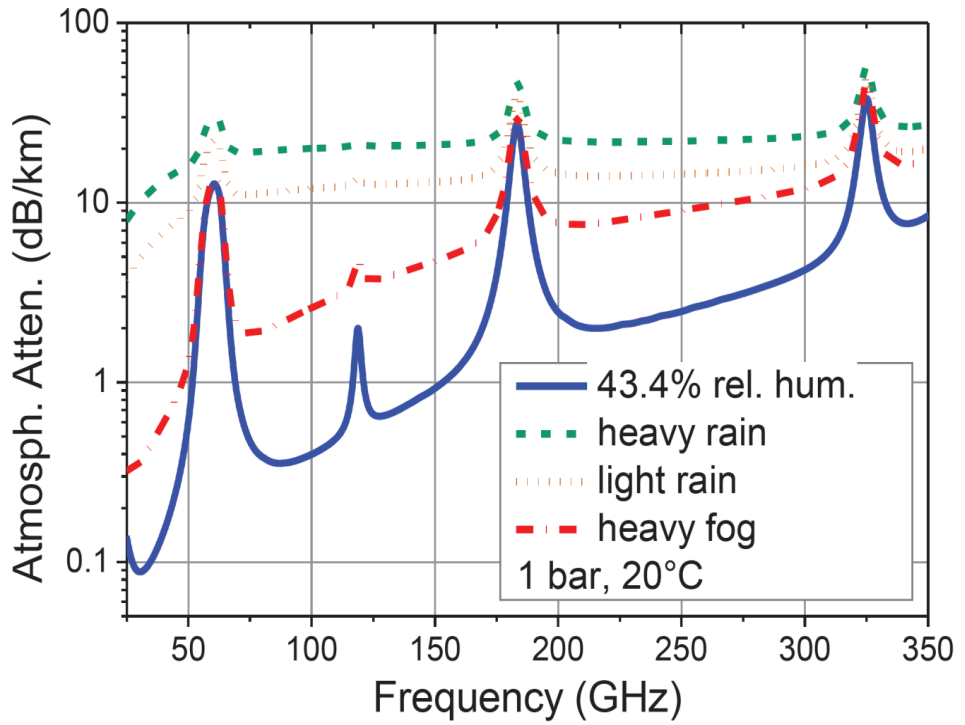
Marinating Rx aperture -> narrow beams = adds array gain
Use Beamforming for flexible pointing

Atmospheric Loss



At 100M range the atmospheric absorption loss is negligible at 60GHz

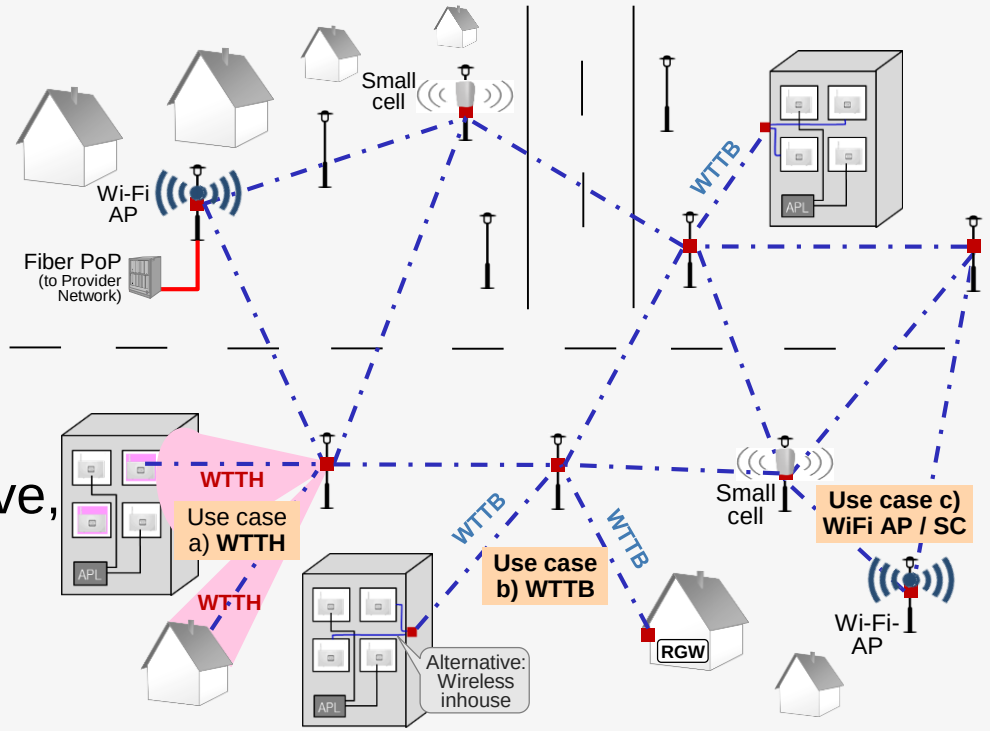
Precipitation Loss



At 100M range the precipitation loss is negligible at 60 GHz

MDN – Area View

- Narrow 2-4 Deg. Beams both ends of link
- LOS
- DNs on Lamp Post, Roof Top, Bldg. Side
- CNs on Window, Under Eave, Bldg. Side



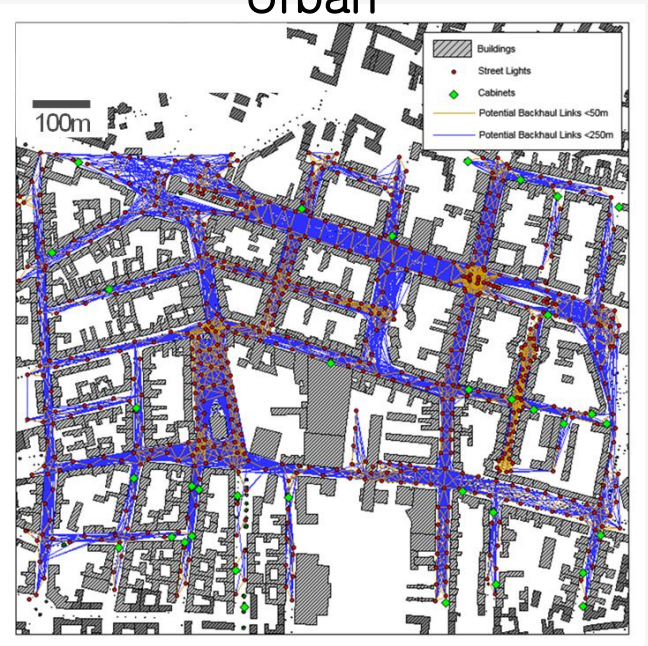
Deliver 5–10 Gbps every 50M Sq.

Source IEEE 802.11TGay

MDN Deployment

- Urban
  - LOS shoot must be above or below or away to avoid foliage
  - DN to CN 20 – 50M
  - DN to DN 60- 200M (300M)
- Suburban
  - Roof top also possible

Urban



Source IEEE 802.11TGay

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MDN – 802.11ad Based

- MDN is currently based on 802.11ad WiFi / WiGig 60 GHz Unlicensed Band
- 11ad designed for indoor access application – multiple use cases. MDN is retargeting it for an outdoor backhaul application
- KPIs in a backhaul application are more stringent on throughput variability, delay and delay jitter than access application
- Unlicensed band MDN is vulnerable to out of network interference

MDN – Current Eco System

- Semiconductors: Qualcomm, Intel, (Broadcom), Blu, Peraso,.. (11ad standard PHY / MAC or with prop. MAC)
- OEMs: Siklu, Nokia-FB, Vivint, Radwin, Airspan, Huawei, Taiwan ODMs
- Carriers: WISPs – Vivint,…, Deutsche Telekom, Jio, …
- Ongoing Trials FB (San Jose), Jio (Mumbai), Vivint (Phoenix, Draper), ,,,

MDN 60 GHz Propagation

- Foliage losses are high – a single tree can insert a 10-20 dB loss. We need to run links avoiding foliage
- Links have to be LOS - weak diffraction and strong shadowing. Cannot go through buildings,,…
- Very poor outdoor-indoor penetration
- 60 GHz oxygen absorption is ~ 1.5 dB per 100 M, Rain ~2 dB per 100 M

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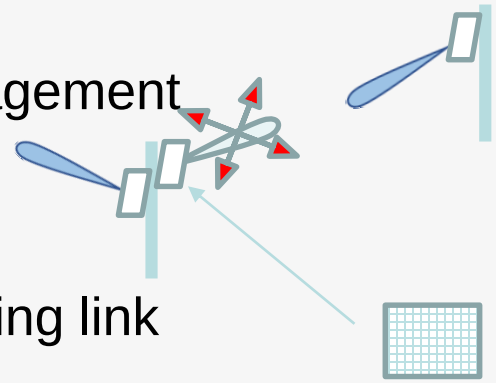
PHY

	Current /11ad	11ay WDN Proposal
Band	57-64 GHz	Same
Channel	2.16 GHz x 4 (max)	Same
Modulation	Single Carrier	Same
Beam Mgt.	Node	Network
MIMO Streams	Single	Same
Interference Management	CSMA/CA	Interference Scan / Beam Nulling Power Control

Beamforming

- Needs beamforming at both ends.
- Needs Sector Searching and Beam Management to establish and maintain links
- Beamforming also causes deafness, making link management complicated
- Interference is spiky – search-light effect
- Adaptive beamforming to cancel interference



32 to 256 Patch Element Beamformer

MAC

Current / 11ad TDD	11ay WDN Proposal
CSMA/CA or Prop. TDM	TDD / TDM
No slot structure (CSMA/CA) or Fixed TDM. GPS lock	Hierarchical slot structure GPS Lock
Fixed Allocation	Demand Based Allocation
Per packet Ack	Block Ack delayed to next slot
Single Golay Code	Multiple Golay Codes

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Deployment

- Effective monitoring and operations is critical (high density and expensive to touch)
- Harder to bring up isolated nodes quickly – beam search
- GPS lock not reliable in urban canyons
- Picking good DN sites is complex (mmWave) and needs lots of foliage, bldg. and terrain data
- Rooftop vs Street Furniture

Scheduling / SLAs

- Hop depth - Ingress to CN: ~3 for Backhaul, ~8 for WTTH
- Current TDM use “nailed up” Tx – Rx slots, moving to demand based adaptive TDM (in 11ay)
- Global Scheduling (TDD Dl/UL ratios set every 20 ms)
- Fixed Ingress / egress policing for QOS moving to dynamic slicing

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Forwarding : L2 vs TRILL vs L3

- L2 Switching – uses Spanning Tree Protocol
- TRILL – Transparent Interconnections of Large Number of Links
- SPB – Shortest Path Bridging (Q in Q)
- L3 Routing - OSPF (Mostly used now)



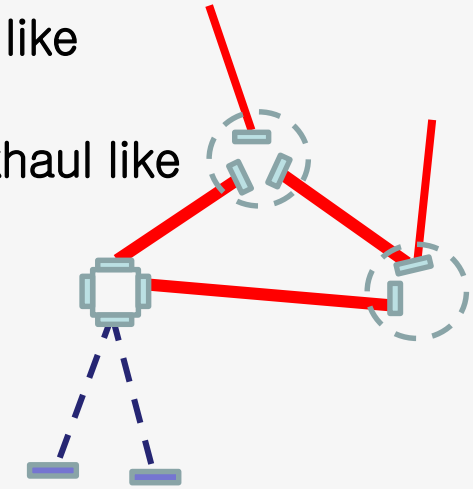
L2 Switching	TRILL	L3 Routing
Minimal Config	Minimal Config.	Geo addressing
Flat addressing	Hierarchical Forwarding	Hierarchical Forwarding
Plug and Play	Plug and Play	Plan and Play
Slow Convergence	Fast Convergence	Fast Convergence
Single Path / STP	Multi Path	Multi path / Mul Tree
Low Scalability	Highly Scalable	Highly Scalable

Some MDN Debates

- PmP vs P2P on back bone / BH
- CSMA/CA vs TDD/TDM
- Managing interference L2 vs L1
- Unlicensed vs licensed bands
- Access and Distribution on same freq. channel
- Forwarding – TRILL / SPB vs L3
- Single vs multiple radio housing

Wifi like

Backhaul like



Applications - Outdoor

- High density backhaul (and later front haul)
- Add small cell LTE, WiFi and later 5G (eMBB, V2X)
- Add lighting, sensor package (cameras, gun shot, parking, Env. & Traffic)
- Add Edge Computing, and NFV
- With PV solar, grid free / wire free infrastructure!!

Applications – Large Indoor / Stadiums

- Backhaul for consumer access on LTE, WiFi, and later 5G
- Backhaul for Cameras, Skycam and other robotic Drone cameras
- Facilities control and monitoring
- VR backhaul

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Some Research Areas

- You need a test bed!
- Adaptive beamforming for Intf. Management
- SDN ideas to centrally manage per link TDD slotting and frequency assignment
- Low order MU-MIMO
- Isolated node / segment recovery
- Antennas and RF circuit design

Summary

- Small eco-system (for now), fragmented
- MDN leverages major investments made in WiFi 11ad / WiGig
- A few trials in progress, plenty of lessons for 28, 39 GHz 5G!
- Maturing technology
- **Huge Opportunity**

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Questions