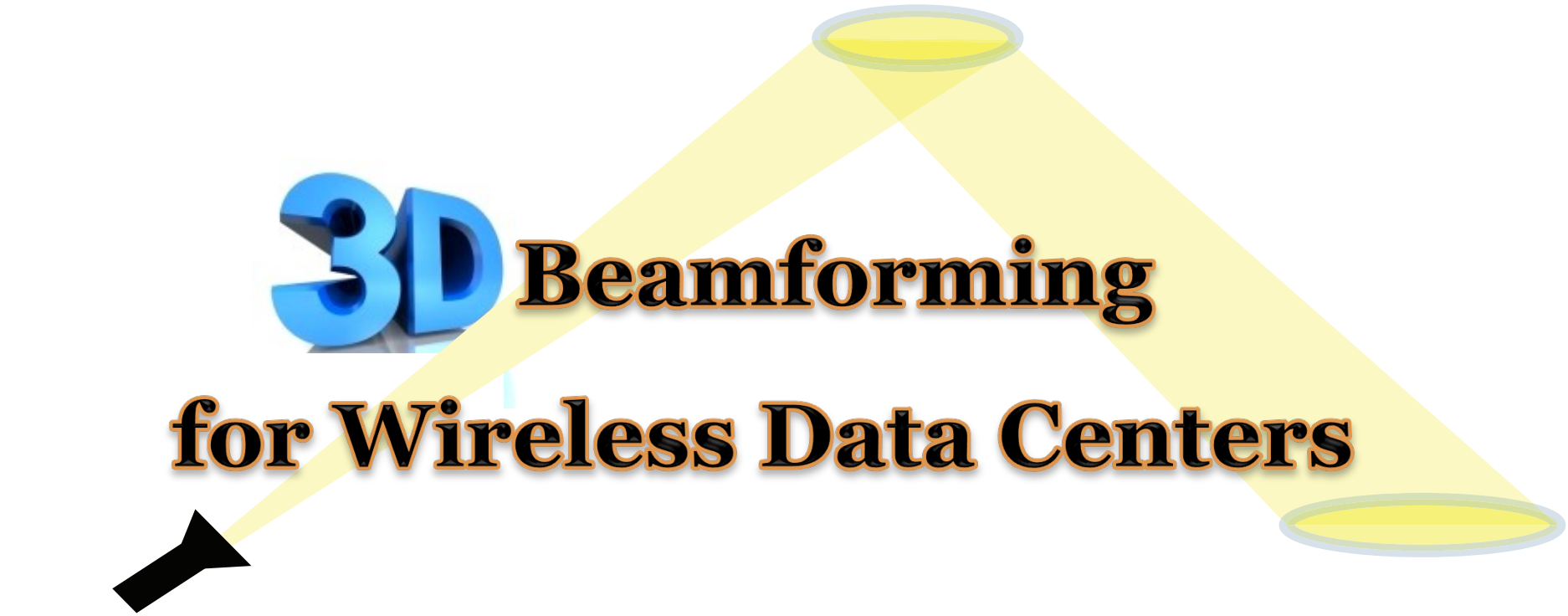

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Challenges in Data Centers

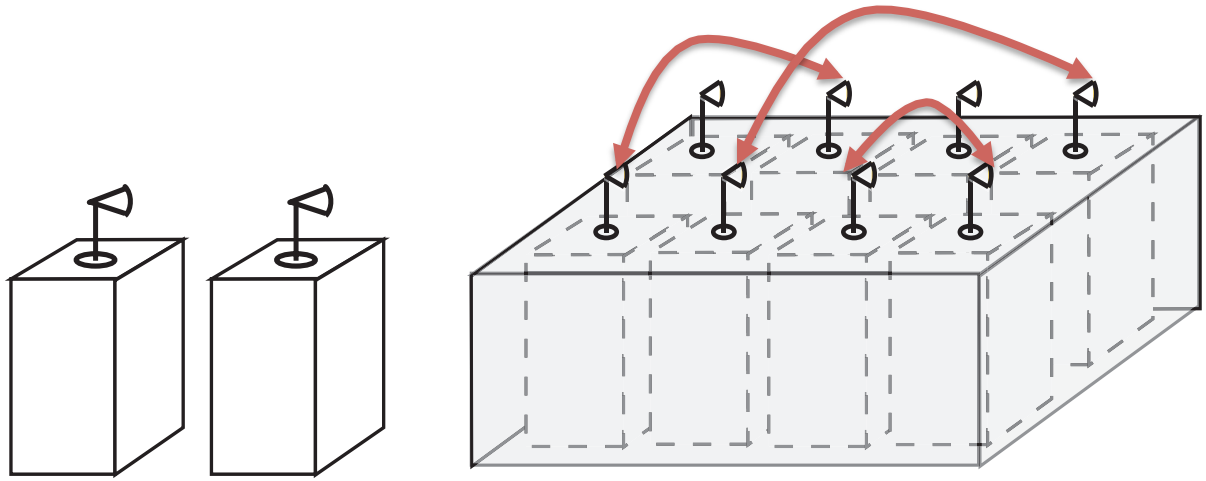
- Measurements show that many applications generate short-lived traffic bursts across racks
  → Sporadic congestion

Possible Solutions

- Add wired links/switches for capacity
  - Extremely high cost
- Change data center architecture
  - High complexity in wiring + labor cost

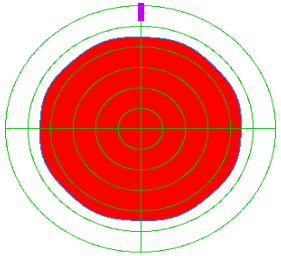
Wireless Data Centers

- Augmenting data center with **wireless** links
- 60 GHz wireless technology
  - 7 GHz unlicensed band → multi-Gbps data rate
  - Fast signal attenuation → short transmission range
- Key benefit: Flexible link configurations

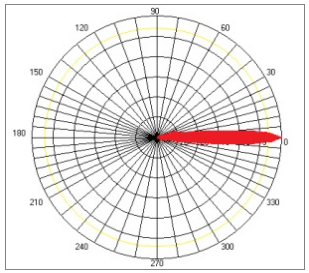


60GHz Beamforming

- Extend transmission range by concentrating energy in desired direction

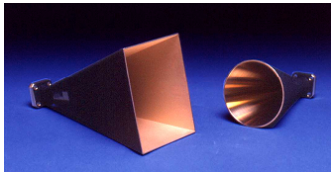


Omni antenna



Directional antenna

- Achievable using horn antenna or antenna array

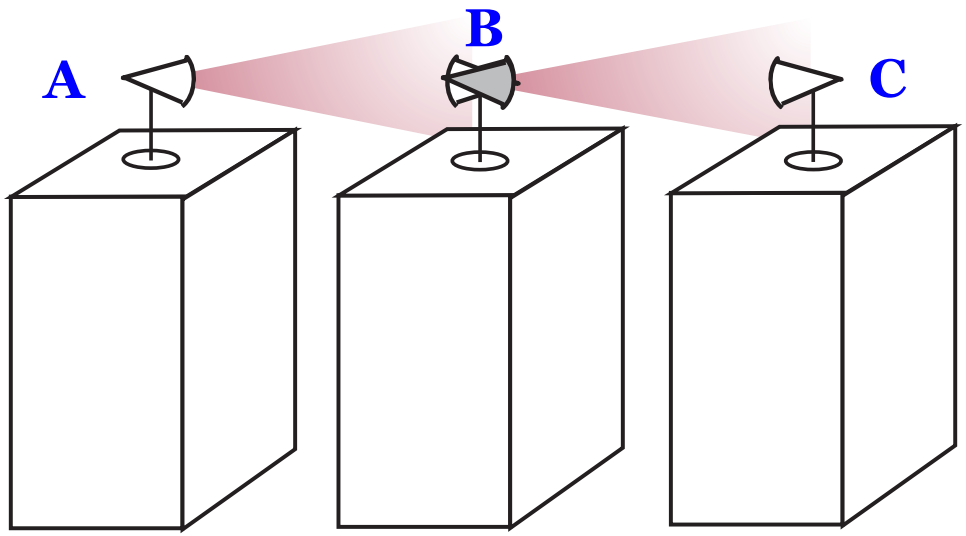


- But there are limitations

Limitation #1: Link Blockage

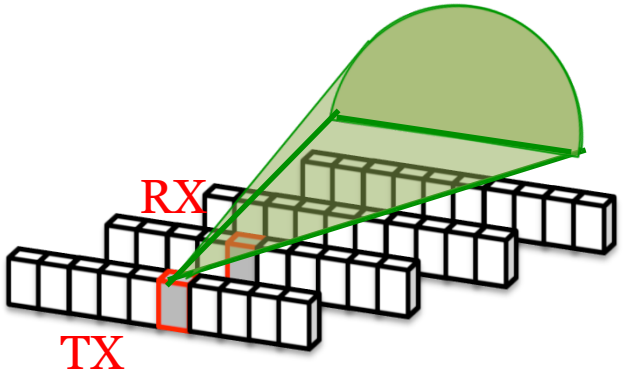
- Transmissions easily blocked by small obstacles
  - Wave length of 60 GHz signal is only **5mm**
  - Any obstacle larger than **2.5mm** can block the signal!

- Must use multi-hop forwarding
  - Particularly harmful due to antenna rotation overhead

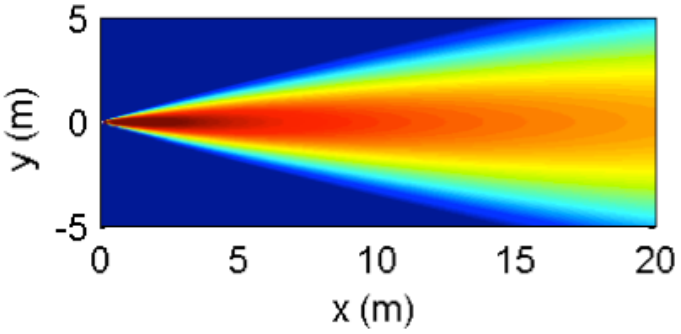


Limitation #2: Radio Interference

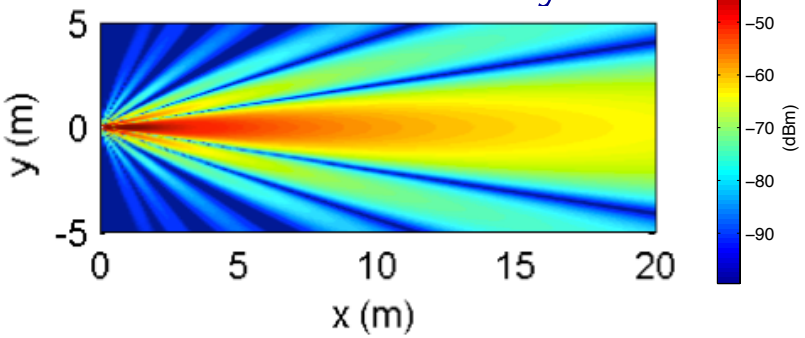
- Beam interferes with racks in its direction
  - Exacerbated by dense rack layouts
  - Signal leakage makes it worse
  - Result: very few links can be active at the same time



Horn antenna

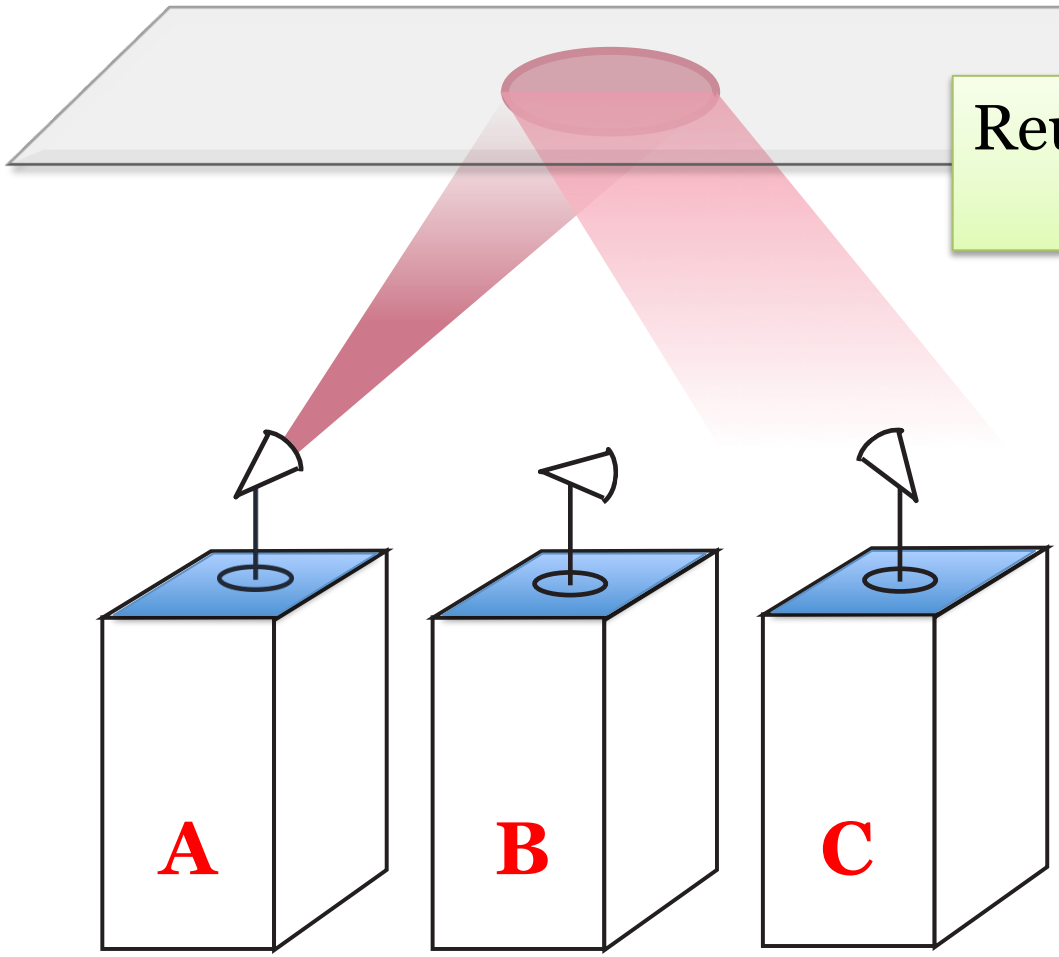


Antenna array



How do we address these limitations?

3D Beamforming

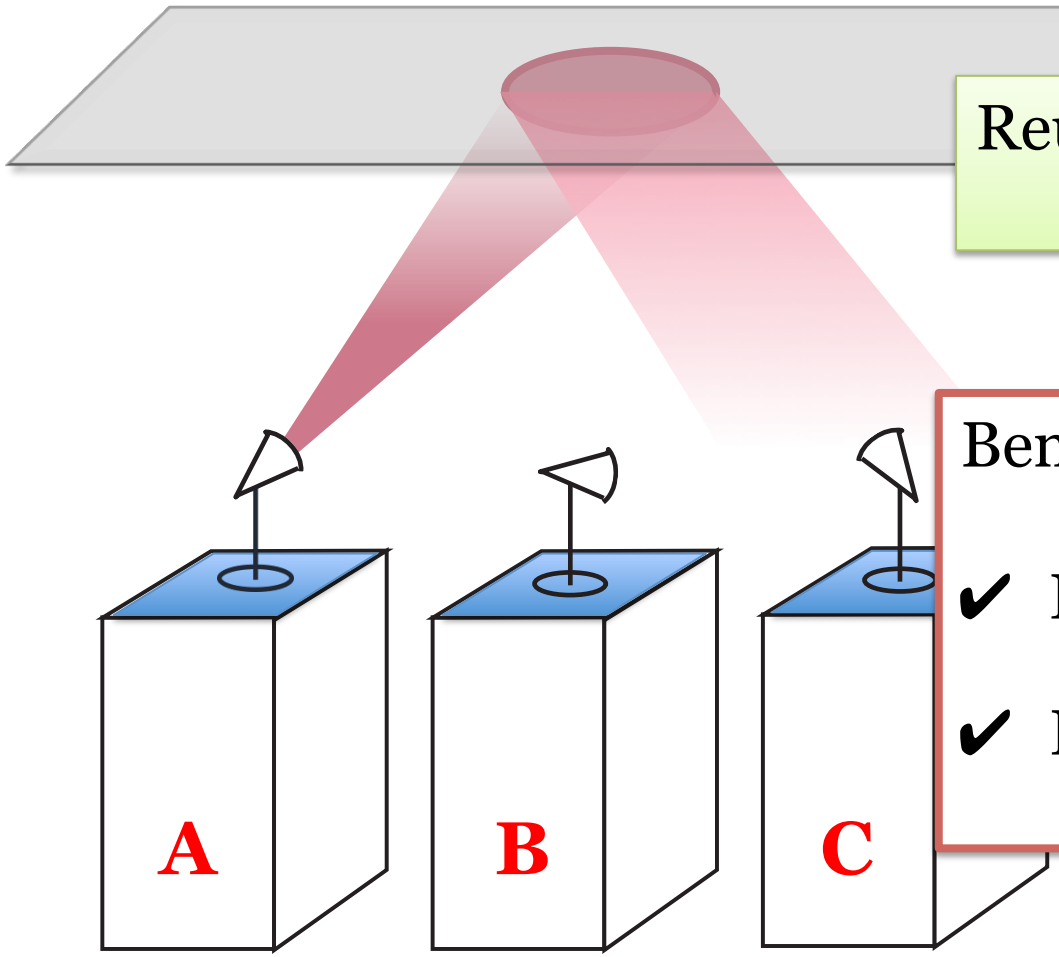


Reuse existing hardware, low maintenance cost!

Reflector

Absorber

3D Beamforming

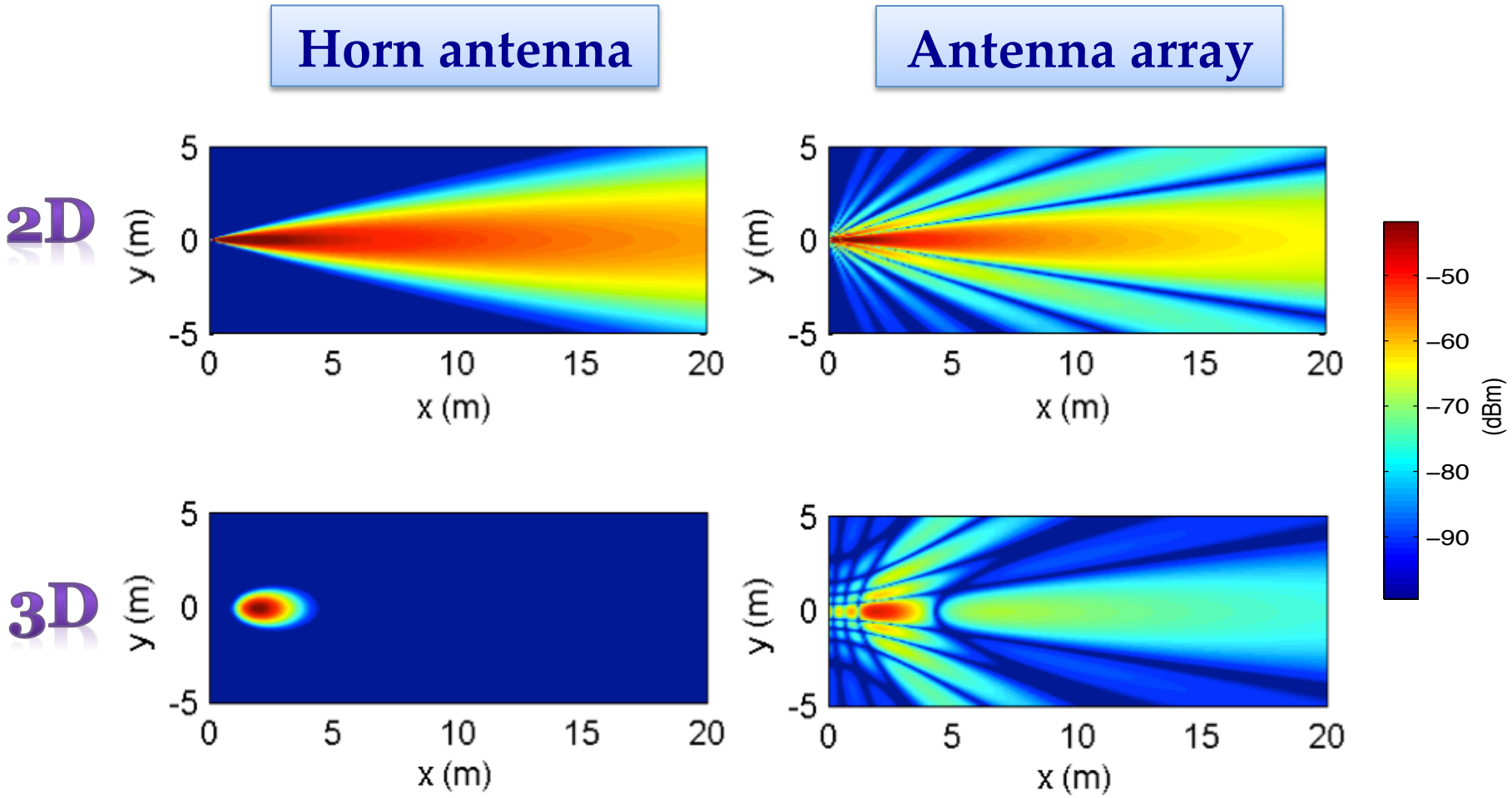


Reuse existing hardware, low maintenance cost!

Benefits over 2D Beamforming

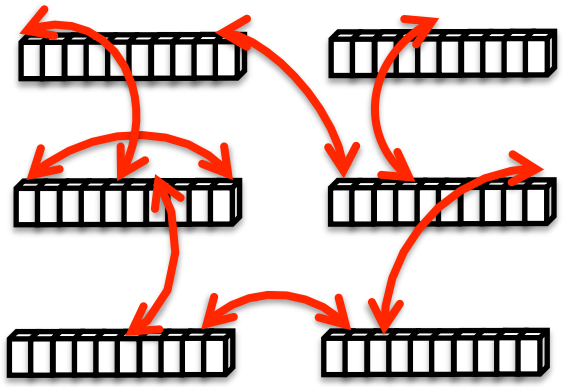
- ✔ Extended connectivity
- ✔ Reduced interference

A Closer Look at Reduced Interference



Impact on Data Centers

- Case study
  - Rack-based layout (160 racks, SIGCOMM'11)
  - Bi-directional link w/ data rate ≥ 5.53 Gbps



- Observations

➡ Connect any two racks via a **single hop**

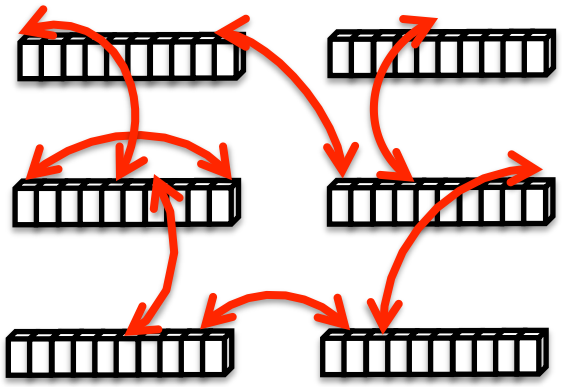
➡ **75%** of them can be on **concurrently**!
94% of links can be on concurrently when using ≤ 2 hops

➡ More than half w/ data rate > **10 Gbps**! (**0.5 Tbps** to the network)

Similar observations hold for container-based layout

Impact on Data Centers

- Case study
  - Rack-based layout (160 racks, SIGCOMM'11)
  - Bi-directional links w/ data rate ≥ 5.53 Gbps



- Observations

Connect any two racks via a single hop

Create a highly flexible network with data rates closed to wired networks

More than half w/ **10+ Gbps** data rate! (**0.5 Tbps** to the network)

Similar observations hold for container-based layouts

Long-Term Implications

- Flexible traffic scheduling
  - Point-to-point link, eliminating cable constraints
- Easy rack movement/replacement
  - Quick calibration of beam direction

→ Moving towards full wireless data centers

Deployment Challenges

- Placing racks/reflectors
  - Raised floor
  - Use existing metal surface
  - Use cable trays to cover wiring

- Rotating antenna to meet traffic dynamics
  - Horn antenna: a few seconds
  - Antenna array: 50ns

- Connection management
  - Coordinating TX and RX
  - Scheduling concurrent links
  - Diagnosing network faults

Conclusion

- 3D beamforming as a new wireless primitive for wireless in data centers
  - Extends the reach of wireless links and reduces interference
  - Solves key limitations of today's 60GHz links
- Still, challenges ahead towards fully-wireless data centers
  - Physical and network management
  - Experimental testbed

Thank you!