Multi-Gigabit Wireless LANs

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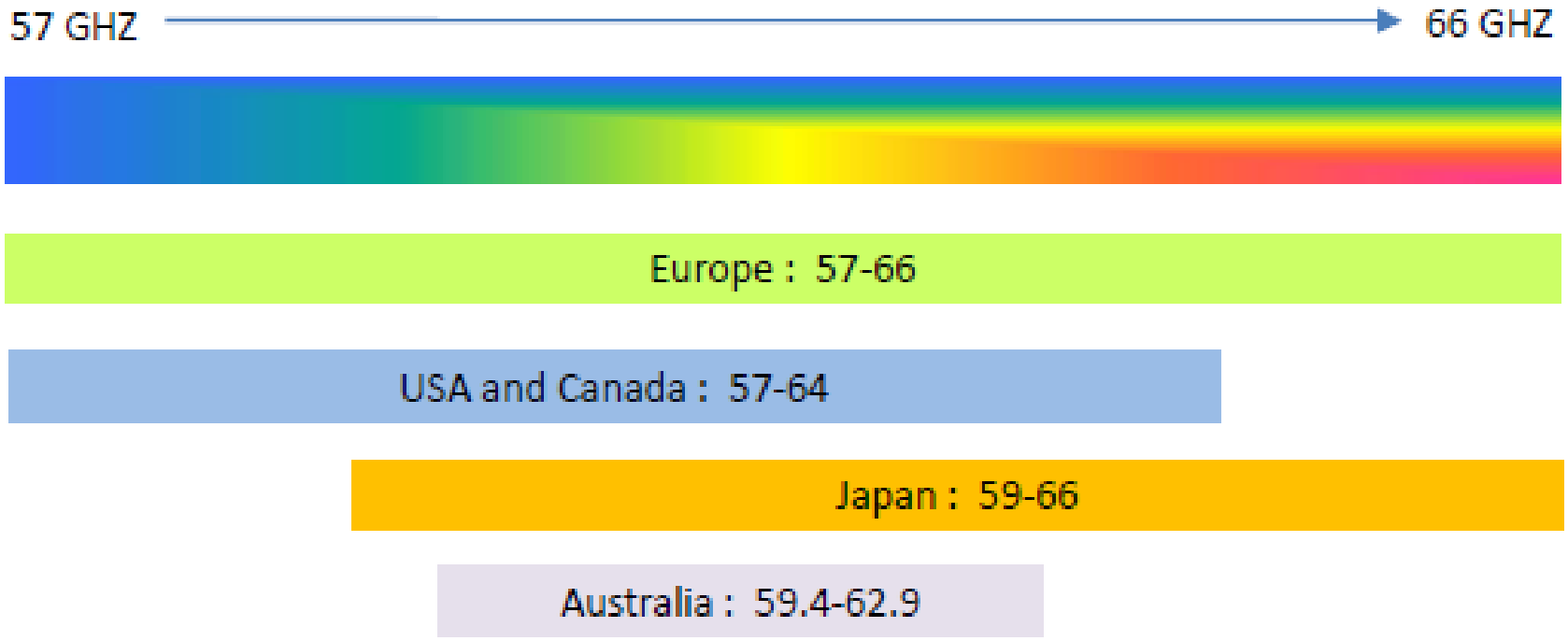
The Next Wireless Revolution is at 60GHz

- Large amounts of spectrum at 60GHz opened up for unlicensed use.
- Several GHz wide. Enables multi gigabit speeds.
- CMOS designs have matured to enable RF circuits at 60GHz.
- Follows success of WiFi, Bluetooth and Zigbee in unlicensed ISM bands.

Wireless Catches up with Wires!

Spectrum Allocation at 60GHz



- Also called mm wave band.

App 1: Wireless Video

- Stream uncompressed HD video wirelessly across room.

App 1: Wireless Video

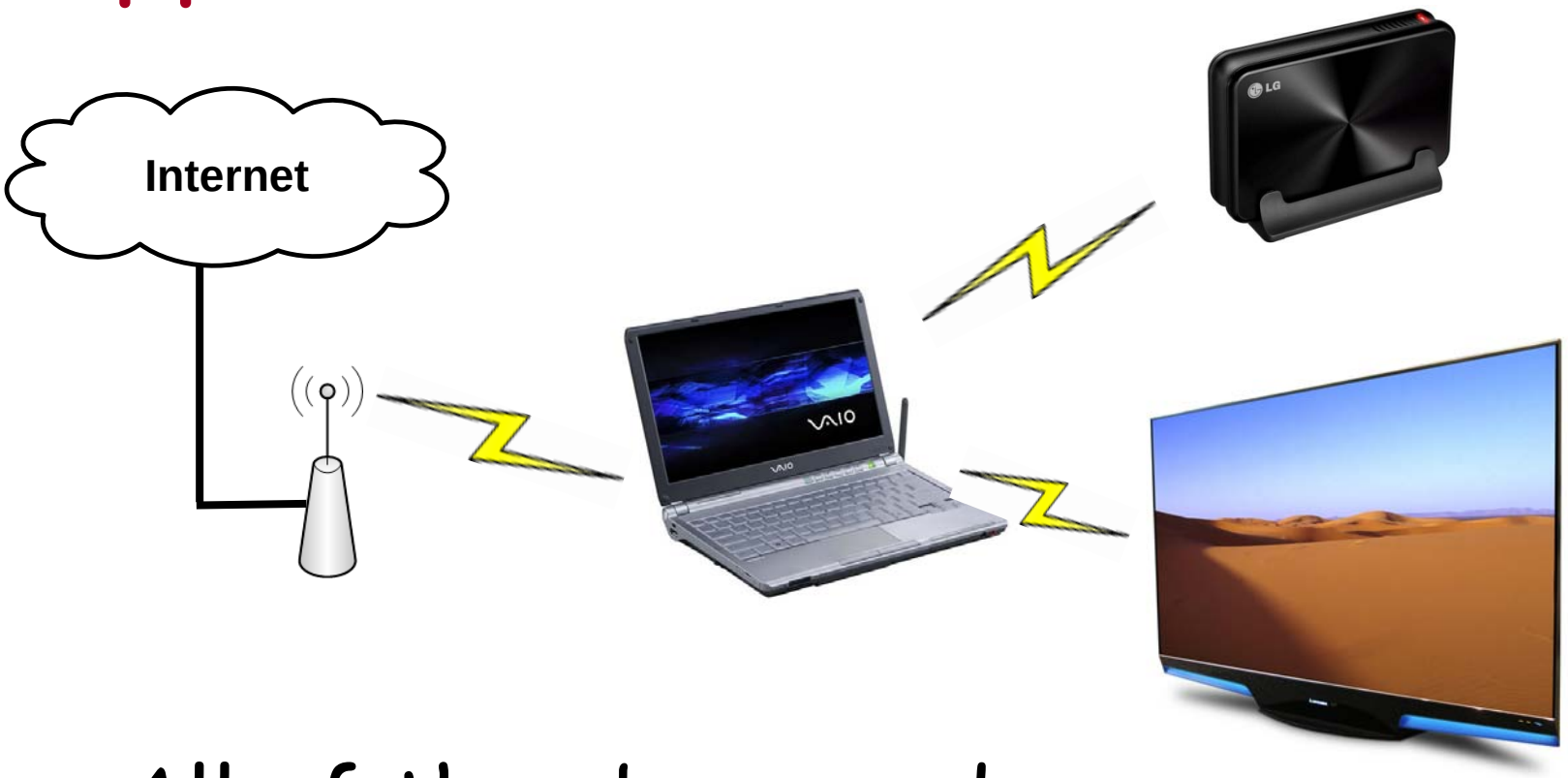
- Stream uncompressed HD video of unprecedented quality wirelessly across room.

App 2: Wireless Backup

- Backup instantly.

App 3: Sync and Go

App 4: Wireless Dock

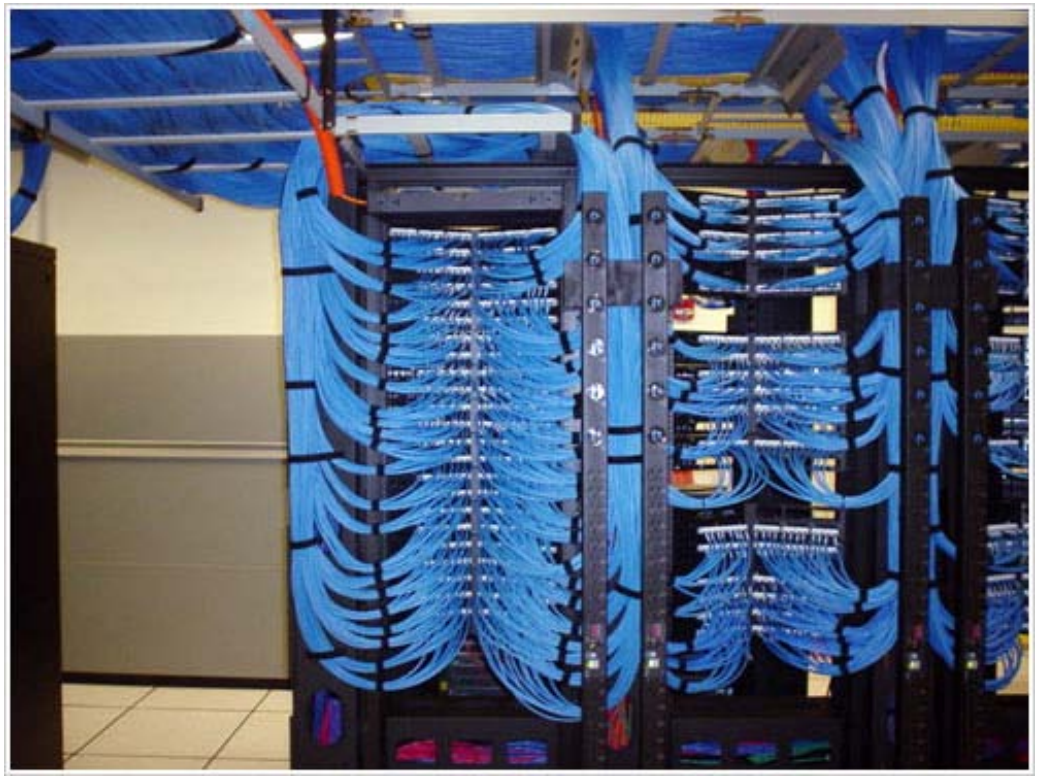


- All of the above and more ..
- May be CPU-memory subsystem can be physically disconnected from I/O and Storage.

App 5: Gigabit Wireless Interconnect for Data Centers

- Link power budget roughly similar.
- 10G Ethernet
  - Copper PHY 4W
  - Optical PHY 1W
- Wireless 60Hz up to 10G
  - 1W (upto ~10m)
- Significant energy savings in cooling. Cables hinder airflow.

Cables hinder airflow ..



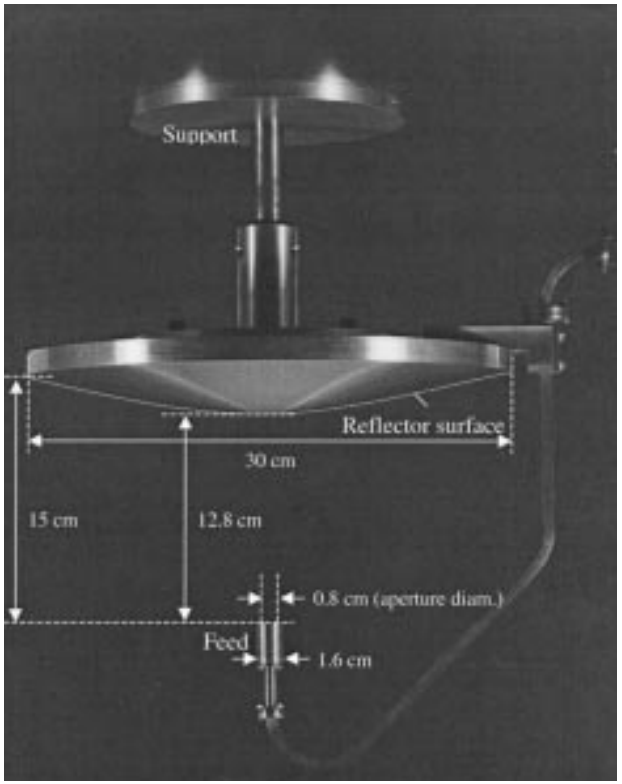
[Image Courtesy: Pingdom]

Characteristics of 60 GHz Transmission .. The Bads

- Path loss significant
  - Path loss inversely proportional to $freq^2$
  - Atmospheric path loss higher due to oxygen absorption.
- Mainly Line-of-Sight (LoS)
  - Mm scale waves cannot diffract around obstacles easily.
  - Attenuation by obstacles also high due to high frequency.

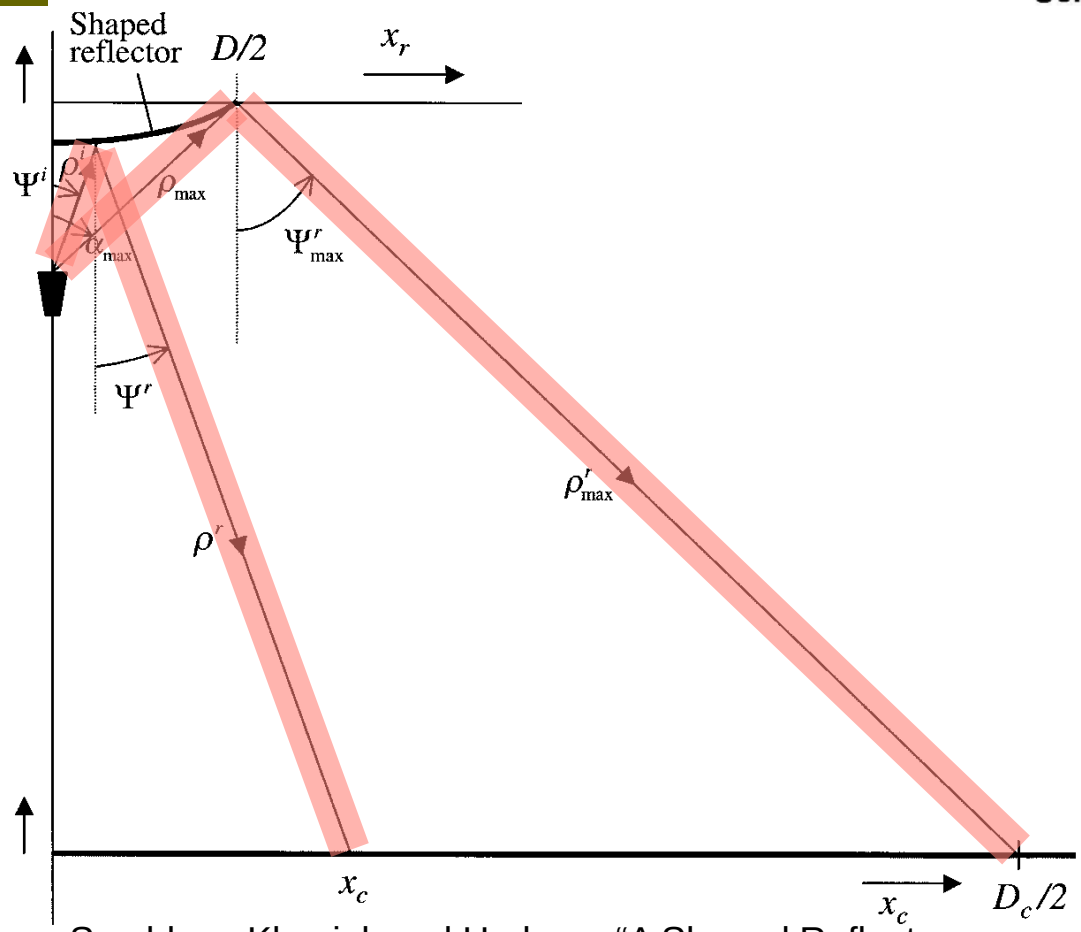
Characteristics of 60 GHz Transmission .. The Goods

Perfect communication via reflection is possible.



[Smulders, Khusial, and Herben, "A Shaped Reflector Antenna for 60-GHz Indoor Wireless LAN Access Points," *IEEE Trans. Veh. Tech*., 50(2), 2001.]

Reflectors could be part of the design ..



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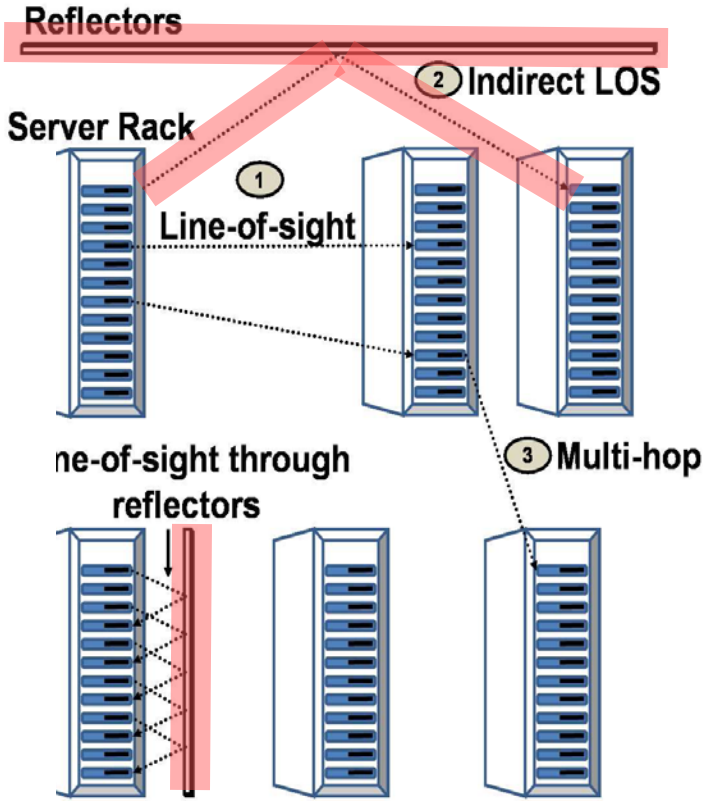
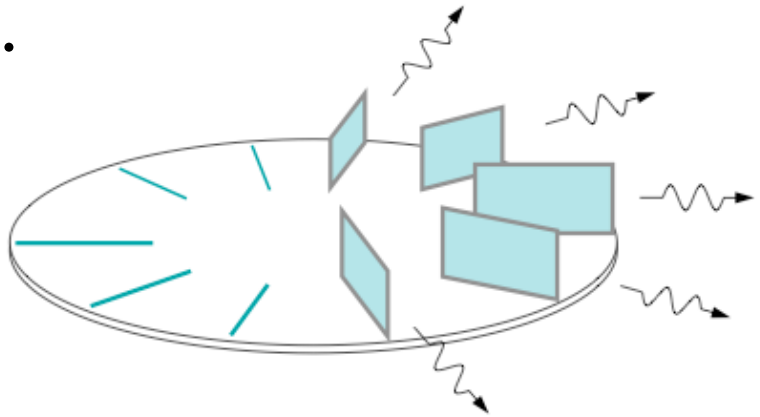


Ramachandran, Kokku, Mahindra, Rangarajan, "60 GHz Data-Center Networking: Wireless - Worry less?" *NEC Lab Tech Report, 2008.*

Highly Directional Transmission: Both Good and Bad

- Need to boost link budget. Use directional antennas.
  - Directivity inversely proportional to $freq^2$
- Small wavelength means smaller antennas.
  - Steerable antenna arrays can be produced on the same packaging as the RF circuits.



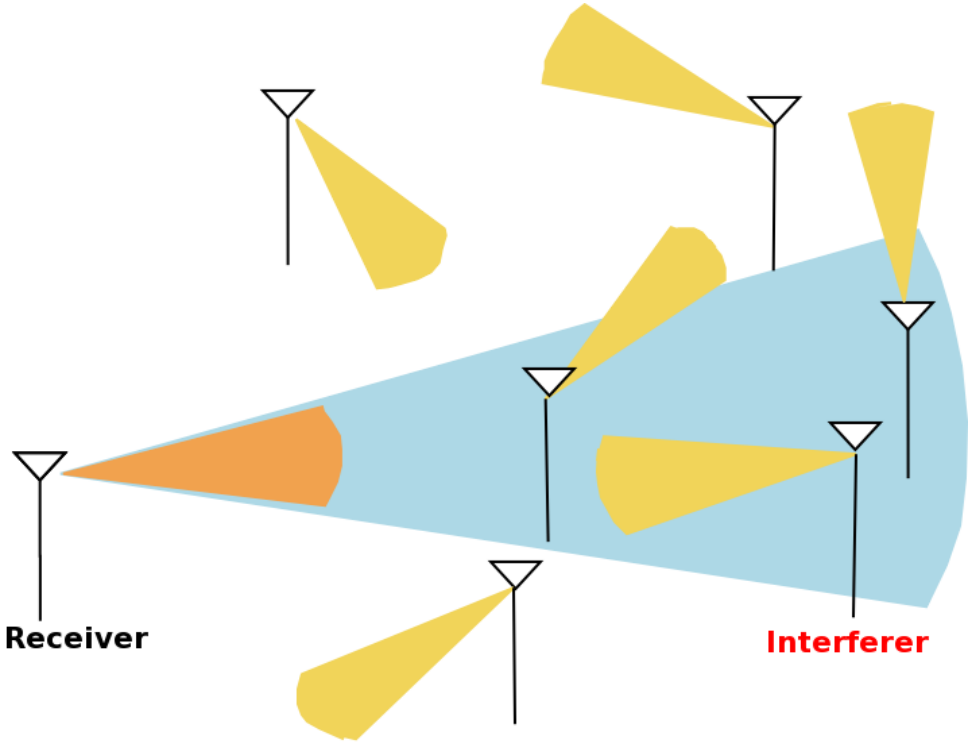
Reconfigurable circular array
Total 10 angular slots; 5 slots installed

[Image courtesy: Madhow, Comnets, 2010]

CSMA and Directional Antennas

- CSMA wildly successful for shared LANs for 30+ years.
- Steerable directional transmission makes CSMA-based design much harder.
- Cannot hear in the direction not looking.

"Pseudo-wired" Model



Collision only when interferer within range, AND within receiver beamwidth, AND pointing to receiver.

- With narrow beams (e.g., less than 10 deg) collision probability low.

[Mudumbai,Singh, Madhow, "Medium Access Control for 60 GHz Outdoor Mesh Networks with Highly Directional Links, *Infocom 2009*]

Implications of "Pseudo-Wired" Model

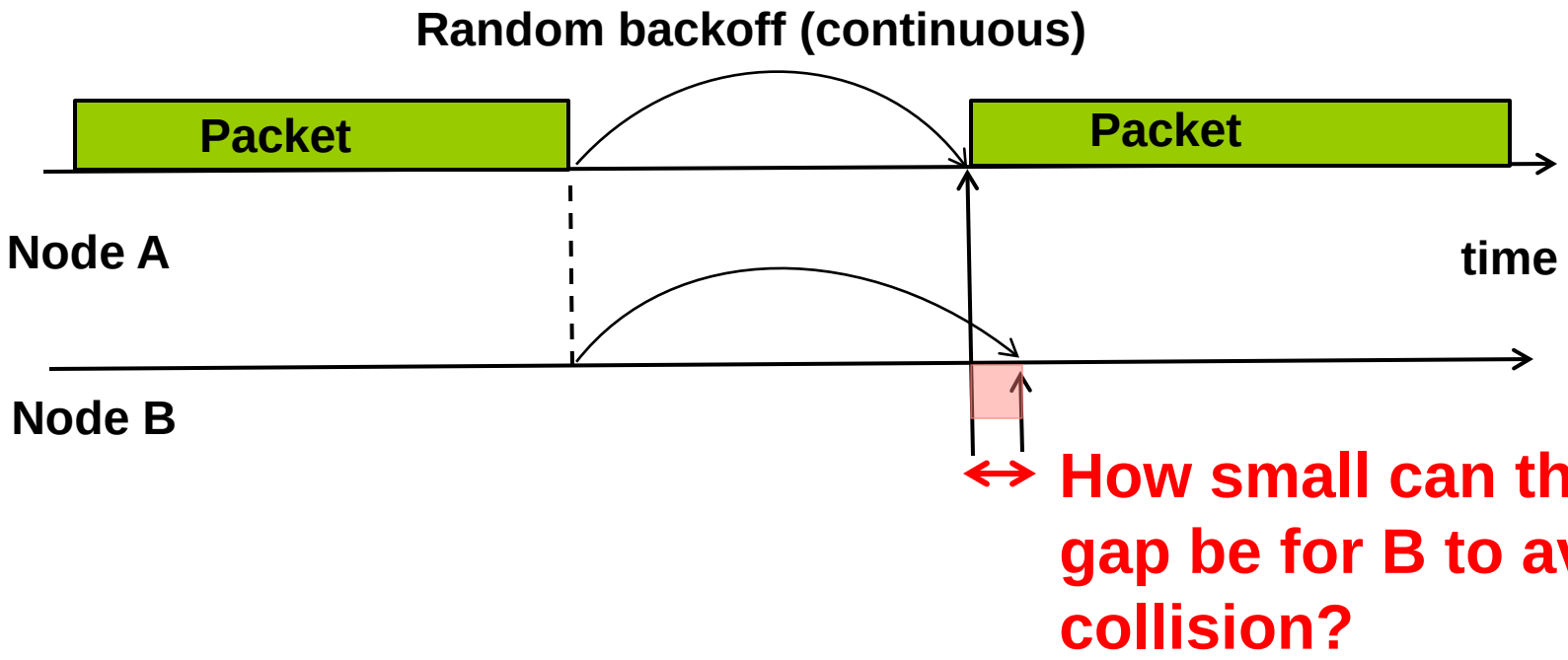
- Less effort needed on interference management.
- But deafness still a problem.
- Neighbor discovery is harder.
- Some coordination is needed.

[Mudumbai,Singh, Madhow, "Medium Access Control for 60 GHz Outdoor Mesh Networks with Highly Directional Links, *Infocom 2009*]

Muli-Gigabit is not limited to 60GHz only ..

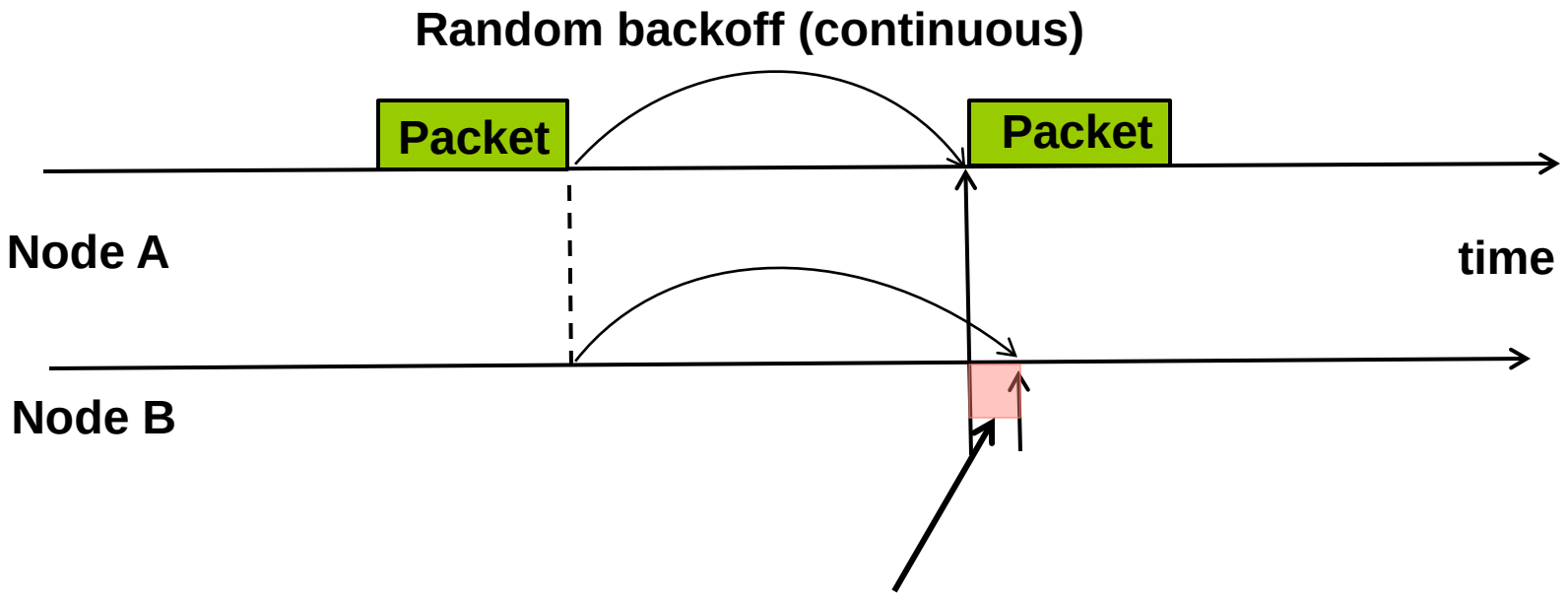
- Example: 802.11ac in <6GHz band.
  - More familiar propagation characteristics.
  - Can use familiar CSMA (802.11 like).
- Major Issue: BW-independent overhead dominates.
  - BW independent overhead = carrier sensing time, propagation time, ..

Implication of BW-Independent Overhead



- Too small a gap may make B misjudge the state of the channel.
- Min. gap = prop. Time + carrier sense time.

Packet Time Short at High Speeds



- Limit of slot size for discrete backoffs.
- In the order of 10 micro-sec in 802.11ac standard.
- Sub-microsec is virtually impossible because of propagation time limits.

So where is this going?

- Take some examples.
- Packet time for a 1000B packet is
  - 8 micro-sec at 1Gbps.
  - 0.8 micro-sec at 10Gbps.
- Slot size is
  - In the order of 10 micro-sec in practice
  - In the order of 1 micro-sec in extreme limit.
- Packet time counted in slots small.
  - In the order of 1.

How to Improve MAC Efficiency?

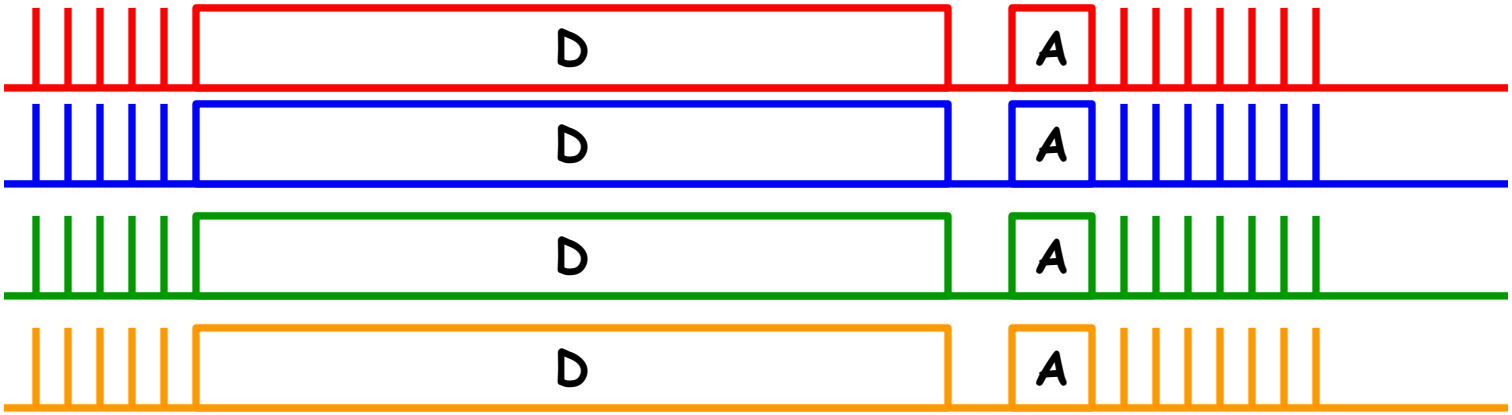
Backoff slots

(a) Slow data rate, single channel

Backoff slots

(b) High data rate, single channel

(c) High data rate, single channel, with block transmissions, aggregated ACK

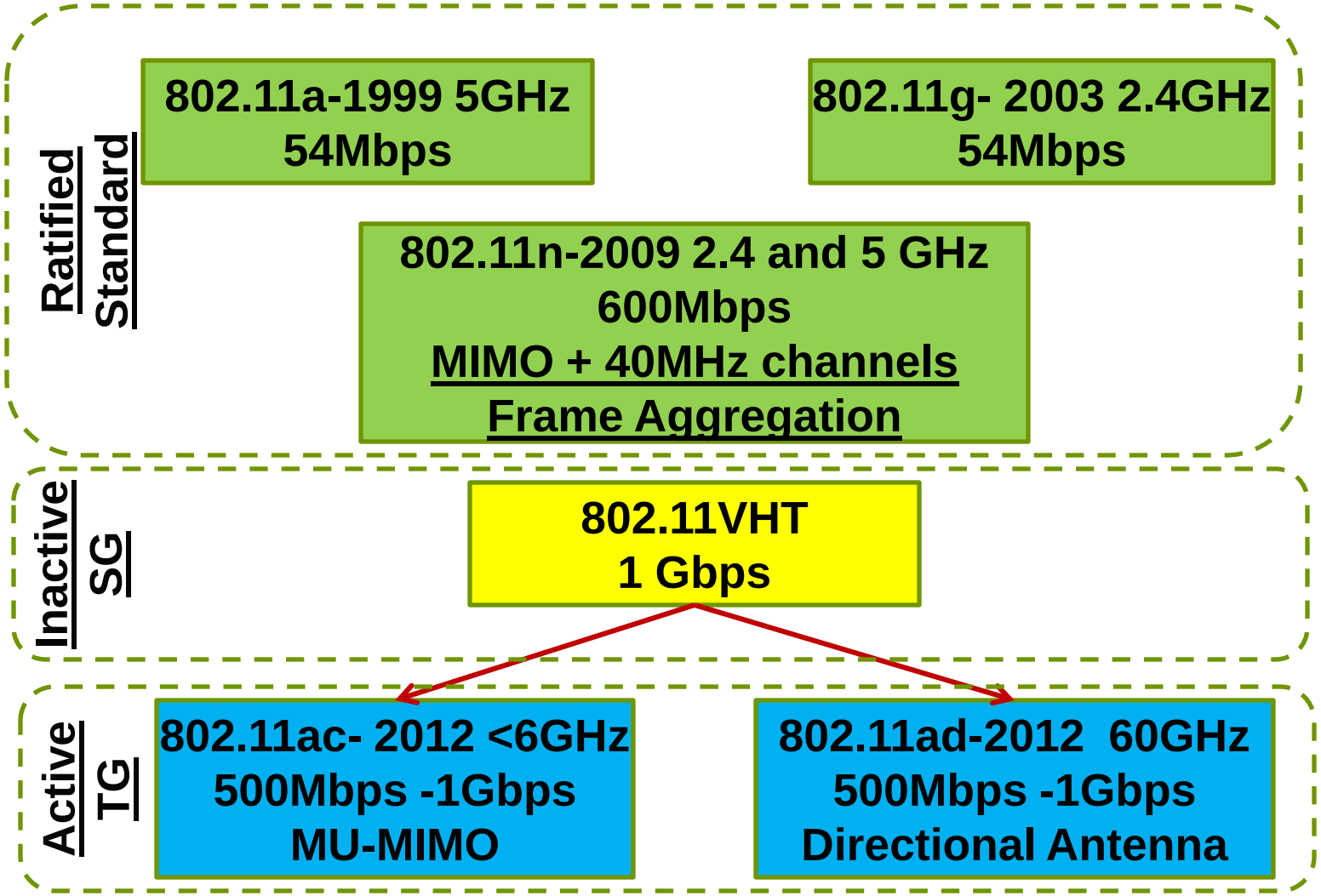


Backoff slots

(d) High data rate, multichannel (4 channels)

Standards

Very High Throughput WLAN



High Definition Multimedia

Wireless Gigabit Alliance

ECMA 387 (Wireless HDMI)

802.15.3c

All 60 GHz

Confusing array of standards

Wireless HD

WHDI™
Wireless Home Digital Interface

Concluding Remarks

- Wireless is finally catching up with wires.
  - Currently driven by needs of infotainment.
- Little existing work on link layer.
  - How to design effectively for high degree of directionality?
  - How to hide BW-independent overheads?