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60 GHz mmWave Multimedia Wireless Systems: Issues and Solutions

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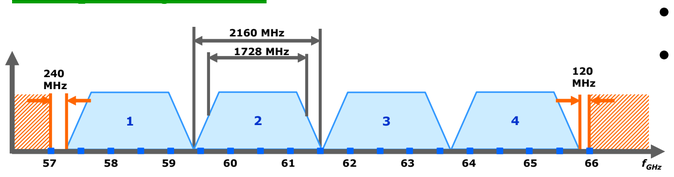
Introduction to 60 GHz Wireless Systems

Why 60 GHz Millimeter Wave (mmWave) is attractive?

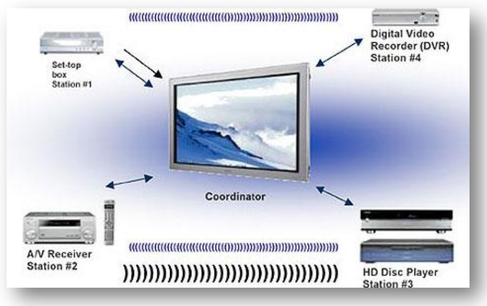
- Enabling Wireless ***Gigabit*** Networking!
- Enabling ***Uncompressed HD Video Wireless*** Transmission!
  - Around 7GHz bands are available.
  - Low latency wireless transmission
  - No data loss due to compression
- ***Unlicensed*** Band, i.e., free to use
- ***Sharing same band for all countries***
  - Do not need to design customized antennas for each country

Frequency Plan



- Sub-Channel BW: 2.16 GHz
- 4 Sub-Channels are available.

User Scenario



- 1080p HD uncompressed video stream can be transmitted if more than 1.5 Gbps is guaranteed. In the 60 GHz mmWave band, each sub-channel can guarantee 2.16Gpbs, hence uncompressed 1080p HD video transmission is possible.

Current IEEE Standards and Industrial Solutions

- ***IEEE:*** 802.15.3c WPAN, 802.11ad Very High Throughput (VHT)
- ***Industry:*** WirelessHD Consortium, Wireless Gigabit Alliance (WiGig)

Wireless HDTV Applications

Mobile Applications

802.11ad VHT *802.15.3c*

Participants

- ***Chip Vendors***
  - Intel
  - SiBEAM
  - Broadcom
  - Qualcomm
  - AMD
  - MediaTek, and so forth
- ***Consumer Electronics Companies***
  - Apple
  - Dell
  - LG Electronics
  - Samsung Electronics
  - Sony
  - Toshiba
  - Panasonic, and so forth
- ***Research Institute***
  - ETRI
  - IBM, and so forth

Challenges and General Solutions

Research Challenges

- ***High Path Loss*** due to high frequency
  - ***Friis Path Loss Model***

$$P_{RX} = \frac{G_{TX} G_{RX} c^2}{(4\pi d)^2 f_c^2} P_{TX}$$

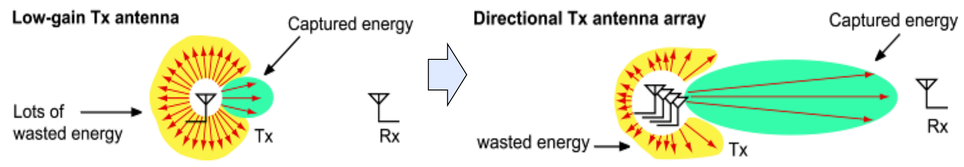
Communication range is limited according to this property of 60 GHz.

Parameters

- P_{TX}: transmitted power (unit: W)
- P_{RX}: received power (unit: W)
- G_{TX}: transmitter antenna gain
- G_{RX}: receiver antenna gain
- d: distance (unit: meter)
- **f_c: center frequency (unit: Hz)**
- c: speed of light in a vacuum

General Solutions

- ***Directional Data Transmission*** via ***Beamforming***



- ***Relaying***
  - Extending wireless networking coverage with additional relay nodes.
  - Can achieve capacity gain if one relay node is added in the networks.
  - However, multiple relays can extend the coverage but cannot increase the capacity significantly compared to the capacity of one-relay case.

Current Relaying Theories for 60 GHz mmWave: IEEE 802.11ad VHT Relaying

Basic mmWave Relay Operation

- Details are in Ref. #5.

- Two types of relays: (1) Link Switching Type, (2) Link Cooperating Type

Link Switching Type

- If the *s*-*d* direct PHY link is disrupted, the source (*s*) redirects the transmission of frames addressed to the destination (*d*) via the relay (*r*).
- Direct link between the source (*s*) and destination (*d*) can resume after the direct link between them is recovered.

Link Cooperating Type

- The relay (*r*) is actively involved in the direct link communication between *s*-*d*.
- At the same time, a frame transmission from the source (*s*) to the destination (*d*) is repeated by the relay (*r*).
- It can possibly increase the signal quality received at the destination (*d*). [cooperative diversity]

Future Research Directions

- Customized relaying scheme for 60 GHz mmWave is required, i.e.,
  - Considering *Uncompressed HD Video Stream Factors*
  - Considering *Cooperative Diversity Impacts*

Considering Problems

- Relay Selection
- Multi-Hop vs. Single-Hop
- Cooperation Mode, i.e., Amplify-and-Forward vs. Decode-and-Forward
- Optimizing HD Video Coding Rate
- And so forth.

References

1. WirelessHD Consortium: http://wirelesshd.org
2. Wireless Gigabit Alliance: http://wirelessgigabitalliance.org
3. IEEE P802.11 TGad: Very High Throughput in 60 GHz: http://www.ieee802.org/11/Reports/tgad_update.htm
4. IEEE 802.15 WPAN TG3c Millimeter Wave Alternative PHY: http://www.ieee802.org/15/pub/TG3c.html
5. C. Cordeiro, *et al.*, "**Relay Operation in IEEE 802.11ad**," *IEEE 802.11-10/0494r1*, May 2010.