802.11ad In Smartphones: Energy Efficiency And Impact on Applications

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Motivation

AR/VR, Miracast, UHD videos require Gbps speeds

IEEE 802.11ad

- **60 GHz band with 2 GHz** wide channels
- Data rates **up to 6.7 Gbps,** a multi-fold increase against 802.11ac/ax
- Highly susceptible to **blockage and mobility**
- **Higher data rates** --> **Higher power?**

Contributions

- **Performance evaluation** of 802.11ac/ad/ax
- **Power characteristics** of all 3 technologies
- **Application performance and energy consumption**

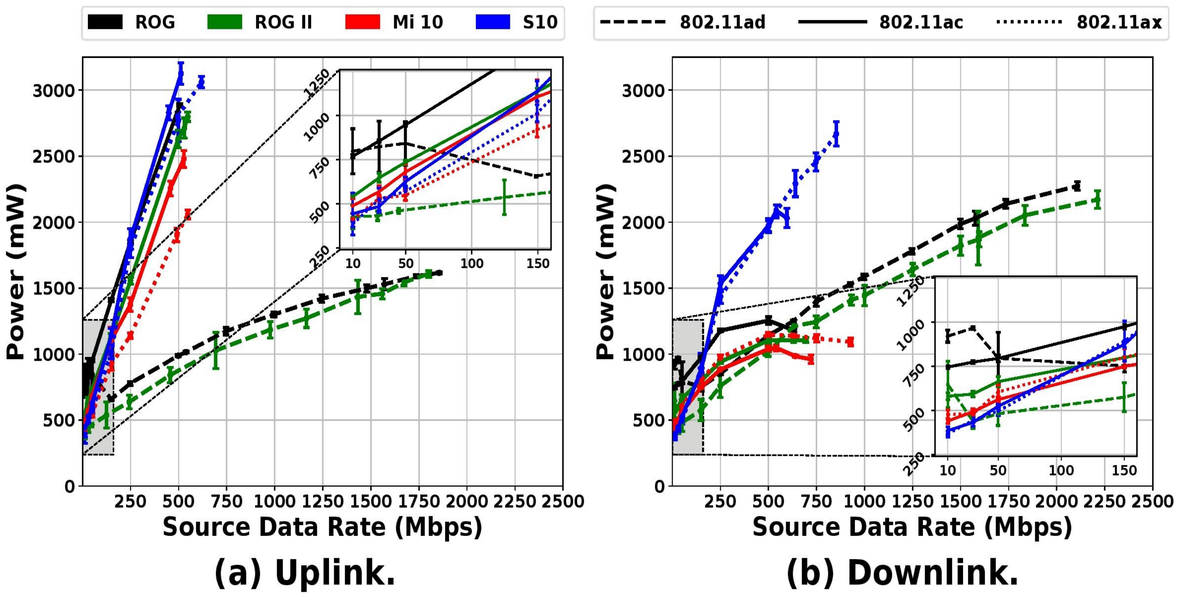
Performance – Different Phones and Technologies

Downlink/Uplink Throughput (Mbps)

	ROG	ROG II	S10	Mi 10
802.11ad	2100/1800	2200/1800	N/A	N/A
802.11ax	N/A	N/A	900/600	920/540
802.11ac	630/540	650/600	650/530	720/520

- Throughput – Downlink **higher** than uplink for all technologies
- **802.11ad – only technology with Gbps throughput**

Active Power Consumption



- 802.11ad **Rx power higher than Tx power** contrary to 802.11ac/ax
  - 802.11ad **Tx Power is the lowest**
  - 802.11ad **Rx Power** – **low till 500 Mbps** and then increases
- Due to **PSM**, 802.11ad **low data rates have non-monotonic power**

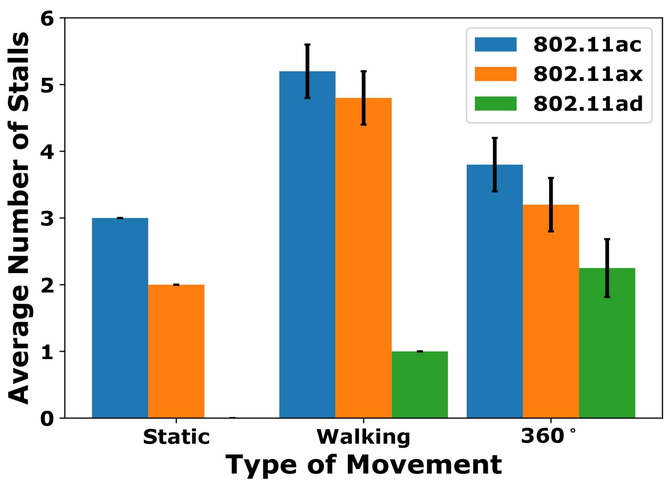
Power Saving Policies in 802.11ad

Packet Inter Arrival Time (Tp)	Rule
Tp >= 92 ms	Standard PSM Timeout of 15ms is maintained
Tp >= 14ms and Tp < 92 ms	Packets are buffered at AP or Phone and sent/received at the beginning of the next beacon period. 15ms timeout is still maintained.
Tp < 14 ms	For first 0.5s, standard PSM timeout is maintained. As Tp starts decreasing, the phone wakes up periodically every ΔT to send/receive a batch of packets. ΔT decreases with the value of Tp

- **PSM Timeout** - time between a **Tx/Rx** activity and the radio **going to sleep**
  - 802.11ac – Fixed at 200ms
  - 802.11ad – **Complex set of policies** based on inter packet arrival time.
- **Radio** on the phone **"learns" the traffic pattern** and sets an appropriate **ΔT**

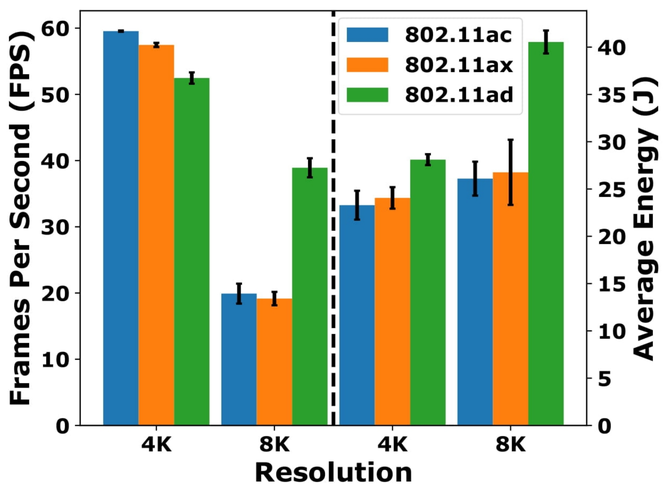
Impact on Applications

UHD Video Streaming (1.33 Gbps)



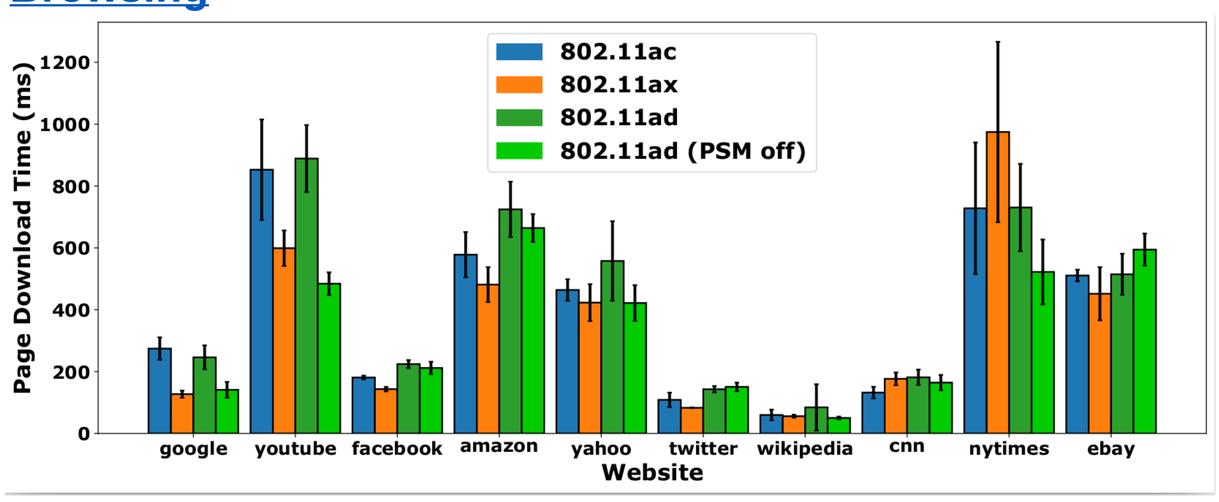
- **802.11ad** is the **clear winner**
  - **No stalls** in static scenario
  - **Fewer stalls** in motion scenarios (high data rates allow buffering of frames)
- **Energy slightly higher** for 802.11ad than for 802.11ac/ax

Virtual Reality



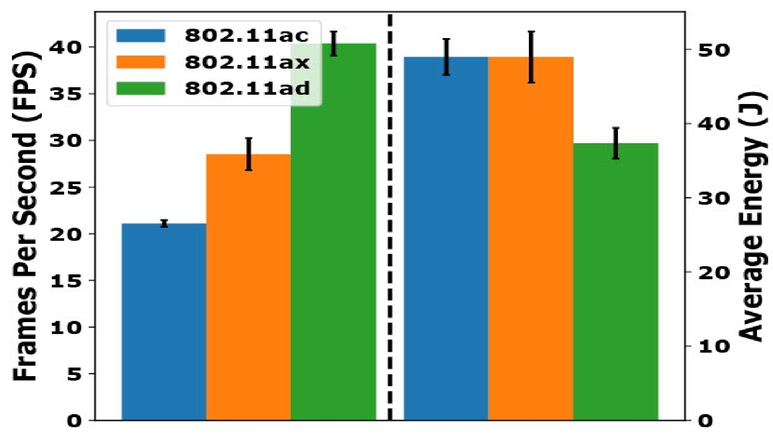
- 802.11ad **does not meet** the app's demands **(60 FPS)**
  - 4K: **Slightly worse** than **802.11ac/ax**
  - 8K: **60-65% higher** than **802.11ac/ax – promising!**
- Beamforming **increases** 802.11ad's energy consumption

Browsing



- 802.11ax has the **shortest Page Load Time (PLT)**
- 802.11ad's **Page Load Time/energy**
  - **Longer/Higher** with **PSM on**
  - **Shorter/Lower** with **PSM off**

Miracast



- 802.11ad
  - **Only technology** to meet the app's demands
  - **Most energy efficient**

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