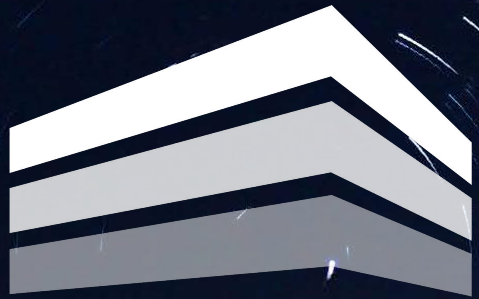
Multi-Channel Mobile Access Point in Next-Generation IEEE 802.11be WLANs

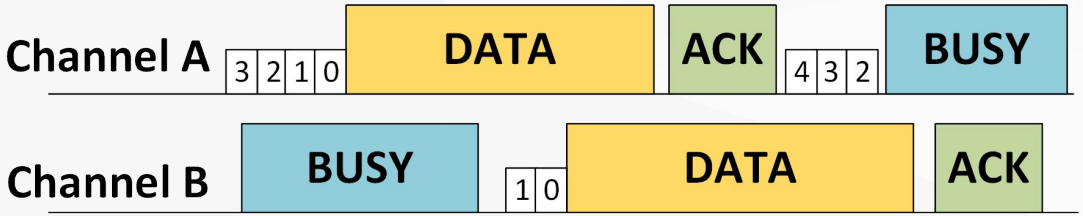


Sharan Naribole, Srinivas Kandala and Ashok Ranganath
Samsung Semiconductor, Inc. San Jose, CA USA

IEEE ICC Conference 14-23 June, 2021

IEEE 802.11be Multi-Channel Operation

- IEEE 802.11be
  - Next-generation IEEE 802.11 standard project after IEEE 802.11ax
- Multi-Channel Operation
  - Emergence of dual-radio end user devices (STAs) and tri-band Access Points (APs)
  - Data from same traffic session over multiple channels using first available channel
- Asynchronous operation
  - By default, independent medium access on each channel



STR Constraints at Multi-Channel Devices

- **STR**: simultaneous transmission and reception over a pair of channels

- STR capability
  - Ability to support reception on one channel while transmitting on other channel
  - Depends on RF design and operation parameters including channel location, bandwidth of each channel, antenna distribution, etc.

- Regular AP routers expected to be STR capable
  - Typically many-antenna systems and selects the channels of operation

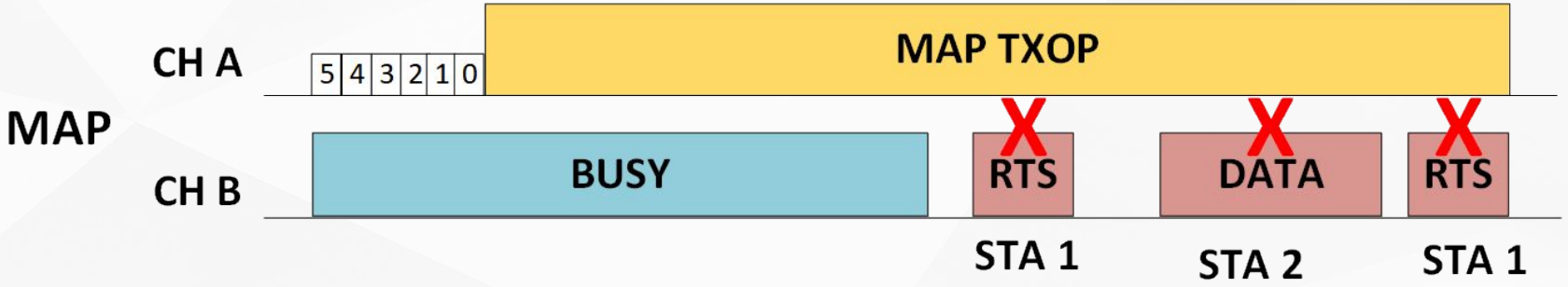
- **Non-STR STAs**
  - STAs may lack STR capability due to smaller form factor and simpler design
  - Indicate capability to AP dynamically based on operation parameters
  - Example: two channels on 5 GHz band

Mobile Access Point

- Rapid growth of smartphones and tablets with Mobile AP feature
- Soft AP/ personal hotspot/ mobile hotspot
- Convenient, on-the-move, cost-effective gateway to Internet
- STA establishes a Wi-Fi network (BSS) to operate as a Wi-Fi AP (MAP)
- Typically, MAP uses in-device cellular interface as Internet backhaul
- 802.11be STAs can establish multi-channel MAP BSS e.g. to support newly unlicensed 6 GHz operation as well as legacy support for 2.4 GHz and 5 GHz

Multi-Channel Non-STR MAP Challenge

- MAP expected to be non-STR when operating two links on 5 GHz and 6 GHz



- MAP fails to receive on Channel B during an ongoing frame exchange on Channel A
  - Might lead to significant performance degradation of associated devices and misinterpretation for STA-side link adaptation

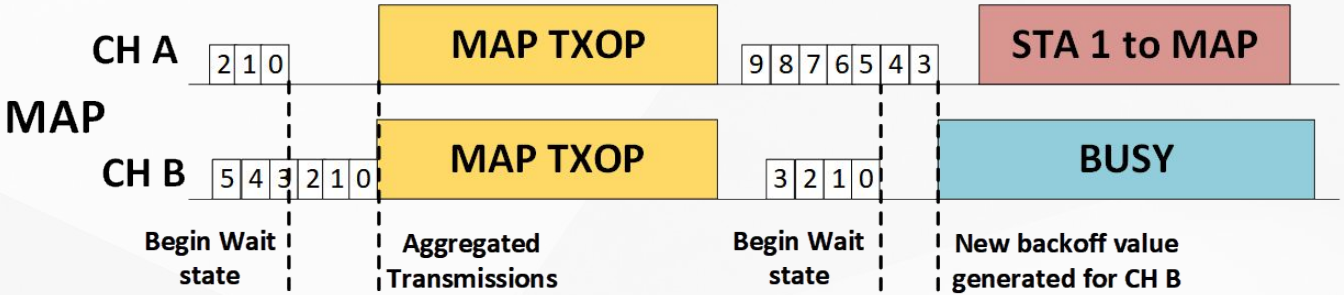
Contributions

We propose Mobile AP Medium State-based Transmission Alignment and Recess protocc
(**MobiSTAR**)

- **Opportunistic Alignment of Simultaneous Downlink Transmissions**
  - Improves downlink throughput and prevent reception failure at MAP
- **Downlink Transmission Ending Alignment with Overlapping BSS frame (OBSS)**
  - Utilizes PHY header information to determine ongoing OBSS frame exchange
- **Access Recess at STAs**
  - Minimize access attempts by STAs on other channels during MAP's TXOP
- Using custom ns-3 simulator, we analyze MobiSTAR's performance

MobiSTAR Simultaneous Downlink Transmissions

- On reaching backoff counter zero on one channel, if other channel is idle, MAP will try to aggregate transmissions on both links

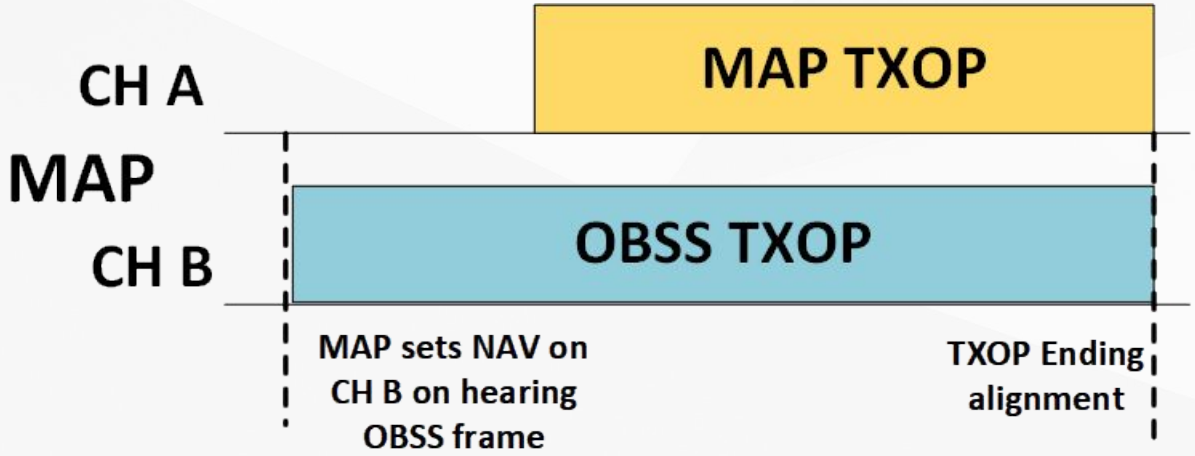


- In waiting state on a link, MAP monitor CCA on this link while waiting for other link's backoff counter to reach zero.
  - If other link reaches zero, aggregated transmission is performed.
  - If waiting link gets busy, transmission is aborted and a new backoff is generated.
  - If other link gets busy during wait, then transmission performed only on waiting link

MobiSTAR Downlink Alignment with OBSS

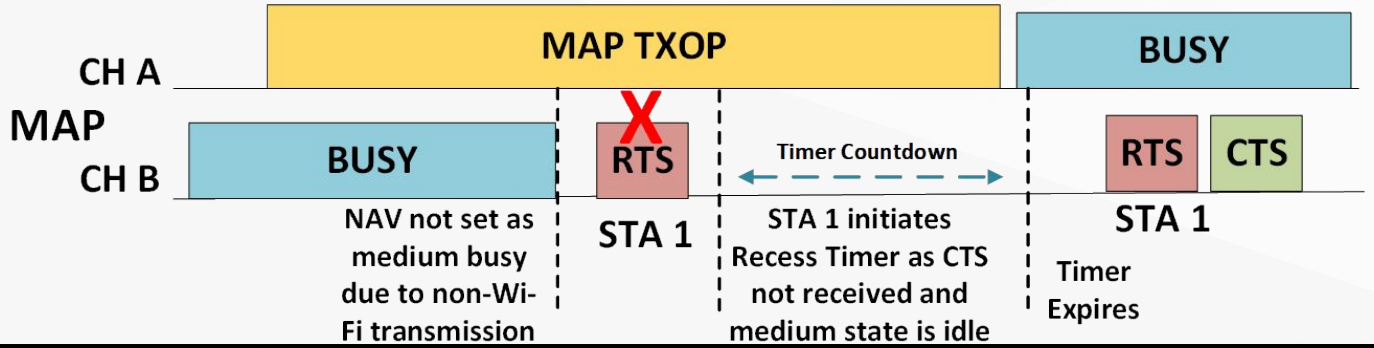
- If other channel is busy and NAV is set, TXOP align with NAV set on other link

- If other channel is busy but NAV is not set
  - Possible due to non-Wi-Fi transmissions
  - Alignment is not possible in this case
  - We propose STA-side access recess protocol in next slide



MobiSTAR Access Recess at STA

- STA attempts RTS and if no CTS is heard and CCA state is IDLE for PIFS then activates Recess timer countdown
- STA continues to monitor the channel and can have an early timer expiry if it hears any frame from the AP not necessarily to itself
- Another intra-BSS frame not from AP won't lead to timer expiry because those frames might also fail
- Timer value can be in the order of max PPDU duration
- If an OBSS frame is heard during countdown and TXOP Duration indicates ending after timer expiry, then STA updates its NAV



Performance Evaluation

- Implemented MobiSTAR and alternative strategies in ns-3 simulator

- Network model
  - Single Mobile AP operating a two-channel BSS
  - To isolate multi-channel performance, we focus on single non-STR STA
  - Varying number of single channel STAs on each channel
  - 80 MHz on 5 GHz band and 80 MHz/160 MHz on 6 GHz band
  - PHY data rate of 480 Mbps for transmissions per channel
  - Varying number of interfering neighboring BSS (OBSS) traffic flows

- Traffic model
  - Full-buffered uplink traffic generated at associated STAs to MAP
  - Full-buffered traffic from MAP to non-STR STA
  - OBSS traffic flow uses channel access for a random duration up to 5 ms

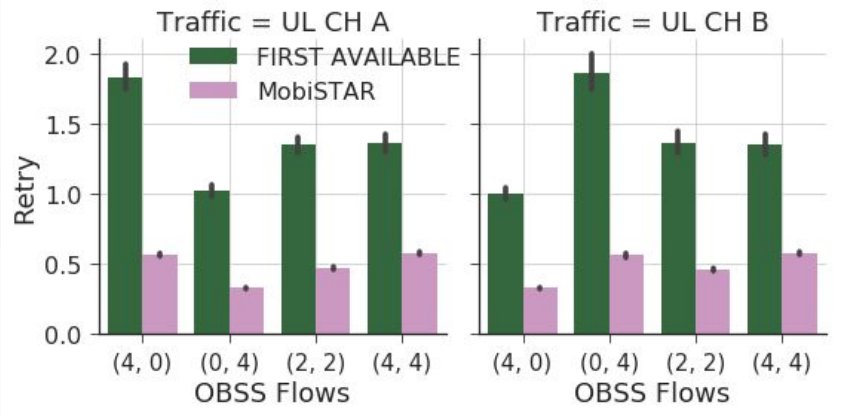
- Over 100 separate runs of 10 seconds in network time per configuration

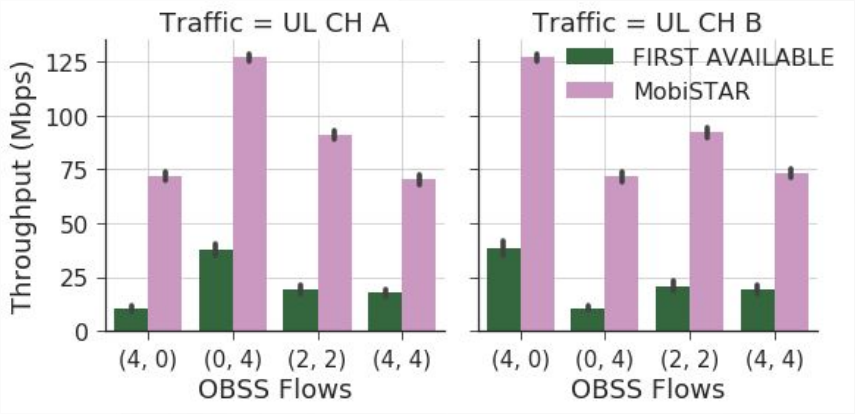
Alternative Strategies

- **First Available Channel**
  - MAP utilizes first available channel for transmission
  - Access deferred on CH B if receiving intra-BSS frame being received on CH A
  - Single channel STAs can operate on any channel

- **Mandatory Channel**
  - MAP classifies channels into mandatory channel and conditional channel
  - Single channel STAs associate only on the mandatory channel
  - **Any transmission in this multi-channel BSS shall include mandatory channel**
  - Conditional channel can be utilized for aggregated transmission
  - To maximize medium access, 802.11 backoff can be performed on both mandatory channel and conditional channel by multi-channel devices.
    - **If backoff on conditional channel reaches zero and mandatory channel is busy, the transmission is aborted**
    - If conditional channel is busy, only mandatory channel is used

MobiSTAR vs First Available

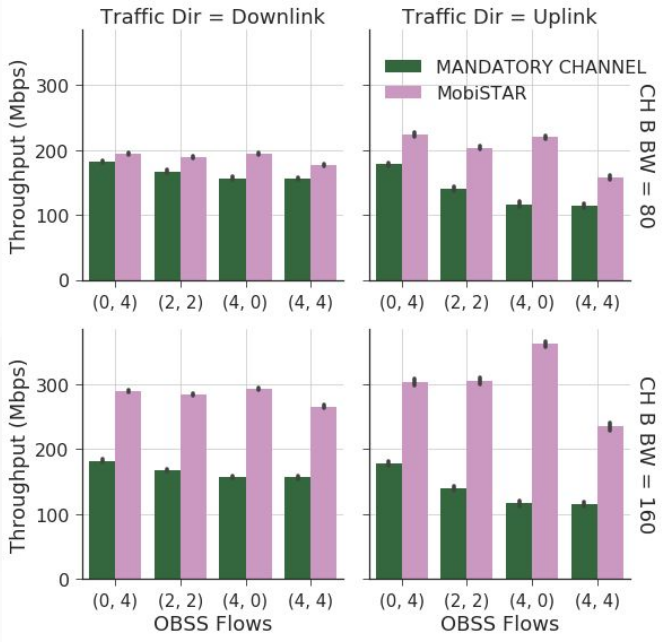




- Focus on uplink medium access performance comparison
- 80 MHz channel on 5 GHz and 80 MHz channel on 6 GHz
- Varying combinations of OBSS flows
  - (x , y) = x OBSS flows on CH A and y OBSS flows on CH B
- MobiSTAR's transmission alignment by MAP and access recess by STAs results in fewer retries by STAs and improved uplink throughput compared to First Available strategy

MobiSTAR vs Mandatory Channel

- Uplink and Downlink throughput comparison
- 80 MHz channel on 5 GHz (CH A) and 80 MHz/160 MHz channel on 6 GHz (CH B)
- CH A is selected as mandatory channel for Mandatory Channel strategy to enable support for legacy devices operating on 5 GHz
- In uplink, greater congestion on CH A in Mandatory Channel strategy and MobiSTAR's gain increases with increase in CH B's operation bandwidth
- In downlink, MAP shall always include mandatory channel in any transmission thereby aborting access obtained only on conditional channel



Conclusion and Related Work

- **Proposed MobiSTAR protocol to address the challenges introduced by simultaneous transmit-receive constraints at a mobile Access Point operating on multiple channels.**
- In [1], we proposed mechanisms for improving the uplink medium access of non-STR STAs participating in asynchronous multi-channel operation
- In [2], we proposed mechanisms for improving the downlink data delivered by STR AP to non-STR STAs
- Several topics for further research including Transmit and receive chain sharing within a multi-channel device

[1] Naribole et al., “Simultaneous Transmit-Receive Multi-Channel Operation in Next-Generation WLANS”, *IEEE WCNC* 2020
[2] Naribole et al., “Simultaneous Multi-Channel Downlink Operation in Next Generation WLANs”, *IEEE GLOBECOM* 2020