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Experimental Investigation of Static Channel Bonding Performance in Competitive Environment
－Impact of Different MAC Procedures in 802.11ac－

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Abstract　Channel bonding technology, which bundles multiple adjacent channels for frame transmission, is one of the promising way for improving throughput performance in IEEE802.11ac wireless LANs. However, channel bonding technology leads to co-channel interference with other access points (APs) within the bonded channels. In our previous study, we investigated transmission performance of several commercially-available 802.11ac APs. As a result, we clarified three communication procedures from difference in method of implementation of Request To Send (RTS) / Clear To Send (CTS) or not. Furthermore, we investigated the impact of RTS/CTS on transmission performance by conducting experiments where two APs using RTS/CTS are competing in a bonded channels. However, we have not investigated transmission performance in the case that APs with different transmission procedures compete with each other in a bonded channels. Therefore, in this study, we conducted experiments using real WLAN products. Then, we compared and evaluated the communication performance in the case that two APs with different transmission procedures compete in the same channel. As a result, we showed that the AP employing CTS-to-self doesn't set duration time in CTS frames, thereby the communication performance of the AP using RTS/CTS in channel bonding degrades due to frequent collisions in conflict channel. On the other hand, since AP not using RTS/CTS dynamically adjusts the number of data frames for each transmission opportunity to avoid frame collisions, we confirmed that the communication performance can be relatively maintained even under the competitive environment.

Keywords　IEEE802.11ac, Channel bonding, Static channel bonding, Access Point (AP), RTS/CTS frame, CTS-to-self

Experimental Investigation of Static Channel Bonding Performance in Competitive Environment – Impact of Different MAC Procedures in 802.11ac –

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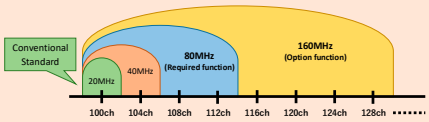
1. Background

Spread of Wireless LAN

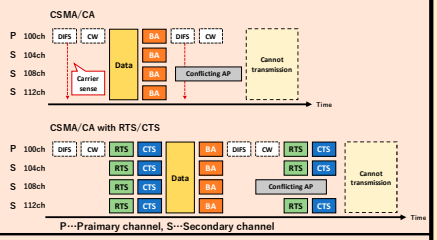
- The communication speed of the wireless LAN gets faster and faster, and several Wi-Fi standards have been standardized so far.
- IEEE802.11ac is the latest Wi-Fi standard.
- One of the core technology employed in 11ac is Channel Bonding (CB).

Channel Bonding (CB)



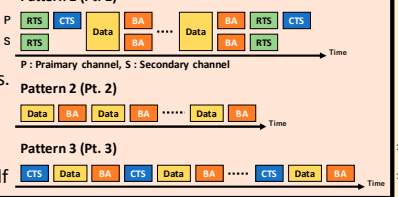
Static Channel Bonding

- It always tries to hold a certain communication band.
- If other communication is detected within bonded channels, a sender needs to wait until the channel is idle.



Previous research

- Found out three communication procedures in commercially available APs.
  - **Pattern 1** : Use of RTS/CTS
  - **Pattern 2** : Without use of RTS/CTS
  - **Pattern 3** : Use of CTS-to-self



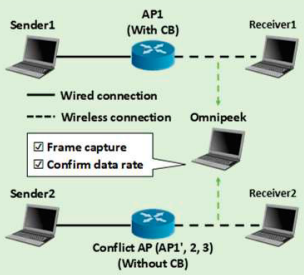
2. Objective of Research

- To investigate how the coexistence of APs with different communication procedures could affect communication performance.
- In particular, it is not clear how the function of RTS/CTS affects communication performance in CB.

- Conducting experiment in cases where the AP of the pattern 1 with CB competes with the AP of the patterns 1 to 3 without CB, respectively.

3. Experiment

AP's ID	Procedure
AP1, AP1'	Pt. 1
AP2	Pt. 2
AP3	Pt. 3

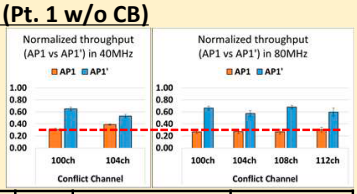


- Bonding Width
  - AP1 : 40, 80MHz (w/ CB)
  - AP1', 2, 3 : 20MHz (w/o CB)
- UDP flow by iperf3 for 30 sec
- Performance measure
  - Normalized throughput $= \frac{\text{Throughput in a competitive environment}}{\text{Throughput in non-competitive environment}}$

4. Experimental Results and Discussion

AP1 (Pt. 1 w/ CB) vs. AP1' (Pt. 1 w/o CB)

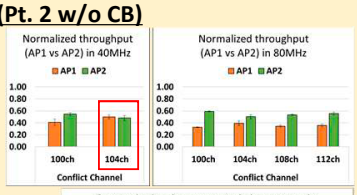
- Normalized throughput of AP1 is about half of that of AP1'.
- The number of frames to be aggregated in an A-MPDU of AP1 and AP1' is fixed (32 frames).
- Even though data rate of AP1' is low, AP1' sent three A-MPDUs.
- So, **duration time per transmission opportunity of AP1' is longer than that of AP1.**

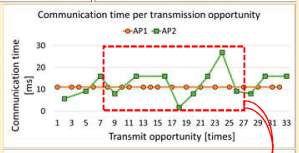


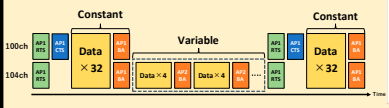
Bonding Width	Data Rate [Mb/s]	The number of continuous transmission of A-MPDU	Duration time per transmission opportunity [usec]
20MHz (AP1')	86.7	3	1762
40MHz (AP1)	150	4	1378
80MHz (AP1)	325	8	1319

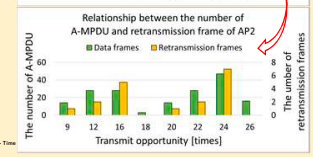
AP1 (Pt. 1 w/ CB) vs. AP2 (Pt. 2 w/o CB)

- In the case of contention at 104ch in 40 MHz bonding width, normalized throughput of AP1 and AP2 are **almost same**.
- Communication time for each transmission opportunity.
  - AP1: Constant
  - AP2: Variable
- Relationship between the number of A-MPDU and retransmission frames.
  - **The number of A-MPDU tends to be dynamically changed depending on the number of retransmission frames.**



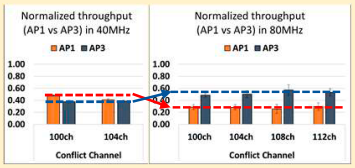






AP1 (Pt. 1 w/ CB) vs. AP3 (Pt. 3 w/o CB)

- In 80MHz bonding width, normalized throughput of AP1 decreases to about 0.3, whereas that of AP3 increases.
- **The duration time in CTS frames sent by AP3 was set to 0 sec.**
  - Frame collision between AP1 and AP3 is likely to occur.



5. Conclusion

- In case that two APs using RTS/CTS compete each other, their communication performance depends on balance between communication duration.
- On the other hand, as the AP not using RTS/CTS pre-checks the channel status before communication, the impact of communication performance of other AP is reduced.
- Finally, because the AP using CTS-to-self doesn't set duration time, the communication performance of AP with CB degrades.
  - **As a result, RTS/CTS function is not needed for conflict AP to suppress bad influence on communication performance of AP with CB.**

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