Uplink multi-user MAC protocol for 11ax

Date: 2014-05-11

Authors:

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliations</th>
<th>Address</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tran Thi Thao Nguyen</td>
<td>Kyushu Institute of Technology</td>
<td>〒820-8502 Kawazu 680-4, Iizuka City, Fukuoka Japan</td>
<td>+81-948-29-7692</td>
<td><a href="mailto:nguyen@dsp.cse.kyutech.ac.jp">nguyen@dsp.cse.kyutech.ac.jp</a></td>
</tr>
<tr>
<td>Leonardo Lanante</td>
<td>Kyushu Institute of Technology</td>
<td>〒820-8502 Kawazu 680-4, Iizuka City, Fukuoka Japan</td>
<td>+81-948-29-7692</td>
<td><a href="mailto:leonardo@dsp.cse.kyutech.ac.jp">leonardo@dsp.cse.kyutech.ac.jp</a></td>
</tr>
<tr>
<td>Hiroshi Ochi</td>
<td>Kyushu Institute of Technology</td>
<td>〒820-8502 Kawazu 680-4, Iizuka City, Fukuoka Japan</td>
<td>+81-948-29-7692</td>
<td><a href="mailto:ochi@cse.kyutech.ac.jp">ochi@cse.kyutech.ac.jp</a></td>
</tr>
<tr>
<td>Tatsumi Uwai</td>
<td>Radrix co.ltd</td>
<td>〒820-8502 Incubation Facilities, Kawazu 680-4, Iizuka City, Fukuoka Japan</td>
<td>+81-948-29-7937</td>
<td><a href="mailto:uwai@radrix.com">uwai@radrix.com</a></td>
</tr>
<tr>
<td>Yuhei Nagao</td>
<td>Radrix co.ltd</td>
<td>〒820-8502 Incubation Facilities, Kawazu 680-4, Iizuka City, Fukuoka Japan</td>
<td>+81-948-29-7937</td>
<td><a href="mailto:nagao@radrix.com">nagao@radrix.com</a></td>
</tr>
</tbody>
</table>
Abstract

● The support for Uplink multi-user (UL MU) for 802.11ax is currently unclear.
● However, numerous studies have shown the benefit UL MU schemes in high-density environments.
● This presentation aims to start the discussion to formally support UL MU in 802.11ax.
● We also present a simple UL MU MAC Protocol to support our objective.
Background

- In a highly dense Wireless LAN environment, many collisions occur reducing the total network throughput and possibly lead to congestive collapse.

**Figure 1: Multi-user transmit their data to AP at the same time[1]**
Background

- Uplink Multi-user transmission reduces collision and hence the total throughput by allowing multiple transmission in a single TXOP. Multi-user transmission can be done in the frequency or spatial domain.

- This figure is the result of combination of the OFDMA access and a CSMA scheme to improve efficiency.
- By adjusting the number of sub-channels, as the number of stations grows → maintain a higher throughput than CSMA/CA based schemes.

Figure 2: Benefit of UL MU (OFDMA) in frequency domain [2]
Uplink Multi-user Transmission

Definition

- Users transmit their data to an AP at the same time. [3]

Type of uplink multi-user transmission

<table>
<thead>
<tr>
<th>Type</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Domain Multiplexing</td>
<td>• OFDMA in a channel or in multiple channels such as LTE or WiMAX</td>
</tr>
<tr>
<td>(FDM)</td>
<td></td>
</tr>
<tr>
<td>Spatial Domain Multiplexing</td>
<td>• UL MU MIMO such as LTE</td>
</tr>
<tr>
<td>(SDM)</td>
<td></td>
</tr>
<tr>
<td>Code Domain Multiplexing</td>
<td>• UL feedback in cellular network such as 3G cellular</td>
</tr>
<tr>
<td>(CDM)</td>
<td>• E.g. IDMA, CDMA</td>
</tr>
<tr>
<td>Hybrid Multiplexing</td>
<td>• E.g. Multicarrier-CDMA, OFDM-IDMA</td>
</tr>
</tbody>
</table>
UL MU MAC Protocol

- The benefit of UL MU can be easily demonstrated by the figure below.

![UL MU Diagram](image1)

![Conventional Diagram](image2)

- However, the benefit of this scenario is limited because it is highly dependent on the transmitted DL frame.
UL MU MAC Protocol for general case

Data transmission opportunities are signaled by the AP.

STA inform the AP of transmission intent via a short request packet

AP schedules UL MU Traffic

UL MU Transmission

Figure 4: An example of stand-alone UL data frame

- Many UL MU MAC protocol in literature follows this protocol [2][3]
- In this protocol, the sequence is initiated by the AP similar to a point coordinator in PCF.
- We refer to this as **centralized UL MU**
Our ideas

- A UL MU MAC Protocol should be
  - Applicable to many scenarios to maximize its effect.
  - Initiated by a participating STA and not the AP.
    - Users that obtain TXOP should be able to send right away regardless of UL MU is used or not.
    - If UL MU is used, users with TXOP don’t have to wait for UL transmission timing. It means each users can initiate UL MU data frame transmission without any control from AP.
  - We call this kind of protocol as **Distributed UL MU**.

- In contrast, in the case of **Centralized UL MU** protocol, frame transmission timing is always come from the AP.
  - Minimal overhead
  - Applicable in DCF/EDCA.
Environment scenario

Figure 5: Environment scenario

Grouping concept here is the same as 11ac DL MU-MIMO grouping.

User1
User2
User3
User4
User5
User6
User7

11ax Users supporting UL MU belonging to Group 1
11ax Users supporting UL MU belonging to Group 2
Legacy device
**Distributed UL MU frame transmission (Example)**

**Scenario 1: UL MU permitted**

- Transmission sequence -

**Figure 6a: RTS and Group-CTS exchange**

**Figure 6b: UL MU Frame transmission**

**Figure 6c: Group-ACK transmission**

Distributed UL MU frame transmission (Example)

Scenario 1: UL MU permitted

- Transmission sequence -

**Figure 6a: RTS and Group-CTS exchange**

**Figure 6b: UL MU Frame transmission**

**Figure 6c: Group-ACK transmission**
Distributed UL MU frame transmission (Example)

Scenario 1 : UL MU permitted

- Timing Diagram -

Figure 7: An example of Distributed UL MU frame transmission

G CTS

CTS frame with Group ID for UL

G ACK

ACK frame with Group ID for UL MU Frame
Distributed UL MU frame transmission (Example)

Scenario 2 : UL MU not permitted
- Transmission sequence -

Figure 8a: RTS and CTS exchange

Figure 8b: UL Frame transmission

Figure 8c: ACK transmission

Distributed UL MU frame transmission (Example)
Distributed UL MU frame transmission (Example)
Backward compatibility

- When any legacy device use RTS, the 11ax AP will always send normal CTS for backward compatibility. Hence, a normal RTS/CTS frame exchange will occur.

- When any legacy device hear a distributed UL MU sequence, it will be as if a normal RTS/CTS frame exchange has occurred.
# Summary

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Centralized</th>
<th>Distributed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“Guarantees” latency.</td>
<td>Low overhead</td>
</tr>
<tr>
<td></td>
<td>Might have better theoretical performance benefit than distributed.</td>
<td>Symmetric with current 802.11ac DL MU scheme.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages</th>
<th>Centralized</th>
<th>Distributed</th>
</tr>
</thead>
<tbody>
<tr>
<td>High overhead</td>
<td></td>
<td>Effect is dependent on whether users within the same group have the same traffic characteristics.</td>
</tr>
<tr>
<td>Neighbor BSSes operating in the same mode will hinder performance.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
New frame type definition

- The function same as 11ac CTS or ACK, but is for a Group.

- **G CTS frame** (Same control frame Subtype as CTS)

  - Frame Control
  - Duration
  - RA
  - FCS

  - b0 - b5
  - b6
  - Indication of group ID
  - Used to differentiate between CTS and G CTS
  - Predefine pattern

- **G ACK frame**

  - Frame Control
  - Duration
  - RA
  - Group-ACK Bitmap
  - FCS

  - New control frame Subtype
Conclusion and Future Work

- We show a UL MU MAC Protocol which has low overhead and easily applicable in frequency domain or spatial domain UL MU.

- We plan to show MAC simulation results of the proposed scheme in a future contribution.
References

