

The MU-RTS/CTS process in the HE (802.11ax) -standard

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Constructive feedback are welcome



Background

- The 802.11ax standard consists of several new technologies
- This powerpoint is the second in a series where I will try to explain ODFMA at a deep level
- My main reference guide is the IEEE 802.11 ax draft version 4.0, amendment 1: Enhancements for High Efficiency WLAN
- Other good references
 - Cleartosend's podcast series about 802.11ax
 - David Colemans presentation at WLPC_US Feb 2019
 - Wifininjas.net



Intention

- This presentation is about the MU-RTS/CTS process that could precede either a DL ODFMA or a UL OFDMA transmission
- The DL/UL ODFMA transmissions are optionally preceded by MU-RTS/CTS

Remarks

- The technologies are called Legacy OFDM, HT, VHT or HE instead of 802.11a/n/ac/ax
- The presentation is based on using a 20MHz channel on the 5GHz band
- Figures are self produced or from the IEEE802.11ax draft 4.0, unless particularly noted
- Many slides have a page reference to the IEEE draft
- All STAs that are not AP are called non-AP STAs



The MU-RTS/CTS process at a high level #1

- The main intent with the RTS/CTS-process is to reserve the channel and enhance the virtual carrier sense process
 - Prepare the receiver
 - Let all other STAs update their virtual carrier (NAVs) so that they can defer any transmission from the channel during that TXOP
 - Secondary effect is to get rid of the hidden node problem
- The HE-standard has a variant of the RTS called MU-RTS, multi user RTS

The MU-RTS/CTS process at a high level #2

- Legacy RTS-CTS
 - The STA that wins a TXOP sends a RTS to the receiver
 - The NAV settings in the RTS is for the rest of the transmission (SIFS-CTS-SIFS-MPDU (the data)-SIFS-ACK(B-ACK))
 - The receiver responds with a CTS with updated NAV-settings
 - The senders sends its data (MPDU) and the receiver answer with a ACK (B-ACK)
- All STAs, both in the BSS and in other BSS on the same channel, will hear either the RTS, the CTS or both and will update their NAV-timer and defer their own transmissions on the channel

The MU-RTS/CTS process at a high level #3

- Legacy RTS/CTS is typically sent at one of the basic (mandatory) data rates and in a legacy OFDM (non-HT) frame format
- Legacy RTS/CTS is a Control type of frames
 - RTS has a MPDU-size of 20 byte
 - Frame Control(2), Duration(2), RA(6), TA(6), FCS(4)
 - CTS has a MPDU-size of 14 byte
 - Frame Control(2), Duration(2), RA(6), FCS(4). No TA

Frame format

Non-HT (legacy) PHY header

MPDU(RTS or CTS)

The MU-RTS/CTS process at a high level #4

- HE/802.11ax
 - The new MU-RTS in the HE protocol is also a Control type of frame and is sent in legacy OFDM/non-HT frame format. Typically at one of the basic (mandatory) data rates.
 - Inside this frame each STA is informed in specific User fields
 - CTS is the response, sent by all the informed STAs, in legacy OFDM/non-HT frame format. The IEEE 802.11ax draft says that the data rate for the CTS is always 6mb/s
 - This MU-RTS/CTS process is not implemented by any vendors yet

This figure shows an example of a MU-RTS and CTS during a DL or UL OFDMA transmission.

MU-RTS/CTS in DL OFDMA

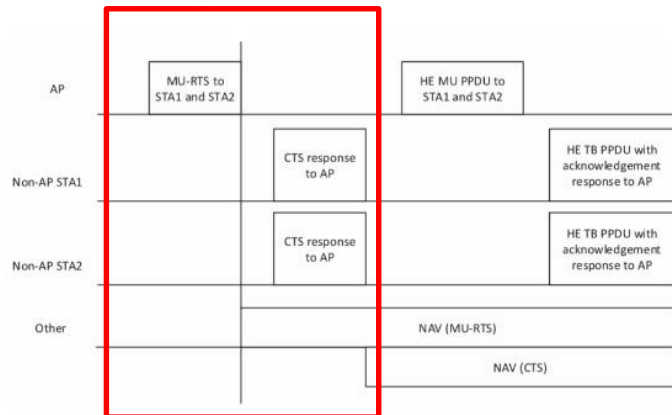


Figure 26-1—Example of MU-RTS/CTS/DL MU PPDU/Acknowledgment Response and NAV setting

MU-RTS/CTS in UL OFDMA

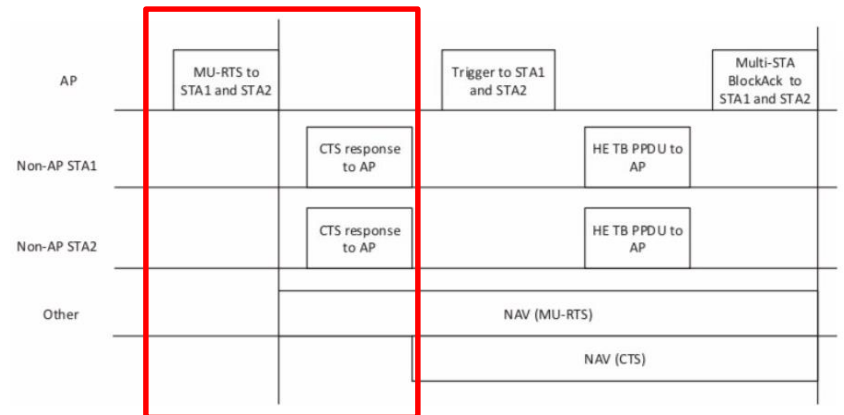


Figure 26-2—Example of MU-RTS/CTS/Trigger/HE TB PPDU/Multi-STA BlockAck and NAV setting

Trigger frames, page 102

- The HE standard uses Trigger frames to allocate resources for and solicits one or more trigger based transmissions
 - The AP uses Trigger frames to both inform and ask for information from non-AP STAs
- The non-AP STAs responds to the Trigger frame with information inside a Trigger based PPDU (HE TB PPDU)

Trigger Frame types, page 102

- There are several variants of the Trigger frames
 - Basic Trigger frame
 - Beamforming Report (BFRP)
 - Multi-user block ack request (MU-BAR)
 - Multi-user request to send (MU-RTS)
 - Buffer Status Report (BSRP)
 - GCR MU-BAR
 - Bandwidth Query Report (BQRP)
 - NDP Feedback Report Poll (NFRP)

Trigger Frame format, page 103

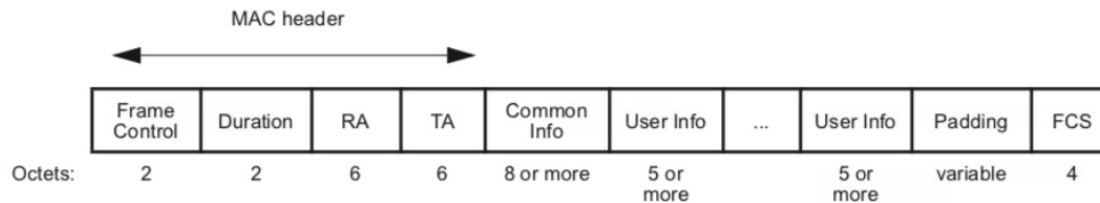


Figure 9-64a—Trigger frame

- This is the frame format of a Trigger Frame
- Mac header
 - Frame Control field
 - Duration, the NAV-timer
 - RA (receiver address). The different Trigger frames have different RAs. The MU-RTS Trigger frames use the broadcast address as RA
 - TA is the transmitting AP's address
- Common Info and User Info, next slides
- All Trigger frames are Control type of frames and are sent in legacy OFDM/non-HT frame formats. Inside the Frame Control field of the Mac header these frames use subtype numbers that were reserved in previous versions of the 802.11 protocol.

Common Info field in the Trigger frame, page 103

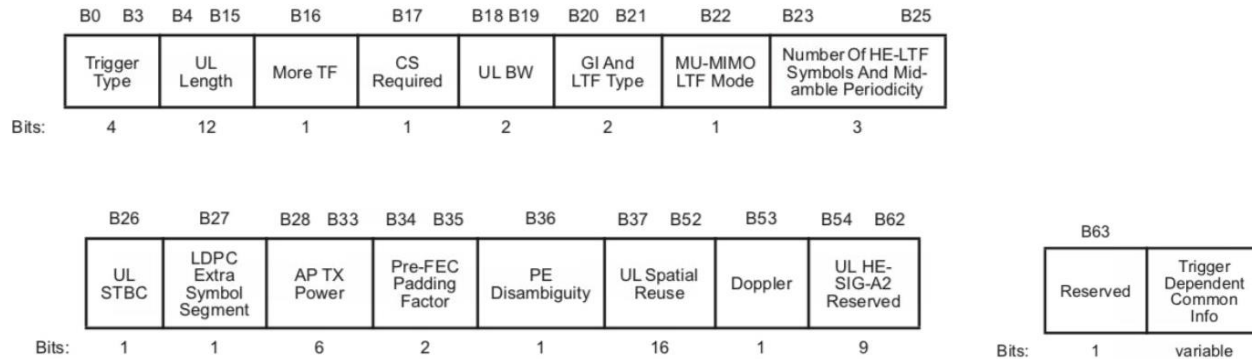
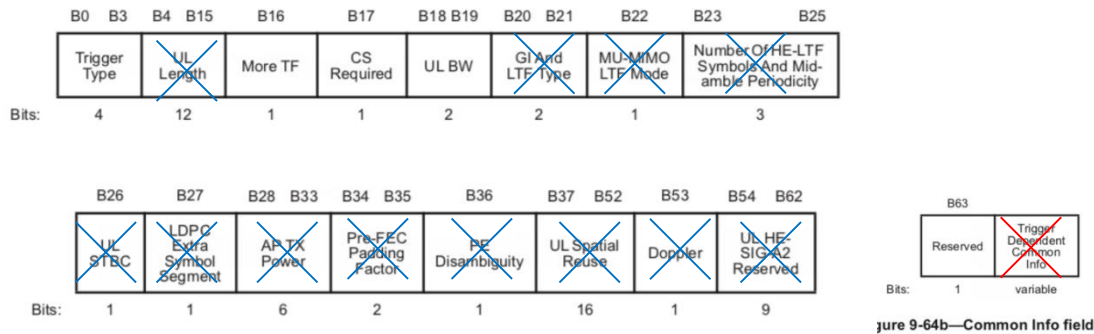


Figure 9-64b—Common Info field

- The intent with the Trigger frame is to solicit a respond from the STAs
- The different fields in the Common Info Field is therefore to inform the responding STAs on how they should set up the frame in the response. The response is sent in the HE TB PPDU frame format
- But the response to an MU-RTS is a legacy CTS frame in the non-HT format. At 5GHz that means legacy OFDM. Most of the subfields in the Common Info field for MU-RTS is therefore not needed

Common Info field for the MU-RTS variant, page 113



- Field marked red is not present in the MU-RTS variant
- All fields marked blue is reserved in the MU-RTS variant
- Trigger type is set to 3 for MU-RTS
- More TF is used for TWT or Power save with UORA. Otherwise set to 0
- CS Required is set to 0 if the responding STAs are not required to consider the medium or the NAV in determining whether or not to respond.
CS Required is set to 1 if responding STAs are required to use ED (Energy Detect) to sense and consider the medium and the NAV in determining whether or not to respond
- UL BW is usually to describe the bandwidth of the response in the HE TB PPDU, but for MU-RTS it describe the bandwidth of the frame carrying the MU-RTS. 0=20MHz, 1=40MHz, 2=80MHz, 3=80+80MHz or 160MHz

User Info field for the MU-RTS, page 108

- Frame format for the User info field of a Trigger frame

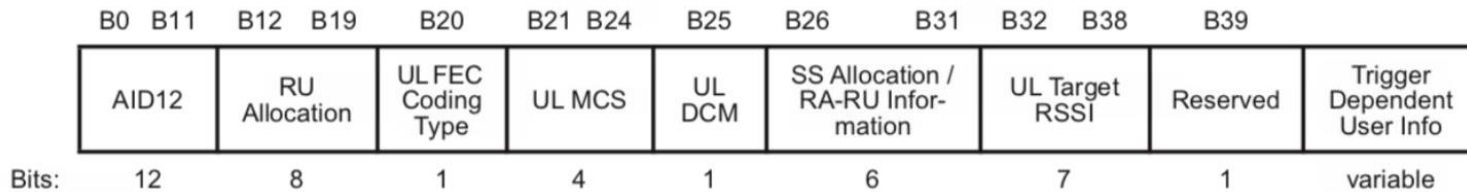


Figure 9-64d—User Info field

- Frame format for the MU-RTS variant
 - Since the response to MU-RTS is the legacy CTS in non-HT format, several of the subfields are not needed. The blue ones are reserved. Red are not present

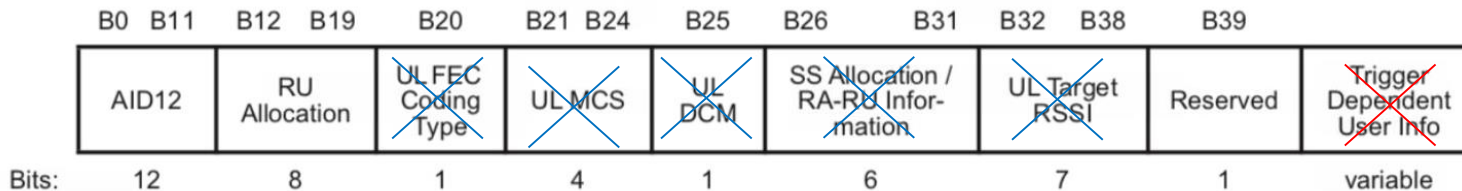


Figure 9-64d—User Info field



User field for the MU-RTS, page 113

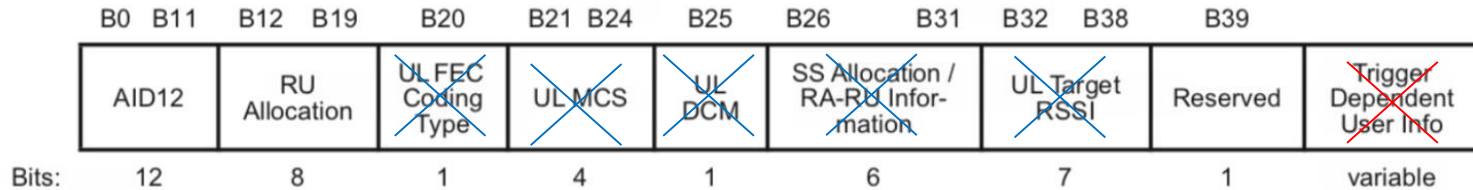


Figure 9-64d—User Info field

- AID12 field is indicating the STA-id (associations ID) for each recipient.
 - Value 1-2007.
 - Value 4095 indicates start of the Padding field, the last User Info field
 - All other values are for other variants of the Trigger frame
- RU Allocation is used to indicate which primary channel the responding CTS should be sent on
 - This is particular to 40MHz and 80MHz channels. Whether the primary channel are the lowest channel, next lowest channel, and so on....
- The User Info field is repeated for every STA that is the recipient of the MU-RTS

Example of one type of the MU-RTS

- Example: in my presentations of DL OFDMA I used four STAs that needed data. If that DL OFDMA should be preceded by a MU-RTS and CTS, the MU-RTS will look like this (only the MPDU)

MAC-header with Frame Control, NAV for the TXOP, RA as the broadcast address and TA	Common Info Field for the MU-RTS, type 3	User Info field for STA1	User Info field for STA2	User Info field for STA3	User Info field for STA4	User Info field, start of Padding	Padding	FCS
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- Remarks:
 1. It is a Control type of frames and there is no resource allocation (subdividing of the subcarriers) in this MU-RTS
 2. The receiving STAs is addressed by their association ID, STA-id, not by MAC-addresses as in legacy RTS

The CTS #1

- The CTS (Clear to send) is the response to a MU-RTS
- The CTS is sent in non-HT format(legacy OFDM at 5GHz) at rate of 6mbs.
- NB!!: The HE standard (draft) says 6mbs for the CTS in response to the MU-RTS. The legacy RTS/CTS process uses one of the basic (mandatory) data rates
- Since the CTS is sent in legacy non-HT all STAs that hear the frame will also understand it and update its NAV-timer (but: see next slides)
- All STAs that are addressed in the User Info field of the MU-RTS trigger frame should respond with a CTS
- When the STAs send their CTS, they use only the TA address, the address of the STA (AP) that should receive the CTS.
- Example:
 - If four STAs are addressed in the MU-RTS User Info field, all of them should respond with a CTS a SIFS-time after receiving the MU-RTS
 - The AP will, because of its MIMO capabilities, be able to differentiate and decode those frames.
 - The difference in phase, received power level and the use of several antennas will make it work for the AP. Just like a MIMO-transmission with several spatial streams
- It is some big BUTs here



The CTS, but #1

- The CS Required subfield in the MU-RTS Common Info field is set to 1. That means that the STA shall consider the status of the CCA (using Energy Detect) during the SIFS between the MU-RTS and the CTS
- Depended of how sensitive that process is, it could lead to a reduction of how many STAs that sends their CTS
- The AP is happy when it receives at least one CTS from the STAs and will asume the MU-RTS as successful. It doesn't need CTS from all STAs

The CTS, but #2

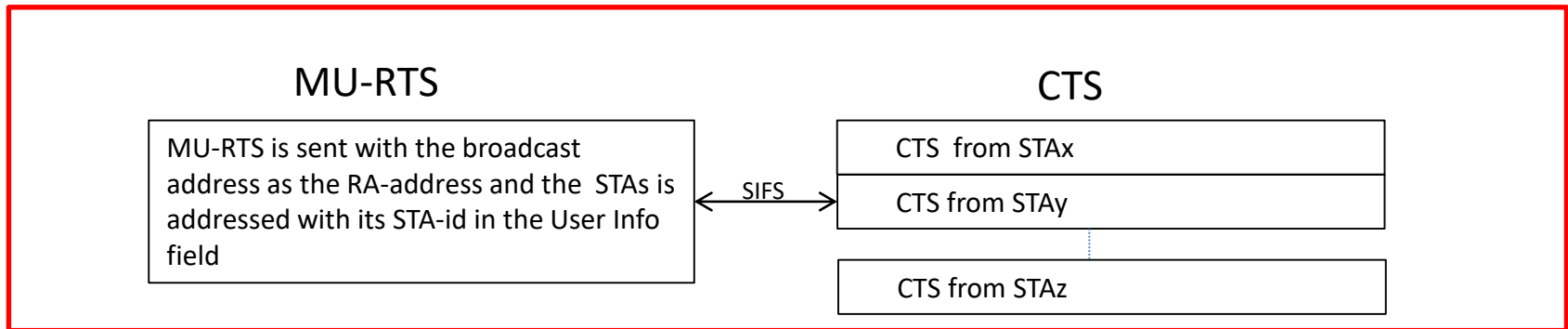
- A CTS consist of the RA address only, not TA.
- In legacy systems only one STA was the receiver of the RTS and when a CTS was transmitted a SIFS after the RTS, the reciever of the CTS assumed that is was from the RA of the RTS
- Now, with several transmitted CTS without a TA, the AP will receive several identical copies of CTS without a transmitter address (TA)
- Therefore (copy from previous slide): The AP is happy when it receives at least one CTS from the STAs and will assume the MU-RTS is successful. It doesn't need CTS from all STAs

But #3

- This MU-RTS is a Control type of frame and is sent in legacy OFDM/non-HT frame format, so all STAs are able to understand and decode it
- But it uses subtypes in the Frame Control field of the MAC header that was reserved values in previous versions of the 802.11 protocol.
- This should lead to that only 802.11ax capable clients will understand the MU-RTS, unless it is possible to update drivers in older chipsets (my thoughts)



Overview of a MU-RTS/CTS transmission



- MU-RTS is sent, from the AP, as a broadcast packet where the RA in the Mac header is the broadcast address. All STAs that will receive or send data after the CTS is addressed with its STA-id in the User Info field
- CTS is sent in response from multiple STAs
- My thoughts
 - The MU-RTS is sent with a Control frame subtype that is reserved values in previous versions of the 802.11 protocol
 - The CTS is sent from multiple STAs simultaneously and in previous versions of the 802.11 it is the definition of a collision
 - That would lead to that only HE capable STAs will update their NAVs during the MU-RTS/CTS process
 - My opinion for a mixed environment: Maybe it's better to use legacy RTS/CTS and just pick one of the non-AP STAs as the receiving address (RA) in the RTS. This to make sure all the STAs in the BSS and at the channel understands it and updates their NAVs

Closing remarks

- The information in this ppt-series is based on information from the IEEE802.11ax, draft 4.0
- Nothing is testet in real world
- If I have interpreted the draft wrong, please inform me
- Constructive feedback are welcome



End

I hopes it has been useful
Constructive feedback are welcome

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