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Wireless LANs

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| “Proposal for New Annex G Frame Exchange Sequence Descriptions”  |
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Abstract

This proposal seeks to introduce the reader to an alternative version of Annex G for describing at a high level, each frame exchange sequence specified in the draft P802.11-REVme/D0.3 document.

Rev 1 First draft of the proposal.

# Background

The Architecture Standing Committee has extensively debated the disposition of Annex G for many meetings. In the course of those discussions, the definition of the term "frame exchange sequence" has been proposed. Below, is one of the more recent definitions:

***frame exchange sequence:*** *a sequence of frames that has control of the medium (there is no longer a single “medium”. A frame exchange sequence may include a sequence of frames for numerous wireless media (e.g., MU-MIMO frame exchange sequences) (see §§10.39.12.4.2, 10.39.12.4.3, and 10.39.12.4.4). (Besides, in a multi-AP overlap region, there is no way for any AP to control the medium) and continues if:*

* *the STA that starts the frame exchanges sequence transmits a packet with an RA that was included in the frame that started the frame exchange sequence;*
* *a STA with an address equal to an RA in the frame that started the frame exchange sequence, transmits a frame with an RA that is the same as the TA included in the frame that started the frame exchange sequence; and*
* *the medium is not idle*

Another way of describing a frame exchange sequence is below:

***frame exchange sequence****: a sequence of frame transmissions across the WM between two peer PHY entities, in which the time delay between successive transmissions is either pre-determined (in which case the time delay is always an IFS) or scheduled by the first frame in the frame exchange sequence.*

*In other words, only the first transmission is allowed to do CSMA/CA. (e.g., a multi-block ack is a frame exchange sequence because the initiating frame determines when the ACKs from each STA will occur. Simply controlling the medium doesn't make all transmissions in that time period a frame exchange sequence. Also, a sequence of beacons would be a frame exchange sequence if the AP didn't do CSMA/CA before transmitting. In other words, it is perfectly acceptable for frame exchange sequences to overlap in time, as long as the transmitters never do CSMA/CA. This allows for simultaneous DMG and MIMO use cases, and allows for co-existence with non-802.11 systems, such as 5G)*

*Indeed, every ACK and Block ACK terminates a frame exchange sequence, unless the time delay until the transmission that immediately follows was also either pre-determined or scheduled by the first frame transmission in the frame exchange sequence.*

It is implied that such frame exchange sequences are only applicable within the context of transmissions between STAs within a basic service set (BSS), and do not apply to communication between STAs over the distribution system (DS).

Current esimtates of the number of times specific terms appear in 802.11-REVme/D0.0 appear below:

“frame exchange” 388 instances, of which “frame exchange sequence” 128,
“frame exchange sequences” 35
“valid response” 4 instances
“frame sequence” 23 instances
“see Annex G” 5 instances
“in Annex G” 9 instances

These instances are incomplete in their identification of all frame exchange sequences, and inconsistent in their description of frame exchange sequences. This can cause significant misunderstandings about what is a frame exchange, and what is a frame exchange sequence. This document proposes to completely revise Annex G to make it more approachable to a novice reader of the standard, who is searching for understanding about frame exchange sequences in accordance with the IEEE 802.11 Standard. For example, to find the definition of a basic frame exchange sequence comprised of a non-QoS Data frame followed by an ACK, the reader must search for the clause §10.3.2.11 on page 2052 of D0.3, which is titled "Acknowledgment procedure", and wherein the text of this clause describes frame exchange sequences without ever using the term.

This document proposes the revised Annex G be more than a simple composite list of all frame exchange sequences, but proposes to organize them by STA type (where appropriate), to include their figures (where missing in the current normative text), and to include references to relevant clauses where normative text provides more details.

Descriptions of frame exchange sequences are generally included in the corrected D0.3 normative text in multiple PHY clauses (i.e., Clauses 26 through 28 (each describing a different peer PHY entity), in addition to Clause 10, and Clause 11). Within these clauses, there are many places where the frame transmissions during frame exchange sequences are portrayed using a figure. For those situations, the revised Annex G need only reference the figure in the existing text to avoid duplication. However, there are many other places where such a figure does not appear in the normative text. For those situations, the revised Annex G would provide its own figure to portray those frame exchange sequences.

Thus, Annex G should be the reference for locating or describing the myriad uses of frame exchange sequences in the normative text to make clear to the reader when the frame exchange sequence starts and when the frame exchange sequence ends. If desired, we can expand Annex G to support interoperability testing of frame exchange sequences for each relevant Clause.

# Corrected D0.3 Normative Text related to the definition of a frame exchange sequence

## Clause 3.1 - p. 201, l. 25; Clause 3.1 - and p. 188, l. 40

“**wireless medium (WM):** The medium used to implement the transfer of protocol data units (PDUs) between peer physical layer (PHY) entities of a wireless local area network (LAN).”

“**channel:** An instance of [a] wireless medium (WM) use[d]?sp for the purpose of passing physical layer (PHY) protocol data units (PDUs) between two or more stations (STAs).”

There has been some discussion about the use and/or control of the wireless medium during a frame exchange sequence. This normative text defines an instance of a wireless medium as a channel, and further that a wireless medium is used for ***peer PHY entities*** to exchange frames. Certain PHY clauses describe peer PHY entity support for multiple channels, which means the AP can support one or more wireless media simultaneously.

It is entirely possible for 802.11 STAs to operate in a heterogenous environment, where there can be different peer PHY entities operating in accordance with different PHY clauses in the same geographic area. This means a simple definition for frame exchange sequences needs to be supported with examples of how frame exchange sequences work within the context of each PHY clause. Even for certain PHY clauses, there could be several simultaneous “wireless media”, due to sectorization, beamforming, and MU-MIMO.

## Clause 3.1 - p. 195, l. 7

“**network allocation vector (NAV):** An indicator, maintained by each station (STA), of time periods whentransmission onto the wireless medium (WM) is not initiated by the STA regardless of whether the STA’s clear channel assessment (CCA) function senses that the WM is busy.”

This normative text definition suggests that the NAV does not control the WM, since CCA can indicate the medium is busy or idle during the NAV period. Rather, the NAV controls the behavior of the STA by inhibiting the initiation of a transmission. This may seem to be a distinction without a difference, until we appreciate that there can be extended periods when the CCA senses the WM is idle because no peer STA is transmitting. This can allow other non-peer STAs to transmit in the channel of the peer STAs during the NAV. This can happen, for example, when multiple WLANs partially overlap in the same geographic space and share the same frequency.

## Clause 3.1 - p. 200, l. 39;Clause 10.2.3.2 - p. 2024, l. 25; Clause 10.23.3.3 – p. 2177, l. 6

“**transmission opportunity (TXOP):** An interval of time during which a particular quality-of-service (QoS)station (STA) has the right to initiate frame exchange sequences onto the wireless medium (WM).”

“During an EDCA TXOP won by an EDCAF a STA may initiate multiple frame exchange sequences to transmit MMPDUs and/or MSDUs within the same AC.”

“Within a polled TXOP, a STA may initiate the transmission of one or more frame exchange sequences, with all such sequences nominally separated by a SIFS.”

This normative text suggests that a TXOP does not define the start time and end time of a singular frame exchange sequence. Even a frame exchange that reserves a TXOP (such as a transmitted RTS, MU-RTS Trigger, or CTS frame) for the purpose of controlling the wireless medium for an interval of time, does not indicate the beginning of a single frame exchange sequence. Rather, a TXOP is simply a time period during which any QSTA has the ***right*** to send one or more frame exchange sequences. Thus, the definition of a TXOP does not make clear the definition of a frame exchange sequence.

In addition, there could be arbitrary-length time gaps between frame exchange sequences initiated by any QSTA during a TXOP. Note, the normative text says the “CSMA/CA distributed algorithm mandates that a gap of a minimum specified duration exists between frame exchange sequnences. A transmitting STA shall verify the medium is idle for this required duration before attempting to transmit.” §10.2.2, p. 2002, l. 38. These time gaps allow for non-peer STAs to take control of the WM, unless peer QSTAs always initiate the next frame exchange sequence after the minimum IFS (which is not a requirement for all TXOPs, only polled TXOPs).

Thus, the normative text does not support the notion that a TXOP holder is guaranteed to control the wireless medium for an uninterrupted exchange of frames spanning the entire duration of the TXOP.

## Clause 10.39.3 - p. 2321, l. 14, 37, 41

“An example of an ATI is shown in Figure 10-67 (Example of frame exchanges during the ATI).”

“Figure 10-67 – Example of frame exchanges during the ATI”

“The AP or PCP initiates all frame exchanges that occur during the ATI.”

This normative text is actually describing frame exchange sequences. See the normative text below which also appears in the same subclause:

“During the ATI, after an AP or PCP transmits an individually addressed request frame (such as an Announce frame) to a non-AP and non-PCP STA, and the STA receives the frame, the STA shall transmit a response frame addressed to the AP or PCP. The transmission of the response frame shall commence one SIFS after the reception of the request frame. The AP or PCP shall interpret the receipt of the response frame as an acknowledgment of the request frame.”

## Clause 10.23.2.8 - p. 2161, l. 58

“A frame exchange, in the context of multiple frame transmission in an EDCA TXOP, may be one of the following:

. . .

* A frame requiring immediate acknowledgment (such as an individually addressed frame transmitted with an ack policy that requires immediate acknowledgment) or an A-MPDU containing at least one such frame, followed after SIFS by a corresponding acknowledgment frame.”

This normative text describes a frame exchange sequence as a frame exchange.

## Clause 10.23.4.2.3 - p. 2181, l. 31

“The MAC variable used\_time is the amount of time used, in units of 32 I s, by the STA in dot11EDCAAveragingPeriod.

. . .

The MPDUExchangeTime is the duration of the frame exchange sequence. For the case of an MPDU transmitted with Normal Ack ack policy and without RTS/CTS protection, this equals the time required to transmit the MPDU plus the time required to transmit the expected response frame plus one SIFS.”

This normative text for the EDCAF contradicts §11.2.6 which says the CS mechanism does not declare the medium to be idle until after a PIFS. There is a normative text conflict for measuring the end of the frame exchange sequence.

See §11.2.6:

“The STA can determine the end of the frame exchange sequence through any of the following:

* It receives an individually addressed frame addressed to another STA.
* It receives a frame with a TA that differs from the TA of the frame that started the TXOP.

. . .

* The CS mechanism (see 10.3.2.1 (CS mechanism) indicates that the medium is idle at the TxPIFS slot boundary (defined in 10.3.7 (DCF timing relations)).”

## Clause 9.2.5.4 - p. 928, l. 42

“1) If the frame is a nonfinal frame in a TXOP with multiple frame exchanges, the remaining duration of the TXOP.

required to transmit the expected response frame plus one SIFS.”

This normative text should refer to a frame exchange sequence, since nonfinal frames are fragment frames requiring acknowledgement.

# Perspectives on the frame exchange sequence time interval

For any given frame exchange sequence (FES), there can be different understandings among the peer STAs about when the FES terminates. Nonetheless, this is not a problem. For example,

Persepctive #1: The STA that initiates the FES (STA #1) identifies the end of the FES as the end of a PIFS interval following the last transmission during the FES. This last transmission during the FES is either pre-determined by the particular FES (e.g., RTS / CTS) or is scheduled by STA #1 (BAR frame).

Perspective #2: The peer STA to STA #1 (STA #2) identifies the end of the FES as the end of a PIFS interval following the last transmission during the FES from its perspective. This understanding may differ from STA #1. For example, if STA #1 transmits PPDUs to STA #2 through STA #5 on the same channel, and STA #2’s CCA function indicates the medium idle when the BlockAcks from STA #3 through #5 are transnmitted, then STA #2 will declare the end of the frame exchange sequence a PIFS interval after its BlockAck transmission. Note, however, that the NAV protection signaled by STA #1 still prevents STA #2 from initiating any transmission until STA #5 has transmitted, regardless of CCA sensing. If STA #2’s CCA function indicates the medium is busy when the BlockAcks from STA #3 through #5 are transmitted, then STA #2 will immediately terminate its FES with STA #1 if it can decode the PPDU, per the normative text. See §11.2.6:

“The STA can determine the end of the frame exchange sequence through any of the following:

* It receives an individually addressed frame addressed to another STA.
* It receives a frame with a TA that differs from the TA of the frame that started the TXOP.

. . .

* The CS mechanism (see 10.3.2.1 (CS mechanism) indicates that the medium is idle at the TxPIFS slot boundary (defined in 10.3.7 (DCF timing relations)).”

This nuance is not currently captured in the normative text, and should be explained to the reader in Annex G where appropriate.

# Additional frame exchange sequences not labelled as such

* DTI Transmission Rules (§10.39.4)

“During the DTI, a STA may initiate a **frame exchang**e (following the DMG channel access ruls for DMG STAs and following the CMMG channel access rules for CMMG STAs) if any of the following conditions are met . . . and shall not initiate a **frame exchange** if none of these conditions are met. A STA initiating data transfer shall check that the transaction, including acknowledgmenets, completes before the end of the CBAP or SP in which it was initiated.”

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**Annex G (revised)**

(normative)

**Frame Exchange Sequences**

**G.1 General**

There are several types of IEEE 802.11 LANs, described in this Standard, including the independent BSS (IBSS), the personal BSS (PBSS), the QoS BSS, the S1G BSS, the mesh BSS (which is subset of the QoS BSS functionality), and the directional multi-gigabit (DMG) BSS (which is another subset of the QoS BSS functionality). Each of these BSS types allow for the operation of various types of STAs, each with their own capabilities for transmiting and receiving frames within frame exchange sequences. The allowable frame exchange sequences for each STA type are described in this Annex.

There are two categories of frame exchange sequences. The basic frame exchange sequence is a frame exchange sequence involving a pair of frame exchanges between peer STAs on the channel (instance of a WM) with a time delay between transmissions that is predetermined. The extended frame exchange sequence is a frame exchange sequence involving three or more frame exchanges on the channel (instance of a WM) that are exchanged during a time period that is either pre-determined or scheduled by the first frame exchange of the extended frame exchange sequence. Examples include a TXOP containing a VHT MU PPDU or EDMG MU PPDU, or a Trigger frame followed by parallel HE TB PPDUs, followed by either parallel BlockAcks or a Multi-STA BlockAck.

Both the basic frame exchange sequences, and the extended frame exchange sequences are constructed from a combination of frame transmissions arranged sequentially. The extended frame exchange sequences are constructed from a combination of frame exchange sequences and an optional additional frame transmission that are arranged sequentially on the WM.

By definition, multiple frame exchange sequences can be sequentially aligned on the medium with no overlap, simultaneously aligned on the medium with perfect overlap, or partially aligned across the medium where the endings of multiple partially overlapping frame exchange sequences are sequentially aligned (in this scenario, their beginnings could be sequentially or simultaneously arranged on the medium). For example, an AP might perform a TXOP-based sectorization operation, or schedule multiple PSMP sessions to start simultaneously (see §10.30.3) and end at the same time with perfect overlap. Alternatively, an AP can setup a Block Ack agreement that enables it to initiate multiple overlapping frame exchange sequences, that terminate in a sequential fashion with a Block ACK transmission from individual STAs, resulting in partial overlapping frame exchange sequences.

# Frame Exchange Sequences for all STAs

All STAs may transmit and receive frame exchanges that are part of the following frame exchange sequences.

## Acknowledgment frame exchange sequence

See §10.3.2.11, Figure 10-12. This is a basic frame exchange sequence, that is initiated by a Data frame and terminated by either an ACK or BlockAck frame. See also, §§9.2.4.5.4, 10.3.2.3.3, 10, 10.3.2.12, and Table 9-13. These frame exchange sequences are terminated by either an (NDP) Ack frame, (NDP) BlockAck frame, NDP PS-Poll-Ack frame, BAT frame, TACK frame, or STACK frame followed by a PIFS.

## Fragment Burst frame exchange sequence

See §10.3.4.5, Figure 10-26. This is an extended frame exchange sequence that is a sequence of basic frame exchange sequences (within which a fragment is exchange), separated by a SIFS within a Fragment Burst followed by a PIFS.

See §10.3.2.6, Figure 10-8. This frame exchange sequence can be prepended by a RTS/CTS exchange to form a larger extended frame exchange sequence.

## RTS / CTS frame exchange sequence

See §10.3.2.3.4, Figure 10-6. This is a basic frame exchange sequence for DCF and EDCAF controlled STAs, that is initiated by a RTS frame exchange and terminated by a (NDP) CTS frame exchange followed by a PIFS. See also, §§10.3.2.6, 10.3.2.9, 10.3.2.3.3, and Figure 10-9.

## UL MU CS mechanism (indicating no CS requirement) frame exchange sequence

See §26.5.2.5. This is a basic frame exchange sequence that is initiated by a Trigger frame with the CS Required subfield set to 0 that is transmitted by the AP and terminated by an A-MPDU response frame that is transmitted by a non-AP STA followed by a PIFS, when the CS Required subfield in the Trigger frame is 0, or a frame that includes a TRS Control subfield and solicits a response is received.

*“If the CS Required subfield in a received Trigger frame is 0 or a frame that includes a TRS Control subfield and solicits a response is received, then the non-AP STA may respond without regard to the busy/idle state of the medium.*

*NOTE 1 – Responding without regard to the busy/idle state of the medium means that a non-AP STA can respond without the need to check the medium indication from physical CS and virtual CS (i.e., basic NAV and intra-BSS NAV).”*



## MU Cascading frame exchange sequence

See §26.5.3, Figure 26-5. This is an extended frame sequence that is iniaited by a HE MU PPDU transmitted by an AP and terminated by a Multi-STA BlockAck, followed by a PIFS.

## Link adaptation frame exchange sequence

See §10.32.1. This is a basic frame exchange sequence that is initiated by MRQ frame and terminated by a MFB frame, followed by a PIFS, when the responder chooses an immediate response within the TXOP of the TXOP holder.

 

# QSTA Frame Exchange Sequences

## EDCA TXOP Holder frame exchange sequence

See §§10.3.2.3.4 and 10.23.2.8. The normative text describes a series of basic frame exchange sequences within an EDCA TXOP that are initiated by the TXOP Holder transmitting a PPDU and terminated by an ACK from the peer STA that received the PPDU, followed by either a PIFS interval or the transmission of a PPDU from the TXOP holder to another peer STA. See also Figure 10-33.



# HT STA Frame Exchange Sequences

## Antenna Selection (ASEL) frame exchange sequence

See §10.35.2, Figure 10-61 and Figure 10-62. This is a basic frame exchange sequence, where the ASEL Transmitter transmits a frame exchange sequence as a consecutive series of sounding PPDUs, that is initiated by a first sounding PPDU and terminated by a final sounding PPDU, followed by a PIFS.

## Dual CTS protection mechanism frame exchange sequence

See §§10.3.2.3.4, 10.3. 2.10.2, and Figures 10-10 and 10-11. This is an extended frame exchange sequence that is initiated by an RTS or CTS transmitted by a non-AP STA, and is terminated by a CF-End transmitted by an AP STA.

## HT NDP frame exchange sequence

See §10.36.1. This is an extended frame exchange sequence that is initiated by the transmission of an HT NDP Announcement for sounding and is terminated by the transmission of the last HT NDP in the announcement.



# VHT STA Frame Exchange Sequences

## VHT NDP frame exchange sequence

See §10.36.5.2, Figure 10-63. This is an extended frame exchange sequence that is initiated by the transmission of an VHT NDP Announcement by a VHT beamformer, followed by the transmission of a VHT NDP, followed by the transmission of a VHT Compressed Beamforming feedback by the VHT beamformee.

See §10.36.5.2, Figure 10-64. This extended frame exchange sequence can be appended with additional frame exchanges between the VHT beamformer and additional VHT beamformees, that terminates with the last transmission of a VHT Compressed Beamforming feedback by the VHT beamformee.

# HE STA Frame Exchange Sequences

## DL MU frame exchange sequence terminated by Parallel BlockAcks

See §10.3.2.13.3, Figure 10-17. This is an extended frame exchange sequence with a pre-determined SIFS time delay between successive frame exchanges. This frame exchange sequence is initiated by a A-MPDUs, each containing a Trigger frame, and terminated with immediate DL PPDUs, each containing a BlockAck frame.

## UL MU frame exchange sequence terminated by Parallel BlockAcks

See §10.3.2.13.3, Figure 10-18. This is an extended frame exchange sequence with a pre-determined SIFS time delay between successive frame exchanges. This frame exchange sequence is initiated by a Trigger frame, and terminated with immediate DL PPDUs, each containing a BlockAck frame.

## UL MU frame exchange sequence terminated by a Single Multi-STA BlockAck

See §10.3.2.13.3, Figure 10-19. This is an extended frame exchange sequence with a pre-determined SIFS time delay between successive frame exchanges. This frame exchange sequence is initiated by a Trigger frame, and terminated with an immediate DL PPDU containing a Multi-STA BlockAck frame.

## UL MU frame exchange sequence terminated by Parallel Multi-STA BlockAcks

See §10.3.2.13.3, Figure 10-20. This is an extended frame exchange sequence with a pre-determined SIFS time delay between successive frame exchanges. This frame exchange sequence is initiated by a Trigger frame, and terminated with immediate DL non-HT duplicate PPDUs, each containing a Multi-STA BlockAck frame.

## HE sounding protocol frame exchange sequence

See §26.7.3, Figure 26-7. This is an extended frame exchange sequence that is initiated by the transmission of an HE NDP Announcement by an HE beamformer, followed by the transmission of a HE Sounding NDP, and terminated by the transmission of an HE Compressed Beamforming feedback by the HE beamformee.

See §26.7.3, Figure 26-8. This is an extended frame exchange sequence that is initiated by the transmission of an HE NDP Announcement by an HE beamformer, followed by the transmission of a HE Sounding NDP, and terminated by one or more sequences the transmission of a BRFP Trigger followed by an HE Compressed Beamforming/CQI frame.

# Additional VHT STA or HE STA Frame Exchange Sequences

## Immediate Acknowledgement for DL MU PPDU frame exchange sequence

See §10.3.2.13.1, Figure 10-13. This is an extended frame exchange sequence with a pre-determined SIFS time delay between successive frame exchanges. This frame exchange sequence is initiated by a VHT MU PPDU frame exchange, followed by an immediate BA/ACK, and terminated by a sequence of frame exchange sequences (BAR followed by BA/Ack).

Although Figure 10-13 only shows a VHT MU PPDU as the first frame in the frame exchange sequence, the figure applies equally when the first frame is an HE MU PPDU.

## Non-Immediate Acknowledgement for DL MU PPDU frame exchange sequence

See §10.3.2.13.1, Figure 10-14. This is an extended frame exchange sequence with a pre-determined SIFS time delay between successive frame exchanges. This frame exchange sequence is initiated by a VHT MU PPDU frame exchange, and terminated by a sequence of frame exchange sequences (BAR followed by BA/Ack).

Although Figure 10-14 only shows a VHT MU PPDU as the first frame in the frame exchange sequence, the figure applies equally when the first frame is an HE MU PPDU.

# DMG STA Frame Exchange Sequences

## Grant / Grant Ack frame exchange sequence

See §10.39.4. This is a basic frame exchange sequence that is initiated by a DMG STA transmitting a Grant frame and terminated by a DMG STA transmitting a Grant Ack frame, followed by a PIFS, when the Grant Ack Supported field is equal to 1.



*“A STA that receives a Grant frame and that has the Grant Ack Supported field equal to 1 in the STA’s DMG Capabilities element shall respond with a Grant Ack frame SIFS after reception of the Grant frame.”*

## Request / Response within an ATI period frame exchange sequence

See §§10.3.2.3.3, 10.39.3. This is a basic frame exchange sequence that is initiated by a request frame transitted by an AP during an ATI, and terminated by a response frame transmitted by a non-AP STA during an ATI, followed by either a PIFS interval or the transmission of a PPDU to another peer STA. During an ATI, a sequence of such frame exchange sequences is supported. See also Figure 10-67.



*“During the ATI, after an AP or PCP transmits an individually addressed request frame (such as an Announce frame) to a non-AP and non-PCP STA, and the STA receives the frame, the STA shall transmit a response frame addressed to the AP or PCP. The transmission of the response frame shall commence one SIFS after the reception of the request frame. The AP or PCP shall interpret the receipt of the response frame as an acknowledgment of the request frame.”*

## Compressed Block Ack / Compressed BlockAckReq frame exchange sequence

See §10.25.5. For DMG STAs, the Compressed BlockAck and Compressed BlockAckReq can replace the BlockAck and BlockAckReq frames related to the HT-immediate agreement-based extended frame exchange sequence.

See §10.25.5. For DMG STAs, the Extended Compressed BlockAck and Extended Compressed BlockAckReq can replace the BlockAck and BlockAckReq frames related to the HT-immediate agreement-based extended frame exchange sequence.

## Isochronous allocation frame exchange sequence

See §11.4.13.2, and Figure 11-28. This is an extended frame exchange sequence that is initiated by a QoS CF-Poll frame transmitted by an HC STA, and terminated by a final QoS Null frame before the expiry of an inactivity timer.

## Initiator Sector Sweep frame exchange sequence

See §10.42.2.2.2, 10.42.10.5.1, and Figure 10-87, Figure 10-126. This is a basic frame exchange sequence that is initiated by a first BF Frame and terminated by a final BF Frame, followed by a PIFS.

## Responder Sector Sweep frame exchange sequence

See §10.42.2.2.3, 10.42.10.5.1, and Figure 10-88, Figure 10-126. This is a basic frame exchange sequence that is initiated by a first SSW Frame and terminated by a final SSW Frame, followed by a PIFS.

## Beam Refinement Protocol frame exchange sequence

See §10.42.6.3.1 Figure 10-104 (with SBIFS), Figure 10-106. This is a basic frame exchange sequence that is initiated by a SSW Feedback frame and terminated by a final BRP frame, followed by a PIFS.

## A-BFT Beamforming training frame exchange sequence

See §10.42.5.2 and Figure 10-94, and Figure 10-95. This is a basic frame exchange sequence that is initiated by a first SSW frame and terminated by a final SSW frame within an A-BFT interval.

## Beam Refinement Protocol frame exchange sequence

See §§10.42.3.1 and 10.42.3.2, and Figure 10-90, Figure 10-91, and Figure 10-02. This is a basic frame exchange sequenc, that is initiated by Transmit BRP request frame, and terminated by a BRP Response Frame.

## MIMO BF Setup phase frame exchange sequence

See §10.42.10.2.2.4, 10.42.10.2.2.5, Figure 10-116 and Figure 10-117. This is an extended frame exchange sequence that is initiated with a MIMO BF Setup frame and is terminated with a MIMO BF Feedback frame, that supports beam refinement in the initiator SU-MIMO BF setup subphase.

## MIMO phase frame exchange sequence

See §10.42.10.2.2.4, 10.42.10.2.2.5, and Figure 10-116. This is an extended frame exchange sequence that is initiated with a EDMG BRP PPDU frame and is terminated with a MIMO BF Feedback frame, that supports the SMBT Subphase.

## SU-MIMO BF feedback Subphase of MIMO phase frame exchange sequence

See §10.42.10.2.2.4, 10.42.10.2.2.5, Figure 10-116 and Figure 10-117. This is an extended frame exchange sequence that is initiated with a MIMO BF Setup frame and is terminated with a MIMO BF Feedback frame, that supports beam refinement in the initiator SU-MIMO BF feedback subphase.

## SISO Feedback Subphase of SISO phase frame exchange sequence

See §10.42.10.2.3 and Figure 10-118. This is a basic frame exchange sequence that is initiated with a BRP Frame and is terminated by a BRP Frame.

## MU-MIMO BF feedback Subphase of MIMO phase frame exchange sequence

See §10.42.10.2.3.4 and Figure 10-119 and Figure 10-120. This is a basic frame exchange sequence that is initiated with a MIMO BF-Poll Frame and is terminated by a MIMO BF Selection, that supports beam refinement in the initiator MU-MIMO BF feedback subphase.

## MU-MIMO BF setup Subphase of MIMO phase frame exchange sequence

See §10.42.10.2.3.4 and Figure 10-119 and Figure 10-120. This is a basic frame exchange sequence that is initiated with a MIMO BF Setup Frame and is terminated by a MIMO BF Setup, that supports beam refinement in the initiator MU-MIMO BF setup subphase.

# EDMG STA Frame Exchange Sequences

## TXOP containing EDMG MU PPDU frame exchange sequence

See §10.3.2.13.1, Figure 10-16. This is an extended frame exchange sequence with a time delay between successive frame exchanges after the immediate response BlockAck, scheduled by the downlink A-MPDU frames. This frame exchange sequence is initiated by a parallel A-MPDU frame exchange, and terminated by a sequence of BlockAck frame exchanges.

## Compressed Block Ack Request / EDMG Compressed Block Ack frame exchange sequence

See §10.25.5 and Figure 10-51. This is an extended frame exchange sequence that is initiated when an RD initiator transmits an MU PPDU containing a Compressed BlockAckReq, and is terminated when the receiving EDMG STA transmits a PPDU containing the EDMG Compressed Block Ack.

*“In a DMG BSS, BlockAck and BlockAckReq frames transmitted between EDMG STAs as part of the HT-immediate agreement shall be of EDMG Compressed BlockAck frame variant and Compressed BlockAckReq variant or of EDMG Multi-TID BlockAck variant and Multi-TID BlockAckReq variant, respectively.”*

## Multi-TID Block Ack Request / EDMG Multi-TID Block Ack frame exchange sequence

See §10.25.5, 10.25.6.1,10.25.6.5, and Figure 10-51. This is an extended frame exchange sequence that is initiated when an RD initiator transmits an MU PPDU containing a Multi-TID BlockAckReq, and is terminated when the receiving EDMG STA transmits a PPDU containing the EDMG Multi-TID Block Ack related to the HT-immediate agreement.

*“In a DMG BSS, BlockAck and BlockAckReq frames transmitted between EDMG STAs as part of the HT-immediate agreement shall be of EDMG Compressed BlockAck frame variant and Compressed BlockAckReq variant or of EDMG Multi-TID BlockAck variant and Multi-TID BlockAckReq variant, respectively.”*

## Extended Compressed Block Ack / Extended Compressed BlockAckReq frame exchange sequence

See §10.25.5. For DMG STAs, the Extended Compressed BlockAck and Extended Compressed BlockAckReq can replace the BlockAck and BlockAckReq frames related to the HT-immediate frame exchange sequence.

## Beam Refinement Protocol frame exchange sequence

See §10.42.3.1, and Figure 10-89. This is a basic frame exchange sequence, that is initiated by Transmit BRP request frame, and terminated by a BRP Response Frame.

## Unsolicited RSS frame exchange sequence

See §10.42.10.1 and Figure 10-97. This is a basic frame exchange sequence that is initiated by one or more SSW Frames and is terminated by an SSW Ack Frame in support of EDMG beamforming.

# CMMG STA Frame Exchange Sequences

## Grant / Grant Ack frame exchange sequence

See §10.39.4. This is a basic frame exchange sequence that is initiated by a CMMG STA transmitting a Grant frame and terminated by a CMMG STA transmitting a Grant Ack frame followed by a PIFS.



## Link Beamformee Transmit Beamforming Response frame exchange sequence

See §10.34.5. This is a basic frame exchange sequence that is initiated when a CMMG beamformee transmits a sounding frame to a CMMG beamformee that advertises it is capable of sending an immediate feedback response by sending the “Immediate” or “Immediate and Delayed” response capability in the Explicit Compressed Beamforming Feedback Capable subfield. The frame exchange sequence is terminated by either a CTS frame, Ack or BlockAck frame, or an A-MPDU containing an explicit feedback response, depending on the rules described in Table 10-33.



## CMMG NDP frame exchange sequence

See §10.37.1. This is an extended frame exchange sequence that is initiated by the transmission of an CMMG NDP Announcement by a CMMG beamformer, followed by the transmission of a CMMG NDP, followed by the transmission of a CMMG Compressed Beamforming feedback by the CMMG beamformee.

# S1G Frame Exchange Sequences

## Group AID frame exchange sequence

See §10.55. This is a basic frame exchange sequence that is initiated by a S1G AP transmitting a beacon frame indicating buffered data for a group AID, and is terminated at the end of an assigned time slot that carries buffered group data, followed by a PIFS interval.

*“The S1G STAs that detect this indication will wake up at the assigned beacon interval to determine the TIM and extract the assigned time slots that carry the buffered group data. The S1G AP transmits the buffered group data wihin the assigned time slots for the S1G STAs’ reception.”*

## BAT frame exchange sequence

See §10.25.5. This is a basic frame exchange sequence that is initiated by an A-MPDU and terminated by a BAT frame instead of a BlockAck frame during an HT immediate block ack agreement negotiated with a BAT ADDBA.



## PV1 frame exchange sequence

See §9.8.3.2. This is a basic frame exchange sequence that is initiated by a PV1 frame with an Ack policy of “Normal Ack” or “Implicit BAR”and terminated by a NDP BlockAck or BAT frame.



# GLK STA Frame Exchange Sequences

## GCR (block ack retransmission policy) frame exchange sequence

See §§10.25.5, 10.25.8.4, 11.21.16.3 and Figure 10-45. This extended frame exchange sequence is initiated when several A-MSDUs followed by a BlockAckReq frame are transmitted by the AP, and is terminated by a BlockAck from the last GCR group member during a GLK-GCR block ack agreement.

## GCR MU-BAR Trigger block ack (block ack retransmission policy) frame exchange sequence

See §§10.25.8.4, 11.21.16.3 and Figure 10-46. This is an extended frame exchange sequence that is initiated by a parallel transmission of A-MSDUs, followed by a GCR MU-BAR Trigger frame are transmitted by the AP, and is terminated by a BlockAck from the last GCR group member.

## GLK-GCR (GLK-GCR block ack retransmission policy) frame exchange sequence

See §§10.25.8.3, 10.25.8.4, 11.21.16.4 and Figure 10-46. This is an extended frame exchange sequences that is initiated by a parallel transmission of several A-MSDUs and is terminated by a BlockAck from the last GCR group member.

# Additional Frame Exchange Sequences for HT STA, S1G STA, and DMG STA

## Reverse Direction frame exchange sequence

See §§10.29.2, 10.29.3, 10.29.4. There are several variants to the RD frame exchange sequence. Several of these frame exchange sequences may appear in a single TXOP. One variant of an RD exchange sequence consists of an RD initiator that initiates an extended frame exchange sequence by transmitting a PPDU, followed by a sequence of frame exchanges from an RD responder in an RD response burst, and is terminated by the RD initiator transmitting a PPDU containing a BlockAck.

## Reverse Direction frame exchange sequence with EDMG DL MIMO

See §§10.29.2, 10.29.3, 10.29.4, and Figure 10-51. There are several variants to the RD frame exchange sequence. Several of these frame exchange sequences may appear in a single TXOP. One variant of an RD exchange sequence consists of an RD initiator that initiates an extended frame exchange sequence by transmitting an EDMG MU PPDU to multiple STAs followed by scheduled responses from the multiple STAs, terminated by a BlockAck transmission from the RD initiator, with an immediate BlockAck that has a Response Offset set to SIFS. The RD initiator could continue the extended frame exchange sequence by combining a next PPDU with the BlockAck additional transmissions that may require additional scheduled responses.