IEEE P802.11
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 (in the case of MU-MIMO, what is "the medium"? (see §§10.39.12.4.2, 10.39.12.4.3, and 10.39.12.4.4)) (in a multi-AP overlap region, there is no way for any API 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 STAs, in which the time delay between successive transmissions is either pre-determined (in which case the time delay is always an IFS) or determined 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 determined 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” 309 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.

In the normative text, 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 refer to the figure in the existing text. 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 the transmissions.

# Additional frame exchange sequences not labelled as such

## Request/Report Radio Measurement Frame Exchange Sequences (Figure 6-3 / Figure 6-4)

* Beacon (see §4.3.11.2, §§4.3.25.5, 11.10.10, 9.4.2.20.7, 11.10.9.1)
* Frame (see §4.3.11.4, §§9.4.2.20.8, §11.10.9.2)
* Channel Load (see §§4.3.11.5, 11.10.9.3)
* Noise Histogram (see §§4.3.11.4, 11.10.9.4)
* STA Statistics (see §§4.3.11.4, 9.4.2.20.9, 11.10.9.5)
* Location Configuration (see §§4.3.11.8, 9.6.13.6, 9.4.2.21, 9.6.13.7, 11.10.9.6, Figure 6-14)
* Neighbor Report (see §§4.3.11.10, 11.10.10, 9.6.6.6, 9.6.6.7)
* Link Measurement (see §§4.3.11.11, 9.6.6.4, 9.6.6.5, 11.10.11)
* Transmit Stream/Category Measurement (see §§4.3.11.12, 11.10.9.8)

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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 allows 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 transmissions on the WM. The extended frame exchange sequence is a frame exchange sequence involving three or more frame transmissions on the WM that are transmitted during a time period where the WM has been reserved for the extended frame exchange sequence. Extamples of medium reservation time intervals include NAV periods, service periods, DMG or CMMG TSPECs, and scheduled TWT(s) within the resource protection for S1G STAs in non-TIM mode.

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 procedure

This is a basic frame exchange sequence defined in §§9.2.4.5.4, 10.3.2.3.3, 10.3.2.11, and 10.3.2.12, and portrayed in Figure 10-12 and Table 9-13, that is initiated by certain frames requiring an immediate acknowledgment. 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.



## Transmission of a fragmented MSDU

This is an extended frame exchange sequence defined in §10.3.4.5 and portrayed in Figure 10-26, that is initiated by the transmission of the first MSDU fragment, and terminated by an ACK frame transmission at the end of the NAV period.



## PSMP Acknowledgment (obsolete)

This is a basic frame exchange sequence defined in §§9.2.4.5.4, and 10.30.2.7 used to transmit non-GCR-SP group addressed frames. Other examples of obsoleted frame exchange sequences include:

## RTS / (NDP) CTS

This is a basic frame exchange sequence defined in §10.3.2.3.3 that is terminated by a (NDP) CTS frame. This frame exchange sequence has the additional property that although both frame transmissions are between two STAs, their NAV is broadcast to all STAs on the WM.



## Probe Request / Probe Response

This is a basic frame exchange sequence defined in §11.1.4.3.4 that is initiated by a Probe Request frame.

## (Extended) Channel Switch Announcement

This is a basic frame exchange sequence defined in §§10.3.2.3.4, 11.8.8, and 11.9.3 that includes a Channel Switch Annoucement frame in the frame exchange sequence.

## UL MU CS mechanism (indicating no CS requirement)

This is a frame exchange sequence defined in §§10.3.2.3.3 and 26.5.2.5 that is initiated by a (MU-BAR/GCR MU-BAR/BFRP/BSRP/BQRP) Trigger frame sent by the AP.

## MU Cascading Sequence

As defined in §26.5.3 and portrayed in Figure 26-5, the MU Cascading Sequence is a parallel combination of multiple overlapping extended frame exchange sequences. This parallel combination is initiated by a single multicast HE MU PPDU transmitted by the AP, and is terminated by a BlockAck.



## Transmit Antenna Selection (ASEL) Sounding

This is a basic frame exchange sequence defined in §10.35 and Figure 10-61 that is initiated by the ASEL transmitter.

## Link adaptation

This is a basic frame exchange sequence defined in §10.32.1 that is supported by immediate response.

# Mesh STAs

## Channel Switch Announcement

This is a basic frame exchange sequence defined in §10.3.2.3.4, and §11.8.8.4 that includes a Channel Switch Annoucement frame in the frame exchange sequence.

# Additional Frame Exchange Sequences for non-VHT non-HE STAs

## RTS / CTS

This is a basic frame exchange sequence that is defined in §10.23.2.4 for the EDCAF.

# Additional Frame Exchange Sequences for non-VHT non-S1G STAs

## RTS / CTS

This is a basic frame exchange sequence that is defined in §10.23.2.4 for the EDCAF.

# Additional Frame Exchange Sequences for VHT or HE STAs

## RTS / CTS

This is a basic frame exchange sequence that is defined in §10.23.2.4 for the EDCAF, and in §10.3.2.9.

## Link adaptation

This is a basic frame exchange sequence defined in §10.32.3 that is supported by immediate response.

# Additional Frame Exchange Sequences for DMG STAs

## Grant / Grant Ack

This is a basic frame exchange sequence defined in §§10.39.4, that is initiated by a Grant frame.

## RTS / DMG CTS

This is a basic frame exchange sequence defined in §§10.3.2.3.3, and 10.3.2.9.

## Request / Response

This is a basic frame exchange sequence defined in §§10.3.2.3.3, and 10.3.9.3, and portrayed in Figure 10-67, that is terminated by a response frame during an ATI.

## Compressed Block Ack / Compressed BlockAckReq

This is an extended frame exchange sequence defined in §10.25.5, 10.25.6.5, that is related to an HT-immediate aggrement.

# Additional Frame Exchange Sequences for EDMG STAs

## RTS / DMG CTS

This is a basic frame exchange sequence that is defined in §10.3.2.9 that terminates with the transmission of a DMG CTS frame.

## Compressed Block Ack / Extended Compressed Block Ack

This is an extended frame exchange sequence defined in §10.25.5 and Figure 10-51, that is initiated by an RD initiator.

## HT-immediate block ack with EDMG flow control extension

This is an extended frame exchange sequence defined in §10.25.6.1, and 10.25.6.5, that is related to an HT-immediate aggrement.

# Additional Frame Exchange Sequences for CMMG STAs

## Grant / Grant Ack

This is a basic frame exchange sequence defined in §§10.39.4, that is initiated by a Grant frame.

## RTS / CTS

This is a basic frame exchange sequence that is defined in §10.23.2.4 for the EDCAF, and in §10.3.2.9.

## Request / Response

This is a basic frame exchange sequence defined in §§10.3.2.3.3, and 10.3.9.3, and portrayed in Figure 10-67, that is terminated by a response frame during an ATI.

## TXOP Holder

This is a frame exchange sequence defined in §§10.3.2.3.4 and 10.23.2.8 within a TXOP, that is initiated by a TXOP Holder to transmit multiple MPDUs in possibly multiple frame exchange sequences.



## Link adaptation

This is a basic frame exchange sequence defined in §10.32.4 that is supported by immediate response.

## Link Beamformee Transmit Beamforming Response

This is a basic frame exchange sequence defined in §10.32.4 where a CMMG beamforme is capable of sending an immediate feedback response.

# Additional Frame Exchange Sequences for S1G STAs

## RTS / (NDP) CTS

This is a basic frame exchange sequence defined in §10.3.2.9 that terminates with the transmission of an (NDP) CTS frame.

## TXOP Holder

This is a frame exchange sequence defined in §§10.3.2.3.4 and 10.23.2.8 that is initiated by a TXOP Holder to transmit multiple MPDUs.

## Group AID

This is a frame exchange sequence defined in §10.55 that is initiated by a S1G AP indicating buffered group data and assigned time slots that carry the buffered group data.

# Additional Frame Exchange Sequences for QSTAs

## TXOP Holder

This is a frame exchange sequence defined in §§10.3.2.3.4 and 10.23.2.8 that is initiated by a TXOP Holder to transmit multiple MPDUs.

## QoS (+)CF-Poll

This is a basic frame exchange sequence defined in §§10.3.2.3.4 and 10.23.3.2.2 that is initiated when the HC needs access to the WM to start a CAP.

## Recovery

This is the continuation of a frame exchange sequence to recover from the absence of an expected reception, as defined in §§10.3.2.3.4 and 10.23.3.2.3.

## MCCAOP Reservations

This is a basic frame exchange sequence defined in §10.24.3 that transmits at reserved scheduled times in the DTIM interval.

* !!!! MCCAOP duration (§§10.24.3.9.1) (need to discuss impact on frame exchange sequences)
* !!!! Reservation Allocation Vector (§§10.24.3.9.2) (need to discuss impact on frame exchange sequences)

# Additional Frame Exchange Sequences for GLK STAs

## GCR (block ack retransmission policy)

As defined in §§10.25.8.4, 11.21.16.3 and portrayed in Figure 10-45, this is a parallel combination of multiple overlapping extended frame exchange sequences. This parallel combination 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.

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

As defined in §§10.25.8.4, 11.21.16.3 and portrayed in Figure 10-46, this is a parallel combination of multiple overlapping extended frame exchange sequences. This parallel combination is initiated when several 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)

As defined in §§10.25.8.3, 10.25.8.4, 11.21.16.4 and portrayed in Figure 10-46, this is a parallel combination of multiple overlapping extended frame exchange sequences. This parallel combination is initiated when several 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.

# Additional Frame Exchange Sequences for DMG STAs

## Isochronous allocation

This is an extended frame exchange sequence defined in §11.4.13.2, and portrayed in Figure 11-28, 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.

## Beam Refinement Protocol

This is a basic frame exchange sequence defined in §§10.42.6.3.1 and Figure 10-100, Figure 10-101, Figure 10-103, Figure 10-104 (with SBIFS), Figure 10-106, Figure 10-108, Figure 10-109) that supports beamforming training.

## Beam Tracking Frame Exchange

This is a basic frame exchange sequence defined in §§10.42.7 and Figure 10-110, and Figure 10-111 that supports beam tracking.

## A-BFT Beamforming training

This is a basic frame exchange sequence defined in §§10.42.5.2 and Figure 10-94, and Figure 10-95 that supports beamforming.

## Beam Refinement Protocol

This is a basic frame exchange sequence defined in §§10.42.3.1 and 10.42.3.2, and Figure 10-89, Figure 10-90, Figure 10-91, and Figure 10-02, that supports beamforming training. A beam refinement request is followed by a beam refinement response.

## Unsolicited RSS

This is a basic frame exchange sequence defined in §§10.42.10.1 and Figure 10-97 that supports EDMG beamforming.

## Beamforming

This is a basic frame exchange sequence defined in §§10.42.10.1 and Figure 10-114, and Figure 10-115 that supports EDMG beamforming.

## Sector-level Sweep

This is a basic frame exchange sequence defined in §§10.42.1, 10.42.2 and Figure 10-84, Figure 10-85, and Figure 10-86 that supports beamforming training.

## Sector Sweep Feedback

This is a basic frame exchange sequence defined in §§10.42.2.4 and 10.42.2. that supports beamforming training.

## Initiator TXSS or RXSS

This is a basic frame exchange sequence defined in §§10.42.2.2.2, 10.42.10.5.1, and Figure 10-87, Figure 10-126, Figure 10-127, Figure 10-128, Figure 10-129, Figure 10-130, and Figure 10-131 that supports beamforming training.

## SMBT Subphase of MIMO phase

This is a basic frame exchange sequence defined in §10.42.10.2.2.4 and Figure 10-116, that supports beam refinement in the initiator SMBT subphase.

## SU-MIMO BF feedback Subphase of MIMO phase

This is a basic frame exchange sequence defined in §10.42.10.2.2.4 and Figure 10-116, that supports beam refinement in the initiator SU-MIMO BF feedback subphase.

## SU-MIMO BF setup Subphase of MIMO phase

This is a basic frame exchange sequence defined in §10.42.10.2.2.5 and Figure 10-117, that supports beam refinement in the initiator SU-MIMO BF setup subphase.

## SISO Feedback Subphase of SISO phase

This is a basic frame exchange sequence defined in §10.42.10.2.3 and Figure 10-118, that supports beam refinement in the initiator SISO feedback subphase.

## MU-MIMO BF feedback Subphase of MIMO phase

This is a basic frame exchange sequence defined in §10.42.10.2.3.4 and Figure 10-119 and Figure 10-120, that supports beam refinement in the initiator MU-MIMO BF feedback subphase.

## MU-MIMO BF setup Subphase of MIMO phase

This is a basic frame exchange sequence defined in §10.42.10.2.3.4 and Figure 10-119 and Figure 10-120, that supports beam refinement in the initiator MU-MIMO BF setup subphase.

## SU-MIMO hybrid beamforming Sounding

This is a basic frame exchange sequence defined in §10.42.10.2.4.6 and Figure 10-121, Figure 10-123, and Figure 10-124, that supports beam refinement in the initiator SU-MIMO hybrid beamforming sounding.

## Dual-polarization TRN beamforming training

This is a basic frame exchange sequence defined in §10.42.10.7 and Figure 10-132, that supports beamforming training.

## TDD individual beamforming training

This is a basic frame exchange sequence defined in §10.42.11.1 and Figure 10-133 and Figure 10-136, that supports beamforming training.

## TDD group beamforming training

This is a basic frame exchange sequence defined in §10.42.11.1 and Figure 10-134, that supports beamforming training.

## TDD SSW Feedback

This is a basic frame exchange sequence defined in §10.42.11.2 and Figure 10-135, Figure 10-138, Figure 10-139 that supports beamforming training with a responderFeedbackOffset.

## Fast Link Adaptation Procedure

This is a basic frame exchange sequence defined in §10.43.3 and Figure 10-140 that supports fast link adaptation.

# Additional HT STA Frame Exchange Sequences

## TXOP Holder

This is a frame exchange sequence(s) defined in §§10.3.2.3.4 and 10.23.2.8 that is initiated by a TXOP Holder to transmit multiple MPDUs.

## Link adaptation

This is a basic frame exchange sequence defined in §10.32.2 that is supported by immediate response.

## PPDU exchange – Unidirectional implicit transmit beamforming

This is a basic frame exchange sequence defined in §10.34.2.2 and Figure 10-56, that is initiated by an unsteered PPDU transmission, followed by a sounding PPDU.

## PPDU exchange – Bidirectional implicit transmit beamforming

This is a basic frame exchange sequence defined in §10.34.2.3 and Figure 10-57, that is initiated by an unsteered PPDU transmission, followed by a sounding PPDU.

## Calibration PPDU exchange

This is a basic frame exchange sequence defined in §10.34.2.4.3 and Figure 10-58, that is initiated by a Calibration Start frame transmission, followed by a Calibration Sounding Response frame.

## HT-immediate block ack

This is an extended frame exchange sequence defined in §10.25.6.1, and 10.25.6.5, that is related to an HT-immediate aggrement.

## Dual CTS protection mechanism

This is an extended frame exchange sequence defined in §§10.3.2.3.4, and 10.3.2.10.2, and portrayed Figure 10-10 and Figure 10-11.

# Additional Frame Exchange Sequences for HE STAs

## Multi-TID BlockAckReq (with an exception for non-HE STA usage)

This is an extended frame exchange sequence defined in §10.25.5.

# Action Item Further Review List

* Timing Measurement (§§9.6.13.28, 11.21.5, Figure 6-16)
* Fine Timing Measurement (§11.21.6, Figure 6-17, Figure 11-38, Figure 11-39, Figure 11-40)
* There is a potential problem with the "frame exchange sequence" edit at [1694.23] because §10.23.2.8 redefines the term "frame exchange" in the context of multiple frame transmission in an EDCA TXOP to be equivalent to a frame exchange sequence.

 **“Frame Exchange Sequence” AND “Frame Exchange Sequences”**

**1821.25 After the last frame of all other nonfinal frame exchange sequences (e.g., sequences that convey individually addressed QoS Data or Management frames) during an HCCA TXOP, the holder of the current HCCA TXOP shall wait for one SIFS before transmitting the first frame of the next frame exchange sequence.**

**(Note: this maybe OK because the next Frame exchange sequence is between two other STAs (?), BUT needs checking what a “nonfinal” is)**

1828.47 The MPDUExchangeTime is the duration of the frame exchange sequence