IEEE P802.11
Wireless LANs

|  |
| --- |
| **Specification Framework for TGba** |
| **Date:** 2017-11-20 |
| **Author(s):** |
| **Name** | **Affiliation** | **Address** | **Phone** | **email** |
| Po-Kai Huang | Intel | 2200 Mission College Blvd, Santa Clara, CA 95054 | +1-765-418-6733 | po-kai.huang@intel.com |

Abstract

This document provides the framework from which the draft TGba amendment will be developed. The document provides an outline of each the functional blocks that will be a part of the final amendment. The document is intended to reflect the working consensus of the group on the broad outline for the draft specification. As such it is expected to begin with minimal detail reflecting agreement on specific techniques and highlighting areas on which agreement is still required. It may also begin with an incomplete feature list with additional features added as they are justified. The document will evolve over time until it includes sufficient detail on all the functional blocks and their inter-dependencies so that work can begin on the draft amendment itself.

**Revision history**

|  |  |  |
| --- | --- | --- |
| Revision | Date | Changes |
| 0 | April 10, 2017 | Added motioned text agreed in March IEEE F2F [1] |
| 1 | May 30, 2017 | Added motioned text agreed in May IEEE F2F [2] |
| 2 | Aug 7, 2017 | Added motioned text agreed in July IEEE F2F [3]. Updated abbreviations and acronyms. |
| 3 | Aug 8, 2017 | Revised motioned text related to 17/964r4 based on the latest revision of July IEEE F2F minute [3].  |
| 4 | Sep 25, 2017 | Added motioned text agreed in Sep IEEE F2F [4]. Have the folloing editorial reivison:* Replace “packet” or “signal” with PPDU or frame based on the context to comply with the suggestion in editorial style guide [5].
* Replace “wake-up packet” with “WUR PPDU” in the WUR PHY section.
* Create data rate and symbol structure subsection in the WUR Payload section.
* Create channel access subsection in WUR MAC section.
* Remove corresponding TBD for the past motions related to data rate
 |
| 5 | Sep 29, 2017 | Have the folloing editorial reivison:* Remove corresponding “may” statement for the past motions about carrying Partial TSF in WUR Beacon
 |
| 6 | Nov 20, 2017 | Added motioned text agreed in Nov IEEE F2F [6]. Marked motions assigned for spec text writing of D0.1 as [Assigned D0.1]. Have the folloing editorial reivison:* Create Non-WUR portion subsection and WUR SYNC field subsection in WUR preamble section
* Replace “WUR preamble” with “WUR SYNC field” in the WUR PHY section based on the context.
* Replace “payload” with “Data field” in the WUR PHY section
 |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

# Definitions

# Abbreviations and acronyms

|  |  |
| --- | --- |
| AC  | access category |
| AP | access point |
| BPSK | binary phase shift keying |
| CL | constant length |
| CRC | cyclic redundancy code |
| CW | contention window |
| EDCA | enhanced distributed channel access |
| EDCAF | enhanced distributed channel access function |
| DFS | dynamic frequency selection |
| FCS | frame check sequence |
| HT | high-throughput |
| L-LTF | non-HT Long Training field |
| L-SIG | non-HT SIGNAL field |
| L-STF | non-HT Short Training field |
| MAC | medium access control |
| OFDM | orthogonal frequency division multiplexing |
| OOK | on-off keying |
| PCR | primary connectivity radio |
| PHY | physical layer |
| PPDU | physical layer protocol data unit |
| PS | power save |
| STA | station |
| TBD | to be determined |
| TD | type dependent |
| TSF | timing synchronization function |
| TWT | target wake time |
| VL | variable length |
| WNM | wireless network management |
| WUR | wake-up radio |
| WURx | wake-up receiver |

# WUR Physical Layer

## General

This section describes the functional blocks in the physical layer.

1. [Assigned D0.1] IEEE 802.11ba shall define an upper limit on the time duration of a WUR PPDU, to a TBD value that is less than the L-SIG LENGTH field limitation.

[Motion, Nov 2017, See [6] [7]]

## WUR Premable

### Non-WUR portion

1. [Assigned D0.1] A 20 MHz non-HT preamble is prepended in any WUR PPDU, including L-STF, L-LTF and L-SIG fields. A 20 MHz OFDM symbol, with tone spacing 312.5 kHz and BPSK, and of duration 4 us, is present immediately after the L-SIG field and right before the narrow band portion of any WUR PPDU.

[Motion, May 2017, See [2] [8]]

1. [Assigned D0.1] Following the 20 MHz non-HT preamble and the additional 20MHz BPSK OFDM symbol as defined in R.3.2.1.A, the narrow band portion of a WUR PPDU is composed by a Synchronization (SYNC) field and a Data field.

[Motion 1, Nov 2017, See [6] [9]]

### WUR SYNC field

1. [Assigned D0.1] The SYNC field is composed only of pre-defined sequences to differentiate the two data rates.

[Motion 2, Nov 2017, See [6] [9]]

1. [Assigned D0.1] The SYNC field duration depends on the data rate of the Data field. When the Data field uses the low data rate, the duration of the SYNC field is 128 µs. When the Data field uses the high data rate, the duration of the SYNC field is 64 µs.

[Motion 1, Nov 2017, See [6] [10]]

1. [Assigned D0.1] The SYNC field structure depends on the data rate of the Data field. When the Data field uses the high data rate, the structure of the SYNC field is $\overbar{S}$, where $S$ is a sequence of bits, and $\overbar{S}$ is the complementary sequence of $S$. When the Data field uses the low data rate, the structure of the SYNC field is $[S,S]$. The duration of each bit in the SYNC field is TBD (either 2 or 4) µs. The specific bit sequence of $S$ is TBD.

[Motion 2, Nov 2017, See [6] [10]]

## WUR Data field

1. [Assigned D0.1] Use OOK for modulation of the Data field of the WUR PPDU. The WUR SYNC field design is TBD. The operation in DFS channels is ~~TBD~~disallowed.

[Motion, March 2017 and Nov 2017, see [1] [11] [6] [12]]

1. [Assigned D0.1] The OOK waveform of WUR PPDU is generated by populating TBD number of 802.11 OFDM subcarriers:
* The WUR SYNC field part is TBD.
* The operation in DFS channel is ~~TBD~~disallowed.

[Motion, March 2017 and Nov 2017, see [1] [13] [6] [12]]

1. [Assigned D0.1] When a single band is used for transmission of WUR PPDU, the OOK waveform of WUR PPDU is generated by using contiguous 13 subcarriers with the subcarrier spacing of 312.5 kHz:
* The center subcarrier is ~~TBD~~null.

 [Motion, July 2017 and Nov 2017, see [3] [14] [6] [15]]

### Data Rate

1. [Assigned D0.1] IEEE 802.11ba supports multiple data rates for the Data field of the WUR PPDU.

[Motion 1, May 2017, see [2] [16]]

1. [Assigned D0.1] The lowest data rate for the Data field of WUR PPDU is 62.5 kb/s.

[Motion, July 2017, see [3] [17]]

1. [Assigned D0.1] IEEE 802.11ba supports the following data rates: 62.5 kb/s and 250 kb/s.
* ~~Support of any data rates higher than 250 kb/s is TBD~~

[Motion, July 2017 and Sep 2017, see [3] [18] [4] [19]]

1. [Assigned D0.1] IEEE 802.11ba has only two data rates: 62.5 kb/s and 250 kb/s.

[Motion, Sep 2017, see [4] [19]]

### Symbol Structure

1. [Assigned D0.1] Use Manchester Coding in the WUR PHY Design:
* ~~The structure of the OFDM symbol and the data rate is TBD~~.
* The WUR SYNC field design is TBD.

[Motion, May 2017, Sep 2017, and Nov 2017, see [2] [20] [4] [19] [21] [6] [22]]

1. [Assigned D0.1] Manchester code shall be used for all of the data rates for the Data field of the WUR PPDU. [Motion 2, May 2017, see [2] [16]]
2. [Assigned D0.1] Symbol structure of the data rate of 250 kb/s for each information is as follows:



* For 2us ON-signal, there is always energy.

[Motion, Sep 2017, see [4] [21]]

1. [Assigned D0.1] Symbol structure of the data rate of 62.5 kb/s for each information is as follows



* For 4us ON-signal, there is always energy

[Motion, Nov 2017, see [6] [22]]

# WUR MAC

## General

This section describes general MAC functional blocks.

1. IEEE 802.11ba shall provide mechanisms to enable re-discovery of WUR stations by AP. [Motion, March 2017, see [1] [23]]
2. A STA shall not transmit WUR frame if the primary connectivity radio of the STA is turned off. [Motion 2, March 2017, see [1] [24]]

## WUR Negotiation

1. [Assigned D0.1] Define WUR Action frame to enable WUR negotiation and WUR mode signaling:
* Note that WUR Action frame is sent through primary connectivity radio.

[Motion, March 2017 and Nov 2017, see [1] [25] [6] [26]]

1. [Assigned D0.1] The frame body of WUR Action frame can include the following:
* Category field that indicates WUR Action
* WUR Action field that includes the following indications: WUR Mode Setup and WUR Mode Teardown
* Dialog Token field
* WUR Mode Element includes necessary WUR parameters

[Motion 1, Nov 2017, see [6] [27]]

1. [Assigned D0.1] The WUR Mode element can include the following:
* Element ID and Element ID Extension fields that indicate WUR Mode Element
* Length field
* Action Type field that includes the following indications:
	+ Enter WUR Mode Request
	+ Enter WUR Mode Response
	+ Enter WUR Mode Suspend Request
	+ Enter WUR Mode Suspend Response
	+ Enter WUR Mode Suspend
	+ Enter WUR Mode
* WUR Mode Response Status field that includes the following indications: Enter WUR Mode Accept, Enter WUR Mode Suspend Accept, and Denied
* WUR Parameters field that includes the indication for WUR parameters

[Motion 2 and Motion 4, Nov 2017, see [6] [27]]

1. [Assigned D0.1] WUR Parameters field of WUR Mode element, if present, may include either the following
* WUR ID information
	+ Individual ID
* Duty cycle information
* WUR channel information

or the following

* Preferred duty cycle parameter (e.g. ON Duration, Period, etc...)

[Motion 2, Nov 2017, see [6] [28]]

1. [Assigned D0.1] The WUR Action frame sent by an AP through the PCR includes a WUR ~~receiver~~ identifier (WID):
* The WID uniquely identifies a WUR STA within ~~a~~the BSS of the AP.
* The WID is included in a unicast wake-up frame ~~as the receiver identifier~~ to identify the intended immediate recipient ~~wake up the~~ WUR STA within the BSS of the AP.
* The size of the WID is TBD, and how it is computed is TBD.

[Motion, Sep 2017, see [4] [29] [30]]

1. AP may negotiate one or more Group IDs to a STA through PCR
* The assigned Group ID is used in a wake-up frame
* The details for group ID (e.g., ID allocation procedure (e.g., WUR Action frame or others similar to 11ac procedure), ID structure, etc.) are TBD

[Motion 2, Nov 2017, see [6] [31]]

1. [Assigned D0.1] AP decides the WUR operating channel in the band(s) supported by the associated non-AP STA operating in WUR Mode.

[Motion, Sep 2017, see [4] [32]]

1. [Assigned D0.1] IEEE 802.11ba shall define Information Element for WUR capability that include following information
* Supported operating class for WUR operating channel
* PCR transition delay from doze state to awake state after receiving wake-up frame at STA side
* Nonzero-length Frame Body support

[Motion 1, Nov 2017, see [6] [28]]

## WURx Schedule

1. [Assigned D0.1] STA can have Duty cycle mode for wake-up receiver (WURx).

[Motion 2, March 2017, see [1] [25]]

1. The period of the WUR duty cycle as shown below is a multiple of a basic unit. The basic unit is indicated by the AP. The on duration in each period for WUR duty cycle as shown below is larger than or equal to a minimum wake-up duration. The minimum wake-up duration is indicated by the AP.



[Motion 1 and 2, May 2017, see [2] [33]]

1. AP decides the starting point for one WUR duty cycle schedule. How to indicate the starting point is TBD.

[Motion 3, May 2017, see [2] [33]]

## WUR Beacon

1. [Assigned D0.1] Define a WUR Beacon frame which can be transmitted periodically:
* The WUR Beacon is transmitted to WURs.

[Motion 4, March 2017, see [1] [24]]

1. [Assigned D0.1] WUR Beacon interval can be indicated in WUR Mode element:
* Note that WUR mode element is sent through primary connectivity radio.

[Motion 2, March 2017, see [1] [34]]

1. Define a synchronization mechanism to solve the timing mismatch problems associated with WUR duty cycle mode.

[Motion 1, March 2017, see [1] [35]]

1. The WUR beacon frame ~~may~~ carr~~y~~ies partial TSF for synchronization. The number of bits of the partial TSF is TBD.

[Motion, May 2017 and Sep 2017, see [2] [36] [4] [37]]

## WUR Mode

1. [Assigned D0.1] WUR mode signaling shall be defined for the WUR STA to enter the WUR mode by explicit signalling:
* ~~Explicit or implicit signaling is TBD~~
* ~~If signaling is explicit,~~ WUR mode signaling is done on the Primary connectivity radio.
* Wake-up operating parameter is ~~may be~~ notified in WUR mode signalling:
	+ Detailed parameters are TBD.

[Motion, May 2017 and July 2017, see [2] [38] [3] [39]]

1. [Assigned D0.1] If a non-AP STA is in WUR mode, then:
* the non-AP STA’s WURx follows the duty cycle schedule (including WURx always on) agreed between AP and non-AP STA if the non-AP STA is in the doze state.
* the existing negotiated service period between AP and non-AP STA for the non-AP STA’s PCR schedule (e.g. TWT, schedule for WNM Sleep Mode) is suspended:
	+ STA is not required to wake up during the service period if the service period is suspended.
	+ The parameters of the negotiated service period for the non-AP STA’s PCR schedule is still saved by the AP and non-AP STA when the negotiated service period is suspended.

[Motion, July 2017, see [3] [40]]

1. [Assigned D0.1] If a non-AP STA is in WUR mode, then:
* the non-AP STA may not listen for Beacon frames if the non-AP STA is in PS mode.

[Motion, Sep 2017, see [4] [41]]

1. [Assigned D0.1] The STA may turn off the WURx after a successful frame exchange with AP, which informs the AP that the STA is the awake state, through its PCR in WUR mode.

[Motion, Nov 2017, see [6] [42]]

1. [Assigned D0.1 Define WUR Mode Suspend, and if an non-AP STA is in WUR Mode Suspend, then
* The negotiated WUR parameters between AP and non-AP STA is maintained
* Non-AP STA may turn off the WURx
* Note that negotiated PCR schedule (if any) is active and is not suspended

[Motion 3, Nov 2017, see [6] [27]]

## Channel Access

1. Use EDCA to send wake-up frames:
* The EDCA parameter set for wake-up frames is TBD.

[Motion 5, March 2017, see [1] [24]]

1. An AP reuses existing 4 ACs and corresponding EDCA parameters to transmit WUR frame:
* Note that WUR frame includes unicast wake-up frame, multicast wake-up frame, and WUR Beacon.

[Motion 1, May 2017, see [2] [43]]

1. An AP may use any AC for sending a multicast wake-up frame. An AP may use any AC for sending a WUR Beacon.

[Motion 2, May 2017, see [2] [43]]

1. An AP may use any AC for sending a unicast wake-up frame to a STA if the AP does not have pending buffered frame to the STA.

[Motion 3, May 2017, see [2] [43]]

1. After an AP sends a WUR frame using EDCAF of a particular AC, the AP shall not update CW and retry count of the AC. After identifying failure for a unicast wake-up frame that is sent using EDCAF of a particular AC, AP shall not update CW and retry count of the AC.

[Motion 4, May 2017, see [2] [43]]

## Wake-up Operation

### General

1. The AP can send a Trigger Frame in 11ax to solicit response frames from one or more STAs after sending a wake-up frame to the STA(s).

[Motion 3, March 2017, see [1] [24]]

### Unicast Wake-up Operation

1. After AP sends a unicast wake-up frame to a STA, AP waits for a timeout interval:
* If AP receives any transmission from the STA within the timeout interval, then the wake-up frame transmission is successful.
* Otherwise, the wake-up frame transmission fails, and AP may retransmit the wake-up frame to the STA.

[Motion 3, March 2017, see [1] [25]]

1. A STA should send a response frame to the AP using primary connectivity radio after receiving a unicast wake-up frame.

[Motion 1, March 2017, see [1] [24]]

### Multicast Wake-up Operation

1. IEEE 802.11ba shall define a mechanism to wake up multiple WUR mode STAs (e.g., multi-user wake-up frame).

[Motion 2, March 2017, see [1] [44]]

1. After the transmission of broadcast wake-up frame, the AP can transmit broadcast/multicast frames through primary connectivity radio after the preparation period.

[Motion 3, March 2017, see [1] [45]]

1. A non-individually addressed wake-up frame may include the information for indicating the group addressed frame transmission through PCR
* The details of indicating the group addressed frame transmission (e.g., using Group ID or additional bit) is TBD

[Motion 1, Nov 2017, see [6] [46]]

1. If a STA receives a non-individually addressed wake-up frame indicating a group addressed frame through the PCR, the STA may attempt to receive a group addressed frame through PCR

[Motion 2, Nov 2017, see [6] [46]]

## WUR Discovery

1. Define a type of WUR frame as WUR Discovery frame to assist the STAs to discover the BSS.

[Motion, Nov 2017, see [6] [47]]

## WUR Frame formats

### General

1. [Assigned D0.1] The WUR frame has the following format:



* The length of the MAC header is fixed.
* Whether the Address field contains more than one identifier is TBD.

[Motion 1, Sep 2017, see [4] [37]]

1. [Assigned D0.1] The Frame Control field is 8 bits and contains:
* A Type subfield that identifies the type and, together with the Length field differentiates between constant length (CL) and variable length (VL) WUR frames
* A Length/Misc field which contains:
	+ The length of the Frame Body field for a VL WUR frame
	+ Bits that are expected to be used for other purposes for a CL WUR frames
		- No Length field is present in CL WUR frames



[Motion 1, Nov 2017, see [6] [48]]

1. [Assigned D0.1] A Type subfield identifies the WUR frame type:
* The Type subfield is contained in the Frame Control field of the MAC header.
* One Type subfield value assigned to WUR Beacon and one to wake-up frame.

[Motion 2, Sep 2017, see [4] [37]]

1. [Assigned D0.1] TBD bits Type field is included in the Frame control field of MAC header with the following mapping of the Type field:
* 0 assigned to WUR Beacon
* 1 assigned to Wake-Up frame
* 2 assigned to Vendor specific frame

[Motion 1, Nov 2017, see [6] [31]]

1. [Assigned D0.1] The Address field is 12 bits, and the TD Control field is 12 bits

[Motion 2, Nov 2017, see [6] [48]]

1. [Assigned D0.1] The contents of the Address field are as defined below:



* Where:
	+ WID is the WUR ID provided by the AP and identifies one WUR STA
	+ GID is the GROUP ID provided by the AP and identifies one or more WUR STAs
	+ TXID is a transmitter identifier that is decided by the AP
		- Which bits, from where, and how they are selected is TBD
	+ OUI1 is the 12 MSBs of the OUI

[Motion 3, Nov 2017, see [6] [48]]

1. [Assigned D0.1] The Type Dependent (TD) Control field in the MAC header contains type dependent control information.

[Motion 4, Sep 2017, see [4] [37]]

1. [Assigned D0.1] The WUR frame has an optionally present Frame Body field:
* It is optional for a STA to support reception of a frame with nonzero length Frame Body.

[Motion 5, Sep 2017, see [4] [37]]

1. [Assigned D0.1] When the Frame Body field is present in a WUR frame then:
* The length of the Frame Body field is indicated by the Length subfield in the Frame Control field
* The length is in units of *TBD* octets, and is up to 8 or 16 (*TBD*) octets.

[Motion 4, Nov 2017, see [6] [48]]

1. [Assigned D0.1] The WUR frame has a Frame Check Sequence (FCS) that carries the CRC of the frame:
* Length and computation of FCS is TBD.

[Motion 6, Sep 2017, see [4] [37]]

1. The FCS additionally embeds BSSID information:
	* How to embed the BSSID information in the FCS is *TBD*
	* It is not applicable for pre-association WUR frames

[Motion 5, Nov 2017, see [6] [48]]

### WUR Beacon

1. [Assigned D0.1] The Address field contains an identifier of the transmitter when the frame is WUR Beacon. [Motion 3, Sep 2017, see [4] [37]]
2. The TD Control field of a WUR Beacon contains the partial TSF.

[Motion 4, Sep 2017, see [4] [37]]

### Wake-up frame

1. [Assigned D0.1] The identifier of transmitter and/or receiver in a wake-up frame shall not be the MAC address.

[Motion 1, March 2017, see [1] [45]]

1. [Assigned D0.1] The unicast wake-up frame contains a WUR identifier that identifies both the transmitter and the receiver.

[Motion, Sep 2017, see [4] [30] and [29]]

1. A wake-up frame with variable length may contain the information for the multiple STAs in the Frame Body
* The detailed information of multiple STAs (e.g., bitmap, ID list) is TBD
* Unicast wake-up frame does not carry the information of multiple STAs

[Motion 3, Nov 2017, see [6] [31]]

1. AP indicates a BSS parameter update by incrementing a counter in the wake-up frame.

[Motion, Sep 2017, see [4] [49]]

# References

|  |  |
| --- | --- |
| [1]  | Leif Wilhelmsson (Ericsson), “17/526r0 Meeting Minutes March 2017”.  |
| [2]  | Leif Wilhelmsson (Ericsson), “17/843r0 Meeting Minutes May 2017”.  |
| [3]  | Leif Wilhelmsson (Ericsson), “17/1197r1 Meeting Minutes July 2017”.  |
| [4]  | Leif Wilhelmsson (Ericsson), “17/1522r2 Meeting Minutes Sep 2017”.  |
| [5]  | Adrian Stephens (Intel), “15/1034r11 802.11 Editorial Style Guide”.  |
| [6]  | Leif Wilhelmsson (Ericsson), “17/1800r0 Meeting Minutes Nov 2017”.  |
| [7]  | Hongyuan Zhang (Marvell), “17/1626r2 11ba PHY Frame Format—Length Discussions”.  |
| [8]  | Rui Cao (Marvell), “17/647r4 WUR Legacy Preamble Design”.  |
| [9]  | Jianhan Liu (Mediatek Inc.), “17/1624r3 11ba preamble structure based on analysis of power consumption, cost and complexity”.  |
| [10]  | Steve Shellhammer (Qualcomm), “17/1781r1 Sync Structure Motions”.  |
| [11]  | Shahrnaz Azizi (Intel Corp), “17/368r1 Motion for High Level PHY Design”.  |
| [12]  | Bin Tian (Qualcomm), “17/1666r2 False Radar Pulse Detection on WUR Signals in DFS Channel”.  |
| [13]  | Jia Jia (Huawei Technologies), “17/373r2 Performance Investigations on Single-carrier and Multiple-carrier-based WUR”.  |
| [14]  | Eunsung Park (LG), “17/964r4 Signal Bandwidth and Sequence for OOK Signal Generation”.  |
| [15]  | Eunsung Park (LG Electronics), “17/1613r2 13-Length Sequence for OOK Waveform Generation”.  |
| [16]  | Eunsung Park (LG), “17/654r3 Multiple Data Rates for WUR”.  |
| [17]  | Eunsung Park (LG), “17/965r1 Data Rate for Range Requirement in 11ba”.  |
| [18]  | Steve Shellhammer, “17/1147r0 WUR Data Rate Motion”.  |
| [19]  | Hongyuan Zhang (Marvell), “17/1345r5 11ba PHY Frame Format Proposal”.  |
| [20]  | Steve Shellhammer (Qualcomm), “17/668r1 Motion on Manchester Coding”.  |
| [21]  | Eunsung Park (LG Electronics), “17/1347r3 Symbol structure”.  |
| [22]  | Eunsung Park (LG Electronics), “17/1612r3 Symbol Structure Follow-up”.  |
| [23]  | Jianhan Liu (Mediatek Inc.) , “17/27r4 Re-Discovery Problems in WUR WLAN”.  |
| [24]  | Jason Yuchen Guo (Huawei Technologies), “17/354r2 Initial thoughts on MAC procedures”.  |
| [25]  | Po-Kai Huang (Intel), “17/342r4 WUR Negotiation and Acknowledgement Procedure Follow up”.  |
| [26]  | Lei Huang (Panasonic), “17/1302r7 WUR mode operation procedures”.  |
| [27]  | Po-Kai Huang (Intel), “17/1627r2 WUR Action Frame Format Follow Up”.  |
| [28]  | Suhwook Kim (LG), “17/1657r7 MAC operation of WUR”.  |
| [29]  | Jeongki Kim (LG Electronics), “17/0977r4 Address structure in unicast wake-up frame”.  |
| [30]  | Liwen Chu (Marvell), “17/1115r4 Wakeup Frame Format”.  |
| [31]  | Jeongki Kim (LG Electronics), “17/1638r6 WUR Frame format follow-up”.  |
| [32]  | Po-Kai Huang (Intel), “17/1333r2 WUR Operating Channel”.  |
| [33]  | Po-Kai Huang (Intel), “17/651r1 Indication for WUR Duty Cycle”.  |
| [34]  | Po-Kai Huang (Intel), “17/343r3 WUR Beacon”.  |
| [35]  | Tianyu Wu (Mediatek), “17/371r4 WUR duty cycle mode and timing synchronization follow up”.  |
| [36]  | Steve Shellhammer (Qualcomm), “17/671r2 Considerations on WUR Synchronization”.  |
| [37]  | Alfred Asterjadhi (Qualcomm), “17/1004r4 Considerations on WUR frame format”.  |
| [38]  | Suhwook Kim (LG), “17/379r4 SFD MAC proposal”.  |
| [39]  | Suhwook Kim, “17/954r2 WUR Mode Signaling”.  |
| [40]  | Po-Kai Huang (Intel), “17/972r2 Definition of WUR Mode”.  |
| [41]  | Woojin Ahn (WILUS), “17/1349r4 Discussion on WUR mode”.  |
| [42]  | Ming Gan (Huawei), “17/1369r3 Power save mode transition”.  |
| [43]  | Po-Kai Huang (Intel), “17/652r1 Consideration of EDCA for WUR Signal”.  |
| [44]  | Jeongki Kim(LG Electronics) , “17/54r3 WUR MAC issus”.  |
| [45]  | Liwen Chu (Marvell), “17/124r4 WUR MAC and Wakeup Frame”.  |
| [46]  | Jeongki Kim (LG Electronics), “17/1356r5 PS operation for Duty cycle STAs follow-up”.  |
| [47]  | Guoqing Li (Apple Inc.), “16/1608r7 WUR Discovery Frame for Smart Scanning”.  |
| [48]  | Alfred Asterjadhi (Qualcomm Inc.), “17/1645r3 WUR frame format-follow up”.  |
| [49]  | Ming Gan (Huawei), “17/1368r2 BSS parameters update notification”.  |