MIC MRA International Workshop2019

New Wireless LAN Technology: 802.11ax

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Disclaimer

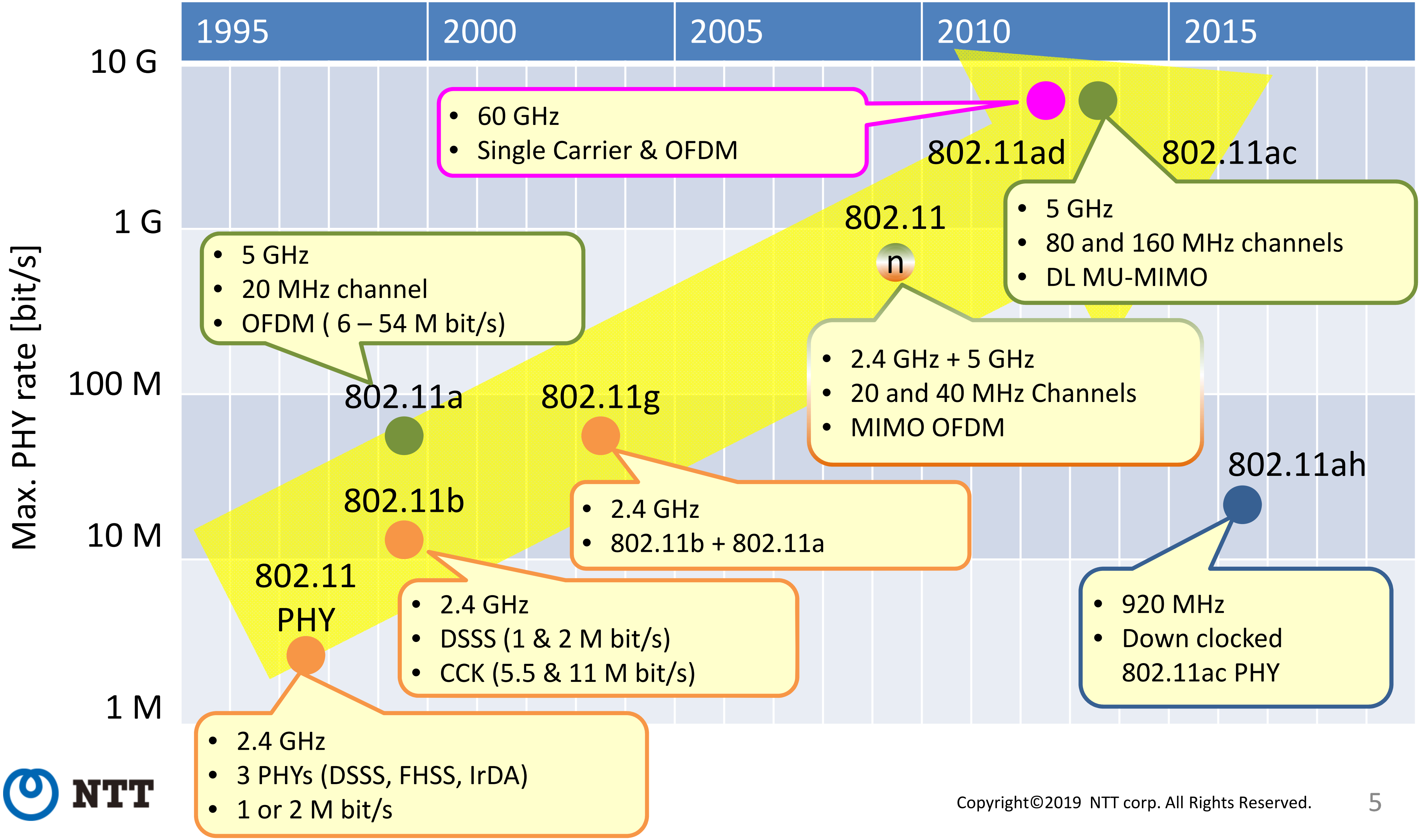
Before We Share our Opinions……

- "At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE."
- IEEE-SA Standards Board Operation Manual (subclause 5.9.3)

History of IEEE 802.11 Standardization

■ History of major amendments related to physical layer[1]

Note: IEEE 802.11a/b/g/n/ac/ad... are released as "amendments" of the baseline standard, IEEE 802.11.

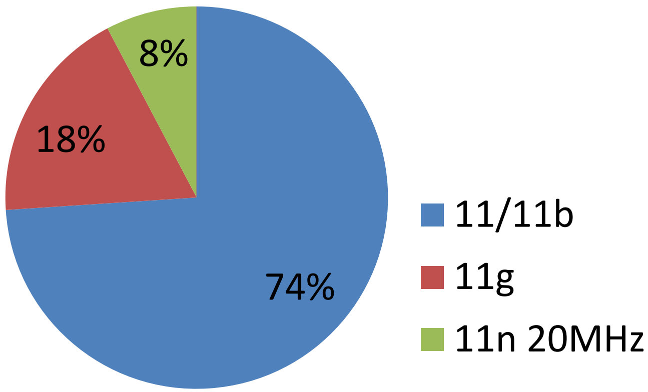


Discussion prior to IEEE 802.11ax Standardization

- Wireless LAN (WLAN) usage in 2013 (just before the start of IEEE 802.11ax standardization)[1]
  - Exploding spread of smart devices such as smart phones and tablets
    - Urgent needs of mobile traffic offloading
  - Dense WLAN deployment
    - Lower user experience (difficult to connect, easily disconnected, poor throughput…)

- 2.4 GHz band (IEEE 802.11b/g/n)
  - Several tens of WLAN networks coexist in a certain area.
  - Throughput performance is constantly poor throughput especially public areas (e.g. train stations).
- 5 GHz bands (IEEE 802.11a/n/ac)
  - Higher throughput performance can be obtained compared to 2.4 GHz band but there are operation restrictions (i.e. indoor use only, DFS function).
  - Expansion of channel bandwidth will make the bands denser.

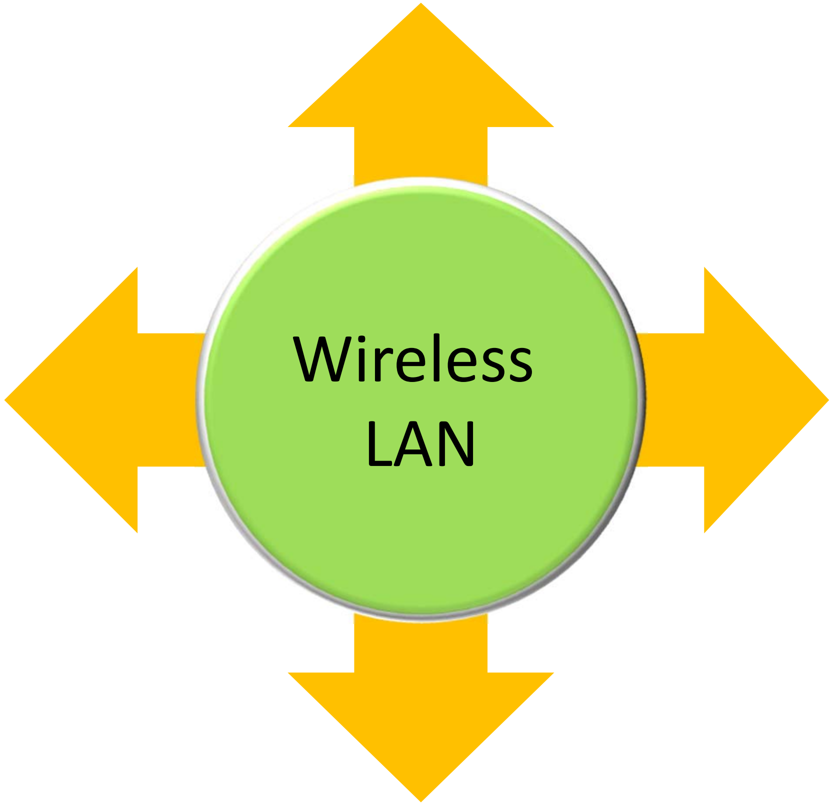
  - Causes for the problems
    - Wireless Frames with low bit rate are dominant.
    - Especially, 80 % of wireless frames of legacy amendment such as IEEE 802.11/11b are control or management frames, which do not carry user traffic.



Requirements for IEEE 802.11ax Amendment

■ Requirements are summarized through discussions on use cases. [1][2]

High transmission efficiency and throughput in dense deployment scenarios of WLANs



Outdoor eployment

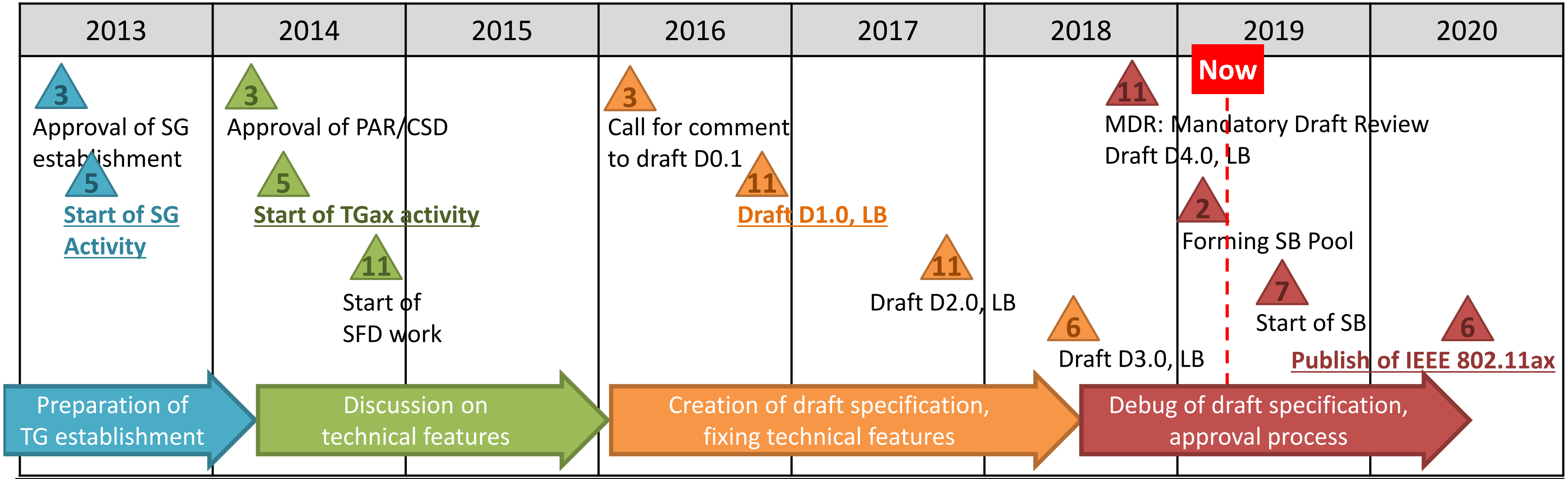
Advanced power-save function

Support of new WLAN markets such as IoT, M2M, V2V, etc.

Timeline of Standardization

- In present (March, 2019), technical specifications are already fixed and the draft is being debugged.
  - ➢ Approval rate of Draft D3.0: 86.5%
    → The rate exceed 75% and thus the standardization process moved to recirculation LB*.
    (* No technical comment is received except for debug.)
- In June 2020, the standardization will be finished (as scheduled).
- Commercial products based on the draft of IEEE 802.11ax will be available since 2019.

<Timeline of IEEE 802.11ax[3]>



SG: Study Group (A group to create PAR/CSD documents, which must be needed to establish Task Group)
PAR: Project Authorization Request (Document to define scope and needs of the new amendment)
CSD: Criteria for Standards Development (Document to define TG activity)
TG: Task Group (A group to create draft of the standard document)
SFD: Specification Framework Document (Table of contents for technical aspects)
Dx.y: Draft version x.y
LB: Letter Ballot (An electrical ballot among IEEE 802.11 members)
SB: Sponsor Ballot (An electrical ballot among sponsors (organizations/individual) of IEEE Standard Association

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Main Technical features in IEEE 802.11ax

- Extension of multiuser transmission technologies
  - (1) Extension of MU-MIMO (UL MU-MIMO)
  - (2) New implementation of OFDMA (UL/DL OFDMA)
- (3) Spatial Reuse (Frequency reuse function)
- Extension of physical (PHY) layer
  - (4) Extension of physical frame format (4x OFDM Symbol)
  - (5) Expansion of supporting frequency channels
  - Higher order of modulation (256 QAM → 1024 QAM)
  - Additional functions for long range transmission and increased robustness
- Extension of Medium Access Control (MAC) layer
  - More efficient ACK/protection mechanisms
  - Expansion of frame aggregation/fragmentation function
- Additional management functions
  - More efficient power save
  - Optimized operation

Today's topics (related to Japanese radio regulation): items (1)–(5)

Comparison of IEEE 802.11an/n/ac and ax [1]

- Major advancement of existing amendments → Extension of Max. PHY bit rate

  IEEE 802.11a-2001 : Max. PHY rate of 54 M bit/s
  - OFDM (Orthogonal Frequency Division Multiplexing)
  - 20 MHz channel bandwidth

  x 11.1

  IEEE 802.11n-2009 : Max. PHY rate of 600 M bit/s
  - OFDM + MIMO (Multiple Input Multiple Output)
  - 20 MHz, (optional) 40 MHz channel bandwidth

  x 11.6

  IEEE 802.11ac-2013 : Max. PHY rate of 6.93 G bit/s
  - DL MU-MIMO (Downlink Multi-User MIMO)
  - 20 MHz, 40 MHz, 80 MHz & (optional) 160 MHz channel bandwidth

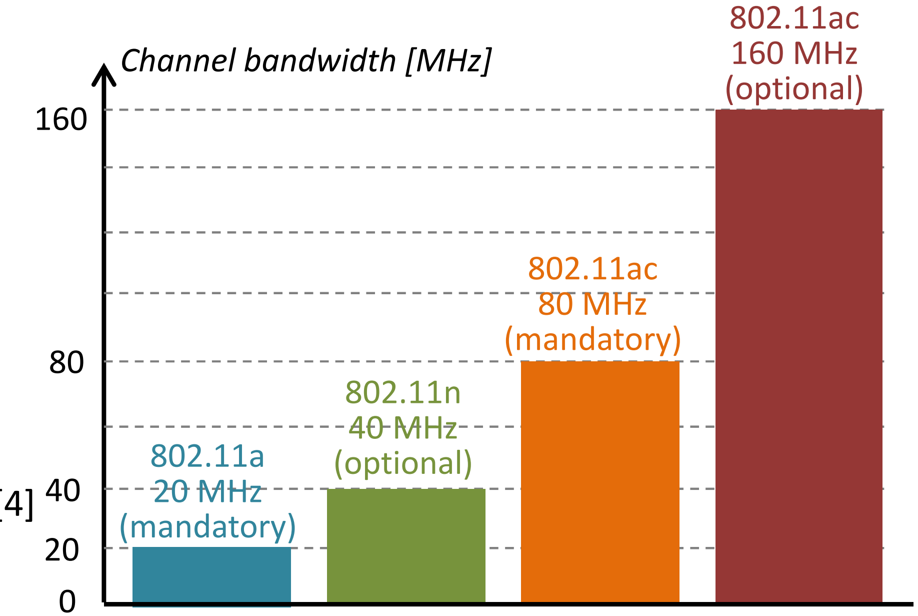
MAC enhancements to support higher bit rates also have been specified.

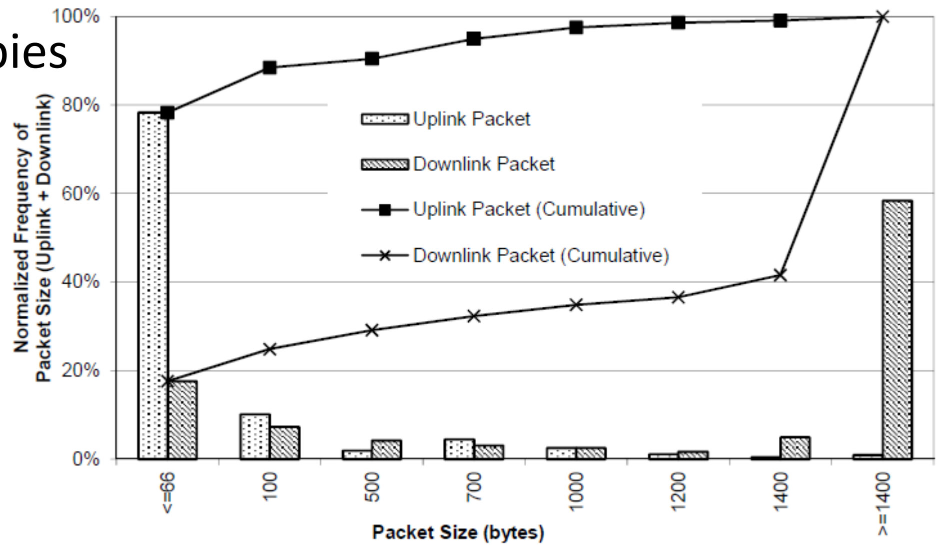
Bandwidth expansion has mainly contributed to throughput increase.

- IEEE 802.11ax
  - Improving area spectrum efficiency in densely deployed scenarios of WLANs

Background of Need of Higher Efficiency

- An issue in throughput enhancement by expanding channel bandwidth [1]
  - When wide band transmissions (e.g. 160 MHz) and narrow band transmissions (e.g. 20 MHz) coexist, efficiency of wireless channel usage severely degraded.
    - Cause: limitation of channel access to keep “backward compatibility to existing amendments.
- Statistical characteristic of traffic (IP packets)[4]
  - Packets with small data size have high percentage. Especially, in uplink transmission, packets with less than 100 Bytes of data occupies more than 80 %.



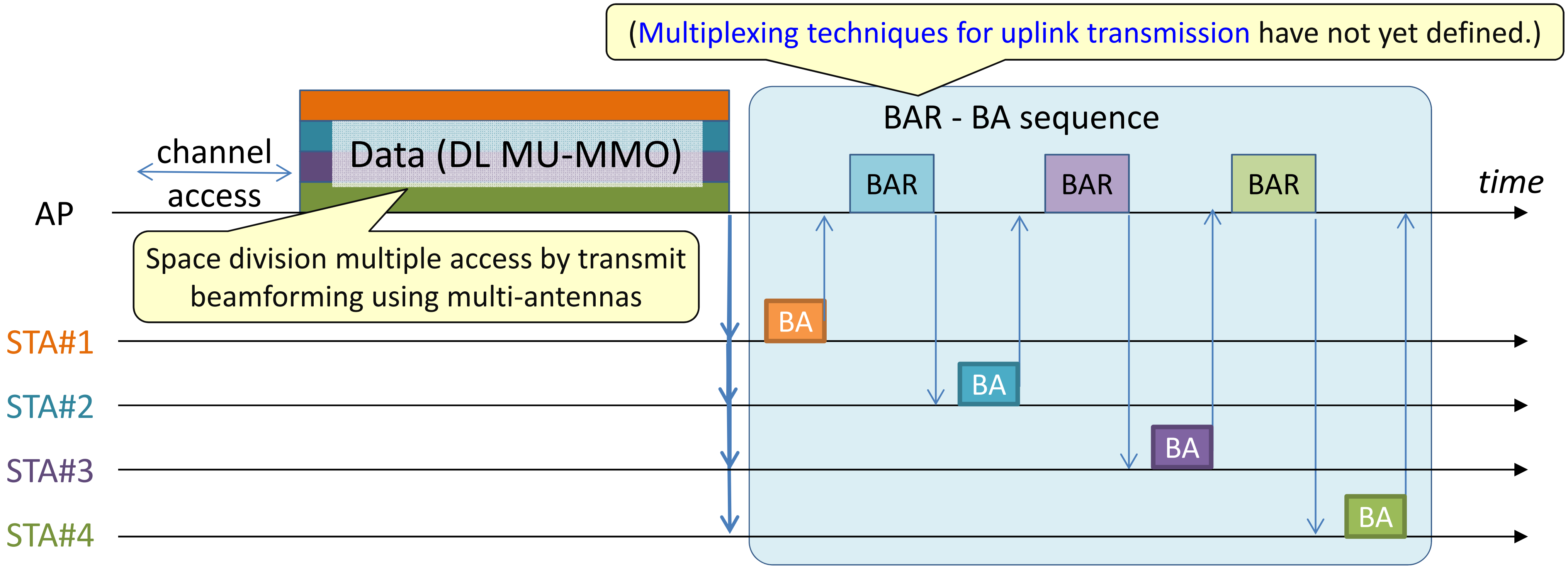


Throughput enhancement cannot be achieved only by bandwidth expansion.

Transmission efficiency would be improved by introducing multiple access per channel.

(1) Extension of MU-MIMO Technology (1/3)

- IEEE 802.11ac has implemented downlink multiuser-MIMO (DL MU-MIMO)[1]
  - Example: Data transmission sequence of DL MU-MIMO
    - AP (Access Point) transmits data frames up to four STAs (stations) simultaneously.
    - Acknowledgement process is carried out on a per-STA basis. (i.e. repetitive exchange of Block ACK Request and Block ACK frames)
    - (Protection process is also done on a per-STA basis.)



Control frame exchange on a per-STA basis is bottleneck of transmission efficiency.

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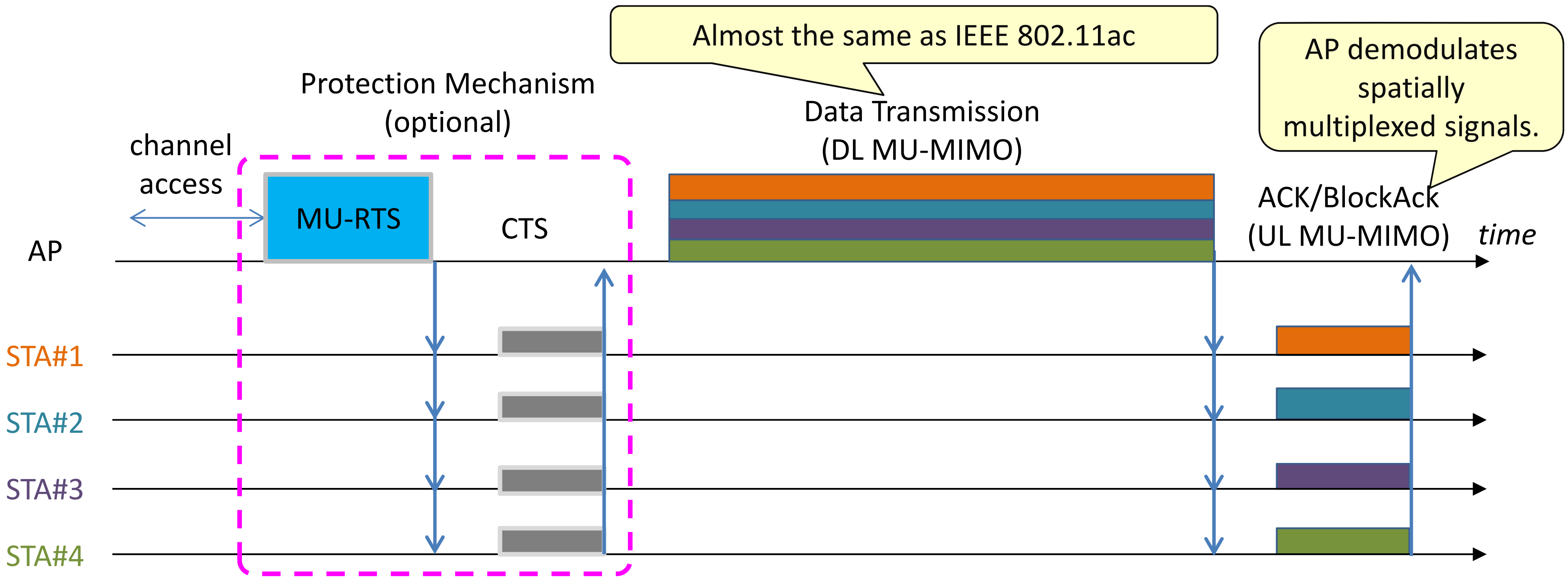
(1) Extension of MU-MIMO Technology (2/3)

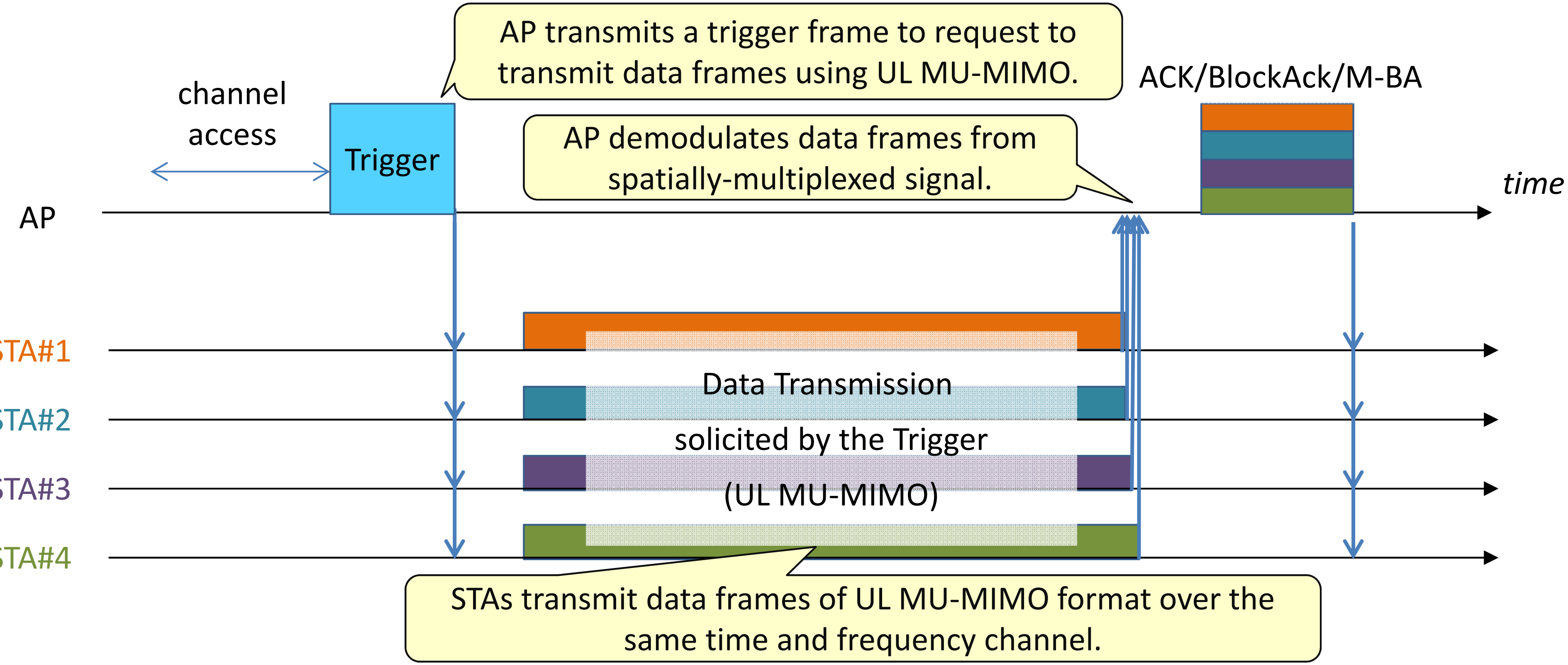
- IEEE 802.11ax implements uplink multiuser-MIMO (UL MU-MIMO)[1]
  - Example: Data transmission sequence of **DL** MU-MIMO
    - Using UL MU-MIMO for ACK/BA exchange
    - Protection sequences can be multiplexed by UL MU-MIMO.



Not only data transmissions but also control frame exchanges become efficient.

(1) Extension of MU-MIMO Technology (3/3)

- IEEE 802.11ax implements uplink multiuser-MIMO (UL MU-MIMO)[1]
  - Example: Data transmission sequence of **UL** MU-MIMO
    - A trigger frame initiates UL MU-MIMO data transmission.
    - Each STA transmit UL data frame followed by a trigger frame.
    - AP responds to uplink data frames by ACK, BlockAck, or Multi-STA BlockAck (M-BA).

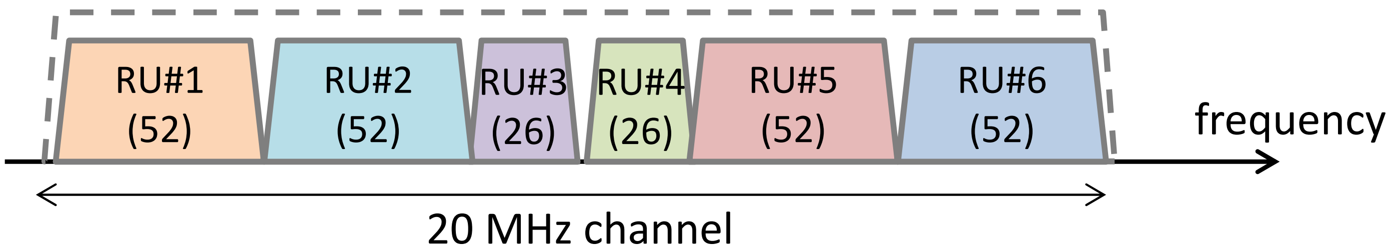


Uplink data transmissions also become efficient using UL MU-MIMO.

(2) Implementation of OFDMA

- IEEE 802.11ax implements OFDMA transmission[1]
  - (3GPP LTE and IEEE 802.16 (WiMAX) have already supported the function.)
  - It based on existing channel access rules (CSMA/CA*, carrier sense based, per-20MHz channel access).
    - To retain backward compatibility to existing amendments (IEEE 802.11a/n/ac)
  - Channel of transmitting a frame is divided into <u>sub-channels</u> for transmission to/from multiple number of STAs.
  - Sub-channel is defined as “Resource Unit(RU)”
    - A RU comprises a group of subcarrier within OFDM symbols.
    - The number of subcarriers per RU:
      - 26 (2 MHz) / 52 (4 MHz) / 106 (8 MHz) / 242 (10 MHz) / 484 (20 MHz) / 996 (40 MHz)
    - A RU size for an STA can be assigned individually.

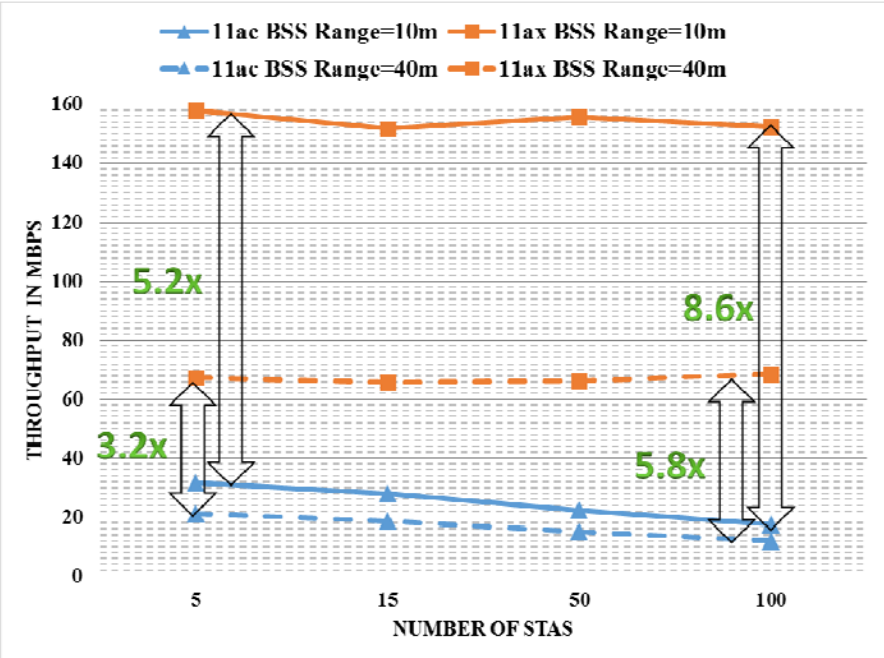
    (Example: 20 MHz transmission including 6 STAs.)



  - Both uplink (optional) and downlink (mandatory) OFDMA transmissions are defined.
    - RU variation is common to UL and DL.
    - Almost the same frame sequence as MU-MIMO transmission is used for OFDMA. A trigger frame initiates UL OFDMA transmission.

Efficiency Improvement by (1)MU-MIMO/(2)OFDMA[5][6]

- Example: MU-MIMO transmission
  - The number of APs: 1
  - Distance between AP and STAs: 10m or 40m
  - The number of STAs: 5, 15, 50, 100
  - Frequency band: 5 GHz, Channel bandwidth: 20MHz
  - The number of antennas: 4 for AP, 1 for STA
  - Traffic model: full-buffer, uplink only
  - Packet size: 1,460 Bytes



- Example: OFDMA transmission
  - The number of APs: 3
  - Distance between AP and STAs: 30m
  - The number of STAs per AP: 13, 26, 52
  - Frequency band: 5 GHz, Channel bandwidth: 80MHz
  - The number of antennas: 1 for AP, 1 for STA
  - Traffic model: full-buffer, uplink only
  - Packet size: 1000 Bytes

When the number of STAs per AP is 52:

	11ac RTS OFF	11ac RTS ON	11ax RTS OFF
MCS5	31.35	133.21 ***(93.47, 22)*** ***(#)***	129.60
MCS9	15.81	98.98 ***(63.41, 14)*** ***(#)***	177.57

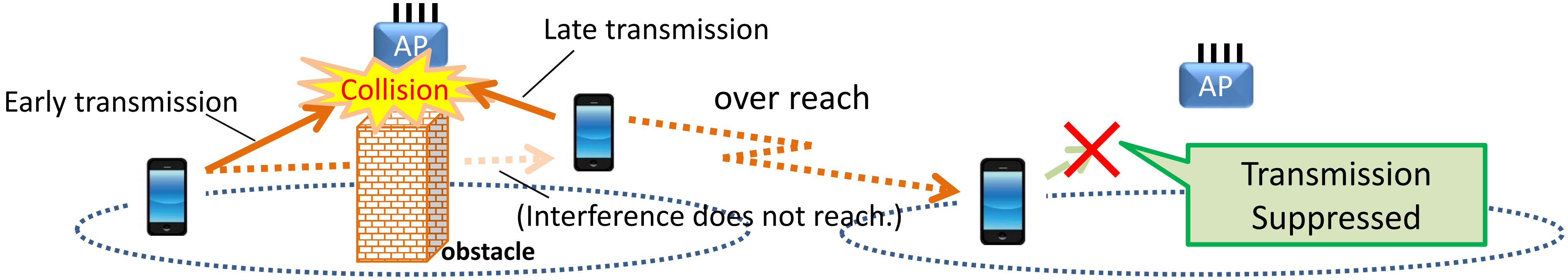
x4.1

x11.2

More than four times of throughput enhancement compared to that of the existing standard (IEEE 802.11ac) in densely deployed environment was confirmed.

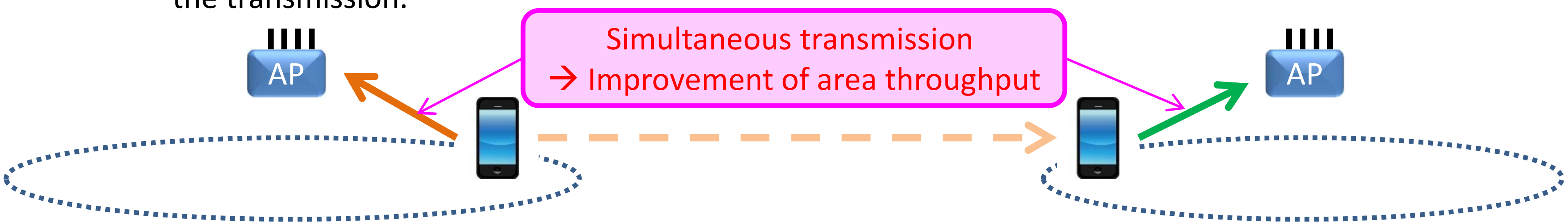
(3) Spatial Reuse (1/3)

- Spatial Reuse (SR) enhances frequency reuse in dense deployment[1]
  - Access Scheme of IEEE 802.11 WLANs： CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) Listen-before-talk.
  - Problem: Throughput degradation caused by hidden/exposed terminal problems



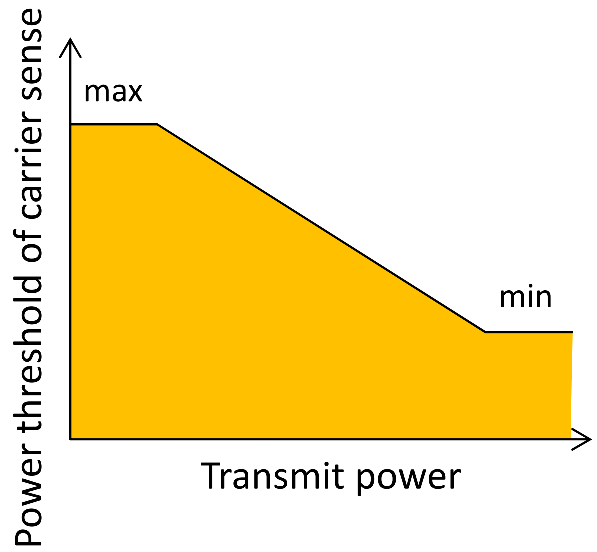
Hidden node problem **Exposed terminal problem**

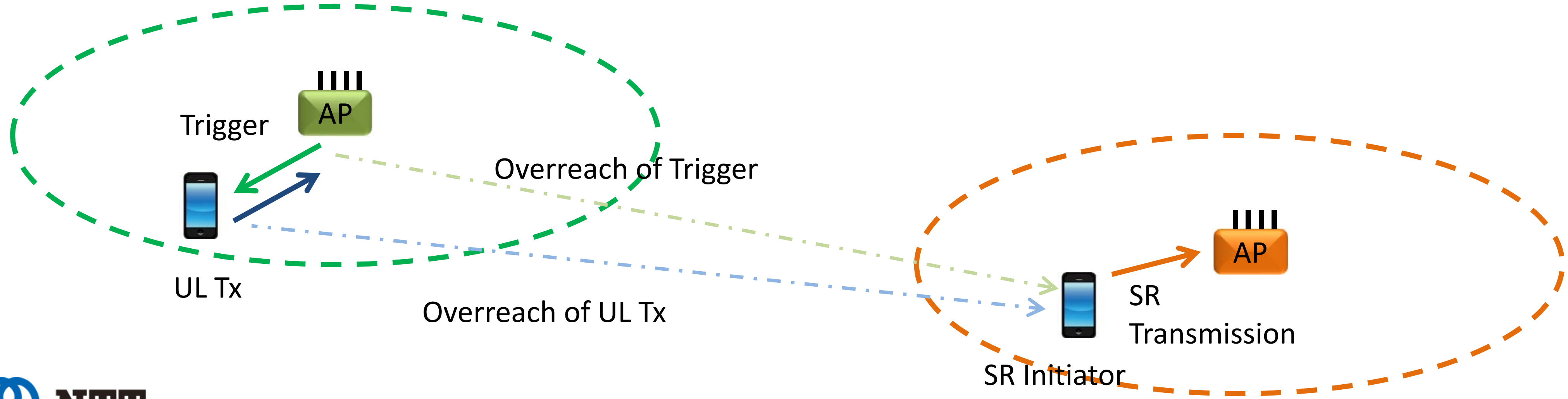
  - Spatial Reuse Technique in IEEE 802.11ax
    - An aim is to reduce the influence of exposed terminal problem.
    - An STA recognizes the cell area from which the received frame is sent.
    - An STA transmits a frame after confirming that the interference from the other cell are is not harmful to the transmission.



(3) Spatial Reuse (2/3)

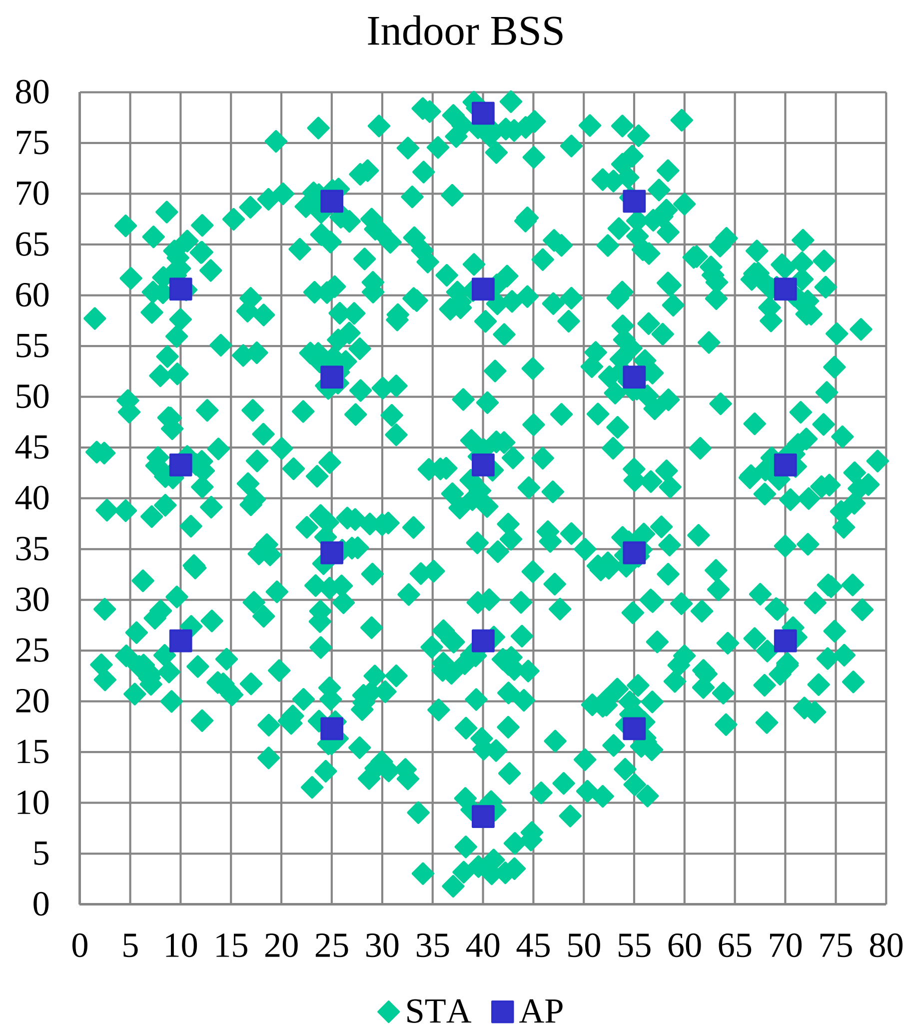
- Two types of SR techniques are defined. [1][5]
  - OBSS_PD-based SR:
    - Transmit power and power threshold of carrier sense threshold are jointly and dynamically controlled.
    - When the power threshold is increased, transmit power is reduced correspondingly.
  - SRP(Spatial Reuse Parameter)-based SR:
    - SR transmission based on pre-defined parameters.
    - Transmitting a frame or not is determined by received signal power during UL sequence.





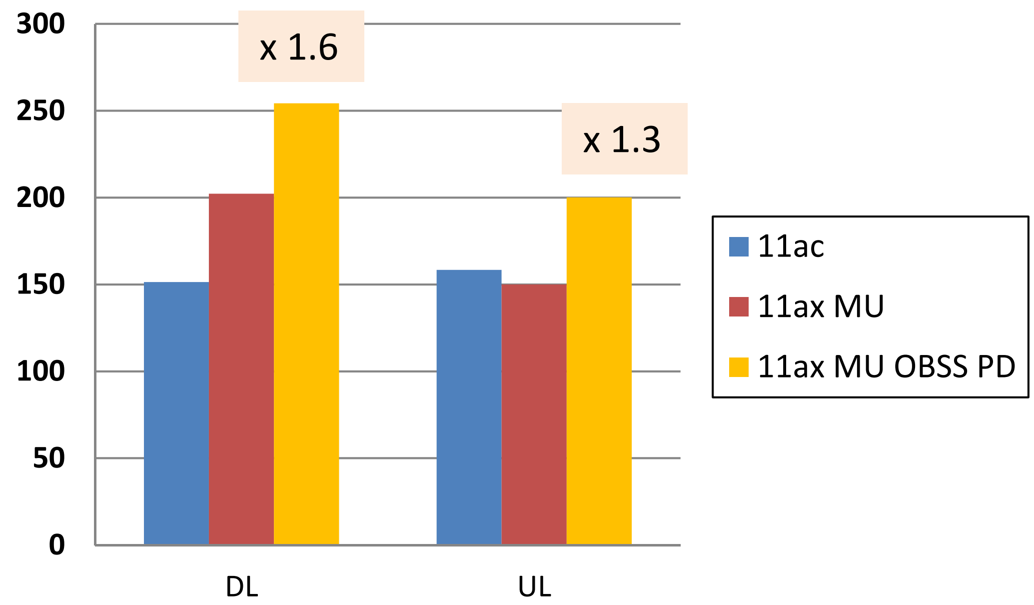
(3) Spatial Reuse (3/3)

■ Performance evaluation by computer simulation[1][7]



➢ Parameters:

- Channel: common to all APs.
- The number APs: 19
- The number of STAs: 30 per AP (total: 570)
- Cell radius per AP: 10 m
- Deployment of APs: hexagonal
- Deployment of STAs: random within a cell

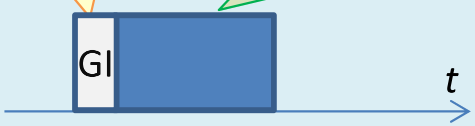
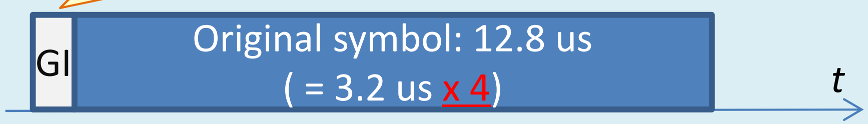
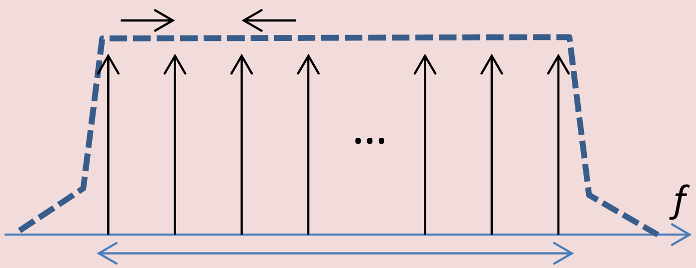
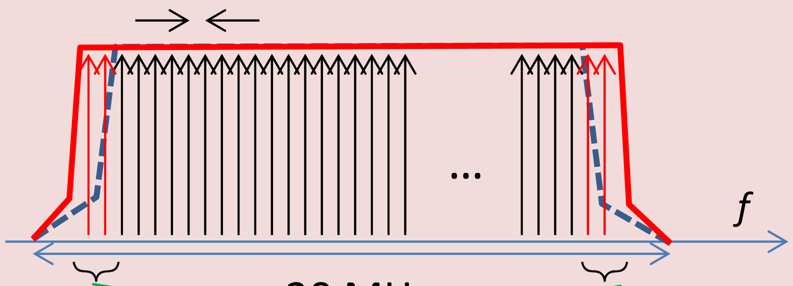


The effect of SR (improvement of throughput) is confirmed.

(4) Expansion of PHY frame format

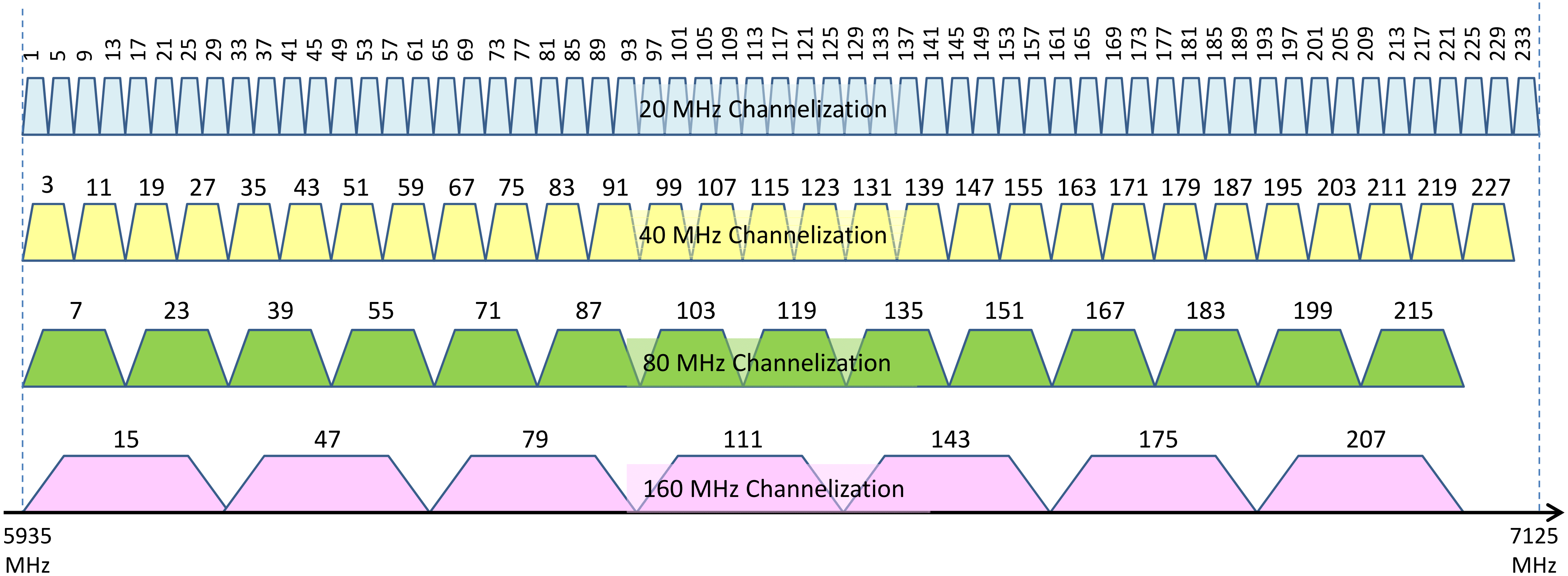
■ OFDM signal format of IEEE 802.11ax [1]

- 4x symbol length → Higher resolution of RUs, Improvement of transmission efficiency (less GI), Robustness against multipath fading and timing fluctuation (for outdoor environment and UL MU transmission)
- Additional data subcarriers at the edges of spectrum → minor increase of data rate

	IEEE 802.11a/n/ac	IEEE 802.11ax
OFDM signals in time domain	Guard Interval (GI) for multipath immunity: 0.8 us Original symbol: 3.2 us  	• Less GI percentage per OFDM symbol → improved transmission • GI length of 1.6/3.2 us for outdoor multipath environment 
OFDM signals in frequency domain	Subcarrier space: 312.5 kHz  	Subcarrier space: 78.125 kHz (1/4 of a/n/ac)  Additional data subcarrier (11 x 2 = 22)

(5) Expansion of Frequency Channels

- Currently, allocation of 6 GHz band for unlicensed wireless systems are actively being proceeded in FCC and ETSI. [1]
  - Channels in 5935 - 7125GHz are added to operating channels of IEEE 802.11ax
  - Specification for efficient channel scan are added.
    - Notification of 6 GHz band operation using beacon frames in 5 GHz band
    - Limitation of primary 20 MHz channel location to reduce scan time



Channel allocation in 5935 – 7125 MHz for IEEE 802.11 TGax Draft D4.0[8]

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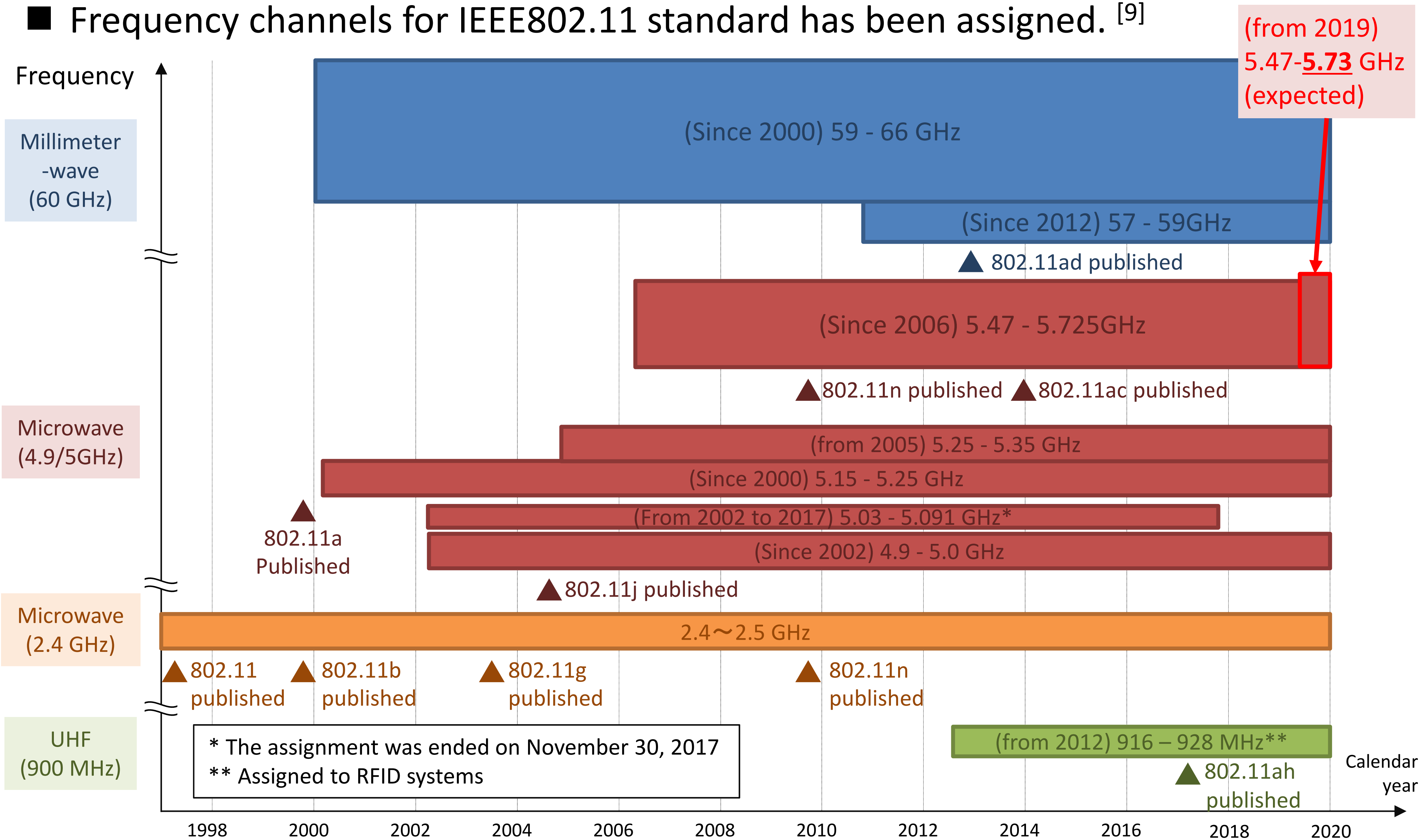
IEEE 802.11 Standard and Japanese Frequency Allocation

- Frequency channels for IEEE802.11 standard has been assigned. [9]



* The assignment was ended on November 30, 2017
** Assigned to RFID systems

History of Regulatory Rule Changes Related to IEEE 802.11 WLANs

- Technical discussion is conducted at a working party in Information and Communications Council directed by Ministry of Internal affair and Communication (MIC).
- The working party cerates a draft version of "technical conditions," which will be the basic idea of the regulatory rule changes.
- Past history of Japanese regulatory rule changes related to IEEE 802.11 WLANs:
  - 1999: 5.2 GHz band (indoor only) was assigned to unlicensed systems.
    → IEEE 802.11g has been available.
  - 2001: 2.4 GHz band rules was revised.
    → IEEE 802.11g has been available.
  - 2004: 5.3 GHz band (indoor only, mandatory of DFS) and 5.6 GHz band (outdoor / mandatory of DFS) were assigned to unlicensed systems.
    → Channels for IEEE 802.11a has been expanded (from 9 to 19 channel).
  - 2006: Channel bandwidth per system for 2.4/5.2/5.3/5.6 GHz band was expanded.
    → 40 MHz operation for IEEEE 802.11n has been available.
  - 2012: Channel bandwidth per system for 5.2/5.3/5.6 GHz band was expanded.
    → 80/160/80+80 MHz operation for IEEE 802.11ac has been available.
  - 2018: Outdoor operation for 5.2 GHz band* and over-the-air operation for 5.6GHz band* were newly defined.
    → Outdoor operation is permitted only for registered AP and STAs associated to the AP.
  - **2019: Updates for IEEE 802.11ax, channel expansion in 5.6 GHz band**, and updates for DFS rules will be in force.
    → IEEE 802.11ax will be fully available.

Today's topics

* Based on this rule changes, Japan are proposing to change ITU RR (Radio Regulatory) in WRC 2019.
** Currently under discussion for new rules.

History of Processes on Regulatory Rule Changes for IEEE 802.11ax in the Council

- April, 2018: 8th and 9th meetings of the working Party for 5 GHz band Wireless LANs
  - Confirming the discussion items on the working party as "IEEE 802.11ax", "DFS rule updates" and "Expansion of channel allocation in 5.6 GHz band"
  - Sharing the discussion status for technical conditions of DFS for 5.3 GHz band WLANs
- July 2018: 10th meeting
  - Conforming the purposes and the technical features of IEEE 802.11ax
- November 2018: 11th meeting
  - Sharing standardizing status of IEEE 802.11ax
  - Discussions on the initial proposal of regulatory rules change
- December 2019: 12th meeting
  - Discussions on the proposal of coexistence studies to the existing services
  - Discussions on the essential features of the draft technical report of the working party
- January 2019: 13th meeting
  - Confirming the draft technical report and submitting it to the parent committee (the committee of land radio communications)
- January 2019: the 46th meeting of the committee
  - Approval of call for "public comments" to the draft technical report
- From January 19 to February 21, public comments have been received.

→ Currently, comment resolution for the public comments are under discussion.

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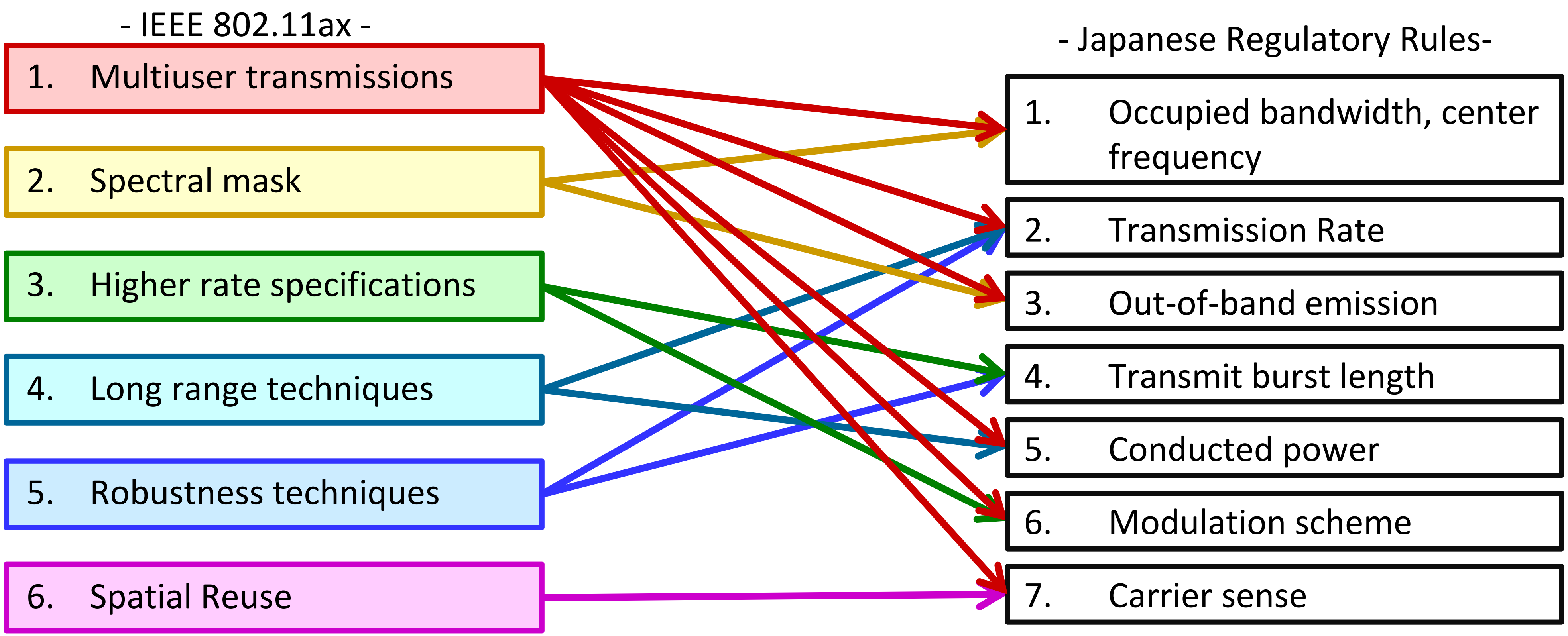
Relation between Technical features of IEEE 802.11ax and Japanese Regulatory Rules

- The working party discussed and concluded the technical condition of the radio regulatory changes for IEEE 802.11ax.
- In addition, coexistence studies were conducted, which shows that IEEE 802.11ax does not cause harmful interference to the existence services.



Following slides explain the conclusions and additional technical aspects, which were discussed and confirmed at the working party for 5 GHz wireless LANs.[10]

1. Occupied Frequency Bandwidth, Center Frequency

- IEEE 802.11ax newly defined dense subcarrier allocation (4x subcarrier) and additional subcarrier at the edges of the spectrum.
  → Occupied frequency bandwidth becomes slightly wider than current rules.
- To consider future expansion (e.g. post-IEEE 802.11ax) in advance, occupied frequency bandwidth should be set to 20 MHz x 2^n (n=0, 1, 2, 3).

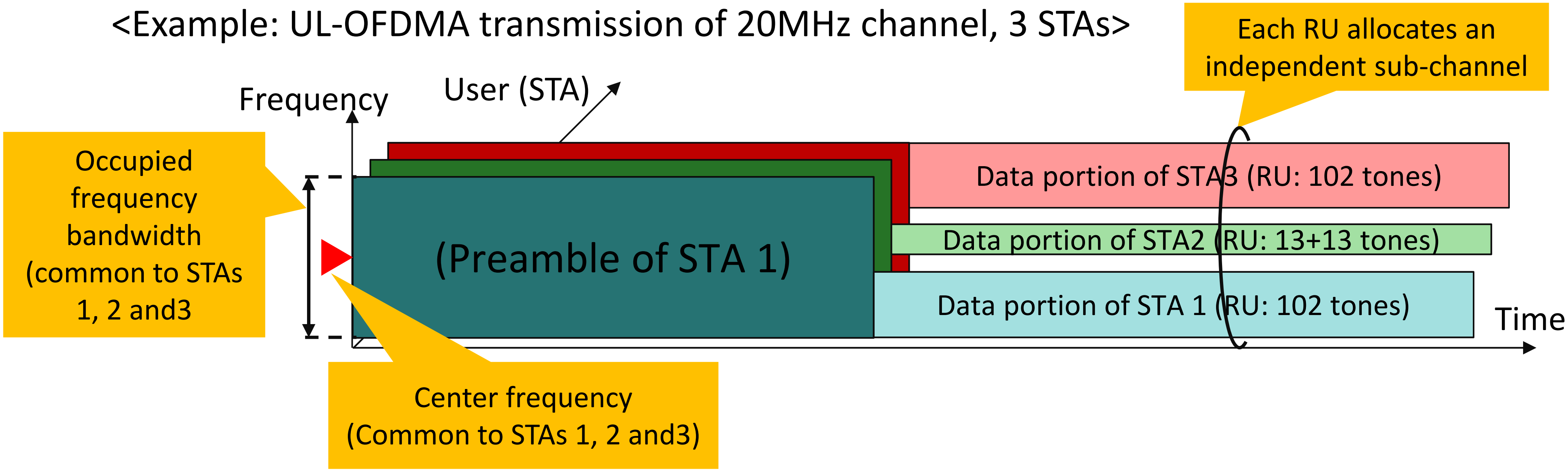
Bandwidth in IEEE 802.11 (a/n/ac/ax)	Maximum occupied frequency bandwidth[1)]	Occupied bandwidth in IEEE 802.11ax (Approximately)	(Proposed change)
20 MHz	5.2/5.3 GHz band: 19MHz 5.6 GHz band: 19.7 MHz	19.14 MHz	20 MHz
40 MHz	38MHz	38.20 MHz	40 MHz
80 MHz	78 MHz	78.20 MHz	80 MHz
160 MHz	158 MHz	158.28 MHz	160 MHz
80+80 MHz	78 MHz (per freq. segment)	78.20 MHz (per freq. segment)	80 MHz (per freq. segment)

[1)] Radio Equipment Regulations, Additional Table, 2-30

1. Occupied Frequency Bandwidth, Center Frequency

- Center frequency and occupied frequency bandwidth for each RU in OFDMA
  - An RU individually occupies a part of entire channel and thus there is no overlap between RUs.
  - Point-to-Multipoint (DL-OFDMA) or Multipoint-to-point (UL-OFDMA) communication
  - On the other hands, preamble part has one of the existing channel bandwidth set (20, 40, 80, 160, or 80+80MHz)

<Example: UL-OFDMA transmission of 20MHz channel, 3 STAs>



→ Proposal: Occupied frequency bandwidth and center frequency should be defined and measured at not data portion (RU) but the preamble portion.

2. Transmission Rate

■ Should transmission rate rule be changed or not ?

→ Proposal: No Changes.

> ホ Signal transmission rate shall be as follows:
> (1) When occupied bandwidth is 19 MHz or less, at least 20 M bit/s shall be supported.

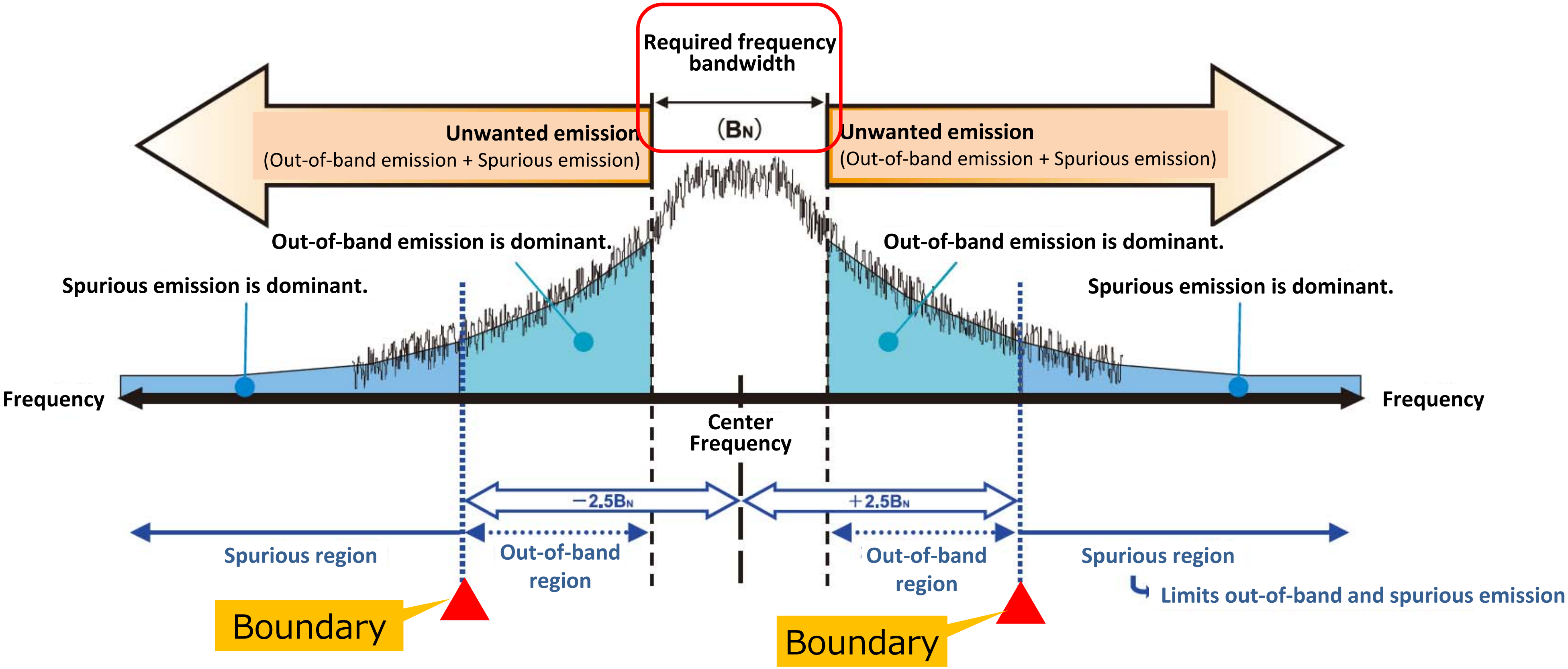
- The transmission rate rules defined in 1999 for broadband wireless services.
- Current rules defines the supported transmission rate of 20/40/80/160/160Mbps to 20/40/80/160/80+80 MHz channels, respectively.
- IEEE 11ax defines narrowband RU (i.e. 2 MHz), which minimum transmission rate is 0.4 Mbit/s*.
- On the other hands, the requirement of transmission rate for lowest spec device in IEEE 802.11ax (20MHz only non-AP HE STA), maximum supported rate shall be 37.5Mbit/s** or more.

  → This means all of IEEEE 802.11ax transceiver achieves more than 20 Mbit/s.

* In the case of 26-tone RU, Nss = 1, MCS = 0, DCM (Dual Carrier Modulation)[8]
** In the case of 106-tone RU, Nss = 1, MCS = 7, GI=0.8us[8]

3. Out-of-band emission (1/3)

- Out-of-band region and spurious region is defined according to required frequency bandwidth (B_N)[11]
  - (Radio Law Enforcement Regulations, 2-62) “Required frequency bandwidth” is defined as the minimum frequency bandwidth to achieve sufficient transmission rate and quality in specific conditions. In this case, required emission of carrier waves in reduced carrier systems to achieve sufficient performance is included in the required frequency bandwidth.



3. Out-of-band emission (2/3)

- Occupied frequency bandwidth and required frequency bandwidth in current rules

	Occupied frequency bandwidth	Required frequency bandwidth(B_N)
20MHz system	5.2/5.3 GHz band: 19MHz 5.6 GHz band : 19.7MHz	18MHz
40MHz system	38MHz	36MHz
80MHz system	78MHz	76MHz
160MHz system	158MHz	156MHz
80+80MHz system	78MHz (per freq. segment)	78MHz (per freq. segment)

→ Proposal: As well as occupied frequency bandwidth, required frequency bandwidth should set to be 20 MHz x 2^n and out-of-band emission masks should be defined the B_N.

	Occupied frequency bandwidth	Required frequency bandwidth(B_N)
20MHz system	5.2/5.3/5.6 GHz band: 20MHz	20MHz
40MHz system	40MHz	40MHz
80MHz system	80MHz	80MHz
160MHz system	160MHz	160MHz
80+80MHz system	80MHz (per freq. segment)	80MHz (per freq. segment)

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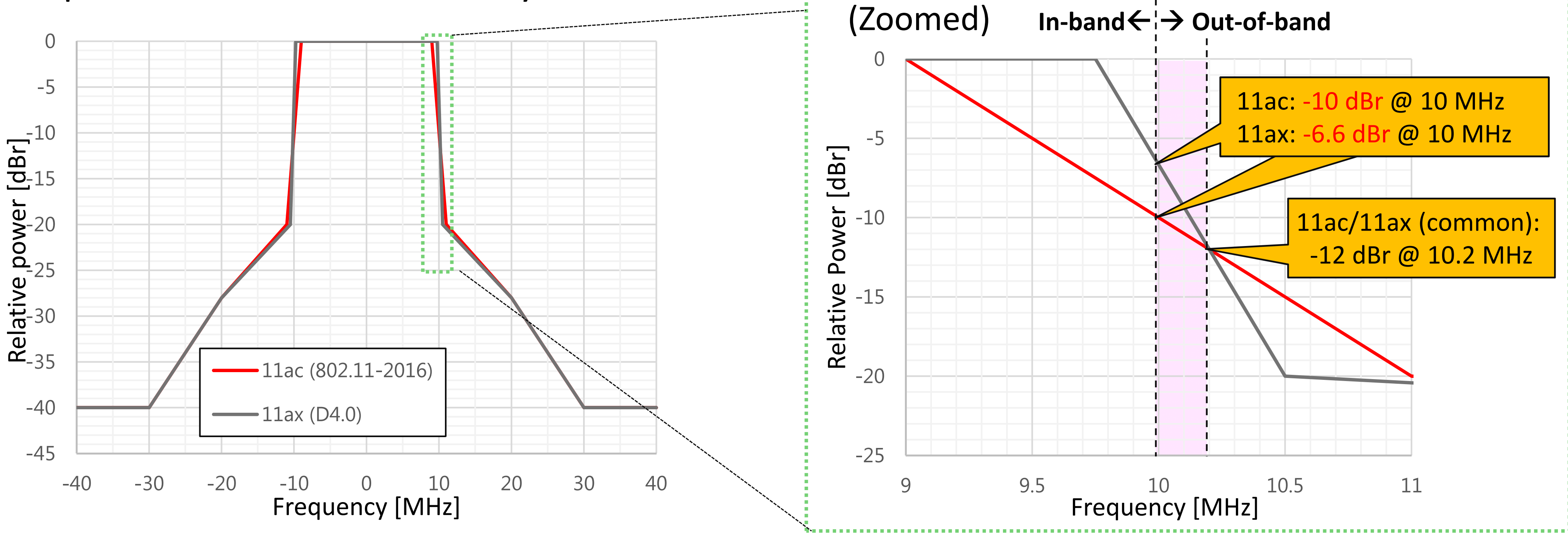
3. Out-of-band emission (3/3)

- Spectrum mask of 20 MHz transmission in IEEE 802.11ax exceeds IEEE 802.11ac's mask. (only one exception)

<Spectrum mask for 20 MHz systems>



- Proposal: Spectrum mask of 20MHz systems operated in 5.2/5.3 GHz bands should be relaxed* .

* The working party confirmed that the increased out-of-band emission does not cause harmful interference to the existing services.

4. Transmission Burst Length (1/2)

Radio Equipment Regulations, 49-20-3
^ Transmit burst shall be equal to or less than 4 ms.

- Existing Rule: 4ms or less
  - The rule is the result of the coexistence study between HiSWANa (Japanese normadic wireless standard compatible with ETSI HIPERLAN/2) and IEEE 802.11a.
    - When HiSWANa (ARIB STD T-70, maximum frame length of 2ms) and IEEE 802.11a (variable frame length) coexist on the same channel, the chance of access to the channel becomes equal by setting the maximum length of burst in IEEE 802.11a.
    - However, in present , wireless devices compliant with HiSWANa is hardly used. (The type approvals of HiSWANa devices are no longer obtained.)
- On the other hands, IEEE 802.11ax requires longer bust length than 4 ms.
  - Merits: Overhead reduction, Single training sequence for transmit beamforming with large number of STAs, Improved channel access for retransmission, etc.
  - IEEE 802.11ax introduces “Mid-amble”, which is a kind of pilot signal to re-estimate channel state information in the middle of frame. Even if channel fluctuation within a long frame is high,
  - Extension of transmission burst length makes transmission time of existing WLAN less; however, carrier sense function guarantees fairness to access to channel among all of WLAN devices.

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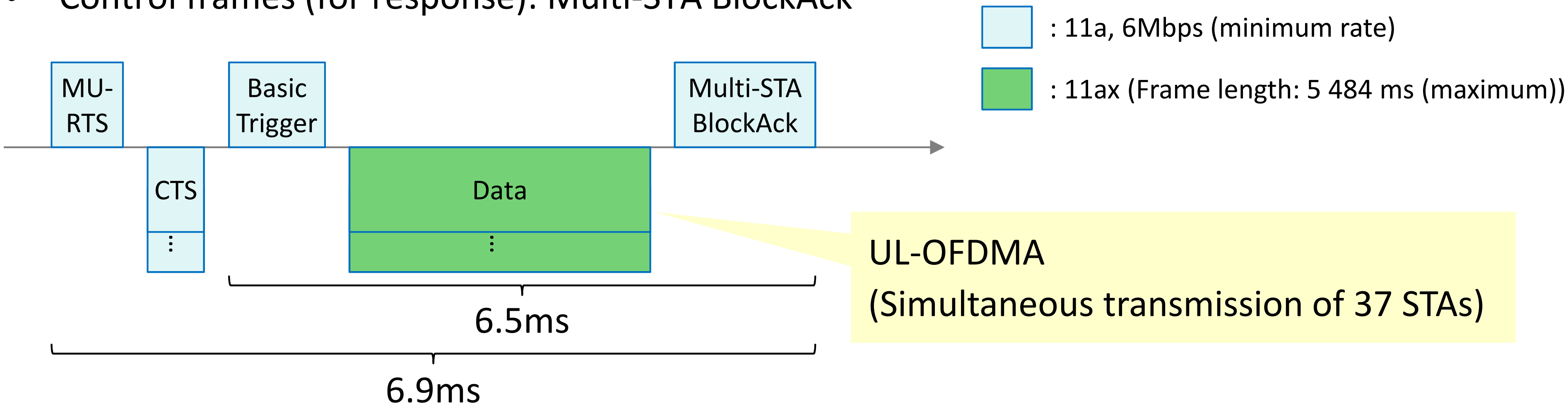
4. Transmission Burst Length (/2)

- The maximum frame sequence length of IEEE 802.11ax
  - ➢ The number of simultaneously transmitting STAs affects the amount of information volume in control frames.
  - ➢ The UL MU-MIMO transmission in IEEE 802.11ax supports up to 37 STAs per 80 MHz channel. The corresponding frame sequence is as follows:
    - Trigger frame: MU-RTS + Basic Trigger
    - Control frames (for response): Multi-STA BlockAck



  - ➢ In addition to this sequence, other frame exchanges such as retransmissions of erroneous frames and training sequences for transmit beamforming should be considered.

→ Proposal: Maximum burst length should be extended to 8 ms.

5. Conducted Power

- The maximum conducted power is defined as power spectrum density (in mW/MHz). Total conducted power is common to all variations of channel bandwidth.
  → Proposal: No change to current rules (except occupied frequency bandwidth)

Occupied frequency bandwidth	Maximum conducted power
19 MHz or less	10 mW/MHz
More than 19 MHz and equal to or less than 38 MHz	5 mW/MHz
More than 38 MHs and equal to or less than 78 MHz	2.5 mW/MHz
More than 78 MHz and equal to or less than 158 MHz	1.25 mW/MHz

→

Occupied frequency bandwidth	Maximum conducted power
20 MHz or less	10 mW/MHz
More than 20 MHz and equal to or less than 40 MHz	5 mW/MHz
More than 40 MHs and equal to or less than 80 MHz	2.5 mW/MHz
More than 80 MHz and equal to or less than 160 MHz	1.25 mW/MHz

- Expansion of occupied frequency bandwidth makes slight increase of total conducted power (e.g. from 190 mW to 200 mW in 20 MHz systems). The past coexistence studies already use the parameter of 200 mW of conducted power per device as in-band emission and thus the results of the coexistence studies are not changed.
- On the other hands, the influence of out-of-band emission should be evaluated.

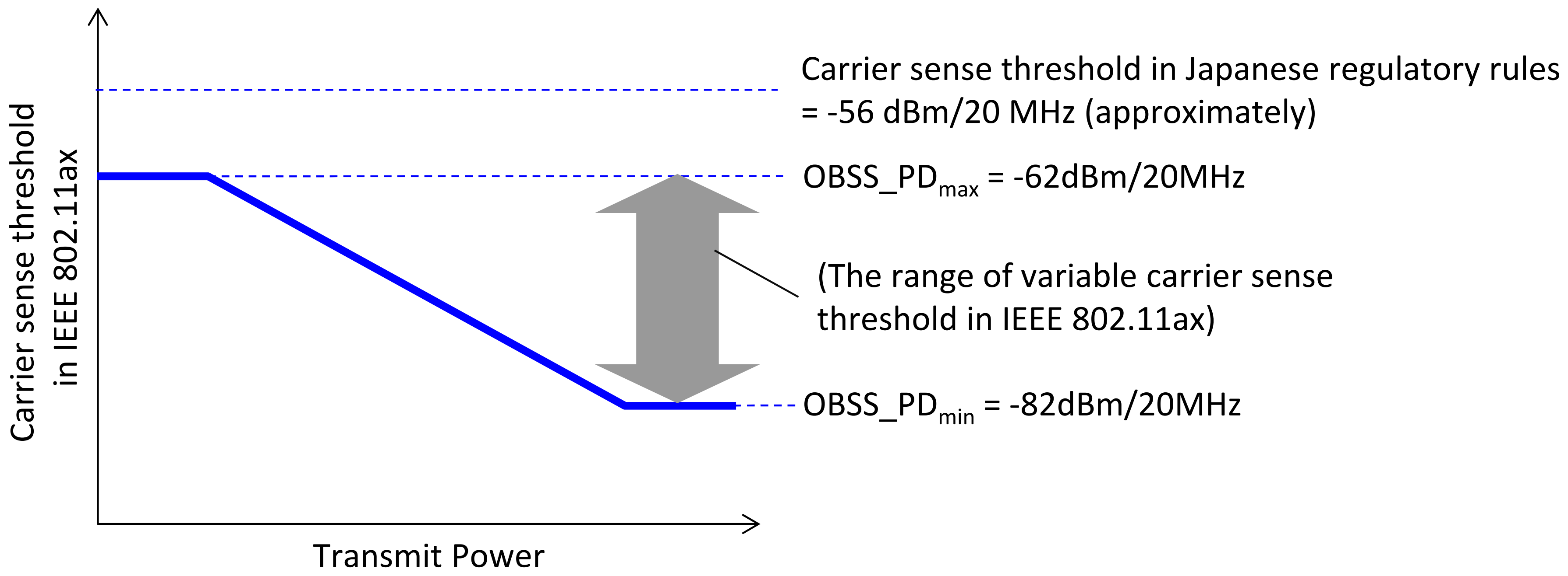
6. Modulation Scheme

- OFDMA transmission is categorized as one variation of OFDM transmission.
- In Japanese regulatory rules, density of tone (subcarrier) is defined as “more than one subcarriers per 1 MHz channel in Radio Equipment Regulations of 49-20-三-リ.
- IEEE 802.11ax uses a subcarrier space of 78.125 kHz, which is narrower than that in IEEE 802.11ax and is included in the current rules.
- A narrowband RU (e.g. 2 MHz) in UL-OFDMA is recognized as sparse subcarrier allocation because the occupied bandwidth is defined as 20MHz x 2^n. Actually, in the three exceptional patterns (out of 113), the number of subcarriers per 1 MHz channel is less than one.
- However, all of UL-OFDMA frames put preamble with 20MHz x $2^n$of bandwidth at the head of a RU, which is considered to meet the subcarrier density rule.
- IEEE 802.11ax newly introduces 1024 QAM. In Japanese regulatory rules, there is no specific requirement regarding subcarrier modulation scheme.

→ Proposal: No change regarding modulation scheme.

7. Carrier Sense (1/2)

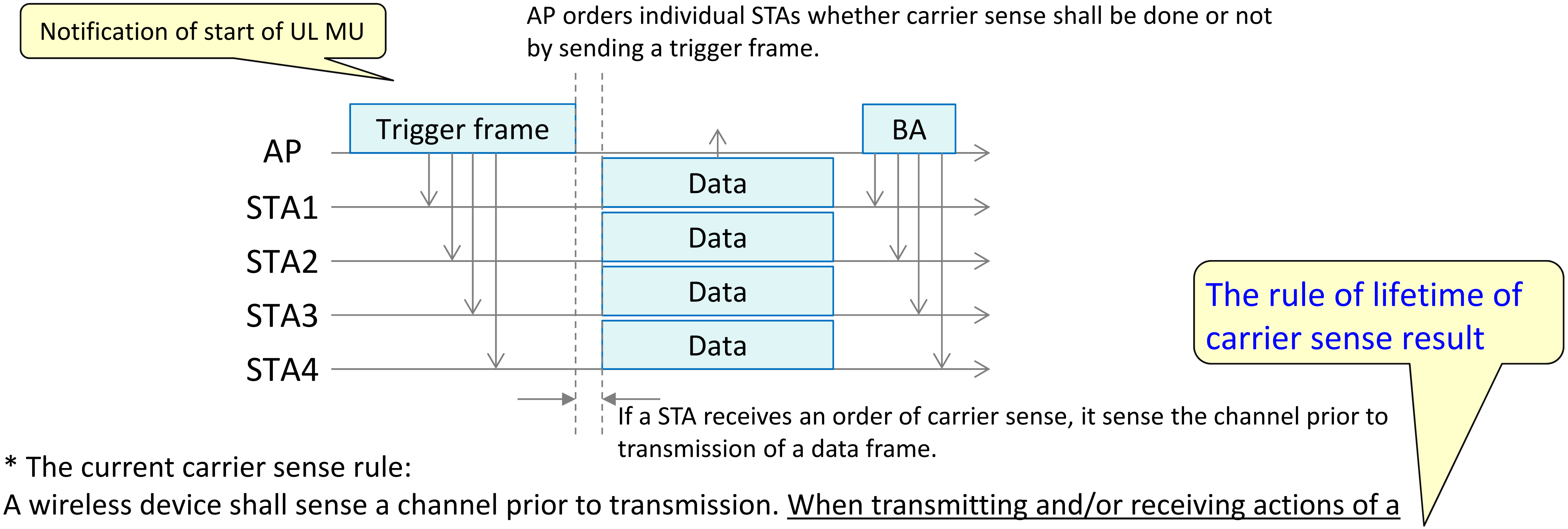
- Japanese regulatory rules define the threshold of carrier sense level as (approximately) -56 dBm/20 MHz channel (original rule is -100uV/m in 20 MHz channel).
- In IEEE 802.11ax, the carrier sense threshold is dynamically controlled; however, the variable threshold is always smaller than the current rules.



→ Proposal: No change in carrier sense threshold.

7. Carrier Sense (2/2)

- When a STA transmit a UL MU frame just after receiving a trigger frame, it is exempted from carrier sense in some cases.
- This exemption rule is matched with the current rule* and thus there is no need for additional rules.

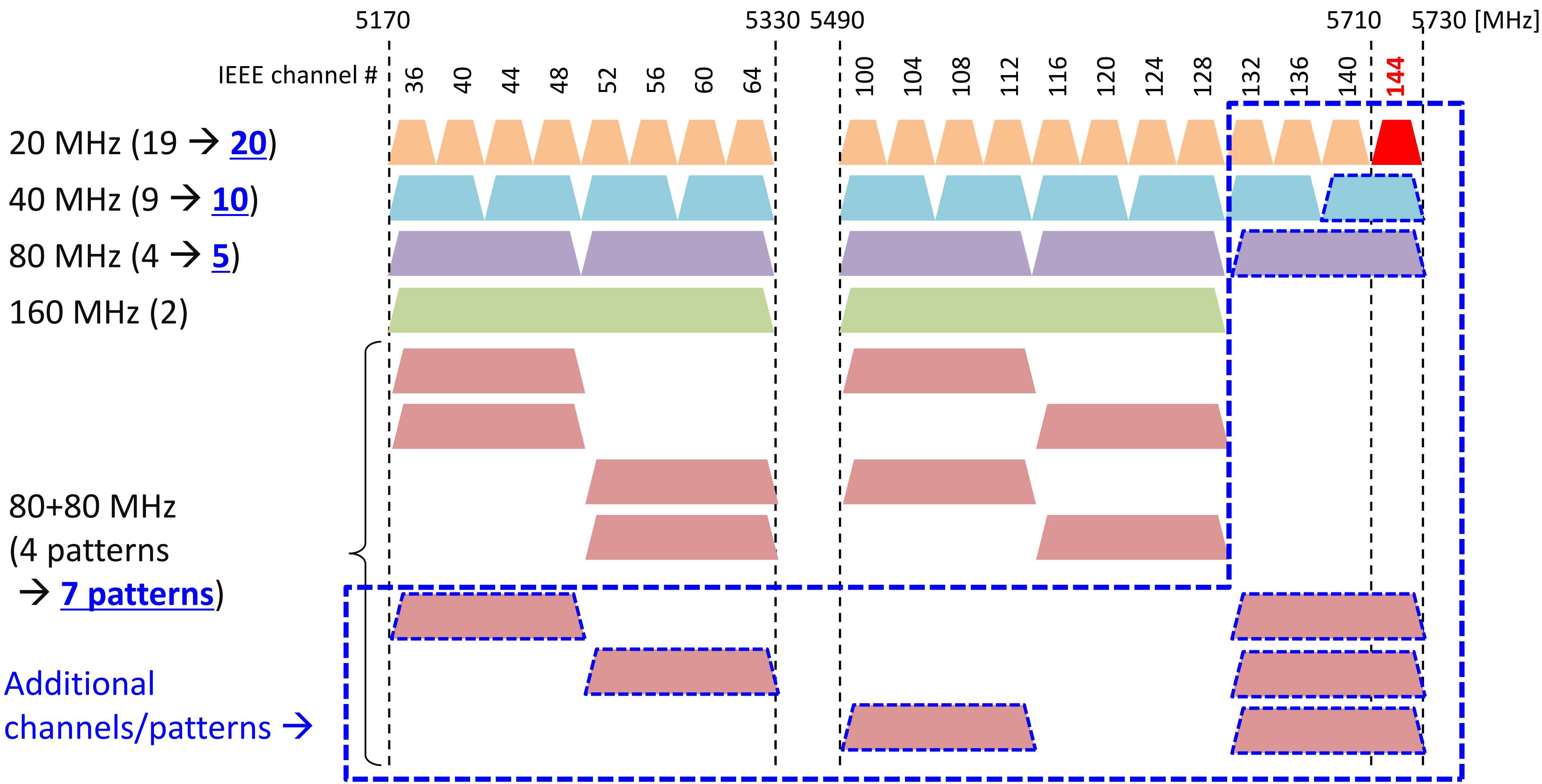


* The current carrier sense rule:
A wireless device shall sense a channel prior to transmission. When transmitting and/or receiving actions of a wireless device is controlled by (an)other wireless device(s), or when a wireless device retransmit a burst **within 4 ms after the previous sensing of a channel,** the device is exempt from carrier sense.

→ Proposal: Lifetime of carrier sense result should be extended to 8 ms, which corresponds to maximum burst length.

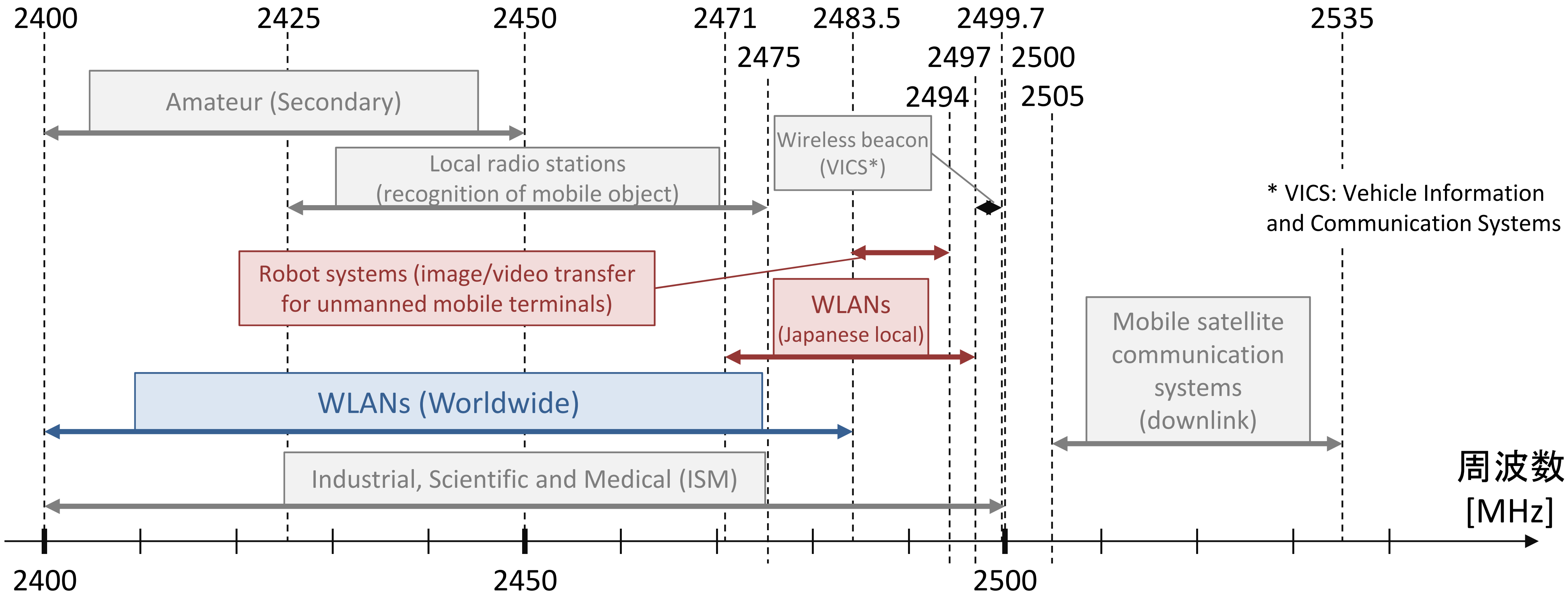
Extension of Frequency Channel in 5.6 GHz Band

- Adding one 20 MHz channel (144ch) enables IEEE 802.11 WLANs to use additional channels (one 40 MHz channel, one 80 MHz channel, three patterns of 80+80 MHz) [12][13]



Coexistence Studies to Existing Systems (2.4 GHz band)

- IEEE 802.11ax can coexist with all of the existing systems in 2.4 GHz band without causing harmful interferences.

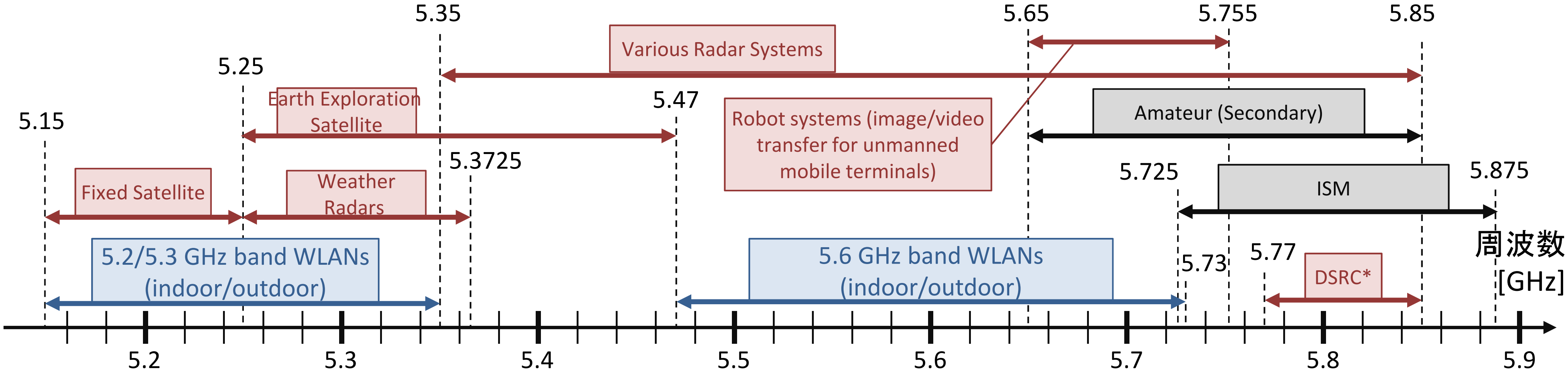


System for coexistence study	Results
Robot systems (image/video transfer for unmanned mobile terminals)	IEEE 802.11ax preserves sufficient interference margin to the robot systems. → O.K.
Existing WLANs (IEEE 802.11b/g/n)	IEEE 802.11ax defines a carrier sense function as a mandatory feature as well as the existing WLANs. Existing carrier sense rules guarantees fair channel access between IEEE 802.11ax and legacy devices. → O.K.

Coexistence Studies to Existing Systems (5 GHz bands)

- IEEE 802.11ax can coexist with all of the existing systems in 5 GHz band without causing harmful interferences. [13][14][15]

* DSRC: Dedicated Short Range Communications



Freq. band	System for coexistence study	Results
5.2 GHz	Fixed Satellite (MSS feeder link)	In indoor usage, as far as maximum EIRP per WLAN device is 200 mW, IEEE 802.11ax can coexist with the fix satellite services. In outdoor usage, elevation angle mask for EIRP and the control of the number of devices by registration process in the existing rules makes sure IEEE 802.11ax does not cause harmful interference.
	Weather Radars (5.3 GHz band)	The same conditions for the fixed satellite services enable the coexistence.
5.3 GHz	Weather Radars	The current conditions (indoor-only usage and mandatory requirements of DFS/TPC) enables the coexistence.
	Earth Exploration Satellite	The current conditions (indoor-only usage and mandatory requirements of DFS/TPC) enables the coexistence.
5.6 GHz	Various Radars	The current conditions (mandatory requirements of DFS/TPC and maximum EIRP of 1 W) enables the coexistence.
	Robot systems	Because the amount of interference from IEEE 802.11ax to the robot systems is identical to the existing WLANs, the current conditions (mandatory requirements of DFS/TPC and maximum EIRP of 1 W) enables the coexistence.
	DSRC	In addition to the current conditions (mandatory requirements of DFS/TPC and maximum EIRP of 1 W), if unwanted emission of WLANs in the band between 5770 and 5777 MHz is kept to the current level, the coexistence between WLANs and DSRC systems is possible.

Summary of Proposed Technical Conditions

- The proposal includes new frequency channel (144ch), increased occupied frequency channel (and related revisions of out-of-band emission mask), extension of maximum transmit burst and lifetime of carrier sense result as highlighted.

Frequency Bands →	2.4GHz band	5GHz bands	
Region of frequency	2400 – 2483.5MHz	5150 - 5250MHz 5250 – 5350MHz	5470 – 5730MHz
Occupied bandwidth	26/40MHz	20/40/80/160 MHz	
Modulation scheme	OFDM	OFDM	
Max. conducted power	200 mW	200 mW	
Max. antenna gain	12.14 dBi	(Not specified)	
Max. EIRP	(Not specified)	200mW/1W* * Only for registered APs in 5.2GHz band	1W
Max. transmit burst length	(Not specified)	8ms	
Carrier sense	Mandatory only to 40 MHz systems	Mandatory to all devices (Lifetime of carrier sense result: 8ms)	
DFS/TPC	Not required	Mandatory only to 5250 – 5350 MHz	Mandatory
Connection topology	Any	Any (For outdoor operation or DFS bands, STA shall be connected to AP)	

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