Power Save on 802.11ax MAC

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Power Save Mode (PSM) on 802.11ax MAC

Key Features of 802.11ax MAC

OFDMA helps realize MU UL in 802.11ax, as a result leading to Trigger-based UL. See figure 1.

PS on 802.11ax will have big difference since UL is scheduled by AP. Proposed PSMs for 802.11ax are as following slides.

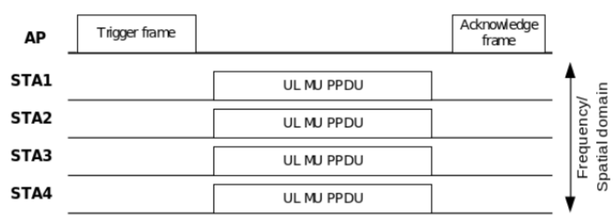


Figure 1: trigger-based MU UL[1]

Passive PS(PPS)

Passive PS save power by turning off its radio until the end of transmission of intra-BSS for others. To realize this mechanism, **BSS color**, **STA identifier**, **UL/DL indicator** are set in HE-SIG-A/HE-SIG-B.

According to [2], an HE STA may enter the Doze state until the end of an PPDU if the following conditions are true:

- same BSS color
- DL but not the same identifier; or UL

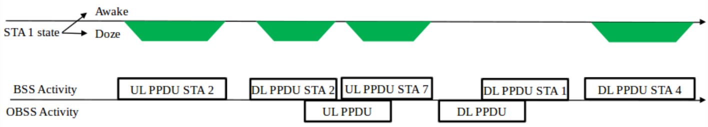


Figure 2: Passive PS for 802.11ax[2]

PS for Random Access(PSRA)

Since trigger frame for random access(TF-R) proceeds the UL transmission, STA couldn't start UL transmission until TF-R arrives. STA could "sleep" until TF arrives. That's the intuitive idea behind PSRA.

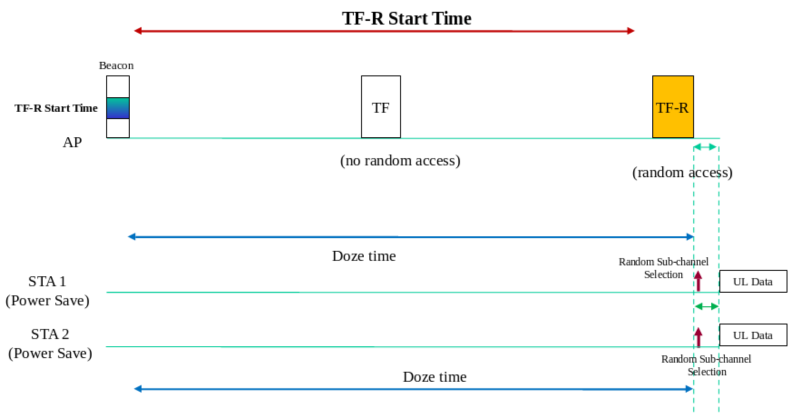


Figure 3: PSRA[3]

Problems of Proposed PSM for 802.11ax

- PPS helps PS with dense scenario. The heavier loading traffic, the more energy are saved. However, when in sparse scenario, only one STA in BSS, the STA will not save any energy.
- Current PSRA is not a complete approach.
- Since in legacy 802.11 versions, UL is scheduled by STAs themselves, PS only considers DL traffic. While trigger-based UL is the main difference from legacy 802.11 versions, we will focus on PS for UL.

My PS design for 802.11ax

My PS design for 802.11ax

Since UL is based on triggered frame(**TF**), the design is as illustrated in figure 4.

1. Two kinds of TF are issued here. **TF-R** for request collection, regular **TF** for resource allocation.
2. TF-R is scheduled periodically with period T, which is well-known by all STAs.
3. **More bit** is set when the allocated resource is not enough for the UL traffic.

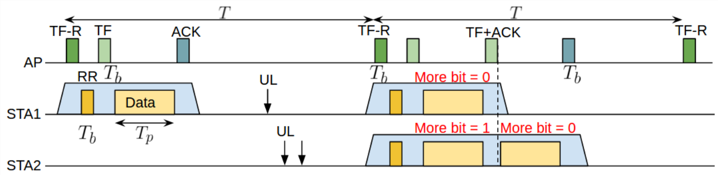


Figure 4: PS for 802.11ax UL

Problem Formulation

Problem Formulation

Assumption

No channel fading

P_{TX} is a constant.

IFS is ignored.

TF-R's DCF contending is ignored.

Poisson Arrival λ for each STA UL

Notations

E: energy consumed

P_{TX}: power consumption of TX

$\triangle_{TX}$: avg prob. in TX state

$$E = \triangle_{RX} P_{TX} + \triangle_{TX} P_{RX} + \triangle_{idle} P_{idle} + \triangle_{doze} P_{doze} \tag{1}$$

We only consider UL traffic here. Since IFS and DCF contending are ignored here and STAs know when TF-R will arrive, with PS, STA could wake up only for transmission. That means no idle state. On the contrary, without PS, duration of doze state is replaced by idle state.

$$\text{with PS: } \triangle_{doze} = 1 - \triangle_{RX} - \triangle_{TX} \tag{2}$$

$$\text{without PS: } \triangle_{idle} = 1 - \triangle_{RX} - \triangle_{TX} \tag{3}$$

Problem Formulation

Notations

T_b: time for transmitting a control frame

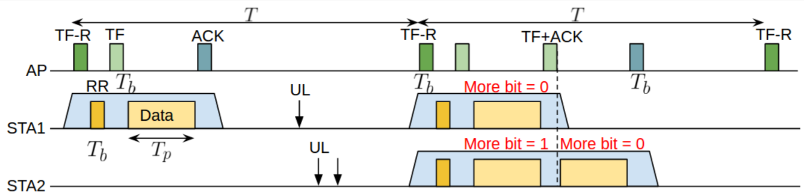
T_p: time for transmitting a data frame under normal data rate

UL: mum. of UL packets to be sent in the current TF period

R: allocated resource (date rate)

$$\triangle_{TX} = (\frac{UL}{R} T_p + T_b)\frac{1}{T} \tag{4}$$

$$\triangle_{RX} = (UL T_b + 2T_b)\frac{1}{T} = (2 + UL)\frac{T_b}{T} \tag{5}$$



Compute UL and R

Notations

UL: mum. of UL packets to be sent in the current TF period
R: allocated resource (date rate)
n_c: num. of channels
N_s: num. of suc RR STA
p_s: prob. of suc RR

$$R = \frac{n_c}{N_s} \tag{6}$$

$$\begin{aligned} UL &= \lambda T + \lambda T(1-p_s) + \lambda T(1-p_s)^2 \cdots \\ &\approx (2-p_s)\lambda T \end{aligned}$$

The approximation is reasonable, since $(1-p_s)$ is tiny. And high order means UL packets are delayed for long time in STA, which should be discarded.

Compute N_s and p_s

Notations

N_s: num. of suc RR STAs

n_s: num. of suc contending STAs

n_c: num. of channels

p_s: prob. of suc RR

p_{cs}: prob. of suc contending

p_{ss}: prob. of being selected

$$N_s = \min\{n_s, n_c\} \tag{7}$$

$$p_s = p_{cs} p_{ss} \tag{8}$$

Compute p_{cs} , p_{ss} and n_s

Notations

n_s: num. of suc contending STAs

n_c: num. of channels

p_{cs}: prob. of suc contending

p_{ss}: prob. of being selected

c_n: num. of contending STA

c_s: contending window size

n: num. of all STAs

$$E[c_n] = (1 - \exp^{-\lambda T})^n \tag{9}$$

$$p_{cs} = (\frac{c_w - 1}{c_w})^{E[c_n]} \tag{10}$$

$$n_s = E[c_n] p_{cs} \tag{11}$$

$$p_{ss} = \frac{n_s}{n_c} \tag{12}$$

Issues

Issues

I will do:

1. Analyze the performance of the design, especially in dense scenario. (With or without PS design)
2. Simulate to invalidate the analysis.

Thanks

References I

UI mu procedure.
2015-03-09.

Identifiers in he ppdus for power saving.
2015-09-12.

Power save with random access.
2015-09-14.

Power Save of infrastructure WiFi

In infrastructure mode, we only care the energy consumption of STA. And because STAs could send the up-link(UL) packets immediately once the UL packet arriving, we regard UL as efficient transmission. We care DL transmission.

A legacy power save mode(PSM) is illustrated here, with parameter beacon interval(BI) and listen interval(LI). See next slide.

PSM

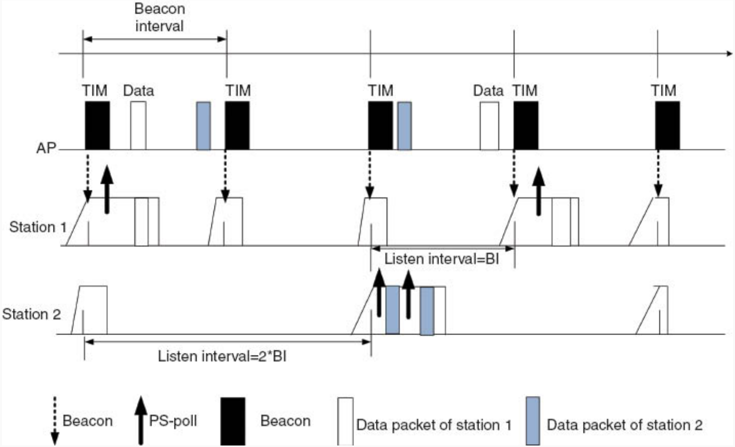


Figure 5: Illustration of PSM