AN14111

Target Wake Time (TWT) on RW61x

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Document information

Information	Content
Keywords	target wake time, wake-up interval, agreement phase, negotiation phase, service period, low-power state, power-down state, active state
Abstract	Describes the target wake time feature and provides examples for RW61x.

1 Overview

IEEE 802.11ax standard supports the target wake time (TWT) feature for 2.4 GHz and 5 GHz. The feature is used to manage the activity of the Wi-Fi stations (STA) and access points (AP) in a basic service set (BSS), where TWT parameter values define how often and for how long a STA is in active state to send and/or receive data.

Compared to the standard power save modes, the power consumption of 802.11ax devices with TWT enabled is significantly reduced. The spectral efficiency is also optimized as there is less contention and overlap between users. TWT is most beneficial for IoT devices such as sensors and actuators.

1.1 Prerequisites

By default, when RW61x is in low-power mode (PM3)[1], the on-chip SRAM is powered down and no data is retained in the memory. To disable the data retention loss in the memory:

- Download the latest SDK from [2].
- Edit *host_sleep.h* file located in *rdrw612bga/wifi_examples/wifi_cli/* directory:
  - Remove the macro `#define WLAN_MEM_PD_CFG (1UL << 8)`
  - Add the macro `#define WLAN_MEM_PD_CFG ((1UL << 8) | 0x3FUL)`

  Note: `0x3FUL` *is the value used to change the configuration of the register that controls the SRAM status in PM3 mode.*
- Build wifi_cli application from MCUXpresso IDE/ IAR/ ARMGCC/ MDK. Refer to [1].

Note: *This change is required to fully utilize and benefit from TWT.*

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1 [Figure 3](#) shows a example of RW61x current consumption measurement when the MCU is in low-power mode.

2 Sequence

The sequence of target wake time includes:

- The negotiation phase: the AP and STA(s) negotiate the TWT parameters to access the medium.
- The agreement phase: the AP and STA(s) agree on the TWT parameters and service period (SP).
- The service period (SP): the wake-up duration. Period of time during which the STA must be awake and active.

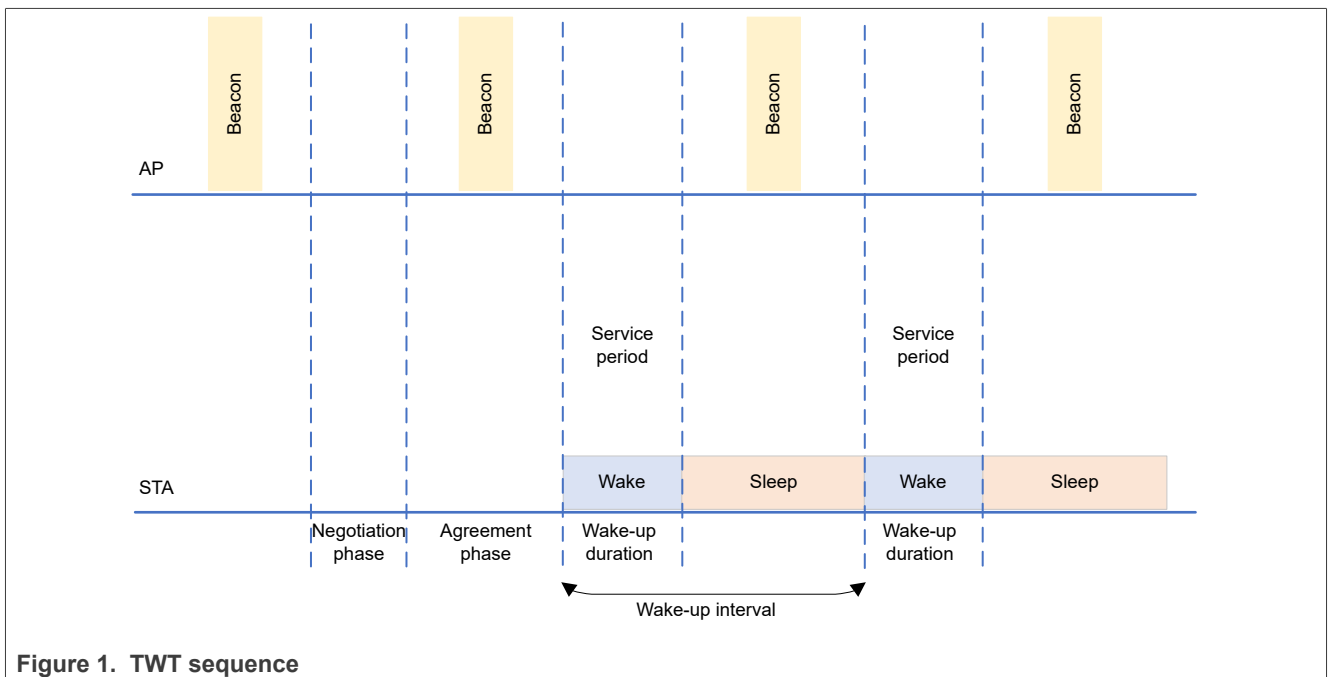Figure 1 shows the negotiation phase, agreement phase, wake-up duration/service period in the TWT sequence.

Figure 1. TWT sequence

3   TWT parameters

During the negotiation phase, the AP and STA(s) define the following TWT parameter values:

- Explicit/implicit: an AP will/will not send frames in the current service period (SP) to notify a STA of the start of the next SP.
- Announced/unannounced: at the beginning of the SP, a STA will/will NOT send a QoS NULL frame with active mode (PM0) to notify the AP that the STA is awake.
- Trigger/non-trigger: an AP will/will NOT use the OFDMA trigger-based mechanism set in the SP. If the trigger-based mechanism is enabled in the SP, the STA does not send data to the AP until a trigger is received.
- TWT info disabled/enabled: indicates whether TWT information frames are acceptable or not during the TWT session
- Individual/broadcast TWT:
  - Individual TWT (ITWT): initiated by a single STA to determine the wake interval (wake-up duration and start of sleep time)
  - Broadcast TWT (BTWT): scheduled by an AP in its beacon frames. Allows an AP to set up a shared TWT session for a group of STAs and restate the TWT parameters
  Note: The RW61x only supports ITWT in STA mode (not BTWT).
- Wake-up duration: period of time during which the STA must be awake and active.
- Flow identifier: up to eight TWT sessions can run in parallel based on a unique 3-bit flow identifier.
- Tweak/Not tweak: if the TWT parameters are not agreed upon, the FW can internally tweak/not tweak the parameters to re-negotiate these.
- Exponent: 1-byte value used to calculate the wake-up interval. See Section 4.
- Mantissa: 1-byte value used to calculate the wake-up interval. See Section 4.
- Request/suggest:
  - Request: the STA requests the TWT parameters from the AP.
  - Suggest: the STA indicates the TWT parameters to the AP.

4 Wake-up interval calculations

The wake- up interval is determined by the target wake time exponent and mantissa ([Section 3](#)).

The formula is:

$$Wake\text{-}up\ interval = Mantissa \times 2^{Exponent} \tag{1}$$

Example:

- Exponent = 0x14 = 20 μs
- 2^20 μs = 1048576 us ~ 1 s
- Mantissa = 0x3c = 60 s
- 60 s/1 s = 60 ticks

For every second (exponent), 60 ticks occur.

5 Commands

Command used to dump, set, and apply the TWT parameters using the Wi-Fi CLI demo application:

```
# wlan-11ax-twt-setup <option> <param_id> <param_data>
```

Table 1. Command parameters

Parameter	Definition
option	dump = show all TWT parameters set = set a single TWT parameter done = apply the TWT parameters
param_id	Only applicable when option = set Identifier of a parameter 0 = explicit/implicit 1 = unannounced/announced 2 = non-triggered/triggered 3 = enable/disable TWT info 4 = individual/broadcast 5 = wake-up duration 6 = flow identifier 7 = hard constraint (tweak/not tweak) 8 = exponent 9 = mantissa 10 = request/suggest TWT
param_data	Only applicable when option = set 2 byte Hexadecimal data corresponding to the value of the parameter identified by param_id (in bytewise little-endian format)

Example of set exponent command:

```
# wlan-11ax-twt-setup set 8 14
```

Output example:

```
twt_exponent #### Range: [0-63]
[8]: 0x14
```

Example of set mantissa command:

```
# wlan-11ax-twt-setup set 9 3c 0
```

Output example:

```
twt_mantissa #### Range: [0-65535]
[9]: 0x3c 0x00
```

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Example of dump command:

```
#wlan-11ax-twt-setup dump
```

Output example:

```
twt_exponent #### Range: [0-63]
cfg[twt_setup] len[12] param_num[11]:
implicit #### 0: TWT session is explicit, 1: Session is implicit
[0]: 0x01
announced #### 0: Unannounced, 1: Announced TWT
[1]: 0x00
trigger_enabled #### 0: Non-Trigger enabled, 1: Trigger enabled TWT
[2]: 0x00
twt_info_disabled #### 0: TWT info enabled, 1: TWT info disabled
[3]: 0x01
negotiation_type #### 0: Individual TWT, 3: Broadcast TWT
[4]: 0x00
twt_wakeup_duration #### time after which the TWT requesting STA can transition to doze
 state
[5]: 0x40
flow_identifier #### Range: [0-7]
[6]: 0x00
hard_constraint #### 0: FW can tweak the TWT setup parameters if it is rejected by AP,
  1: FW should not tweak any parameters
[7]: 0x01
twt_exponent #### Range: [0-63]
[8]: 0x14
twt_mantissa #### Range: [0-65535]
[9]: 0x39 0x00
twt_request #### Type, 0: REQUEST_TWT, 1: SUGGEST_TWT
[10]: 0x00
```

Example of done command:

```
#wlan-11ax-twt-setup done
```

6 Example

The example uses two RW61x boards. One board is brought up as AP and the other board is brought up as STA. Different wake-up intervals are set.

Step 1 – Bring up one RW61x in uAP mode.

```
wlan-set-mac <MAC_address> // set MAC address
wlan-add <profile_name> ssid <ssid> ip:<ip_addr>,<gateway_ip>,<netmask> role uap channel
 <channel> // set the profile name, SSID, IP address, etc
wlan-start-network <profile_name> //start the AP
```

Step 2 – Bring up one RW61x in STA mode and connect the STA to the AP.

```
wlan-set-mac <MAC_address> // set MAC address
wlan-add <profile_name> ssid <ssid> <security> <secret_password> channel <channel> // set
 the profile name, SSID, etc of the uAP joining
wlan-connect test // connect to uAP
```

Step 3 – To further reduce the power consumption, enable IEEE power save mode on the STA.

```
wlan-ieee-ps 1
```

Step 4 – On the STA, configure TWT parameters.

Commands for 1 min wake-up interval:

```
wlan-11ax-twt-setup set 8 14 // configure exponent to 0x14
wlan-11ax-twt-setup set 9 3c 0 // configure mantissa to 0x003c
wlan-11ax-twt-setup done // apply configurations
```

Commands for 5 min wake-up interval:

```
wlan-11ax-twt-setup set 8 14 // configure exponent to 0x14
wlan-11ax-twt-setup set 9 2c 1 // configure mantissa to 0x012c
wlan-11ax-twt-setup done // apply configurations
```

Commands for 10 min wake-up interval:

```
wlan-11ax-twt-setup set 8 14 // configure exponent to 0x14
wlan-11ax-twt-setup set 9 58 2 // configure mantissa to 0x0258
wlan-11ax-twt-setup done // apply configurations
```

Step 5 – To maximize the power save, enable the low-power mode (PM3) on the host side of RW61x (Cortex-M33), and enable TWT on the controller/wireless radio side of RW61x.

```
wlan-host-sleep 1 manual
wlan-suspend 3
```

Command output example:

```
Enter low power mode PM3
```

7 TWT current consumption measurements

Table 2 includes RW61x current consumption values measured on VBAT pins at different wake-up intervals.

Table 2. RW61x current consumption values measured on VBAT pin

Conditions	Wake-up interval	BGA package [1]	QFN package [1]	Unit
MCU in sleep mode (PM3) Wi-Fi subsystem in low power mode Narrowband subsystem in power down mode	1 min	280	285	μA
	5 min	240	250	μA
	10 min	230	240	μA
	20 min	225	235	μA
	30 min	220	230	μA

[1]   0 KB memory retention

8 Appendix

Figure 2 shows the measurement of RW61x current consumption with the MCU (Cortex-M33) in active mode (PM0).
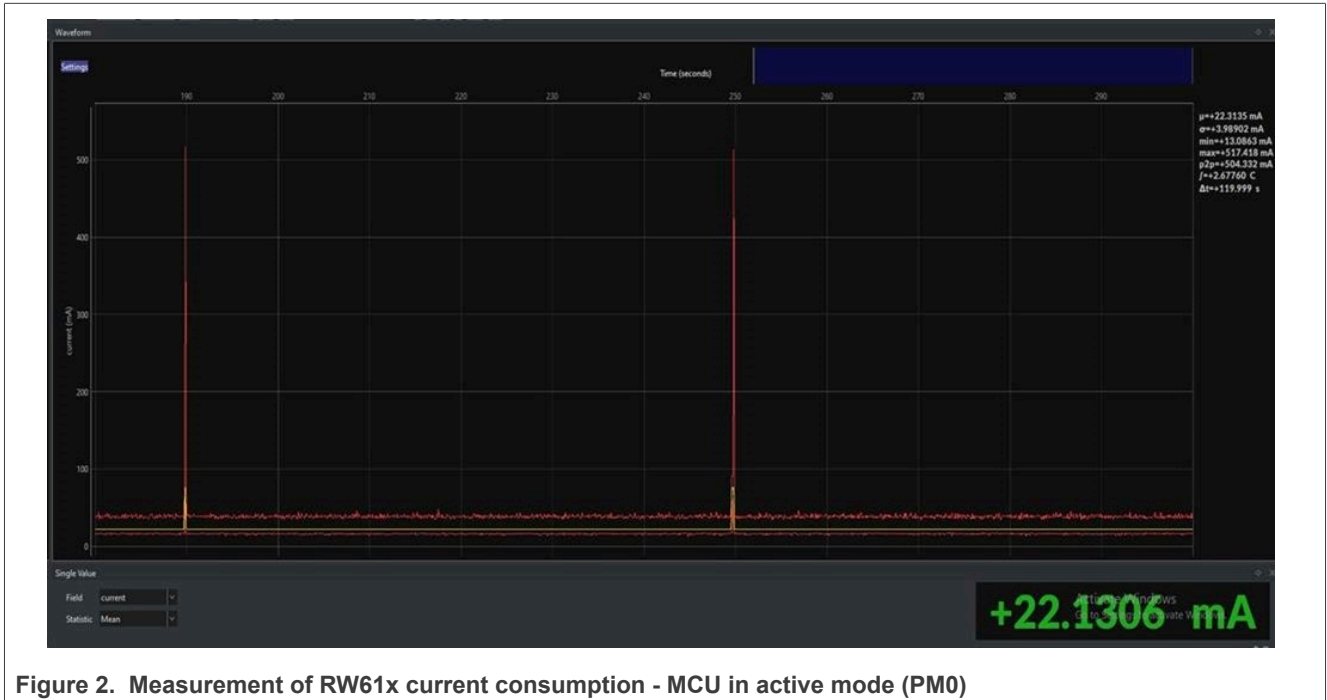

Figure 2. Measurement of RW61x current consumption - MCU in active mode (PM0)

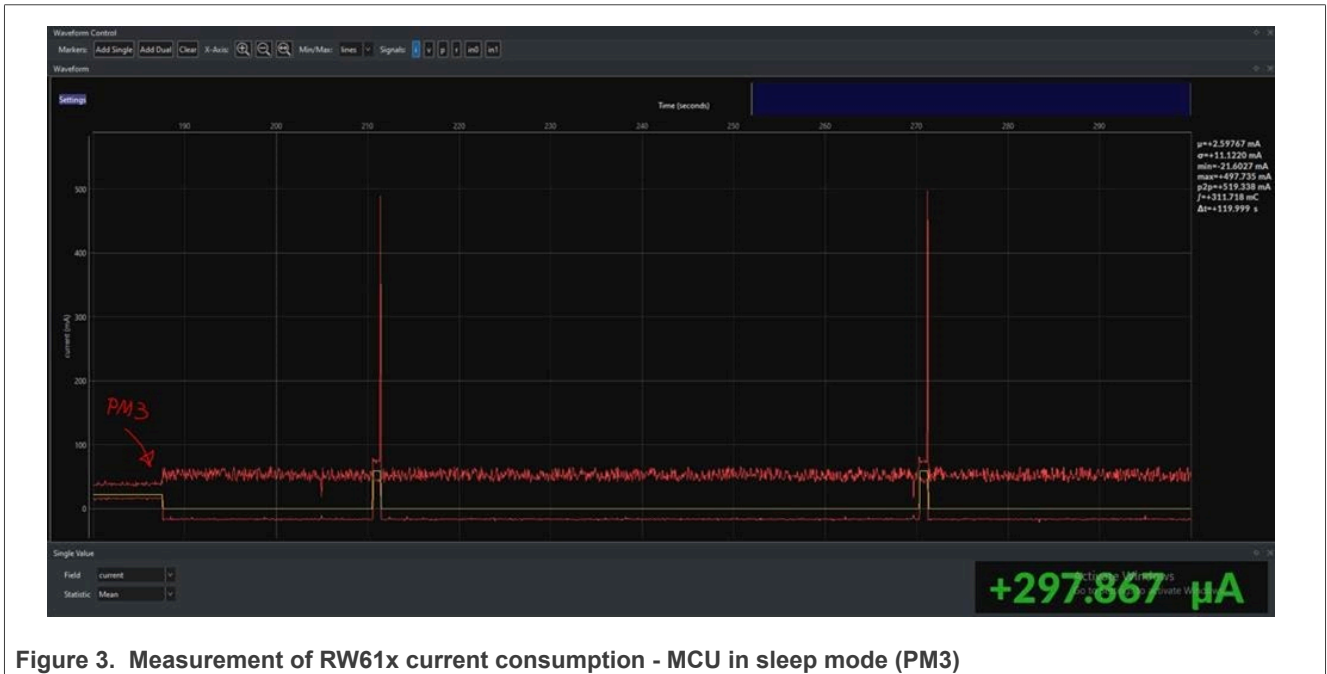Figure 3 shows the measurement of RW61x current consumption with the MCU (Cortex-M33) in sleep mode (PM3).

Figure 3. Measurement of RW61x current consumption - MCU in sleep mode (PM3)

9 Abbreviations

Table 3. Abbreviations

Acronym	Description
AP	Access point
BSS	Basic service set
BTWT	Broadcast TWT
ITWT	Individual TWT
QoS	Quality of service
SP	Service period
STA	Station
TWT	Target wake time

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10   References

[1]   User manual - UM11799 - NXP Wi-Fi and Bluetooth Demo Applications for RW61x

[2]   Web page – Select board | MCUXpresso SDK builder (link)

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12 Revision history

Table 4. Revision history

Document ID	Release date	Description
AN14111 v.1.0	21 June 2024	• Initial version

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