# BALI/EVIA series

**WiFi 802.11ac + BT5.0 LGA Wireless Modules**

# BALI/EVIA BALI M.2/EVIA M.2 SDIO Power Measurement Guide

**Version 0.4**

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# 1. Scope of the Document

This document describes how to measure Power consumption numbers on BALI SDIO and SDIO M.2 EVK in different modes like Standby mode and Power save mode, also describes what is Standby mode and what power save mode how it is enabled, those all things are covered in this document.

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# 2. Introduction

## 2.1 How do you save power

- Physical
    - Sending information determined by physics of RF transmission
    - 802.11 specifications is defined and limited by regulatory limits
    - Existing Transmit power management in proprietary hardware
- Transmit efficiency
    - Increasing the % of real data in the information consuming energy
- Turning things off
    - Minimizing power draw while waiting for information to send

## 2.2 Power save in WLAN

- Power save modes have always been part of 802.11 specification
    - Included in original 1999 specification
- Originally designed for wirelessly connecting laptops to networks
    - Large batteries
- Only recently with the addition of WiFi to mobile devices have smaller batteries been used with WiFi enabled devices
-  Greater focus on power save within WLAN
- Latest applications are the motivation
    -  IP phones
    - IP video distribution (Netflix, Hulu, etc.)
    - Internet radio (Milk, Slacker, etc.)

Here we are discussed about Deep sleep, Legacy Power Save Mode and Wake on Wireless

Standby mode means when device is receiving power but is not running, that mode is named as standby mode. In standby mode the device goes to Deep sleep state, it is not completely turned off.

## 2.3 Power save mode

- Part of the original 802.11 standard
- Constrained by the infrastructure (AP and STA)
- Looking to address the demands of the modern platforms (1999)
- What is PSM?
    - It utilizes the beacon period of the AP
    - A Power save bit in the packet from the client
    - The Traffic Indication map (TIM)
    - A listening period called DTIM
    - A PS-Poll packet to initiate information delivery
- Why use it?
    - Provides a method by which the STA can sleep when information is not being transferred

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- Below diagram represents the difference between Active mode station and Power Save Mode enabled station.
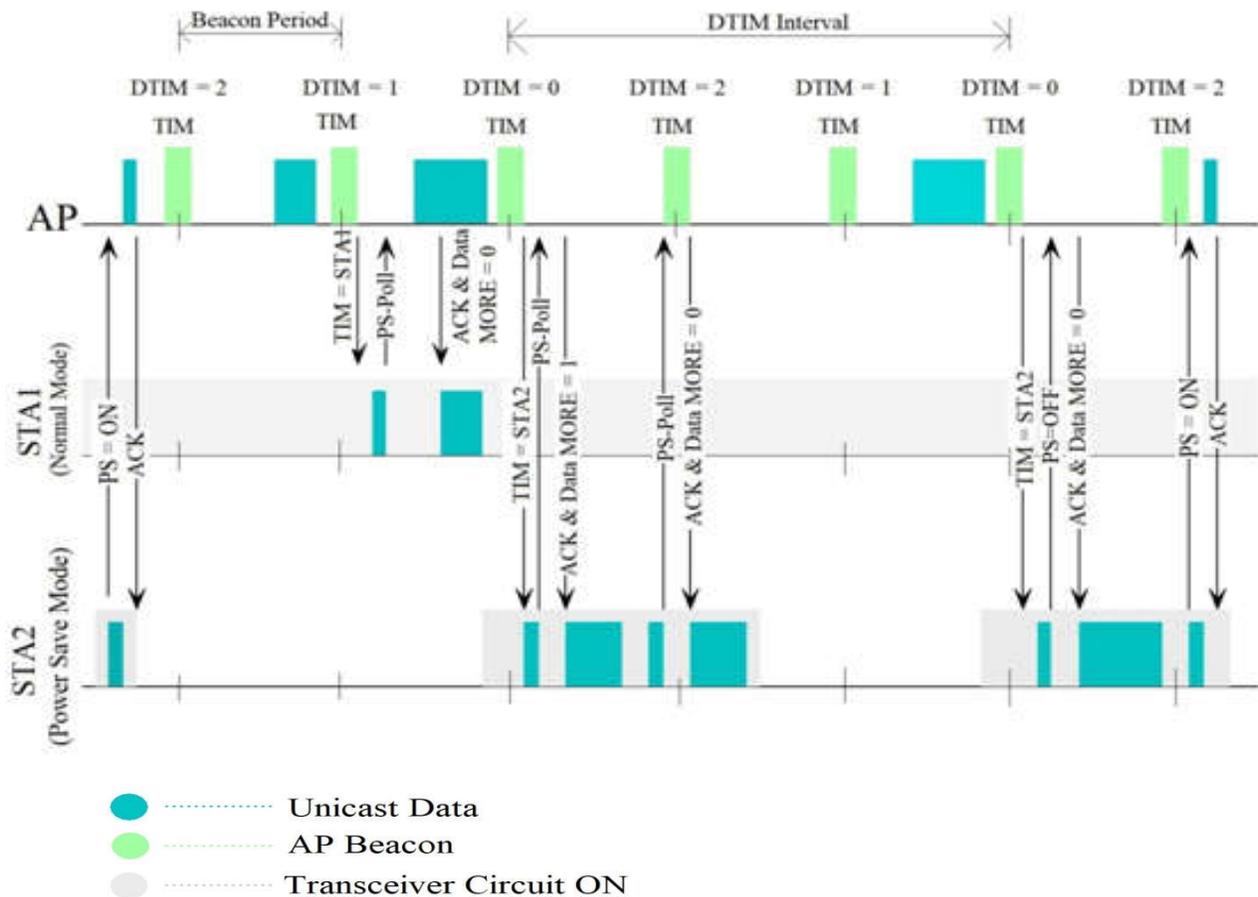


*Figure 1: Active mode vs Power save mode*

**Beacon Period:**

A beacon is a packet broadcast sent by the router that synchronizes the wireless network. A beacon is needed to receive information about the router, included but not limited to SSID and other parameters.

The beacon interval is simply the frequency of the beacon – how often the beacon is broadcast by the router. Most routers are automatically set to a default of 100 milliseconds.

**DTIM Period (Listen Interval):**

The Listen Interval field is used to indicate to the AP how often a STA in power save mode wakes to listen to Beacon management frames. It is expressed in units of beacon interval. The value 0 might be used by a STA that never enters power save mode.

DTIM stands for Delivery traffic indication map or message. It is basically an additional message added after the normal beacon broadcast by your router or access point.

Depending on the timing set for your router, the router "buffers" broadcast and multicast data and let your mobile devices or clients know when to "wake up" to receive those data.

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The more often that DTIM is transmitted, the more often that your mobile devices wake up, and the more battery that it uses (due to the lack of "sleep"). By setting a low value of DTIM and beacon interval, you can effectively keep your devices awake indefinitely so they never go into sleep mode when idling. In some cases the "no sleep" setup can use up to 10~20% additional power consumption.

The following is a tool-tip message when you check for DTIM setting for Asus branded routers: DTIM (Delivery Traffic Indication Message) is included in Beacon packet. The DTIM interval (1-255) means the period of time to wake up wireless clients from Sleep Mode. The default value is 3.

Router settings typically let you setup the "DTIM Interval" where you can calculate the DTIM period. However, some routers may also let you setup the period directly but that is rare.

Coming to BALI, the BALI SDIO and SDIO M.2 supports Legacy power save mode, it is DTIM based power save. The Legacy power save management is summarized with followed below steps,

- Before STA_UT goes into the doze state, it sends a frame, usually null data frame, to the AP indicating that power management is enabled.
- Once STA_UT indicates that it is in Power Save mode, the AP begins to buffer all frames destined to that station.
- When the STA_UT goes into awake state, it sends a PS-Poll frame to the AP in order to begin the data retrieval process
- When AP has finished sending all buffered data to the station, the STA_UT goes back into the doze state

## 2.4 Wake on Wireless

The Wake on Wireless (WoW) feature is the implementation of a more complete system level power save scheme.

Wake on Wireless (WoW) is a mechanism in which host CPU can go to sleep and it can be woken up by the WLAN subsystem if certain conditions are met. The aim here is to conserve system power. When WoW is enabled in the radio it allows the host system to enter deep sleep mode while there is no activity from WLAN.

Here three types of conditions can trigger WoW feature to wake up the host platform

- Some specific WoW events
- Magic packet
- Pattern match

Specific WoW events which will trigger Host wake-up

- Authentication/Association
- Deauthentication/Disassociation
- AP lost (Beacon Miss)

Host wake-up using Magic packet

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- BALI can be woken up by a specifically designed packet called Magic packet during WoW suspend
- Send a Magic packet to BALI Interface by using below command

    *$ wakeonlan <Interface-mac-address-here>*

    **Example**: *$ wakeonlan 00:00:03:00:5A:AD*

- While trying above command you need to connect common AP

Host wake-up using Pattern match

- Users can configure wow patterns to the WLAN FW before platform suspend by using below command

    *#iwpriv wlan0 wowlAddPtrn [pattern size]:[pattern mask size]:[pattern]:[pattern mask]*

- Patterns should be set based on Ethernet-II format as WLAN H/W converts 802.11 packet into Ethernet-II format. Ex. UDP packet header is 42 bytes (Ethernet-II:14, IP:20, UDP:8).
- For example, if we want to wake up host platform when receiving an UDP packet including "55555555555555555555555555555000000000000" in UDP payload, we can use the following commands:
    *Iwpriv wlan0 wowlAddPtrn*
    *40:08:00000000000000000000000000000000000000000000000000000000000000000000000000 00000000000055555555555555555555555555555000000000000:00000000003fffff*
- In above command,
    - ○ "40" means the pattern length is 0x64 bytes, i.e. 60 bytes.
    - ○ "08" means the pattern mask length is 0x08 bytes, i.e. 8 bytes.
    - ○ "00000000003fffff" indicates that we don't care about the first 42 bytes in the pattern, i.e. first 42 "00" in the pattern. It means we want to skip the content of Ethernet-II header, IP header and UDP header.

## 2.5 Constraints of Power Save Mode

- Latency vs. band width vs. power
    - ○ Bound to AP beacons
    - ○ Trade-off between latency and power
    - ○ Leads to a trade-off between bandwidth and power
- Compatibility with AP, too long a DTIM and data can be discarded and even stability of association to AP's can suffer.
- PSM is not suited to high data demand due to PS-Poll packet.
- Applications like IP phones and video streaming impacted by the PSM process.
- Difficult to balance network performance and power save demands
    - ○ AP's set conditions
    - ○ STA are driven by applications

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# 3. BALI SDIO and SDIO M.2 Power Measurement procedure

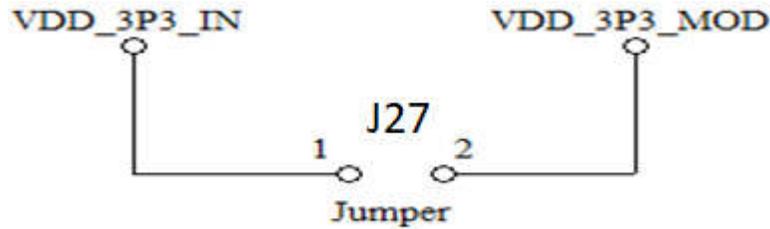On BALI SDIO the Power measurement tapping point is J27



*Figure 2: Power measurement tapping point on BALI SDIO*

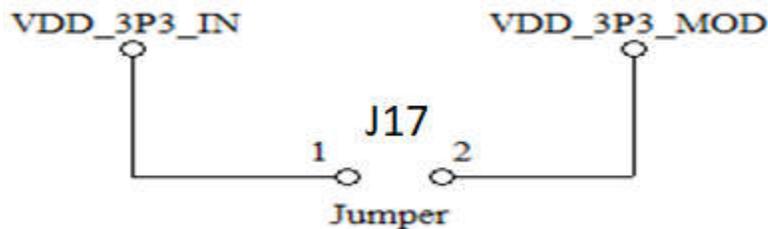On BALI SDIO M.2 the Power measurement tapping point is J17



*Figure 3: Power measurement tapping point on BALI SDIO M.2*

## 3.1 Measurement Setup

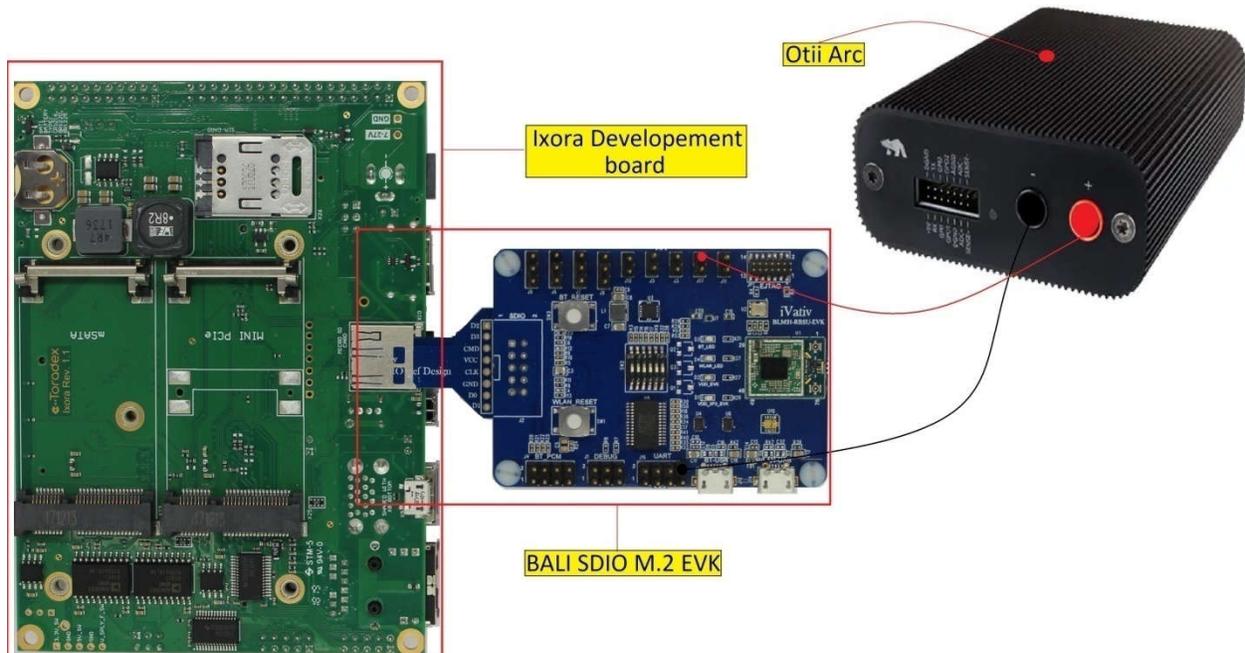The BALI SDIO/SDIO M.2 Power consumption numbers are measured with below setup



*Figure 4: BALI SDIO M.2 Power consumption measurement setup*

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Here the Otii Arc is used as a current measurement unit for BALI SDIO/SDIO M.2 EVK.

The Otii Arc acts both as a power supply to the IoT device being tested, and as a current and voltage measurement unit. It provides up to 5 V output voltage and 5 A current, and runs nA resolution current measurements with a sample rate up to 4 ksps.

You connect the main out of the Otii Arc to either the DC-input, or for a battery powered device, to the battery connectors of your device (remember to remove the battery first).

The Power measurement device (Otii Arc) can either be powered by USB, or by using an external DC-adapter.

## 3.1.1 Procedure with Power measurement device

- Connect the Power measurement device –ve to any Ground pin on EVK(In above image –ve is connected to J16 8$^{th}$(Ground) pin on BALI SDIO M.2 EVK)
- For BALI SDIO EVK connect the Power measurement device +ve to J27 2$_{nd}$ pin(VDD_3P3_MOD)
- For BALI SDIO M.2 EVK connect the Power measurement device +ve to J17 2$_{nd}$ pin(VDD_3P3_MOD)
- Follow below link and connect Power measurement device to PC and then in Quick configuration give input voltage as 3.3V/1.8V
  https://www.qoitech.com/products/standard
- Now insert the EVK into proper slot and power ON the Ixora board

  **Note:** Here you need to turn on Ixora board as well as 3.3V/1.8V from Otii Arc then only device is detected

## 3.2 Deep sleep Power save measurement procedure

- Enable Deep sleep by using below configuration in *qcom_cfg.ini(/lib/firmware/qcom_cfg.ini)* file
    **gEnableSuspend=3**
- Insert the EVK, load the driver files and up the Interface
- Give below command to enter into the Deep sleep mode
    - *$ sudo sh –c 'echo mem > /sys/power/state'*
- Observe the current in Power measurement device(Otii Arc), that is the Deep sleep current in standby mode

- The output is just like below

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*Figure 5: Deep sleep current measurement in Power measurement device(Otii Arc)*

- Measure the average current in Power measurement device
- In above image the average current is the deep sleep current for BALI SDIO

## 3.3 Legacy (DTIM) Power save measurement procedure

Make sure the DTIM is enabled in AP and set DTIM value and beacon interval, by default beacon interval is 100ms. Based upon the DTIM value and beacon interval the power values are changed.  If the DTIM value increased, the power values are decreased i.e., the DTIM value is directly proportional to the power save. Increase the DTIM value until the loose connection from AP to STA_UT. The power save time is calculated by using below formula,

Power save time = DTIM interval * beacon interval

For suppose DTIM value is 2 and beacon interval is 100 means, for every 200ms the STA_UT sends PS-Poll control frame to request AP to send a buffered unicast frame. In that frame if AP set "more data" bit to 1 the STA_UT understand AP has more data to send & therefore remain in awake state & send another PS-Poll frame to get next frame. After that the STA_UT again goes to sleep state for 200ms.

Below image represents communication between AP and STA_UT, while ST A is in power save mode. The above procedure is diagrammatically represented in below picture.
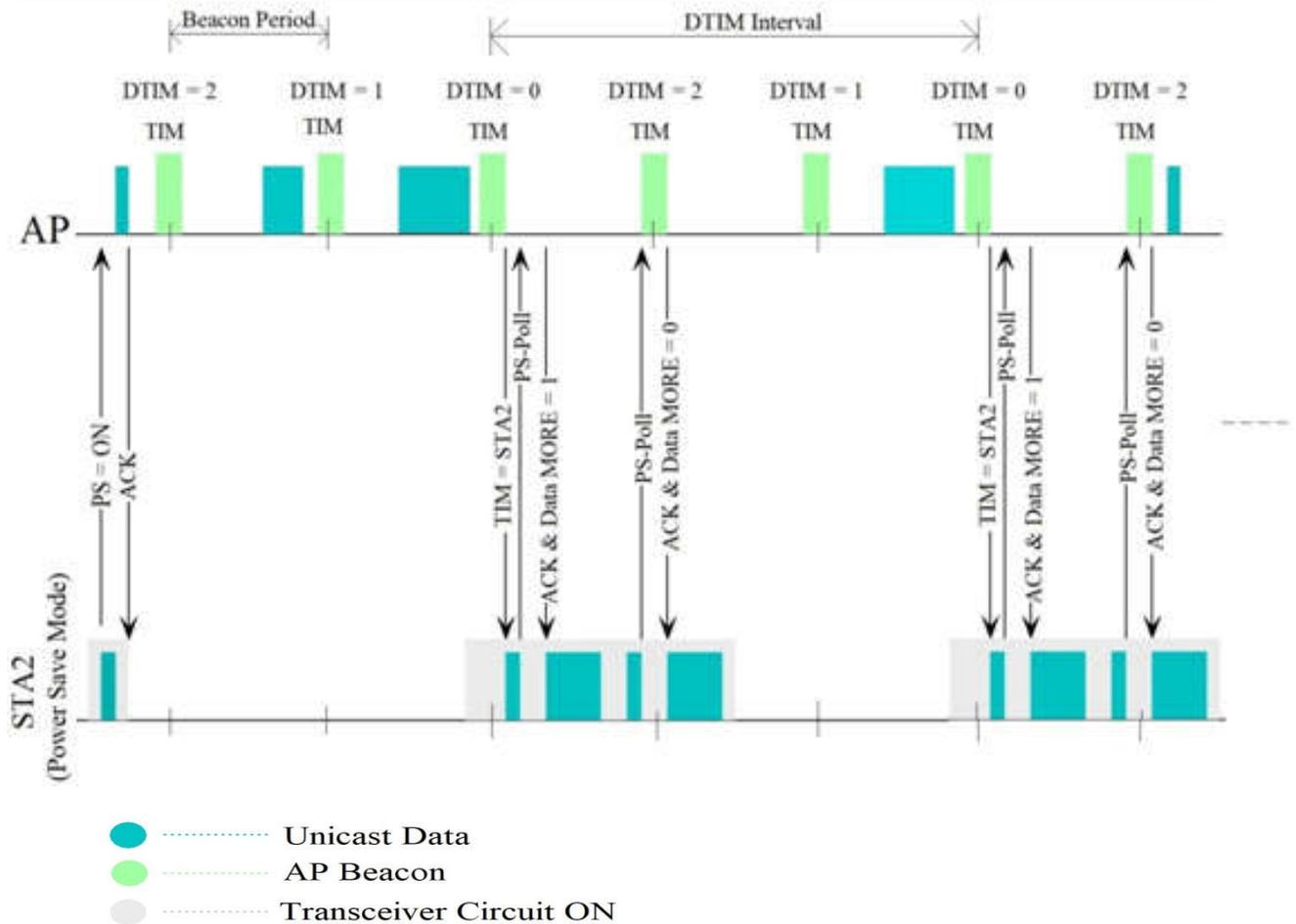
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*Figure 6: Communication between AP and STA while STA is in PSM*

- After changes done in the AP, save the settings in AP and logout.
- Enable Power save by using below configurations is *qcom_cfg.ini (/lib/firmware/qcom_cfg.ini)* file

    **gEnableBmps=1**

- For getting current numbers on WLAN, need to stop the Bluetooth service so enable continuous BT reset by connecting the jumper J7 on the BALI SDIO EVK and connect J5 on BALI SDIO M.2 EVK.
- Insert the BALI SDIO/SDIO M.2 EVK, load the driver files and up the interface
- Connect to the AP by using below command

    *$ sudo iw dev <wlan_interface> connect <AP_SSID>*

- Now observe the DTIM Power numbers in Otii Arc
- Follow same procedure with different DTIM numbers
- The output is just like below

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*Figure 7: DTIM Power consumption results*

- Measure the average current between two PS-Polls , that is the DTIM current consumption number
- The above diagram represents BALI SDIO DTIM based power consumption numbers

## 3.4 Continuous Tx/Rx Power measurement procedure

- Insert the SDIO EVK, load the driver files and up the interface
- Connect to AP and get the IP by using below commands
  **Note:** Below commands is for connect to open AP.

  *$ sudo iw dev <wlan_interface> scan*

  *$ sudo iw dev <wlan_interface> connect  <AP_SSID>*

  *$ dhclient –i <wlan_interface> -v*

- Ping with AP to verify connection status

  *$ ping <AP_IPaddr>*

- Run the server at another side by using below command

  *$ iperf3 –s –i 1*

- Now run continuous Tx from STA_UT by using below command

  *$ iperf3 –c <servr_IP> -u –i 1 –t 100*

- Now observe the current in Power measurement device for continuous Tx
- Run continuous Rx from STA_UT by using below command

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*$ iperf3 –c <servr_IP> -u –i 1 –t 100 –R*

- Now observe the current in Power measurement device for continuous Rx

## 3.5 Power Consumption numbers on BALI SDIO and SDIO M.2

## 3.5.1 Graphical representation
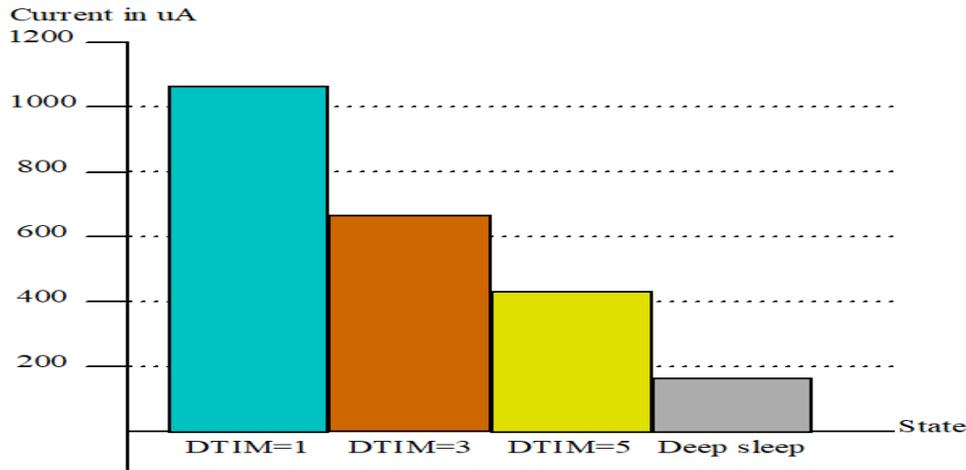
*Figure 8: Power consumption numbers graphical representation*

| Mode | State | Power consumption on BALI SDIO 1.8V (in mA) | Power consumption on BALI SDIO M.2 1.8V (in mA) |
|---|---|---|---|
| Standby | Deep sleep | TBD | TBD |
| Power save 2.4 GHz | DTIM = 1 | TBD | TBD |
| | DTIM = 3 | TBD | TBD |
| | DTIM = 5 | TBD | TBD |
| Power save 5 GHz | DTIM = 1 | TBD | TBD |
| | DTIM = 3 | TBD | TBD |
| | DTIM = 5 | TBD | TBD |
| Regular | Continuous Tx | TBD | TBD |
| | Continuous Rx | TBD | TBD |

*Table 1: BALI/EVIA WLAN current numbers*

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## 3.6 Wake on Wireless Procedure

As already discussed it is not an Interface Power save technique, it is mainly used for Host CPU power save purpose.

- Initially to enable the WoW need to change the configuration file for the host driver(/lib/firmware/qcom_cfg.ini)
    - o Enable Power save by using below configuration

        gEnableBmps=1

    - o Change of listen interval by using below configuration

        gBmpModListenInterval = 1

    - o Enable Wake on Wireless by using below configuration gEnableWoW=3
        - - 1: Case of wake up only in the magic packet
        - - 2: Case of wake up only in the registered pattern
        - - 3: Case of wake up in both
- Insert the EVK, load the driver files and up the interface
- Enable Wake on Wireless Mode by using below commands

    $ sudo iw <phy_name> wowlan enable any

    **Example:** $ sudo iw phy0 wowlan enable any
- Enable WoW by using iwpriv commands also

    *# iwpriv wlan0 wowl 0 -> To Disable WoW*

    *# iwpriv wlan0 wowl 1 -> To Enable WoW for Magic packet*

    *# iwpriv wlan0 wowl 2 -> To Enable WoW for pattern match*

    *# iwpriv wlan0 wowl 3 -> To Enable WoW for both magic packet and pattern Match (default option)*
- Connect to AP by using below command

    *# iw dev <wlan_interfcae> connect <SSID>*

    **Example:** *# iw dev wlan0 connect dlink-42AB*
- Get the IP by using below command

    *# dhclient wlan0 -v*
- Now put the Host in suspend mode by using below command

    *$ sudo sh -c 'echo mem > /sys/power/state'*
- Now connect to the same network from another PC

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- Send a magic packet to Host driver by using below command

  $ wakeonlan <Interface-mac-address-here>

  **Example**: $ wakeonlan 00:00:03:00:5A:AD

- How to confirm WoW wake-up
  - Monitor the level of the WoW pin (GPIO35). Confirm that when the trigger packet is received the pin transitions to a high level.
  - In BALI SDIO EVK the WoW pin is GPIO35
- For Pattern match followed below procedure

---

iwpriv command to configure pattern for pattern match:

*# iwpriv wlan0 wowlAddPtrn [pattern size]:[pattern mask size]:[pattern]:[pattern mask]*

Patterns should be set based on Ethernet-II format as WLAN H/W converts 802.11 packet into Ethernet-II

format. Ex. UDP packet header is 42 bytes (Ethernet-II:14, IP:20, UDP:8).

For example, if we want to wake up host platform when receiving an UDP packet including"5555555555555555555555555555555000000000000" in UDP payload, we can use the following

*iwpriv wlan0 wowlAddPtrn 40:08:0000000000000000000000000000000000000000000000000000000000000000000 000000000000055555555555555555555555555555555000000000000:00000000003fffff*

---

- From PC send the same UDP pattern for pattern match.

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