# MiWi$^{TM}$ v6.1 Developer Guide

## Contents

# 1 Introduction

This guide provides all the information need for a customer or developer to understand the MiWi$^{TM}$ applications implemented on MiWi$^{TM}$ Protocol available in SAM platforms (SAMR21 and SAMR30).

# 2 Background

MiWi$^{TM}$ is Microchip's proprietary Wireless Networking stack is designed to support low rate personal area networks (LRPAN's).
MiWi$^{TM}$ supports three network topologies:

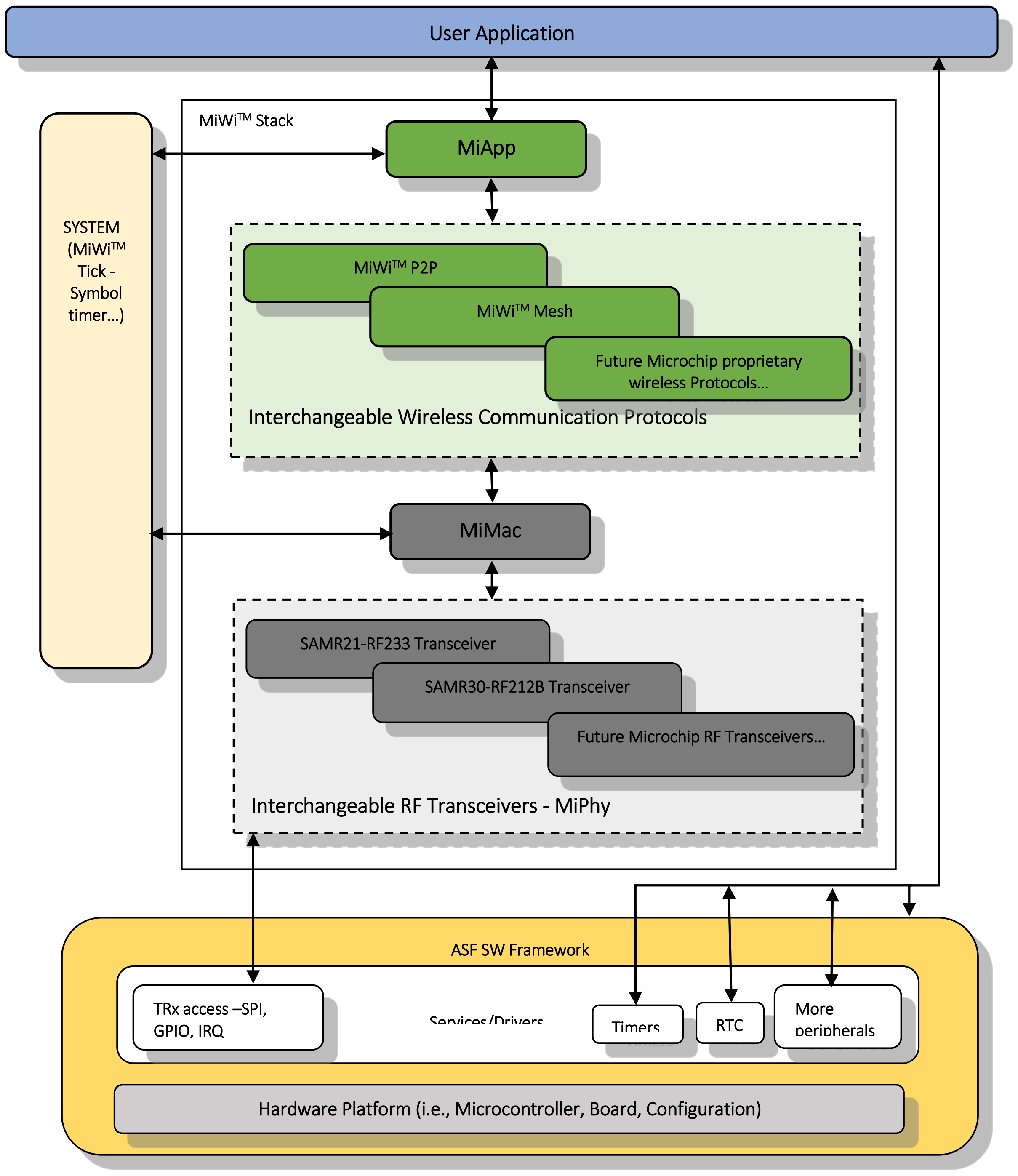
- Peer to Peer (P2P)
- STAR
- MESH

Older versions of MiWi$^{TM}$ Mesh networking stack (i.e. up until version 2.10), released in MiWi$^{TM}$ Protocol v5.30 of MLA version v2017-03-06, supports a library based Mesh networking stack. However, this is been redesigned with following important changes as listed below:

1. Optimization of current APIs to improve simplicity.
2. Redesign of the MiWi$^{TM}$ Mesh with additional features for next generation platforms.
3. A new Commissioning procedure added to improve the secured inclusion of devices to network.
4. Dynamic switching between device types in MiWi$^{TM}$ Mesh.
5. Network Secure feature for all network messages.

## 3 Architecture

Architecture of the MiWi$^{TM}$ Protocol on ASF, which supports additional features for the application developer to pull in required components, services and drivers from ASF Wizard. More details on - http://www.microchip.com/webdoc/asf/asf.ModuleExplorerView.html


User Application
MiWi™ Stack
MiApp
SYSTEM (MiWi™ Tick - Symbol timer...)
MiWi™ P2P
MiWi™ Mesh
Future Microchip proprietary wireless Protocols...
Interchangeable Wireless Communication Protocols
MiMac
SAMR21-RF233 Transceiver
SAMR30-RF212B Transceiver
Future Microchip RF Transceivers...
Interchangeable RF Transceivers - MiPhy
ASF SW Framework
TRx access –SPI, GPIO, IRQ
Services/Drivers
Timers
RTC
More peripherals
Hardware Platform (i.e., Microcontroller, Board, Configuration)

## 4 MiWi$^{TM}$ Mesh – Device Types

There are 3 device types supported in MiWi$^{TM}$ mesh protocol, they are listed below as follows:

1. PAN Coordinator
   a. Start the network
   b. Assigns and maintains the Coordinators and its end-devices addresses.
   c. Behaves as Coordinator for routing frames.
   d. Controls which devices can be included into the network through commissioning.
2. Coordinator
   a. Joins a network as End-device
   b. Requests PAN Coordinator for role upgrade to become Coordinator.
   c. Supports routing of frames within the network.
   d. Stores the commissioning information from PAN Coordinator and allows only the Commissioned devices to participate in the network.
   e. Maintains its end-devices and their addresses.
   f. Maintains data for sleeping end-devices.
3. End-device
   a. Joins to network though available Coordinators.
   b. Supports Rx-On end-device and Sleeping End-device for battery operated devices.
   c. Supports dynamic switching between Rx-On to Sleeping end-deice and vice versa.

## 5 MiWi$^{TM}$ Mesh Frame Format

The MiWi$^{TM}$ Mesh network header and application payload are encapsulated inside the standard IEEE 805.15.4 data frame payload, but the stack itself does not adhere to the standard, so it will not receive and process IEEE 805.15.4 command frames. Figure 1 illustrates a general frame format composed of an IEEE 805.15.4 MAC header, network header, application payload, optional message integrity code (MIC) and a check sum (CRC).

| 2 | 1 | 2 | 2/8 | 2 | 0/2/8 | 1 | 1 | 1 | 0/2 | 0/2 | 0/2 | 0/2/8 | 0/5 | Variable | 0/4 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frame Control | Sequence number | Dest. PANID | Dest. Addr. | Src. PANID | Src. Addr. | Hops | Frame Control | Sequence number | Dest. PANID | Dest. Addr. | Src. PANID | Src. Addr | Auxiliary Security Header | Variable | MIC | CRC |
| MAC Header | | | | | | Network Header | | | | | | | | Payload | Network Footer | |

**Figure 1: General Frame Format**

### 5.1 MAC Header – Frame Control

| Bits: 0-2 | 3 | 4 | 5 | 6 | 7-9 | 10-11 | 12-13 | 14-15 |
|---|---|---|---|---|---|---|---|---|
| Frame Type | Security Enabled | Frame Pending | Ack. Request | PAN ID Compression | Reserved | Dest. Addr. Mode | Frame Version | Src. Addr. Mode |

**Figure 2: MAC Header- Frame Control Field**

The following settings are used for a MAC Frame Control Field as described in [**Error! Reference source not found.**]:

- Frame Type: Data
- Security Enabled: False
- Frame Pending: True if pending data available for sleeping end device or False otherwise.
- Acknowledgment Request: True for unicast frames and False for broadcast frames
- PAN ID Compression: True
- Destination Addressing Mode: 0 for no address fields, 2 for 16-bit short address and 3 for 64-bit extended address
- Frame Version: 0
- Source Addressing Mode: 0 for no address fields, 2 for 16-bit short address and 3 for 64-bit extended address

## 5.2 NWK Header – Hops

The number of hops that the packet is allowed to be retransmitted (00h means don't retransmit this packet – 1 byte)

## 5.3 NWK Header – Frame Control

The Frame Control field is a bitmap as defined below, which defines the behavior of a packet.

| Bits: 0-1 | 2 | 3 | 4 | 5 | 6-7 |
|---|---|---|---|---|---|
| Frame Type | Security Enabled | Intra Cluster | Ack. Request | Address same as MAC | Reserved |

**Figure 3: NWK Header - Frame Control Field**

| | |
|---|---|
| Bit 7-6 | **Reserved:** Maintain as '0' in this implementation |
| Bit 5 | **Address same as MAC:** This bit will be set when the MAC address fields and NWK address fields are the same. This would be useful when the sleeping end device polls the parent for data, with relatively less bytes over-the-air for single hop from network layer. |
| Bit 4 | **Ack Request:** Acknowledge Request bit When set, the source device requests an upper layer Acknowledgement of receipt from the destination device. |
| Bit 3 | **Intra Cluster:** Intra Cluster bit Reserved in this implementation, maintain as '1'. |
| Bit 2 | **Security Enabled:** Security enabled bit When set, data packet is encrypted at the application level. |
| Bit 0-1 | **Frame Type:** Frame type bits |

| Frame Type value $b_1$ $b_0$ | Description |
|---|---|
| 00 | Data |
| 01 | Command |
| 10 | Manufacturer Specific |

|  |  |
|---|---|
| 11 | Reserved |

## 5.4 NWK Header – Sequence Number field

The Sequence Number field is 1 byte in length and specifies the sequence identifier for the frame. The Sequence Number field shall be increased by 1 for every outgoing frame, originating on the node and it should not be change for routed frames.

## 5.5 NWK Header – Source Address field

The Source Address field is 2 bytes or 8 bytes in length and specifies the network address of the node originating the frame.8 bytes are used when security is enabled where source IEEE address is needed for security processing.

## 5.6 NWK Header – Destination Address field

The Destination Address field is 2 bytes in length and specifies the network address of the destination node. The Destination Address field can be set as per below table for other frames except unicast to a node.

| Destination Address value | Description |
|---|---|
| 0xFFFF | Broadcast to every device |
| 0xFFFE | Multicast to all FFD’s |
| 0xFFFD | Multicast to all Coordinators |

## 5.7 NWK Header – Auxiliary security header

| Bytes: 1 | 4 |
|---|---|
| Security Level | Frame Counter |

**Figure 4: NWK Header - Auxiliary Security Header Field**

The Auxiliary Security Header field specifies information required for security processing, including how the frame is protected (security level) and frame counter. This field shall be present only if the Security Enabled subfield is set to one. The supported security level are 0(No Security), 1(Authentication-4bytes MIC), 4(Encryption only), 5 (Encryption with Authentication-4 bytes MIC).

# 6 MiWi$^{TM}$ Mesh – Device Addressing Mechanism

MiWi$^{TM}$ Mesh uses 2-byte short address to specify nodes in the network when performing routing across the network. The lower byte is used to identify the End-devices. The higher byte is used to identify the Coordinators.

| Bit 15:8 | Bit 7 | Bit 6:0 |
|---|---|---|
| Coordinator Identifier | RxOnWhenIdle | End Device Identifier (0x00 to identify Coordinator) |

# 7 Network Freezer

## 7.1 Motivation

Occasionally, a wireless network may lose power. After power is restored, in most of the cases, the wireless nodes might form a different network through different joining procedures. After the power cycle, a wireless node in MiWi network may be assigned with a different network address. As the result, the application layer may have to dedicate more efforts to handle the power cycle scenario. It is important to develop a feature which can release the application layer from handling power cycle.

Additionally, the persistent data fields maintained by the stack during run-time need to be updated “individually” several times during run-time. However, such an update to a “fixed address” in flash would require a full “backup-erase-re-write” cycle on the entire row that the field belongs to due to flash device requirements:

- With write granularity being a page (64 byte), any valid write operation assumes that the entire page is pre-erased to all 0xFFs.
- The erase granularity is row (256 bytes). So even if we want to update within one page, we will need to perform the “back-erase-write” on the entire row unless we know it is pre-erased.

## 7.2 Solution

Network Freezer feature is developed to solve this problem. It saves critical network information into the Non-Volatile Memory (NVM) and restore them after power cycle. In this way, the application does not need to worry about the power cycle scenario and the network can be restored to the state before the power cycle without many message exchanges after the power cycle.

Additionally, Wear-levelling implementation is aimed at drastically reducing the number of such “backup-erase-re-write” cycles and thereby improving the flash life-time.

## 7.3 Interface

Network Freezer feature can be enabled by defining ENABLE_NETWORK_FREEZER in configuration file of application project.

Network Freezer feature is invoked by calling the MiApp function MiApp_ProtocolInit. When Network Freezer is enabled in the application, the network information will be restored from NVM; otherwise, the network information in NVM will be erased and the wireless node start from scratch.

## 7.4 Additional Notes

Network Freezer feature requires NVM to store the critical network information. Currently NVM used for this implementation is internal Flash.

# 8 Sleep Feature

For most of the applications, it is critical to provide long battery life for the sleeping devices. A device can be either in active mode or sleep mode. After being powered up, a node always starts in active mode, with its MCU fully turned on.

Application can check whether the stack is allowing to sleep or not using the given API. If it allows, then application can go to sleep at a maximum of allowable time by stack for proper operation.

In sleep mode, the RF chip and the MCU are in low power states and only the functionality required for MCU wake ups remains active. Thus, the application cannot perform any radio Tx/Rx operations, communicate with external periphery, in sleep mode.

A majority portion of power is consumed when the sleeping device is active, asking for data and sending data in the duty cycle. So, device to be active is based on its polling period. This can be controlled in configuration option.

Among all nodes, only end devices can sleep.

## 8.1 Interface

Sleep feature can be enabled by defining ENABLE_SLEEP_FEATURE in configuration file of application project. API Interface Information can be found in Developer Guide.

# 9 Over-The-Air Upgrade Feature

Below figure shows the firmware architecture of the OTAU…

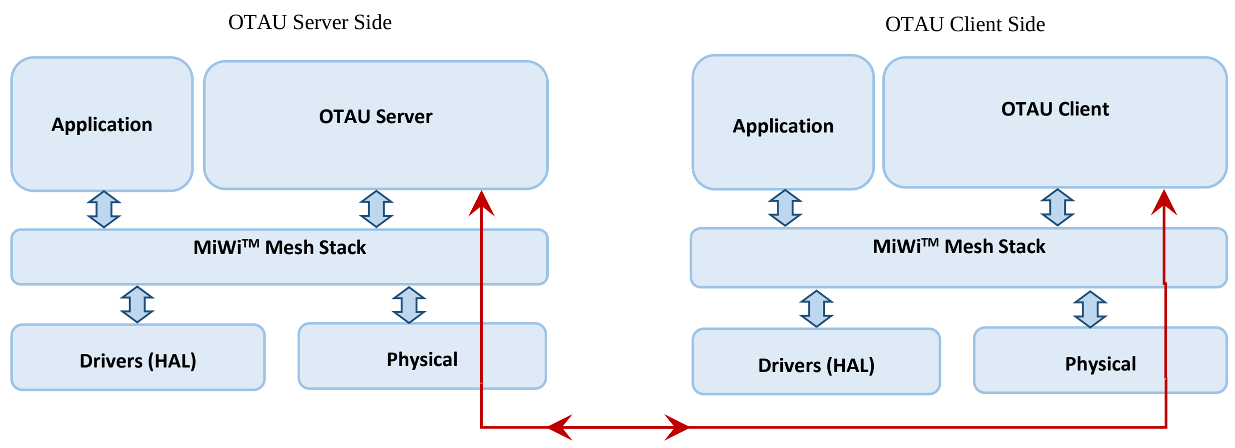


**Figure 5 : Firmware Architecture**

## 9.1 OTAU Server

OTAU server receives/transmits the command from/to PC through UART/USB. Transmits required frames through MiWi$^{TM}$ Mesh stack layer to reach the clients, in order to upgrade. Current implementation of server acts as bridge between the clients to OTAU tool running in PC, i.e. there is no additional intelligence in OTAU module on server end.

## 9.2 OTAU Client

OTAU client receives/transmits the proprietary commands over-the-air to communicate with server.

## 9.3 Domains of OTAU

OTAU on server and client has two domains as listed below…

### 9.3.1 Notify

1. Provides some basic information about the client like, IEEE address, Short address, Next hop address to reach the OTAU server for plotting network topology.
2. Commands to blink LED on clients to identify visually on large network.
3. Provision for user to fetch additional information related to application such firmware name, firmware version, board name and board version.

### 9.3.2 Upgrade

1. Supports over the air upgrade of each client through proprietary protocol exchange.
2. Provides support to Switch to new image individually when all the nodes are upgraded.

## 9.4 Compiler Switches for OTAU

### 9.4.1 OTAU_ENABLED

OTAU_ENABLED switch should be included in project symbols to enable the upgrade support.

### 9.4.2 OTAU_SERVER

OTAU_SERVER, when enabled on the project symbols, the node acts as OTAU server. If this symbol is not enabled, then the node will act as Client for OTAU.

# 10 MiWi$^{TM}$ Mesh – Networking

MiWi$^{TM}$ Mesh network is enriched with features categorized as follows…

1. Network Commissioning
2. Start and Join Network
3. Routing in Network

## 10.1 Network Commissioning

Commissioning the network controls the devices which can participate in the network.

1. Application on PAN Coordinator reads the IEEE address (can be improved to read from Barcode) from one or more devices.
2. PAN Coordinator calculates the 64-byte bloom filter value with the read information.
3. The calculated bloom filter value is sent to all the coordinators in the network.
4. Coordinators provide beacon only to the devices which has its IEEE address in the bloom filter.
5. More information on bloom filter is available in - https://en.wikipedia.org/wiki/Bloom_filter

## 10.2 Start and Join Network

1. Only PAN Coordinator can start a network.
2. Joining device sends beacon request in order to obtain information about the available networks in its personal operating space.

3. The PAN Coordinator or Coordinator evaluates the beacon request by parsing the given IEEE address with the bloom filter value. If found, it sends a beacon frame with a beacon payload which includes PAN Coordinator Hop count and bloom filter value (64 bytes). If not found, it discards the packet.
4. Upon receiving beacon frames, the joining device parses it and checks its own address in the bloom filter value and then decides its parent based on associate permit, children capacity and LQI of the received beacons. After choosing the parent, it unicasts Mesh Connection Request packet (includes its capability and JoinWish field) to the selected parent.

   The Join Wish Byte has two bits C and ED, remaining bits are reserved.

   If both bits are set in JoinWish, then the particular device wishes to join as an End device if coordinator capacity is currently unavailable in the network.

   If only C bit is set, then the device wishes to join as a Coordinator only.

   If only ED bit is set, then the device wishes to join as an End device only.
5. If the Parent is PAN Coordinator and JoinWish filed is set with C and ED or C alone, then PAN Coordinator checks whether it has a new coordinator address. If available, it sends the Mesh Connection Response with device address as allocated new coordinator address. If address is unavailable or JoinWish field has ED alone set, then it will allocate end device address and sends the Mesh connection response.
6. If the Parent is Coordinator, then it allocates end device address and sends Mesh Connection Response with device address as allocated end device address.
7. The Joining device parses the Mesh connection response and use the received network address along with the received network key for further communications in the network.
8. The Joining device which is coordinator capable, receives an end device address, then based on Role Upgrade Timeout (Configurable) will send a Role Upgrade request packet to the PAN Coordinator in order to upgrade its role from an end device to Coordinator.
9. When the PAN Coordinator receives a role upgrade request, it checks whether coordinator address is available. If yes, it allocates a new coordinator address and sends the role upgrade response with the allocated address and status as Success. If an address is unavailable, then it sends Role Upgrade response with failure status.

## 10.3 Routing in Network

1. During the joining procedure and role upgrade, the route table will be updated in all the coordinators.
2. The route table in Coordinators will be used to route the packet to destination device.
3. When the device doesn’t have the next hop address for the destination, it will trigger a broadcast for a Route request to the destination.
4. Unlike the legacy route request in AODV routing protocols, the reply will be generated from any node which has the next hop information in its routing table.
5. The source device (which initiated route request) will select the route reply for the destination based on the fewer hops and best LQI.
6. However, in order to establish and synchronize the network periodically, the Route Table Update will be broadcast to a single hop based on pre-configured intervals.
7. This would ensure that coordinators in the network share the neighbor’s information with its neighbors.

## 11 MACROs for MiWi$^{TM}$ Mesh

| Sl. no. | MACRO | Default Value | Range | Description |
|---|---|---|---|---|
| 1. | CHANNEL_MAP | (1<<25) | -- | Channel map is a bit map used to select appropriate channels for starting or establishing connection in the network.<br>Bitmap based on the physical layer. Set/Clear of any bits in the below range is valid…<br>For 2.4GHz – 0x07FFF800<br>For SubGHz – 0x000007FF |
| 2. | KEEP_ALIVE_COORDINATOR_TIMEOUT_IN_SEC | 25 | 0 - 255 | Timeout in seconds of a coordinator at which the PAN Coordinator would remove the coordinator from the coordinator table. |
| 3. | KEEP_ALIVE_RXONENDDEVICE_TIMEOUT_IN_SEC | 25 | 0 - 255 | Timeout in seconds of Rx On Enddevice at which the Coordinators would remove the Rx On Enddevice from the Enddevice table. |
| 4. | MAX_NUMBER_OF_DEVICES_IN_NETWORK | 32 | 0 - 200 | Table size of the maximum number of devices in the network to generate Bloom filter. This is applicable only for PAN Coordinator. |
| 5. | DEVICE_TIMEOUT1 | 15000 | | Timeout of end device reported to coordinator. |
| 6. | ROLE_UPGRADE_INTERVAL_IN_SEC | 20 | 0 - 255 | Time interval in which a coordinator capable device would request for role upgrade to PAN Coordinator |
| 7. | CONNECTION_RESPONSE_WAIT_IN_SEC | 5 | 0 - 255 | Time interval to wait for connection response from the Coordinator. |
| 8. | NUM_OF_COORDINATORS | 10 | 0 - 200 | Maximum number of Coordinators anticipated for which the route table need to be maintained |
| 9. | NUM_OF_NONSLEEPING_ENDDEVICES | 5 | 0 - 127 | Maximum number of Rx-On end-device anticipated for coordinator. |
| 10. | NUM_OF_SLEEPING_ENDDEVICES | 5 | 0 - 127 | Maximum number of Sleeping end-device anticipated for coordinator. |
| 11. | ROUTE_UPDATE_INTERVAL | 20 | 0 - 255 | Time Interval at which the coordinator sends out Route update |
| 12. | ROUTE_REQ_WAIT_INTERVAL | 5 | 0 - 255 | Time to wait for route replies from other coordinators |
| 13. | INDIRECT_DATA_WAIT_INTERVAL | 10 | 0 - 255 | Time interval to maintain the Indirect data for sleeping devices in coordinator. |
| 14. | DATA_REQUEST_INTERVAL | 5 | 0 - 255 | Time interval to send data request from sleeping end device to coordinator. |

| | | | | |
|---|---|---|---|---|
| 15. | `FRAME_ACK_WAIT_INTERVAL` | 5 | 0 - 255 | Time interval to wait for network level acknowledgement. |
| 16. | `FRAME_RETRY` | 3 | 0 - 255 | Number of retries to be done for application data frames |
| 17. | `REBROADCAST_TABLE_SIZE` | 10 | 0 - 255 | Size for rebroadcast table to maintain rebroadcasted frames in coordinator. |
| 18. | `REBROADCAST_TIMEOUT` | 5 | 0 - 255 | Time out to remove entry from rebroadcast table. |
| 19. | `MESH_SECURITY_LEVEL` | 5 | 0 - 7 | Security levels for CCM* as defined in IEEE 802.15.4 |
| 20. | `PUBLIC_KEY_DEFAULT` | {0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08, 0x09, 0x0A, 0x0B, 0x0C, 0x0D, 0x0E, 0x0F} | -- | Public key of the network used to retrieve network key. |
| 21. | `NETWORK_KEY_DEFAULT` | {0x00, 0x11, 0x22, 0x33, 0x44, 0x55, 0x66, 0x77, 0x88, 0x99, 0xAA, 0xBB, 0xCC, 0xDD, 0xEE, 0xFF} | -- | Network key used to transact after successful join to the network. |

# 12 MiApp API

The following table lists the Supported APIs

| Sl. No. | Supported APIs | Stack Supported |
|---|---|---|
| 1. | bool MiApp_ProtocolInit (defaultParametersRomOrRam_t *defaultRomOrRamParams, defaultParametersRamOnly_t *defaultRamOnlyParams) | P2P/Star/Mesh |
| 2. | bool MiApp_Set(enum id, uint8_t value ) | P2P/Star/Mesh |
| 3. | bool MiApp_StartNetwork( uint8_t Mode, uint8_t ScanDuration, uint32_t ChannelMap, FUNC ConfCallback) | P2P/Star/Mesh |
| 4. | uint8_t MiApp_SearchConnection(uint8_t ScanDuration, uint32_t ChannelMap, FUNC ConfCallback) | P2P/Star/Mesh |
| 5. | uint8_t MiApp_EstablishConnection(uint8_t Channel, uint8_t addr_len, uint8_t addr, uint8_t Capability_info, FUNC ConfCallback) | P2P/Star/Mesh |
| 6. | void MiApp_RemoveConnection(uint8_t ConnectionIndex) | P2P/Star/Mesh |
| 7. | void MiApp_ConnectionMode(uint8_t Mode) | P2P/Star/Mesh |
| 8. | MiApp_SendData(uint8_t addr_len, uint8_t addr, uint8_t len, uint8_t pointer, FUNC ConfCallback) | P2P/Star/Mesh |
| 9. | MiApp_SubscribeDataIndicationCallback(FUNC callback) | P2P/Star/Mesh |
| 10. | uint8_t MiApp_NoiseDetection(uint32_t ChannelMap, uint8_t ScanDuration, uint8_t DetectionMode, OUTPUT uint8_t NoiseLevel) | P2P/Star/Mesh |
| 11. | uint8_t MiApp_TransceiverPowerState(uint8_t Mode) | P2P/Star/Mesh |
| 12. | bool MiApp_InitChannelHopping( uint32_t ChannelMap) | P2P/Star/Mesh |
| 13. | bool MiApp_ResyncConnection(uint8_t ConnectionIndex, uint32_t ChannelMap) | P2P/Star/Mesh |
| 14. | uint8_t Total_Connections(void) | P2P/Star/Mesh |
| 15. | void MiApp_BroadcastConnectionTable() | Star |
| 16. | bool SW_Ack_SrED(uint8_t ) | Star |
| 17. | void send_link_status(void) | Star |
| 18. | void Find_InActiveDevices(void) | Star |
| 19. | void MiApp_leave_network(void) | Star |
| 20. | bool MiApp_UnicastStar (bool SecEn) | Star |
| 21. | bool MiApp_Set(enum id, uint8_t value ) | Mesh |
| 22. | bool MiApp_IsMemberOfNetwork(void) | Mesh |
| 23. | bool MiApp_Get(enum id, uint8_t value ) | Mesh |

|  |  |  |
|---|---|---|
| 24. | bool MiApp_Set(enum id, uint8_t value ) | Mesh |
| 25. | bool MiApp_SubscribeReConnectionCallback(ReconnectionCallback_t callback) | P2P/Star/Mesh |
| 26. | bool MiApp_ResetToFactoryNew(void) | P2P/Star/Mesh |
| 27. | bool MiApp_ReadyToSleep(uint32_t* sleepTime) | Mesh |
| 28. | bool MiApp_ManuSpecSendData(uint8_t addr_len, uint8_t *addr, uint8_t msglen, uint8_t *msgpointer, uint8_t msghandle, bool ackReq, DataConf_callback_t ConfCallback) | Mesh |
| 29. | bool MiApp_SubscribeManuSpecDataIndicationCallback(PacketIndCallback_t callback) | Mesh |
| 30. | bool MiApp_IsConnected(void) | Mesh |

# 13 MiApp API Description

## 13.1 MiApp_ProtocolInit

| | |
|---|---|
| ***API*** | `bool MiApp_ProtocolInit(defaultParametersRomOrRam_t *defaultRomOrRamParams, defaultParametersRamOnly_t *defaultRamOnlyParams)` |
| ***Description*** | This is the primary user interface function to initialize the Microchip proprietary wireless protocol, which is chosen by the application layer. Usually, this function must be called after the hardware initialization, before any other MiApp interface can be called. |
| ***Pre-Condition*** | Hardware initialization has been done. |
| ***Parameters*** | defaultParametersRomOrRam_t defaultRomOrRamParams - Default parameters for MiWi™ Mesh.<br>defaultParametersRamOnly_t defaultRamOnlyParams - Default parameters for MiWi™ Mesh.<br>Ignored in case of P2P / Star |
| ***Returns*** | True if successfully |
| ***Example*** | <code><br>HardwareInit();<br>MiApp_ProtocolInit();<br></code> |
| ***Remarks*** | None |

## 13.2 MiApp_Set

| | |
|---|---|
| ***API*** | `bool MiApp_Set(set_params id, uint8_t *value)` |
| ***Description*** | This is the primary user interface function to set the different values in the MiWi™ stack. |
| ***Pre-Condition*** | Protocol initialization must be done. |
| ***Parameters*** | set_params id - The identifier of the value to be set<br>value - value to be set |
| ***Returns*** | A boolean to indicate if set operation has been performed successfully |
| ***Example*** | <code><br>if( true == MiApp_Set(CHANNEL, 15) )<br>{<br>// channel changes successfully<br>}<br></code> |
| ***Remarks*** | None |

## 13.3 MiApp_StartConnection

| | |
|---|---|
| ***API*** | `bool MiApp_StartConnection(uint8_t Mode, uint8_t ScanDuration, uint32_t ChannelMap,connectionConf_callback_t ConfCallback)` |
| ***Description*** | This is the primary user interface function for the application layer to start PAN. Usually, this function is called by the PAN Coordinator who is the first in the PAN. The PAN Coordinator may start the PAN after a noise scan if specified in the input mode. |
| ***Pre-Condition*** | Protocol initialization must be done. |
| ***Parameters*** | uint8_t Mode - Whether to start a PAN after a noise scan. Possible modes are… <br> START_CONN_DIRECT Start PAN directly without noise scan <br> START_CONN_ENERGY_SCN Perform an energy scan first, then start the PAN on the channel with least noise. <br> START_CONN_CS_SCN Perform a carrier-sense scan first, then start the PAN on the channel with least noise. <br> uint8_t ScanDuration - The maximum time to perform scan on single channel. The value is from 5 to 14. The real time to perform scan can be calculated in following formula from IEEE 802.15.4 specification: 960 (2^ScanDuration + 1) 10^(-6) second <br> ScanDuration is discarded if the connection mode is START_CONN_DIRECT. <br> uint32_t ChannelMap - The bit map of channels to perform noise scan. The 32-bit double word parameter use one bit to represent corresponding channels from 0 to 31. For instance, 0x00000003 represent to scan channel 0 and channel 1. ChannelMap is discarded if the connection mode is START_CONN_DIRECT. <br> connectionConf_callback_t ConfCallback - The callback routine which will be called upon the initiated connection procedure is performed. |
| ***Returns*** | A boolean to indicate if PAN has been started successfully. |
| ***Example*** | &lt;code&gt; <br> // start the PAN on the least noisy channel after scanning all possible channels. <br> MiApp_StartConnection(START_CONN_ENERGY_SCN, 10, 0x07FFF800, callback); <br> &lt;/code&gt; |
| ***Remarks*** | None |

## 13.4 MiApp_SearchConnection

| | |
|---|---|
| ***API*** | `uint8_t MiApp_SearchConnection(uint8_t ScanDuartion, uint32_t ChannelMap, SearchConnectionConf_callback_t ConfCallback)` |
| ***Description*** | This is the primary user interface function for the application layer to perform an active scan. After this function call, all active scan response will be stored in the global variable ActiveScanResults in the format of structure ACTIVE_SCAN_RESULT. The return value indicates the total number of valid active scan response in the active scan result array. |
| ***Pre-Condition*** | Protocol initialization has been done. |
| ***Parameters*** | uint8_t ScanDuration - The maximum time to perform scan on single channel. The value is from 5 to 14. The real time to perform scan can be calculated in following formula from IEEE 802.15.4 specification: 960 (2^ScanDuration + 1) 10^(-6) second. |

| | |
|---|---|
| | uint32_t ChannelMap - The bit map of channels to perform noise scan. The 32-bit double word parameter use one bit to represent corresponding channels from 0 to 31. For instance, 0x00000003 represent to scan channel 0 and channel 1.<br>SearchConnectionConf_callback_t ConfCallback - The callback routine which will be called upon the initiated connection procedure is performed |
| ***Returns*** | The number of valid active scan response stored in the global variable ActiveScanResults. |
| ***Example*** | <code><br>// Perform an active scan on all possible channels<br>NumOfActiveScanResponse = MiApp_SearchConnection(10, 0xFFFFFFFF, callback);<br></code> |
| ***Remarks*** | None |

## 13.5 MiApp_EstablishConnection

| | |
|---|---|
| ***API*** | `uint8_t MiApp_EstablishConnection(uint8_t Channel, uint8_t addr_len, uint8_t *addr, uint8_t Capability_info, connectionConf_callback_t ConfCallback)` |
| ***Description*** | This is the primary user interface function for the application layer to start communication with an existing PAN. For P2P protocol, this function call can establish one or more connections. For network protocol, this function can be used to join the network, or establish a virtual socket connection with a node out of the radio range. There are multiple ways to establish connection(s), all depends on the input parameters. |
| ***Pre-Condition*** | Protocol initialization has been done. If only to establish connection with a predefined device, an active scan must be performed before and valid active scan result has been saved. |
| ***Parameters*** | uint8_t channel - The selected channel to invoke join procedure.<br>uint8_t addr_len - Address length<br>uint8_t *addr - address of the parent<br>uint8_t Capability_info - capability information of the device<br>connectionConf_callback_t ConfCallback - The callback routine which will be called upon the initiated connection procedure is performed |
| ***Returns*** | The index of the peer device on the connection table. |
| ***Example*** | <code><br>// Establish one or more connections with any device<br>PeerIndex = MiApp_EstablishConnection(14, 8, 0x12345678901234567,0x80, callback);<br></code> |
| ***Remarks*** | If more than one connections have been established through this function call, the return value points to the index of one of the peer devices. |

## 13.6 MiApp_RemoveConnection

| | |
|---|---|
| ***API*** | `void MiApp_RemoveConnection(uint8_t ConnectionIndex)` |

| | |
|---|---|
| ***Description*** | This is the primary user interface function to disconnect connection(s). For a P2P protocol, it simply remove the connection. For a network protocol, if the device referred by the input parameter is the parent of the device calling this function, the calling device will get out of network along with its children. If the device referred by the input parameter is children of the device calling this function, the target device will get out of network. |
| ***Pre-Condition*** | Transceiver has been initialized. Node has establish one or more connections |
| ***Parameters*** | uint8_t ConnectionIndex - The index of the connection in the connection table to be removed |
| ***Returns*** | None |
| ***Example*** | <code><br>MiApp_RemoveConnection(0x00);<br></code> |
| ***Remarks*** | None |

## 13.7 MiApp_ConnectionMode

| | |
|---|---|
| ***API*** | `void MiApp_ConnectionMode(uint8_t Mode)` |
| ***Description*** | This is the primary user interface function for the application layer to configure the way that the host device accept connection request. |
| ***Pre-Condition*** | Protocol initialization has been done. |
| ***Parameters*** | uint8_t Mode - The mode to accept connection request. The privilege for those modes decreases gradually as defined. The higher privilege mode has all the rights of the lower privilege modes.<br>The possible modes are…<br>ENABLE_ALL_CONN Enable response to all connection request<br>ENABLE_PREV_CONN Enable response to connection request from device already in the connection table.<br>ENABLE_ACTIVE_SCAN_RSP Enable response to active scan only<br>DISABLE_ALL_CONN Disable response to connection request, including an active scan request. |
| ***Returns*** | None |
| ***Example*** | <code><br>// Enable all connection request<br>MiApp_ConnectionMode(ENABLE_ALL_CONN);<br></code> |
| ***Remarks*** | None |

## 13.8 MiApp_SendData

| | |
|---|---|
| ***API*** | `bool MiApp_SendData(uint8_t addr_len, uint8_t *addr, uint8_t msglen, uint8_t *msgpointer,uint8_t msghandle, bool ackReq, DataConf_callback_t ConfCallback)` |

| | |
|---|---|
| ***Description*** | This is one of the primary user interface functions for the application layer to unicast a message. The destination device is specified by the input parameter DestinationAddress. The application payload is filled using msgpointer. |
| ***Pre-Condition*** | Protocol initialization has been done. |
| ***Parameters*** | uint8_t addr_len - destionation address length<br>uint8_t *addr - destionation address<br>uint8_t msglen - length of the message<br>uint8_t *msgpointer - message/frame pointer<br>uint8_t msghandle - message handle<br>bool ackReq - set to receive network level ack (Note- Discarded for broadcast data)<br>DataConf_callback_t ConfCallback - The callback routine which will be called upon the initiated data procedure is performed. |
| ***Returns*** | A boolean to indicate if the unicast procedure is successful. |
| ***Example*** | &lt;code&gt;<br>// Secure and then broadcast the message stored in msgpointer to the permanent address<br>// specified in the input parameter.<br>MiApp_SendData(SHORT_ADDR_LEN, 0x0004, 5, “hello”,1, callback);<br>&lt;/code&gt; |
| ***Remarks*** | None |

## 13.9 MiApp_SubscribeDataIndicationCallback

| | |
|---|---|
| ***API*** | `bool MiApp_SubscribeDataIndicationCallback(PacketIndCallback_t callback)` |
| ***Description*** | This is the primary user interface functions for the application layer to call the Microchip proprietary protocol stack to register for message indication callback to the application. The function will call the protocol stack state machine to keep the stack running. |
| ***Pre-Condition*** | Protocol initialization has been done. |
| ***Parameters*** | |
| ***Returns*** | A boolean to indicates if the subscription operation is successful or not. |
| ***Example*** | &lt;code&gt;<br>if( true == MiApp_SubscribeDataIndicationCallback(ind) )<br>{<br>}<br>&lt;/code\&gt; |
| ***Remarks*** | None |

## 13.10 MiApp_NoiseDetection

| | |
|---|---|
| ***API*** | `uint8_t MiApp_NoiseDetection( uint32_t ChannelMap, uint8_t ScanDuration, uint8_t DetectionMode, uint8_t NoiseLevel)` |

| | |
|---|---|
| ***Description*** | This is the primary user interface functions for the application layer to perform noise detection on multiple channels. |
| ***Pre-Condition*** | Protocol initialization has been done. |
| ***Parameters*** | uint32_t ChannelMap - The bit map of channels to perform noise scan. The 32-bit double word parameter use one bit to represent corresponding channels from 0 to 31. For instance, 0x00000003 represent to scan channel 0 and channel 1.<br>uint8_t ScanDuration - The maximum time to perform scan on single channel. The value is from 5 to 14. The real time to perform scan can be calculated in following formula from IEEE 802.15.4 specification: 960 (2^ScanDuration + 1) 10^(-6) second<br>uint8_t DetectionMode - The noise detection mode to perform the scan. The two possible scan modes are<br>NOISE_DETECT_ENERGY Energy detection scan mode<br>NOISE_DETECT_CS Carrier sense detection scan mode<br>uint8_t NoiseLevel - The noise level at the channel with least noise level |
| ***Returns*** | The channel that has the lowest noise level |
| ***Example*** | <code><br>uint8_t NoiseLevel;<br>OptimalChannel = MiApp_NoiseDetection(0xFFFFFFFF, 10, NOISE_DETECT_ENERGY, &NoiseLevel);<br></code> |
| ***Remarks*** | None |

## 13.11 MiApp_TransceiverPowerState

| | |
|---|---|
| ***API*** | `uint8_t MiApp_TransceiverPowerState(uint8_t Mode)` |
| ***Description*** | This is the primary user interface functions for the application layer to put RF transceiver into sleep or wake it up. This function is only available to those wireless nodes that may have to disable the transceiver to save battery power. |
| ***Pre-Condition*** | Protocol initialization has been done. |
| ***Parameters*** | uint8_t Mode - The mode of power state for the RF transceiver to be set. The possible power states are following<br>POWER_STATE_SLEEP The deep sleep mode for RF transceiver<br>POWER_STATE_WAKEUP Wake up state, or operating state for RF transceiver<br>POWER_STATE_WAKEUP_DR Put device into wakeup mode and then transmit a data request to the device's associated device |
| ***Returns*** | The status of the operation. The following are the possible status<br>SUCCESS Operation successful<br>ERR_TRX_FAIL Transceiver fails to go to sleep or wake up<br>ERR_TX_FAIL Transmission of Data Request command failed. Only available if the input mode is POWER_STATE_WAKEUP_DR.<br>ERR_RX_FAIL Failed to receive any response to Data Request command. Only available if input mode is POWER_STATE_WAKEUP_DR. |

| | |
|---|---|
| | ERR_INVLAID_INPUT Invalid input mode. |
| ***Example*** | <code><br>// put RF transceiver into sleep<br>MiApp_TransceiverPowerState(POWER_STATE_SLEEP;<br>// Put the MCU into sleep<br>Sleep();<br>// wakes up the MCU by WDT, external interrupt or any other means<br>// make sure that RF transceiver to wake up and send out Data Request<br>MiApp_TransceiverPowerState(POWER_STATE_WAKEUP_DR);<br></code> |
| ***Remarks*** | |

## 13.12 MiApp_Get

| | |
|---|---|
| ***API*** | `bool MiApp_Get(set_params id, uint8_t *value )` |
| ***Description*** | This is the primary user interface function to get the different values in the MiWi™ stack |
| ***Pre-Condition*** | Protocol initialization has been done. |
| ***Parameters*** | get_params id - The identifier of the value to be set |
| ***Returns*** | A boolean to indicate if get operation has been performed successfully |
| ***Example*** | <code><br>value = MiApp_get(CHANNEL)<br></code> |
| ***Remarks*** | None |

## 13.13 MiApp_RoleUpgradeNotification_Subscribe

| | |
|---|---|
| ***API*** | `bool MiApp_RoleUpgradeNotification_Subscribe (roleUpgrade_callback_t callback)` |
| ***Description*** | This is used to subscribe to notify the role upgrade. Upon successful role upgrade, callback will be called with new short address |
| ***Pre-Condition*** | Protocol initialization has been done. |
| ***Parameters*** | roleUpgrade_callback_t callback - The callback routine which will be called upon the role upgrade done |
| ***Returns*** | A boolean to indicates if the subscribtion is success or not |

## 13.14 MiApp_Commissioning_AddNewDevice

| | |
|---|---|
| ***API*** | `bool MiApp_Commissioning_AddNewDevice(uint64_t joinerAddress, bool triggerBloomUpdate)` |

| | |
|---|---|
| ***Description*** | This is used to add a device to bloom filter on PAN Coordinator. This function is applicable only for PAN Coordinator. |
| ***Pre-Condition*** | Protocol initialization has been done. |
| ***Parameters*** | uint8_t joinerAddress - the ieee address to be added.<br>bool triggerBloomUpdate - if set to true then bloom update is sent immediately |
| ***Returns*** | True if successfully added, false otherwise. |

## 13.15 MiApp_SubscribeReConnectionCallback

| | |
|---|---|
| ***API*** | `bool MiApp_SubscribeReConnectionCallback(ReconnectionCallback_t callback)` |
| ***Description*** | This is used to subscribe to notify the reconnection after power recycle when device was in network before power recycle. Upon reconnection on a device, this callback will be called. |
| ***Pre-Condition*** | Protocol initialization has been done. |
| ***Parameters*** | ReconnectionCallback_t callback- The callback routine which will be called upon reconnection |
| ***Returns*** | A boolean to indicates if the subscription is success or not |

## 13.16 MiApp_ResetToFactoryNew

| | |
|---|---|
| ***API*** | `bool MiApp_ResetToFactoryNew(void)` |
| ***Description*** | This is used to erase all the persistent items in the non-volatile memory and resets the system |
| ***Pre-Condition*** | None |
| ***Parameters*** | None |
| ***Returns*** | A boolean to indicate the operation is success or not |

## 13.17 MiApp_ReadyToSleep

| | |
|---|---|
| ***API*** | `bool MiApp_ReadyToSleep(uint32_t* sleepTime)` |
| ***Description*** | This is used to understand the stack is ready to sleep and how much time stack allows to sleep if it is ready |
| ***Pre-Condition*** | None |
| ***Parameters*** | uint32_t* sleep Time - Pointer to sleep time which gets filled with the sleepable time if stack is ready to sleep |
| ***Returns*** | A boolean to indicate the stack is ready to sleep or not |

## 13.18 MiApp_ManuSpecSendData

| | |
|---|---|
| ***API*** | `bool MiApp_ManuSpecSendData(uint8_t addr_len, uint8_t *addr, uint8_t msglen, uint8_t *msgpointer,uint8_t msghandle, bool ackReq, DataConf_callback_t ConfCallback)` |
| ***Description*** | This is interface function for the Manufacturer specific data. The destination device is specified by the input parameter DestinationAddress. Currently the OTAU module uses this API for upgrade support. |
| ***Pre-Condition*** | Protocol initialization has been done. |
| ***Parameters*** | uint8_t addr_len - destination address length<br>uint8_t *addr - destination address<br>uint8_t msglen - length of the message<br>uint8_t *msgpointer - message/frame pointer<br>uint8_t msghandle - message handle<br>bool ackReq - set to receive network level ack (Note- Discarded for broadcast data)<br>DataConf_callback_t ConfCallback - The callback routine which will be called upon the initiated data procedure is performed. |
| ***Returns*** | A boolean to indicate if the unicast procedure is successful. |
| ***Example*** | <code><br>// Secure and then broadcast the message stored in msgpointer to the permanent address<br>// specified in the input parameter.<br>MiApp_ManuSpecSendData(SHORT_ADDR_LEN, 0x0004, 5, “hello”,1, callback);<br></code> |
| ***Remarks*** | None |

## 13.19 MiApp_SubscribeManuSpecDataIndicationCallback

| | |
|---|---|
| ***API*** | `bool MiApp_SubscribeManuSpecDataIndicationCallback (PacketIndCallback_t callback)` |
| ***Description*** | This is the primary user interface functions for the OTAU module to register for manufacturer specific indication callback. |
| ***Pre-Condition*** | Protocol initialization has been done. |
| ***Parameters*** | |
| ***Returns*** | A boolean to indicates if the subscription operation is successful or not. |
| ***Example*** | <code><br>if( true == MiApp_SubscribeManuSpecDataIndicationCallback (ind) )<br>{<br>}<br></code\> |
| ***Remarks*** | None |

## 13.20 MiApp_IsConnected

| | |
|---|---|
| ***API*** | `bool MiApp_IsConnected(void)` |
| ***Description*** | This is used to check whether the MiWi$^{TM}$ Mesh is connected to network or not. |
| ***Pre-Condition*** | None |
| ***Parameters*** | None |
| ***Returns*** | A Boolean true to indicate the node is connected to network. |

# 14 Limitations

The list of known limitations are described below:

1. Functional testing was performed on network consisting of 32 hops with 1 PAN Coordinator and 32 Coordinators.
2. The current MiWi$^{TM}$ P2P/Star protocol frame format and examples are compatible with older versions of MiWi$^{TM}$ P2P/Star.