AN1503: SiWG917 PTA 3-Wire Co-Existence (Wi-Fi)

This application note provides detailed guidance on the implementation of the PTA for the SiWG917 in Wi-Fi environments. It is assumed that readers have a basic understanding of Wi-Fi coexistence principles as applied to BLE devices.

The Silicon Labs Packet Traffic Arbitration (PTA) system facilitates the coordination of 2.4 GHz RF traffic for co-located 2.4 GHz radios and Silicon Labs wireless solutions. This involves the BLE device and SiWG917, which operate on overlapping frequency channels within the 2.4 GHz band while being spatially co-located. For further information, refer to UG103.17: Wi-Fi® Co-Existence Fundamentals.

KEY POINTS

- Introduction to PTA 3-Wire Co-Existence
- PTA Main Application Bring up steps
- PTA Test results under different test scenarios

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1. Introduction

Packet Transmission Arbitration (PTA) is an external coexistence mechanism designed to mitigate packet collisions between devices using different protocols, such as THREAD, Wi-Fi, and BT/BLE. In this document's solution, the SiWx917 device is configured as the PTA Main, supporting PTA 3-Wire Co-Existence for Wi-Fi in the 2.4 GHz mode of operation. Concurrently, the BLE Device is configured as a PTA Secondary, operating in BLE mode. When both devices operate within the 2.4 GHz band, they may have overlapping channels due to their spatial co-location. To prevent this, specific synchronization between the BLE Device and SiWx917 is required to regulate their transmission and reception, ensuring no collisions occur and optimal performance is maintained.

As the PTA Main, the SiWG917 is responsible for deciding which of the two devices will transmit at any given time. This decision is based on handshake signals exchanged over three different GPIO connections between the BLE Device and the SiWG917. The BLE Device, acting as the PTA Secondary, triggers these handshake signals according to the packet transfer requirements of both devices.

The current implementation provides a capability that protects all BLE transmission/reception activities by ensuring no transmission interference from the SiWG917 in Wi-Fi mode. This mechanism also includes provisions to protect Wi-Fi transmissions from possible interference by the BLE Device. However, the current implementation does not ensure the protection of Wi-Fi reception, which will be addressed in future enhancements of this feature.

1.1 Radio Protocol Impact

Globally, Wi-Fi (IEEE 802.11b/g/n) can support up to 14 overlapping channels of 20/22 MHz bandwidth within the 2.4 GHz ISM band, with transmit power levels reaching up to +30 dBm. Bluetooth, on the other hand, operates with 40 non-overlapping channels spaced at 2 MHz intervals, supporting transmit power levels up to +20 dBm, as specified in the Bluetooth Core Specification v5.0.

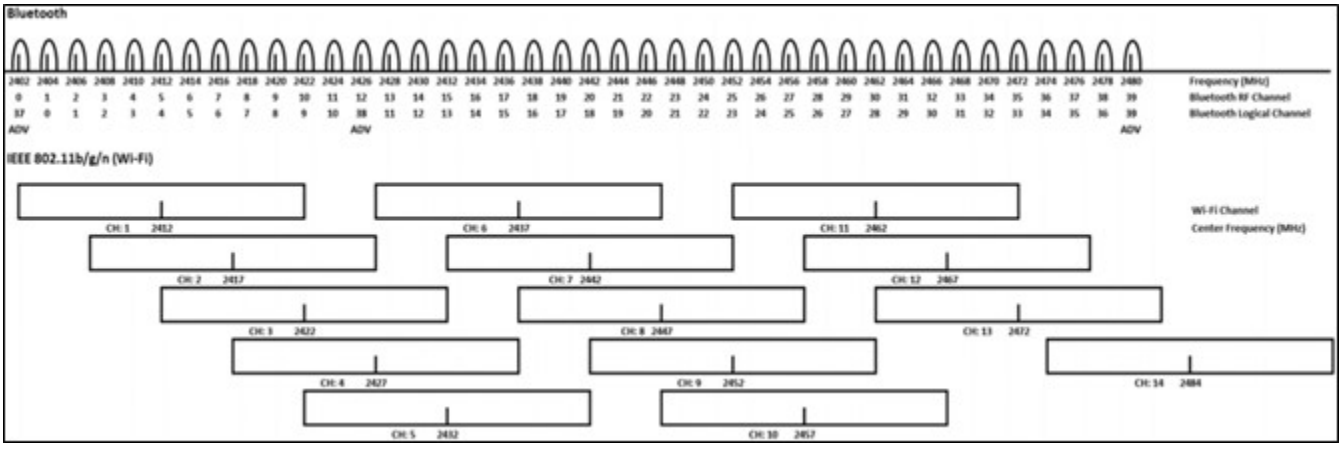

Figure 1.1. BT and Wi-Fi Channels Overlapping Spectrum

The number of available Wi-Fi Channels varies by country. For instance, in Japan, Wi-Fi channels 1 through 14 are available, while in the US, only Wi-Fi channels 1 through 11 can be used. Bluetooth operates 0 through 39 channels which are available globally.

1.2 PTA 3-Wire Co-Ex Mechanism

Packet Transmission Arbitration (PTA) is an external coexistence mechanism designed to reduce packet collisions between devices using different protocols, such as THREAD, Wi-Fi, and BT/BLE. In the described solution, the SiWG917 acts as the PTA Main, controlling access to the spectrum for both itself and the BLE device based on three handshake signals.

The PTA 3-Wire Coexistence Mechanism consists of three signals implemented between the PTA Main (SiWG917 Wi-Fi) and the PTA Secondary (BLE device) are:

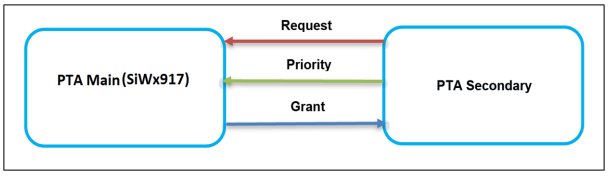

Figure 1.2. PTA 3-Wire Diagram

1. **REQUEST**
   - Input to SiWG917 and Output from BLE device.
   - The BLE device requests for channel access to the 2.4 GHz ISM band for transmission and reception
2. **PRIORITY**
   - Input to SiWG917 and Output from BLE device.
   - The BLE device asserts priority to indicate priority traffic and request access to the 2.4 GHz ISM band for transmission and reception
3. **GRANT**
   - Output from SiWG917 and Input to BLE device.
   - The SiWG917 grants permission to access the 2.4 GHz ISM band for transmission and reception

For spectrum access to either transmit or receive, the BLE device asserts the REQUEST signal. Depending on the Table 4.1 chosen configuration on page 7, the SiWG917 will indicate access by asserting the GRANT signal. The GRANT signal may only be asserted for spectrum access if the BLE device asserts both the REQUEST and PRIORITY signals, based on the configuration selected for the SiWG917.

2. Prerequisites

2.1 Hardware Requirements

- **PTA Main**
  - SiWG917 Pro Kit SiWG917-PK6031A
- **PTA Secondary**
  - BLE device supporting Tx and Rx operation
  - Micro USB Cable (For SiWG917 device power)
- **Windows PC**
- **Linux PC for running Server**
  - To run SiWG917SiWG917 Throughput Example
- **Access Point**
  - Used only in case of throughput runs on Wi-Fi side (PTA-Main)
- **Saleae Logic Analyzer**
  - Used to monitor the Grant, Request, and Priority signals
- **Female to Female connectors**
- **Splitters OR 'Y' connectors**
  - Connection between Saleae analyzer & PTA Slave
  - These splitters are connected to the PTA Main to analyze the Grant, Request, and Priority Signals

2.2 Software Requirements

- WiSeConnect 3 SDK (SiWG917 latest software release)
- For the latest WiSeConnect SDK, the GNU version used is GNU ARM v12.2.1
- Tools like Docklight/Tera term for Application prints.
- Logic 2 analyzer Tool
  - In Silicon Labs, Logic 2.4.14 application is used with Saleae Logic Analyzer
- Simplicity Studio IDE

Note:

Refer to Update the SiWx91x Connectivity Firmware to load the firmware into the SiWx917 device. The firmware binary is found in the <Release_Package >/connectivity_firmware folder.

3. Setup Diagram

In this setup, the SiWG917 operates as the PTA Main (Wi-Fi), with a BLE device connected to it. The SiWG917 throughput application has been executed on a Windows PC to measure Wi-Fi throughput values under various configurations SiWG917 (Config 1, Config 2, and Config 3, 4. Hardware Configurations). To facilitate remote server/client operations, another PC running the iperf application is utilized.

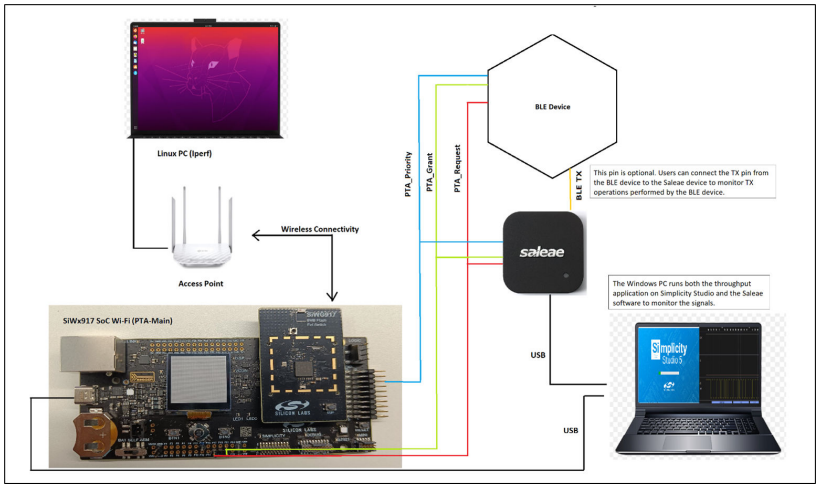

Figure 3.1. Setup Diagram

4. Hardware Configurations

The configuration detailed below describes the GPIO pin connections between the BLE Device and the SiWG917 device, specifically involving the GRANT, REQUEST, and PRIORITY signals.

Table 4.1. GPIO Pin Configurations

Pin Description	Priority signal	PTA master UDP TX (Mbps)
Request	ULP_GPIO_1	P16
Priority	ULP_GPIO_6	I2C_SDA (Expansion Header)
Grant	GPIO_7	P20

5. PTA Configurations for PTA Main (SiWG917)

The SiWG917 PTA feature can be configured by enabling BIT[21] (SL_SI91X_PTA_3WIRE_EN) in the config feature bit-map of the Operation Mode command. There are three different configurations, which can be selected by enabling or disabling Bit [23:22] (SL_SI91X_PTA_3WIRE_CONFIG_SEL(config_sel)). Each configuration modifies the behavior of how the GRANT signal is asserted in response to the REQUEST and PRIORITY signals. The following tables define these configurations:

Table 5.1. PTA Configuration type

BIT 23	BIT 22	Configuration
0	0	Reserved
0	1	Configuration 1
1	0	Configuration 2
1	1	Configuration 3

Table 5.2. PTA Configuration Description

Configuration	Description
Configuration 1	• The PTA Main will aggressively assert the GRANT signal if the REQUEST signal is asserted, regardless of whether the PRIORITY signal is asserted or not. • This means that any ongoing Wi-Fi transmission will be aborted, and GRANT will be provided to the PTA Secondary
Configuration 2	• The PTA Main will aggressively assert the GRANT signal if the REQUEST signal is asserted, regardless of whether the PRIORITY signal is asserted or not, with one exception. • If there is an ongoing ACK/Block ACK transmission in response to a Wi-Fi reception, the PTA Main will grant access only if both the PRIORITY and REQUEST signals are asserted
Configuration 3	• If there is an ongoing Wi-Fi transmission (including ACK/Block ACK), the PTA Main will not assert the GRANT signal in response to an asserted REQUEST. • However, if both PRIORITY and REQUEST signals are asserted, the PTA Main will assert the GRANT signal

5.1 PTA Main Application Configuration

- SiWG917 needs to use the throughput application to show the throughput values. Refer to the throughput application for more details.
- The BIT (21) (SL_SI91X_PTA_3WIRE_EN) of "config_feature_bit_map" is used to enable the PTA 3-wire feature. BIT (22) and BIT (23) (SL_SI91X_PTA_3WIRE_CONFIG_SEL(config_sel)) are used to select the required PTA configurations. This bitmap selection is available in the "app.c" file under the “sl_wifi_device_configuration_t” structure section. The "config_feature_bit_map" gets enabled when BIT (31) is set to '1' in both "tcp_ip_feature_bit_map" and "ext_tcp_ip_feature_bit_map".
- Below is the reference to enable, configure and use the PTA 3-wire feature followed by available different configurations:

```
#define SL_SI91X_PTA_3WIRE_EN BIT(21)
```

- Configurability options for config selection among 1, 2 & 3. Where BIT[22] - BIT[23] are used to set NUM_CONN_EVENTS(the number of BLE connection events.To know more about NUM_CONN_EVENTS please visit the link.
- In below table, '0' is kept reserved for future. PTA 3-wire used at DUT as GPIO_7 (Grant pin driven by DUT), ULP_GPIO_1(Request i/p pin for DUT) and ULP_GPIO_6(PRIORITY i/p pin for DUT).

Table 5.3. PTA Main Application Configuration type

Mode	BIT[23]	BIT[22]
Reserved	0	0
config1	0	1
config2	1	0
config3	1	1

- PTA 3-wire configuration needs to be updated in the "app.c" file as mentioned below to configure the config1, config2 & config3:

```
.config_feature_bit_map =
SL_SI91X_PTA_3WIRE_EN |
SL_SI91X_PTA_3WIRE_CONFIG_SEL(config_sel)
```

whereas "config_sel" will be 1, 2, and 3 based on the "config" mode that user wants to use.

```
static const sl_wifi_device_configuration_t throughput_configuration = {
  .boot_option = LOAD_NWP_FW,
  .mac_address = NULL,
  .band        = SL_SI91X_WIFI_BAND_2_4GHZ,
  .region_code = US,
  .boot_config = { .oper_mode = SL_SI91X_CLIENT_MODE,
                   .coex_mode = SL_SI91X_WLAN_ONLY_MODE,
                   .feature_bit_map =
                     (SL_SI91X_FEAT_SECURITY_OPEN | SL_SI91X_FEAT_AGGREGATION | SL_SI91X_FEAT_WPS_DISABLE),
                   .tcp_ip_feature_bit_map = (SL_SI91X_TCP_IP_FEAT_DHCPV4_CLIENT | SL_SI91X_TCP_IP_FEAT_SSL
                                              | SL_SI91X_TCP_IP_FEAT_EXTENSION_VALID),
                   .custom_feature_bit_map =
                     (SL_SI91X_CUSTOM_FEAT_EXTENTION_VALID | SL_SI91X_CUSTOM_FEAT_SOC_CLK_CONFIG_160MHZ),
                   .ext_custom_feature_bit_map = (MEMORY_CONFIG
#ifdef SLI_SI917
                                                  | SL_SI91X_EXT_FEAT_FRONT_END_SWITCH_PINS_ULP_GPIO_4_5_0
#endif
                                                  ),
                   .bt_feature_bit_map = 0,
                   .ext_tcp_ip_feature_bit_map =
                     (SL_SI91X_EXT_TCP_IP_WINDOW_DIV | SL_SI91X_CONFIG_FEAT_EXTENTION_VALID
                       | SL_SI91X_EXT_TCP_IP_FEAT_SSL_THREE_SOCKETS | SL_SI91X_EXT_TCP_IP_WAIT_FOR_SOCKET_CLOSE),
                   .ble_feature_bit_map     = 0,
                   .ble_ext_feature_bit_map = 0,
                   .config_feature_bit_map  = SL_SI91X_FEAT_SLEEP_GPIO_SEL_BITMAP | SL_SI91X_PTA_3WIRE_EN | SL_SI91X_PTA_3WIRE_CONFIG_SEL(3) },
  .ta_pool = { .tx_ratio_in_buffer_pool     = TX_POOL_RATIO,
               .rx_ratio_in_buffer_pool     = RX_POOL_RATIO,
               .global_ratio_in_buffer_pool = GLOBAL_POOL_RATIO }
};
```

Figure 5.1. Code Snippet

Note: It is advised to run PTA Main i.e., throughput first and then execute commands for PTA Secondary.

6. PTA Observations

6.1 BLE Duty Cycle 20 Percentage, BLE advertise interval: 20ms

Table 6.1. Throughput table (when, BLE Duty Cycle 20 %)

PTA Configuration	Priority signal	Test case	PTA master UDP TX (Mbps)	PTA master UDP RX (Mbps)
Config1	Enabled	BLE Advertise (PTA Slave)	36.55	32.79
	Disabled		37.31	33.24
Config2	Enabled		36.78	32.78
	Disabled		37.2	33.41
Config3	Enabled		37.5	32.86
	Disabled		37.1	32.87

6.2 BLE Duty Cycle Disabled, BLE advertise interval:20 ms

Table 6.2. Throughput table (when, BLE Duty Cycle Disabled)

PTA Configuration	Priority signal	Test case	PTA master UDP TX (Mbps)	PTA master UDP RX (Mbps)
Config1	Enabled	BLE Advertise (PTA Slave)	45.64	48.96
	Disabled		46.56	49
Config2	Enabled		46.08	48.74
	Disabled		46.91	48.92
Config3	Enabled		45.17	48.88
	Disabled		46.82	48.88

7. Use Case Scenario

The current implementation of PTA are suitable for the following scenarios:

- **Low Wi-Fi usage and low Wi-Fi throughput**: In this use case, occasional Wi-Fi disconnects can be tolerated. However, test results do not show any Wi-Fi disconnection unless the REQUEST/PRIORITY frequency increases significantly. All three configurations can be used for this scenario.
- **Moderate traffic on the BLE Device (BT Classic/BLE) with specific transmit throughput requirements on the Wi-Fi side**: Configuration 3 is recommended for this use case
- Moderate traffic on both the BLE Device and Wi-Fi

8. Limitations

The current implementation has the following limitations:

- Heavy interference on Wi-Fi reception on same channel might result in Wi-Fi disconnects, as Wi-Fi reception is not protected
- The mechanism is not sophisticated enough to guarantee strict throughput requirements on both protocols
- PTA functionality will not work with WLAN power save enabled.

Note: Ensure that support for the different pins required for PTA Main, specifically GRANT, REQUEST, and PRIORITY, is enabled from the BLE device. This will facilitate the verification of PTA functionality.

9. Revision History

Revision 1.0

Feburary, 2025

Initial release.

10. References

Following are the references:

- SiWG917 API Documentation
- ZigBee & Open Thread Co-Existence with Wi-Fi
- Bluetooth Co-Existence with Wi-Fi

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