INTRODUCTION

Nowadays, most of the embedded applications require real-time communications to support various applications and user environment. Bluetooth® has emerged as the standard of choice for connecting local embedded applications within operable range, a requirement in line with most of the Internet of Things (IoT) technology.

Bluetooth Classic (BTC) technology is originally designed for continuous data and voice streaming applications, and has successfully eliminated wires in many consumers, industrial, and medical applications. Classic Bluetooth technology continues to provide a robust wireless connection and can stream data between devices, ranging from infotainment in cars to industrial controllers and medical sensors.

Bluetooth Low Energy (BLE) technology is introduced through Bluetooth version 4.0 specification from Special Interest Group (SIG), and with this, there has been a considerable interest in various application possibilities in different market segments. BLE works with extremely low-power consumption, has unique features and also supports new services/profiles. Coin cell battery-operated sensors and actuators in medical, consumer, and fitness applications can now smoothly connect to BLE technology enabled smartphones, tablets or gateways. BLE is ideal for applications requiring periodic transfer of small amount of data.

Bluetooth Classic and BLE technology are quite different from one another, thus, user has to consider the technology which meets the applications requirements. However, both Classic Bluetooth and BLE have found presence with the IoT that requires ease of network connectivity by enabling physical objects or devices to connect and exchange data.

The primary purpose of this application note is to help users or application developers to have a quick understanding of the interface requirements and the process of communication between the RN4677 module and the PIC18 (8-bit) microcontroller over the UART using the ASCII command interface. It essentially supports BTC, BLE, and Dual mode applications.

This application note also showcases the low data rate streaming when Classic Bluetooth technology Serial Port Profile (SPP) and the Bluetooth Low Energy Private Service called Transparent UART are used for data transfer.

CLASSIC BLUETOOTH COMMUNICATION

Bluetooth is a wireless technology standard for exchanging data over short distances from fixed and mobile devices which are part of the Personal Area Networks (PANs). Classic Bluetooth is characterized to provide easy, temporary connectivity to smartphones and tablets, and is supported by Android™ and iOS® applications. It provides a convenient cable replacement option for applications, such as audio and data streaming between devices. Bluetooth initially supported 1 Mbps data transfer rate (Bluetooth 1.2) that has increased to 3 Mbps with the Enhanced Data Rate version (Bluetooth 2.1 + EDR), and further advanced to a high-speed version (Bluetooth 3.0 + HS) to support large file transfers.

Bluetooth Classic uses short-wavelength UHF radio waves that are part of the globally unlicensed Industrial, Scientific and Medical (ISM) 2.4 GHz frequency band. Bluetooth uses frequency-hopping spread spectrum. Classic Bluetooth divides transmitted data into packets, and transmits each packet in one of the 79 designated channels. Bluetooth operates at frequencies between 2400 MHz and 2483.5 MHz that includes guard bands of 2 MHz at the bottom and 3.5 MHz at the top. Each channel has a bandwidth of 1 MHz. The first channel starts at 2402 MHz and continues up to 2480 MHz in 1 MHz steps. It usually performs 1600 hops per second, with Adaptive Frequency Hopping (AFH) enabled. The maximum transmit power within the band is limited to 10 mW as per ISM standards.
BLUETOOTH SMART COMMUNICATION

Bluetooth Low Energy is intended for energy-constrained applications such as sensors or disposable devices, and for low-duty cycle devices that support low-data throughput which can operate for a longer duration compared to other protocols from a coin cell battery. Key benefits of implementing the technology are inexpensive silicon, much less MCU processing requirements, and reduced memory. These are suitable for applications related to the temperature, proximity, alerts, fitness and sports which represents a connectivity bubble belonging to the Body Area Network (BAN).

BLE operates in the spectrum band of 2.400 GHz to 2.4835 GHz, same as Classic Bluetooth technology, but uses a different set of channels. BLE operates in 40 channels, each of 2 MHz wide. Within a channel, data is transmitted using Gaussian Frequency Shift Keying (GFSK) modulation technique, which is similar to Classic Bluetooth's FSK modulation. The maximum over-the-air bit rate is 1 Mbps, and the maximum transmit power is 10 mW.

For additional information related to Bluetooth and its specifications, refer to the “Bluetooth Core Specification V4.0” from the following website: http://www.bluetooth.org.

SIMILARITIES IN BLUETOOTH TECHNOLOGIES AND ARCHITECTURE

Bluetooth Classic and BLE both operate in the 2.4 GHz ISM band and have similar Radio Frequency (RF) output power; however, because a BLE device is in Sleep mode most of the time and wakes up only during data transfer, hence this reduces the power consumption as the number of connection times are only a few milliseconds. BLE connections lose potential power savings as the utilization approaches continuous transmission.

Originally, GFSK modulation is the only modulation scheme available. After the introduction of Bluetooth 2.0+EDR, the π/4-DQPSK (Differential Quadrature Phase Shift Keying) and 8DPSK modulation schemes are also used between compatible devices. Devices functioning with GFSK are operating in Basic Rate (BR) mode where an instantaneous data rate of 1 Mbps is possible. The term Enhanced Data Rate (EDR) is used to describe π/4-DQPSK and 8DPSK schemes, each supporting 2 and 3 Mbps, respectively.

Many features of Classic Bluetooth technology are inherited in Bluetooth Low Energy technology, including the Adaptive Frequency Hopping (AFH) and also part of the logical link control and adaptation protocol (L2CAP) interface. Bluetooth Low Energy technology also implements the same link security with simple pairing modes, secure authentication, and encryption. These inheritances make BLE devices easy to setup, robust, and reliable in rough and varying environments.

Bluetooth protocol supports Master-Slave network architecture. One master can communicate with seven slaves in a Piconet. All devices share the master's clock. Packet exchange is based on the basic clock, defined by the master which ticks at 312.5 µs intervals. Two clock ticks make up a slot of 625 µs, and two slots make up a slot pair of 1250 µs. In single-slot packets, the master transmits in even slots and receives in odd slots. The slave, conversely, receives in even slots and transmits in odd slots. Packets may be 1, 3, or 5 slots long, but in all cases the master's transmission begins in even slots and the slave's in odd slots.

DIFFERENCES IN BLUETOOTH TECHNOLOGIES AND PROFILE SUPPORT

The behavior of a Bluetooth connection, whether Classic or Low Energy, is determined by the Bluetooth profiles or services that the device/module supports. Devices can exchange data only if both share a common Bluetooth profile/service implemented in it. However, there are differences in the available profiles in Classic Bluetooth technology compared to the services in Bluetooth Low Energy technology.

The Classic Bluetooth profiles include Headset (HSP), Hands Free (HFP), Object Exchange (OBEX), Audio Distribution (A2DP), Video Distribution (VDP), and File Transfer (FTP). Many other profiles are not offered for Bluetooth Low Energy due to the differences in the connection models. Bluetooth Low Energy also supports a lot of services through profiles. The BLE profiles are based on the Generic Attribute Profile (GATT), a general specification for sending and receiving short pieces of data known as attributes over a low-energy link. Typical profiles include Health Care, Sports and Fitness, Proximity, Alert and Battery, supporting related services.

Differences are also seen in the serial port emulation. For example, Classic Bluetooth supports the Serial Port Profile (SPP) for emulation of serial data connections. BLE technology, on the other hand, provides no such support in the standard Specification v4.0 although many suppliers provide different services to emulate serial connections. Microchip provides a good level of support on (Serial/UART) profiles like Microchip Low-energy Data Profile (MLDP v1 and v2) with RN4020 BLE modules, and services such as Transparent UART with RN4677 Dual Mode module.

In Bluetooth Low Energy specification, the master can be connected to several slave devices. The number of slaves can be very large depending on the implementation and available memory. In case of BLE, the peripheral (slave) devices can advertise via
advertisement packets to the central (master) devices that are scanning for peripherals. The advertisement packets are editable to contain custom information.

Note: Bluetooth profiles are additional protocol formats that are based on the standard to define the kind of data transmitted by the Bluetooth module. Bluetooth specifications define how the technology works while the profiles define how it is used.

SERIAL PORT PROFILE (SPP)

The SPP defines the specific protocol format and procedures for devices using Bluetooth for RS232 serial cable emulation. SPP is one of the most frequently used Bluetooth profiles to replace RS232 cables as it enables sending bursts of data between two devices. There are no fixed Master/Slave roles in this profile. The Radio Frequency Communication (RFCOMM), transport layer of Bluetooth, is used to transport the user data, modem control signals, and configuration commands.

For the execution of the SPP profile, use of security features such as authorization, authentication, and encryption is optional. Support for authentication and encryption is mandatory if the device has to take part in the security procedures requested from a peer device. The two devices are paired during the connection establishment phase that makes the connections secure. Bonding is not explicitly used in this profile, therefore support for this is optional.

TRANSPARENT UART

In addition to SPP for Bluetooth Classic connectivity, the RN4677 introduces a private GATT service for serial data transfer between two BLE devices. This BLE data streaming service provided in the RN4677 is named Transparent UART.

SINGLE MODE AND DUAL MODE BT DEVICE TOPOLOGIES

Bluetooth Smart Ready indicates a Dual mode device compatible with both Classic and Low Energy peripherals. Bluetooth Smart indicates a Low Energy only device which requires either a Smart Ready or another Smart device in order to function. The two Bluetooth technologies are fundamentally different, giving two implementation options:

- Single mode devices – These devices are stand-alone Bluetooth Low Energy devices or Bluetooth Classic devices are usually optimized for small battery-operated devices with low cost and low-power consumption in focus. A typical Single mode device is a heart rate sensor.

- Dual mode devices – These devices (also known as Smart Ready devices) include both Bluetooth Low Energy technology and Classic Bluetooth technology. Dual mode devices rarely gain in power saving as there is a need to support both technology implementations. Typical Dual mode devices are mobile phone, PC or an Embedded Gateway.

MICROCHIP RN4677 DUAL MODE BLUETOOTH MODULE

The Microchip RN4677 is a fully certified Bluetooth version 4.0 (BR/EDR/LE) Dual Mode module, which enables the designers to easily add Classic Bluetooth and Bluetooth Smart capability to their products. Delivering local connectivity for the IoT, RN4677 bridges product to smartphones and tablets to ensure convenient data transfer, control, and access to cloud applications. This Bluetooth SIG certified module provides a complete wireless solution with Bluetooth stack on board, integrated antenna, and worldwide radio certifications in a compact surface mount package, 22 x 12 x 2.4 mm.

Figure 1 illustrates the RN4677 module mounted on the RN4677 PICtail™/PICtail Plus Daughter board. It supports Generic Access Profile (GAP), Service Discovery Protocol (SDP), SPP, and GATT profiles. Data is transferred over the Bluetooth link via SPP for Bluetooth Classic and Transparent UART for Low Energy, making it easy to integrate with any processor or microcontroller with a UART interface. Configuration is easily made through ASCII commands via UART.

FIGURE 1: RN4677 PICtail™/PICtail PLUS DAUGHTER BOARD
A Microcontroller Unit (MCU) or host processor sends commands to configure module features, read status, and to manage Bluetooth data connections. The UART TX and RX lines are required to communicate with the module and transfer data through the Bluetooth SPP/Transparent UART connection. Connecting the hardware flow control lines, CTS and RTS, is highly recommended for applications that transmit a continuous stream of data.

Note: The RN4677 Bluetooth module can be configured over the Bluetooth link or through the module’s UART using a simple ASCII command language by entering Command mode. Set commands configure the module and Get commands echo the configuration. For details on ASCII commands, refer to the "RN4677 Bluetooth® 4.0 Dual Mode Module User’s Guide" (DS50002377).

RN4677 MODULE AND PIC18 MCU INTERFACE FRAMEWORK

The demo application uses required ASCII commands, issued by the PIC18F87J11 microcontroller, to configure and setup the wireless BT nodes. User input is given through the switches on the PIC18 Explorer Development board. Status messages are displayed on the LCD of PIC18 Explorer Development board. After successfully establishing a Bluetooth connection between two nodes, data in the form of strings/characters are transferred between these nodes, showcasing the SPP profile in BTC mode and Transparent UART service in BLE mode, both emulating the serial RS232 type of connection.

This application note provides the users with the following functionalities:

- Framework for any user application platform using the RN4677 Dual Mode Bluetooth module and PIC18F series of microcontrollers
- Specific interface between the RN4677 Bluetooth module and the PIC18F87J11 microcontroller
- Reference source code to manage connections of RN4677 module through PIC microcontroller
- Technique to enable switching between BTC and BLE modes and vice versa for communication using RN4677 Dual Mode module
- Demonstration of the Classic Bluetooth technology Serial Port Profile (SPP) and the Bluetooth Low Energy Private Service called Transparent UART for emulation of serial data connections

The hardware interface of the RN4677 module with any of the PIC microcontrollers can be called a wireless node. In this demo, the interface between RN4677 PICtail/PICtail Plus Daughter board and the PIC18 Explorer Development board is considered as a BT wireless node. Refer to Figure 2. The demo uses commands issued by the PIC18F87J11 microcontroller to configure and setup the BT Wireless nodes.

There are two components/node types in this demo application:

1. Node A - BTC/BLE device
2. Node B - BTC/BLE device

One of the nodes, say Node A, has to be configured to be either BTC or BLE node and for either Data Sending or Receiving node. The other node, say Node B, follows the configuration of Node A.

User input is taken through the switches on the PIC18 Explorer Development board. Status information displays periodically on the LCD of the PIC18 Explorer Development board. After successfully establishing a Bluetooth connection between the two nodes, data strings are transferred between these nodes showcasing the SPP which emulates the physical serial connection between the Bluetooth nodes.

Note: This application note is not intended to provide a complete understanding of the Bluetooth technology principles or usage of all the ASCII commands related to the RN4677 module. It only uses commands relevant for running the application demo code.
Application Demo Requirements

This section describes the hardware, software and related utility tools required for the demo setup.

HARDWARE REQUIREMENTS

Use the following hardware for the demo application:

• Two Microchip RN4677 PICtail/PICtail Plus Daughter boards
• Two PIC18 Explorer Development boards with PIC18F87J11 PIMs mounted
• Any of the following Microchip development tools for programming and debugging purposes: MPLAB® REAL ICE™ In-Circuit Emulator, MPLAB ICD 3 or PICkit™ 3
• Two power supplies: 9V/0.75A

SOFTWARE/UTILITY REQUIREMENTS

This demo application intends to showcase communication between two Classic or Low Energy Bluetooth wireless nodes using the Dual mode RN4677 modules. The application demo source code related to this application note is available as MPLAB X workspace project file and is available for download from the Microchip website at www.microchip.com. The code is compiled using the Microchip XC8 compiler v1.34 and MPLAB X IDE v3.05.

Note: The RN4677 modules must have firmware version 1.00 and above for the demo code to work. To know the details of the firmware version, refer to the product page from the Microchip website.

Demo source code is available for download from the Documentation and Software link section of the RN4677 product page at www.microchip.com/RN4677. Use the precompiled BTC_BLE_Node.X.production.hex file of the demo or compile the BTC_BLE_Node project code if required. Ensure that the compilation is successful before downloading the program into the MCU. For additional information on the source code, related files with description, and call graph, refer to Appendix A: "Source Code". From MPLAB X, user can generate call graphs related to specific functions of the demo code.

FIGURE 2: APPLICATION DIAGRAM OF BLUETOOTH COMMUNICATION USING RN4677 DUAL MODE MODULES

Note: The application note demo code uses RN4677 module mounted on RN4677 PICtail/PICtail Plus Daughter boards.
HARDWARE DEMO SETUP

This RN4677 based communication requires two wireless nodes. The demo setup consists of two PIC18 Explorer Development boards interfaced with two identical RN4677 PICtail/PICtail Plus Daughter boards as shown in Figure 2. Thus, the two identical RN4677 Dual Mode module-based wireless nodes are used for this application demonstration. For more information on the RN4677 module, refer to the “RN4677 PICtail™/PICtail Plus Board User’s Guide” (DS50002388).

TABLE 1: CONNECTION DETAILS BETWEEN THE RN4677 PICtail™/PICtail PLUS DAUGHTER BOARD AND THE PIC18 EXPLORER DEVELOPMENT BOARD

<table>
<thead>
<tr>
<th>RN4677 PICtail™/PICtail Plus Daughter Board</th>
<th>PIC18 Explorer Development Board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal Header (J1) Pin No.</td>
<td>Connectors J9 and J3 Pin No.</td>
</tr>
<tr>
<td>BT_UART_TXD 9</td>
<td>RC7/RX1/DT1 38</td>
</tr>
<tr>
<td>BT_UART_RXD 11</td>
<td>RC6/TX1/CK1 37</td>
</tr>
<tr>
<td>BT_WAKE_UP 19</td>
<td>RE0/AD8/PMRD(3)/P2D 4</td>
</tr>
<tr>
<td>BT_UART_CTS 25</td>
<td>RB1/INT1/PMA4 57</td>
</tr>
<tr>
<td>BT_UART_RTS 6</td>
<td>RA3/AN3/VREF+ 27</td>
</tr>
<tr>
<td>BT_RST_N 18</td>
<td>RA0/AN0 30</td>
</tr>
<tr>
<td>SW_BTN 1</td>
<td>RA2/AD10/PMBE(3)/P2B 78</td>
</tr>
<tr>
<td>EXT_3V3/VDD 26</td>
<td>VAR/VDD (J9) 5 (+3.3V)</td>
</tr>
<tr>
<td>GND 28</td>
<td>GND (J9) 6 (GND)</td>
</tr>
</tbody>
</table>

Note: VAR/VDD (J9) and GND (J9) indicate the only connections from J9 connector. All the other connections are from J3 connector.

FIGURE 3: PIC18F87J11 TO RN4677 BLUETOOTH INTERFACE DIAGRAM
Hardware Modifications Required in RN4677 PICtail/PICtail Plus Daughter Board

When using the RN4677 PICtail/PICtail Plus Daughter board with the PIC18 Explorer Development board, the user must be careful not to insert the PICtail directly into the J3/J9 connector.

Prior use, ensure to perform the following steps on the RN4677 PICtail/PICtail Plus Daughter board:

1. Remove P3_2 (Pin 8), P3_3 (Pin 10), and P3_4 (Pin 12) from the RN4677 PICtail/PICtail Plus Daughter board as these pins interfere with the functionality of the microcontroller pins.

2. Connect the BT_RST_N pin separately to the RE0/AD8/PMRD(3)/P2D pin on the PIC18 Explorer Development board.

*Figure 4* illustrates the RN4677 board connected to the PIC18 Explorer Development board.

**FIGURE 4:** RN4677 BOARD CONNECTED TO PIC18 EXPLORER DEVELOPMENT BOARD
GETTING STARTED

Setting Up the Bluetooth Nodes

To setup a wireless BT node, perform the following instructions:

1. Insert the RN4677 PICtail/PICtail Plus Daughter board into the connector socket of the PIC18 Explorer Development board.
2. Make note of the switch S4 and set the following jumper positions in the PIC18 Explorer Development board before running the demo code:
   - JP3 to enable LCD
   - JP1 to enable LEDs
   - J13 to ensure that the communication is routed through the RS-232 socket
   - J4 to ensure that the main PIC is programmed
   - Switch S4 to enable Processor In Module (PIM) (pointing towards MPLAB REAL ICE In-Circuit Emulator when ON)

Figure 5 shows the position of jumpers and switches on the PIC18 Explorer board.

3. Use switches (S1 and S2) and LCD (LCD1) on the PIC18 Explorer Development board for configuring and monitoring the wireless terminals.
4. Connect the programmer or debugger (MPLAB, REAL ICE In-Circuit Emulator, MPLAB ICD 3 or PICKit 3) to the PIC18 Explorer Development board.
5. Plug-in the 9V power supply to the PIC18 Explorer Development board through the 9V adapter (wall power) or through 9V Battery as shown in Figure 5.
6. Open the downloaded application demo source code BTC_BLE Node.X and compile (Clean Build). Alternatively, use the pre-compiled BTC_BLE Node.hex file available in the downloaded folder.
7. The generated or pre-compiled BTC_BLE Node.hex file can be programmed into the two wireless nodes, A and B, using any of the Microchip programmers supporting the PIC18F87J11 microcontroller.
8. The boards are ready to run the demo. If needed, the user must perform a Hardware Reset to run the code, specifically in case of PIC18 Explorer Development board.

For additional information on programming and debugging with MPLAB ICD 3, refer to "MPLAB® ICD 3 In-Circuit Debugger User’s Guide for MPLAB X IDE" (DS50002081), and for PIC18 Explorer Development Board, refer to “PICDEM™ PIC18 Explorer Demonstration Board User’s Guide” (DS50001721) which are available for download from the Microchip website at www.microchip.com.

FIGURE 5: SWITCH AND JUMPER POSITIONS ON THE PIC18 EXPLORER BOARD
Application Block Diagram and Flow Chart

Figure 6 shows the Block Diagram of the Application Demo and the components of each BT node.

FIGURE 6: APPLICATION BLOCK DIAGRAM WITH INPUT-OUTPUT INTERFACES

Running the Demo Application

Running the RN4677 demo application involves the following steps:

1. Configure the two wireless nodes, Node A and Node B, such that both nodes function either as Bluetooth Classic nodes or as Bluetooth Low Energy nodes.
2. Configure one of the wireless nodes (for example, Node A) to initiate connection and the other node (for example, Node B) waits for the connection request.
3. Establish connection between the two nodes.
4. Send and receive data strings between the two nodes over Bluetooth.
5. Kill connection and restart the demo.

The LCDs on the PIC18 Explorer board displays the sequence of events happening in the background such as initializing, scanning/inquiring/discovering of nodes, connecting and so on, and then enable the user to operate using the interactive messages. The user must operate using the hardware switches S1 and S2 to provide either a Yes or No responses as inputs to configure and control the demo.

Note: The application demo requires one BT wireless node (Node A) to be configured to initiate/inquire a connection and the other wireless node (Node B) to wait for the connection request in Discoverable mode.
Figure 7 and Figure 8 illustrate the complete cycle of this application demo.

FIGURE 7: APPLICATION DEMO FLOW CHART
FIGURE 8: APPLICATION DEMO FLOW CHART (CONTINUED)

1. Wait for peer BT device
2. Inquire for BT devices?
   - Yes (Node A)
   - No
3. Is the address that of Node B?
   - Yes
   - No
4. Check all the addresses displayed
   - Yes (Node B)
   - No
5. Connect to any MAC_ADDR?
   - Yes
   - No
   - Repeat inquiry
6. The two Nodes, A and B, are connected.
   - The strings to be sent to the remote BT device are displayed
   - Choose string?
     - Yes
     - No
   - Disconnect from peer BT device?
     - Yes
     - No
   - Send the selected data to the peer device
   - Any received data from the peer device?
     - Yes
     - No
   - Display the received data on LCD
8. End
Configuring the Two Wireless Nodes

After programming the boards and connecting the PIC18 Explorer Development boards (BT nodes) to the power supply, switch on the supply for both the nodes. The LCD on the boards displays the message as shown in Figure 9.

To configure the nodes, follow these steps:

1. Configure the two wireless nodes, Node A and Node B, as Bluetooth Classic nodes or Bluetooth Low-Energy nodes. Press S1 or S2 to configure.

FIGURE 9: CONFIGURING WIRELESS NODES AS BTC OR BLE NODES

2. All BT nodes display its MAC_ADDR and the user must make a note of the address for further selection and configuration. Refer to Figure 10.

FIGURE 10: BT NODE DISPLAYING ITS OWN MAC ADDRESS
3. The user can connect to any of the last Paired/Connected devices. Refer to Figure 11. If connection is through the previous connection details, then configure the modules such that one of the nodes (for example, Node A) initiates the connection and the other node (for example, Node B) waits for the connection request from Node A. Refer to Figure 12.

FIGURE 11: CONNECTING TO LAST PAIRED/CONNECTED DEVICES

FIGURE 12: INITIATING OR WAITING FOR A CONNECTION REQUEST
4. Node A can select one of the devices (BT Node MAC Address) from the Trusted Device List (TDL) to enable sending a connection request to Node B. Refer to Figure 13.

FIGURE 13: SELECTING ADDRESSES FROM TRUSTED DEVICE LIST (TDL)

5. An attempt is done to connect to the selected device (BT Node MAC Address). Refer to Figure 14. Upon successful connection, go to Step 1. If there are no devices selected in the previous step, then Node A cannot connect to any of the devices from TDL.

FIGURE 14: CONNECTING TO ANOTHER/SELECTED BT NODE
6. Alternatively, the user can choose if a factory reset must be done. Refer to Figure 15.

FIGURE 15: CHOOSING FACTORY RESET

Note: Only few settings such as the mode, authentication method, and extended status string are considered in the demo code. For other settings affecting the code execution, a factory reset is recommended.
Connecting Two Wireless Nodes

To connect the nodes, follow these steps:

1. Node A can start the Inquiry process to find the Bluetooth devices available, as shown in Figure 16 and Figure 17.

**FIGURE 16: INQUIRY PROCEDURE**

![Image of Inquiry Procedure]

**FIGURE 17: INQUIRY PROCEDURE IN PROGRESS**

![Image of Inquiry Procedure in Progress]
2. Node B continuously waits for the incoming connection request and successfully responds. Refer to Figure 18.

FIGURE 18: WAITING FOR A CONNECTION REQUEST

3. At Node A, list of devices found during the Inquiry process is displayed and the user can select one of the MAC_ADDR from the list. Refer to Figure 19.

FIGURE 19: INQUIRY SCAN RESULT
4. Node A attempts to connect to the selected device as shown in Figure 20. If there are no devices selected from the Inquiry result, a new inquiry scan is performed. Refer to Figure 21.

**FIGURE 20: CONNECTING TO THE SELECTED DEVICE/NODE**

![Figure 20: Connecting to the selected device/node](image)

**FIGURE 21: DISPLAY PROMPTING USER TO PERFORM A NEW INQUIRY PROCEDURE**

![Figure 21: Display prompting user to perform a new inquiry procedure](image)
Sending and Receiving Messages After Establishing Connection

1. After the two nodes (A and B) established a connection, as shown in Figure 22, one of the four data strings “Message 1”, “Message 2”, “Message 3”, “Message 4”, or the combination of these data strings can be selected at the local node to be sent to the remote node. Either of the nodes can initiate the message transfer. Refer to Figure 23.

FIGURE 22: THE TWO WIRELESS BT NODES IN CONNECTED STATE

FIGURE 23: DATA STRING SELECTION AT DATA SENDING NODE
2. The receiver node displays the data/received message on the LCD. Refer to Figure 24.

FIGURE 24: DATA STRING RECEPTION AT THE DATA RECEIVING NODE

3. The user can choose to end the connection by selecting the options from any of the two nodes as shown in Figure 25 and when it is opted, the connection is broken. Refer to Figure 26.

FIGURE 25: DISCONNECTING THE TWO WIRELESS NODES
Note: After disconnection, the user can restart the Configuration/Connection process for running the demo application again by enabling the Reset () function in AfterConnect.c and Checkresponse.c file in the project.
CONCLUSION

Considering both Bluetooth technologies, it is important to understand that adding of Bluetooth communication to any application is simple. For some applications, **Classic** is the best choice while for others **Low Energy** is the best choice. In other words, both Bluetooth Low Energy technology and Classic Bluetooth technology are irreplaceable in their own application space. BLE technology is quite different from Classic Bluetooth technology; hence the user must carefully consider which feature best fits the application needs. With the introduction of BT technology newer capabilities, there has been a great impact on the interest in developers and the market regarding its capabilities and possible applications.

This application note is designed to showcase the BT application developers on how to implement the Low Data Rate Streaming with Serial Port Profile and the Transparent UART Service using the Microchip RN4677 Dual Mode module and the 8-bit PIC® Microcontroller Interface. It also shows the ability of the Bluetooth RN4677 Dual Mode module which supports Bluetooth Classic and Bluetooth Low Energy protocols/services used for data transfer. The users can also get to know the requirements and methods to establish communication links through Bluetooth to facilitate data transfer between the BTC to BTC nodes or the BLE to BLE nodes.

This application note also provides sample source code related to PIC18 MCU for enabling the RN4677 Dual Mode module to function as a BTC device (Inquiry node), another BTC device (Connecting node) and similarly, as a BLE (Advertising node) to BLE (Connecting node) interface. Thus, the interface and code examples can be used further as a framework for any of the user applications or projects for using SPP profile and Transparent UART service.

REFERENCES

This section lists the Microchip Technology Inc. documents and other resources that are referenced in this application note.

Microchip Technology Inc. Resources:
- “RN4677 Bluetooth® 4.0 Dual Mode Module Data Sheet” (DS50002370A)
- “RN4677 Bluetooth® 4.0 Dual Mode Module User’s Guide” (DS50002377A)
- “RN4677 PICtail™/PICtail Plus Board User’s Guide” (DS50002388A)
- “PICDEM™ PIC18 Explorer Demonstration Board User’s Guide” (DS500051721B)
- “PIC18F87J11 Family Data Sheet” (DS39778E)
- “MPLAB® ICD 3 In-Circuit Debugger User’s Guide for MPLAB X IDE” (DS50002081B)

Specification References:
- Bluetooth 4.1 GATT Definitions Browser: [https://developer.bluetooth.org/gatt/Pages/Definition-Browser.aspx](https://developer.bluetooth.org/gatt/Pages/Definition-Browser.aspx)

Note: The referenced documents are identified with a “DS” number. The numbering convention for the DS number is “DSXXXXXXXA”, where “XXXXXXX” is the document number and “A” is the revision level of the document. Visit the Microchip website to get the latest documentation available.
APPENDIX A: SOURCE CODE

Software License Agreement
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All softwares covered in this application note are available as a single WinZip archive file. This archive file can be downloaded from the Microchip website at: www.microchip.com

A.1 Source Code File List

Table 2 provides the list of files that are used as part of the Application Demo.

<table>
<thead>
<tr>
<th>File name</th>
<th>File type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main</td>
<td>.c and .h</td>
<td>Initializes the state machine which is used to demonstrate the Demo Application</td>
</tr>
<tr>
<td>Init</td>
<td>.c and .h</td>
<td>Handles the initialization of the PIC18F87J11 and its various peripherals</td>
</tr>
<tr>
<td>StateMachines</td>
<td>.c and .h</td>
<td>Handles the state machines of the three wireless Bluetooth nodes</td>
</tr>
<tr>
<td>UART</td>
<td>.c and .h</td>
<td>Handles the UART peripheral of the PIC18F87J11</td>
</tr>
<tr>
<td>CheckResponse</td>
<td>.c and .h</td>
<td>Checks the response strings obtained from the RN4677 Bluetooth module</td>
</tr>
<tr>
<td>AfterConnect</td>
<td>.c and .h</td>
<td>Handles the transfer and display of data strings exchanged between the Bluetooth modules</td>
</tr>
<tr>
<td>LCD</td>
<td>.c and .h</td>
<td>LCD interface</td>
</tr>
<tr>
<td>Globals</td>
<td>.c and .h</td>
<td>Contains few global variables used in the code</td>
</tr>
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</table>
A.2 Source Code Call Graph

Figure 27 shows the source code call graph.

FIGURE 27: SOURCE CODE CALL GRAPH
APPENDIX B: CONFIGURING THE RN4677 MODULES USING ASCII COMMANDS

Table 3 and Table 4 list the sequence of commands which must be used to setup a simple Bluetooth connection between two RN4677 Bluetooth modules operating in Bluetooth Classic mode.

### Table 3: SEQUENCE OF COMMANDS USED FOR THE WIRELESS NODE TO WAIT FOR THE CONNECTION

<table>
<thead>
<tr>
<th>User ASCII Commands</th>
<th>Expected ASCII Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>$$$</td>
<td>CMD&gt;</td>
</tr>
<tr>
<td>+\r\n</td>
<td>ECHO ON and AOK\r\nCMD&gt;</td>
</tr>
<tr>
<td>SG,2\r\n or SG,1\r\n</td>
<td>AOK\r\nCMD&gt;</td>
</tr>
<tr>
<td>SA,2\r\n</td>
<td>AOK\r\nCMD&gt;</td>
</tr>
<tr>
<td>R,1\r\n</td>
<td>Rebooting\r\n%REBOOT%</td>
</tr>
<tr>
<td>K,1\r\n</td>
<td>Disconnected\r\n</td>
</tr>
</tbody>
</table>

### Table 4: SEQUENCE OF COMMANDS USED FOR THE WIRELESS NODE TO INITIATE THE CONNECTION

<table>
<thead>
<tr>
<th>User ASCII Commands</th>
<th>Expected ASCII Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>$$$</td>
<td>CMD&gt;</td>
</tr>
<tr>
<td>+\r\n</td>
<td>ECHO ON and AOK\r\nCMD&gt;</td>
</tr>
<tr>
<td>SG,2\r\n or SG,1\r\n</td>
<td>AOK\r\nCMD&gt;</td>
</tr>
<tr>
<td>SA,2\r\n</td>
<td>AOK\r\nCMD&gt;</td>
</tr>
<tr>
<td>R,1\r\n</td>
<td>Rebooting\r\n%REBOOT%</td>
</tr>
<tr>
<td>$$$</td>
<td>CMD&gt;</td>
</tr>
<tr>
<td>I\r\n</td>
<td>Inquiry, T=8, COD=0&lt;List of MAC addresses&gt;\r\nFound &lt;x&gt;&lt;\r\nCMD&gt;</td>
</tr>
<tr>
<td>C,&lt;MAC_Address&gt;\r\n</td>
<td>Trying\r\n%NEW_PAIRING%\r\n%CONNECT,&lt;MAC_ADDR&gt;,0%/r/n</td>
</tr>
<tr>
<td>K,\r\n</td>
<td>Disconnected\r\n</td>
</tr>
</tbody>
</table>

**Note:** When the modules are connected, the data bytes that are sent from one BT module are received by the other BT module, and vice versa. Later, if required, the modules can be disconnected.
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