Using BLE 5.0

# Introduction

This document introduces the reader to some of the BLE APIs available in the SDK through a code sample consisting of a server and a client application.

It covers the usage of:

1. Setting up advertising and connection modes
2. Creating services and its characteristic
3. Assigning UUID to them and handling their access

# Topology

Diagram

Description automatically generated

Figure : Using BLE – Topology

# BT Protocol Stack Structure, APIs & Event Mechanism

SDK’s Bluetooth Protocol stack consists of two parts:

1. Controller Stack – manages PHY layer, baseband, link controller, link manager, device manager, HCI and other modules used for hardware interface and link management.
2. Host Stack – consists of L2CAP, SMP, SDP, GAP, ATT, GATT and various profiles.

Host Stack provides the API interface to the application programmer, through which application layer can access all the features of Bluetooth System.

GAP (Generic Access Profile) defines the discovery, device management and device connection management between BLE devices. GAP APIs provide the way to configure advertising and connection parameters.

ATT (Attribute Protocol) defines attribute protocol for discovering, reading, and writing attributes in a peer device. Attributes are where data resides and they consist of a handle, a type, a value, and permission.

GATT (Generic Attribute Profile) describes a service framework using the ATT protocol for discovering services and for reading and writing characteristic values and their descriptors on a peer device.

GATT APIs provide a way to achieve this by creating services and characteristics, discovering them, and reading descriptors, or requesting for a notification from GATT server.

Once these APIs are called, status of the devices at various states is obtained by events pushed from the stack through the callback functions provided. These callbacks are used for even-handling.

The applications functionality is defined by the way it is programmed to react to these events. For example, by defining what happens next when another device tries to connect and reads or writes some parameters.

# Roles of Server & Client

In BLE terminology, the server acts as a GATT server, a GAP peripheral, and is a slave device. The client acts as a GATT client, a GAP central, and is a master device. The terms server and client are used throughout this document to refer to these roles.

The device in the central role scans, looking for advertisement, and the device in the peripheral role makes the advertisement.

Once they establish connection, what the two devices talk to each other is determined by GATT Server’s and GATT Client’s implementation.

# List of APIs

1. bt\_gap\_init()- Initializes the GAP service. This API must be called before using any of the other functions in the GAP interface.
2. bt\_gatt\_create\_service\_128()- Creates a service declaration from a 128-bits UUID.
3. bt\_gatt\_add\_char\_128()- Adds a 128-bits UUID characteristic to a created service.
4. bt\_gatt\_add\_service()- Adds (a created) service to the local server list.
5. bt\_gap\_addr\_set()- Sets address for given address type.
6. bt\_gap\_cfg\_ext\_set() - Configures extended advertising mode.
7. bt\_gap\_set\_adv\_data() - Sets advertising data for advertising.
8. bt\_gap\_discoverable\_mode()- Sets device in discoverable mode.
9. bt\_gap\_set\_adv\_data()- Sets advertising data for legacy advertising
10. bt\_gap\_server\_link\_add()- Adds a GATT server to the gap connection.
11. bt\_gap\_server\_link\_remove()- Removes GATT server from the gap connection.
12. bt\_gap\_cfg\_conn\_set()- Configures connection.
13. bt\_gap\_connection\_mode()- Sets device in connecting mode.
14. bt\_gap\_connectable\_mode()-Sets device in connectable mode
15. bt\_gap\_client\_link\_add()- Adds a GATT client to the gap connection.
16. bt\_gatt\_discover\_characteristics\_by\_uuid()- Discovers characteristics by UUID.
17. bt\_gatt\_exchange\_mtu()- Sets and exchanges MTU size for reception.
18. bt\_gatt\_read\_characteristic\_value()- Reads characteristic value.
19. bt\_gatt\_add\_char\_128()- Adds a 128-bits UUID characteristic to a created service
20. bt\_gap\_authenticate()- Authenticates connected link.
21. bt\_gap\_cfg\_adv\_set()- Configures advertisement.
22. bt\_smp\_passkey\_set()- Sets the passkey for the link.
23. bt\_smp\_cfg\_set()- Sets bt\_smp\_cfg\_t value to the current setting SMP.

# Server Application

## Overview

The sample code in the path examples\using\_ble\src\ble\_server.c implements a server called InnoServer. It creates and starts a custom GATT service with a single read-only characteristic. Each time the characteristic is read by a client, the read returns a different character string from a set of strings present on the server.

In addition to the custom service, the server also makes use of common server functionality provided by the BLE API. Specifically, this adds the Generic Access, Generic Attribute, and Device Information services to the server.

## Code Walkthrough

**Note**: All the applicable ELFs are available in the following location of the SDK release package: sdk\_x.y\examples\using\_ble\bin.

x and y in sdk\_x.y refer to the SDK release version. For example: *sdk\_2.4\examples\using\_ble\bin*.

### Initialization

The server starts by initializing the GAP Service:

|  |
| --- |
| bt\_gap\_init(); |

The GAP API must be called before using any of the other functions in the Bluetooth GAP interface. It returns zero on success, non-zero otherwise.

### Adding Common Server Functionality

The server uses the API to add common server functionality:

|  |
| --- |
| void common\_server\_create(char \*name, uint16\_t appearance, char \*manufacturer\_name); |

This adds the Generic Access, Generic Attribute, and Device Information services to our server. The server is given the name InnoServer with a manufacturer name of Innophase IoT.

|  |
| --- |
| common\_server\_create("InnoServer", 0, "Innophase IoT"); |

### Adding Custom Service & Characteristic

The server’s custom service and characteristic are implemented in the custom\_server\_create function:

|  |
| --- |
| static void custom\_server\_create(void)  {  srv.cust\_service = bt\_gatt\_create\_service\_128(UUID\_CUSTOM\_SERVICE);  bt\_gatt\_add\_char\_128(srv.cust\_service, UUID\_CUSTOM\_CHARACTERISTIC, char\_access\_cb, GATT\_PERM\_READ, GATT\_CHAR\_PROP\_BIT\_READ);  bt\_gatt\_add\_service(srv.cust\_service);  } |

The bt\_gatt\_create\_service\_128 function creates a GATT service with a 128-bit UUID.

bt\_gatt\_add\_char\_128 is used to add a characteristic with a 128-bit UUID to a service. A callback function char\_access\_cb is provided and will be called when the characteristic is accessed. Properties and permissions for the characteristic are also specified; in this case, the characteristic is read-only.

Finally, bt\_gatt\_add\_service adds the service to our server.

### Starting the Server

Once the server’s services and characteristics are set up, it is started in the start\_server function:

|  |
| --- |
| static void start\_server(void)  { bt\_gap\_cfg\_adv\_t bt\_handle;  /\* Configure advertisement \*/      bt\_handle.fast\_period = 10240;      bt\_handle.slow\_period = 0;      bt\_handle.fast\_interval = 160;      bt\_handle.slow\_interval = 1600;      bt\_handle.tx\_power = 0;     bt\_handle.channel\_map = 0;      bt\_gap\_cfg\_adv\_set(&bt\_handle);      /\* Set our BLE address \*/      bt\_gap\_addr\_set(bt\_hci\_addr\_type\_random, SERVER\_ADDR);      if (adv\_mode != 0) {          os\_printf("Extended\_ADV\_mode \n");          bt\_gap\_cfg\_ext\_t ext;          /\*configure extended advertisement\*/          ext.use = 2;          ext.adv\_pri\_phy = 1; /\*adv\_pri\_phy\*/          if(adv\_sec\_phy != 0)              ext.adv\_sec\_phy = 2; /\*adv\_sec\_phy LE 2 Mbps\*/          else              ext.adv\_sec\_phy = 1; /\*adv\_sec\_phy LE 1 Mbps\*/          ext.adv\_sid = 1; /\*adv\_sid\*/          ext.conn\_phy = 1; /\*conn\_phy\*/          ext.conn\_len = 251; /\*conn\_len\*/          bt\_gap\_cfg\_ext\_set(&ext);          if(adv\_sec\_phy != 0){              os\_printf("Extended ADV payload len = %d \n", adv\_length\_2);              bt\_gap\_set\_adv\_data(adv\_length\_2, adv\_buf\_2); /\*Set advertising data\*/          } else {              os\_printf("Extended ADV payload len = %d \n", adv\_length\_1);              bt\_gap\_set\_adv\_data(adv\_length\_1, adv\_buf\_1); /\*Set advertising data\*/  } }      /\* Make server connectable (will enable advertisement) \*/  bt\_gap\_discoverable\_mode(GAP\_DISCOVERABLE\_MODE\_GENERAL, bt\_hci\_addr\_type\_random, 0,address\_zero, &gap\_ops);  } |

Here bt\_gap\_cfg\_adv sets parameters for advertisement. bt\_gap\_set\_adv\_data sets the advertisement data. bt\_gap\_addr\_set sets our BLE address and address type; the sample server uses a random address that does not change.

bt\_gap\_cfg\_ext\_set() configures the extended advertisement, while bt\_gap\_set\_adv\_data() sets advertising data for advertising.

bt\_gap\_connectable\_mode makes the device connectable and will enable advertisement.

### Connection/Disconnection Callbacks

At this point of execution, the server is advertising and ready to receive a connection from the client. When the client connects, the callback function connected\_cb will be called. In the callback, the GATT server needs to be linked to this GAP connection with the following function call:

|  |
| --- |
| srv.gatt\_link = bt\_gap\_server\_link\_add(param->handle); |

The code sample shows how to obtain the argument required for this function call from the argument provided to the callback by casting hci\_event with bt\_hci\_evt\_le\_conn\_cmpl\_t and fetching its handle.

Similarly, the link is removed in disconnected\_cb, which is the callback function that is called when the client disconnects:

|  |
| --- |
| bt\_gap\_server\_link\_remove(srv.gatt\_link); |

### Characteristic Access Callback

While the client is connected to the server, it can read the custom characteristic. This results in the callback function associated with the characteristic being called. In this case, it is char\_access\_cb. In the sample, this function chooses a string to send to the client as a read response. The length argument specifies the space available in the data array to store the read response. This is dependent on the MTU size used for the connection. The data to send is set in the data array and the length argument is updated to the amount of data set in the array:

|  |
| --- |
| chars\_to\_copy = min((size\_t)\*length, strlen(SERVER\_QUOTES[rsp\_idx]));  memcpy(data, SERVER\_QUOTES[rsp\_idx], chars\_to\_copy);  \*length = chars\_to\_copy; |

Note: The string’s null terminator is not included in the read response.

## Running the Application

Program ble\_server.elf (sdk\_x.y\examples\using\_wifi\bin) using the Download tool(sdk\_x.y\pc\_tools\Download\_Tool)provided with InnoPhase Talaria TWO SDK.

1. Launch the Download tool.
2. In the GUI window:
   1. Boot Target: Select the appropriate EVK from the drop-down
   2. ELF Input: Load the ble\_server.elf by clicking on Select ELF File.
   3. Boot Arguments: Pass the following boot arguments to select the advertising mode and adv\_sec\_phy secondary PHY.

|  |
| --- |
| BLE5\_adv\_mode=<0/1> BLE5\_adv\_sec\_phy=<0/1>  BLE5\_adv\_mode=0 => Advertising mode is Legacy  BLE5\_adv\_mode=1 => Advertising mode is Extended  BLE5\_adv\_sec\_phy=0 => adv\_sec\_phy Secondary PHY is LE 1Mbps  BLE5\_adv\_sec\_phy=1 => adv\_sec\_phy Secondary PHY is LE 2Mbps |

* 1. Programming: Prog RAM or Prog Flash as per requirement.

For more details on using the Download tool, refer to the document: UG\_Download\_Tool.pdf (path: *sdk\_x.y\pc\_tools\Download\_Tool\doc*).

**Note**: x and y refer to the SDK release version.

For example: sdk\_2.4/doc.

## Expected Output

|  |
| --- |
| Y-BOOT 208ef13 2019-07-22 12:26:54 -0500 790da1-b-7  ROM yoda-h0-rom-16-0-gd5a8e586  FLASH:PNWWWWAEBuild $Id: git-a88e30570 $  BLE5\_adv\_mode=1 BLE5\_adv\_sec\_phy=0  $App:git-37cab6b4  SDK Ver: SDK\_2.6.3alpha  Ble Server Demo App  Extended\_ADV\_mode  Extended ADV payload len = 245  InnoServer started  [0.823,544] BT connect[0]: ia:75:20:12:19:81:0f aa:05:04:03:02:01:00 phy2:0/0 phyC:00  Client connected  InnoServer: Hello from InnoServer  InnoServer: You can do anything, but not everything.  InnoServer: The richest man is not he who has the most, but he who needs the least.  InnoServer: You miss 100 percent of the shots you never take.  InnoServer: Courage is not the absence of fear, but rather the judgment that something else is more important than fear.  InnoServer: You must be the change you wish to see in the world.  InnoServer: To the man who only has a hammer, everything he encounters begins to look like a nail.  InnoServer: A wise man gets more use from his enemies than a fool from his friends.  InnoServer: The real voyage of discovery consists not in seeking new lands but seeing with new eyes.  InnoServer: Even if you’re on the right track, you’ll get run over if you just sit there.  InnoServer: People often say that motivation doesn’t last. Well,neither does bathing – thats why we recommend it daily.  InnoServer: Believe those who are seeking the truth. Doubt those who find it.  InnoServer: It is the mark of an educated mind to be able to entertain a thought without accepting it.  InnoServer: I’d rather live with a good question than a bad answer.  InnoServer: We learn something every day, and lots of times its that what we learned the day before was wrong.  InnoServer: I have made this letter longer than usual because I lack the time to make it shorter.  InnoServer: Don’t ever wrestle with a pig. You’ll both get dirty, but the pig will enjoy it.  InnoServer: An inventor is simply a fellow who doesn’t take his education too seriously.  InnoServer: Never be afraid to laugh at yourself, after all, you could be missing out on the joke of the century.  InnoServer: I am patient with stupidity but not with those who are proud of it.  InnoServer: The cure for boredom is curiosity. There is no cure for curiosity.  InnoServer: Advice is what we ask for when we already know the answer but wish we didn’t.  InnoServer: Some people like my advice so much that they frame it upon the wall instead of using it.  InnoServer: The trouble with the rat race is that even if you win,you’re still a rat.  InnoServer: Imagination was given to man to compensate him for what he is not,and a sense of humor was provided to console him for what he is.  InnoServer: When a person can no longer laugh at himself, it is time for others to laugh at him. |

# Client Application

## Overview

The sample code in examples/using\_ble/src/ble\_client.c implements a client called InnoClient which is intended to work with InnoServer. The client scans for and connects to the server based on the server’s BLE address (fixed at compile-time).

Once connected, the client tries to discover the custom GATT service and characteristic present on the server. After this is accomplished, the client reads the custom characteristic on the server several times and prints out the string that it receives to the console.

## Code Walkthrough

### Initialization

Like the server, the client must also initialize the GAP Service before calling other functions in the GAP interface:

|  |
| --- |
| bt\_gap\_init(); |

### Scanning

The function scan\_and\_connect implements functionality of scanning for and connecting to the server.

This function makes use of the following API calls to start the scan: bt\_gap\_cfg\_scan\_t

|  |
| --- |
| bt\_gap\_error\_t scan\_and\_connect(void)  {  bt\_gap\_cfg\_scan\_t bt\_scan\_handle;  bt\_gap\_cfg\_conn\_t bt\_conn\_handle;  bt\_gap\_error\_t result\_gap = GAP\_ERROR\_SUCCESS;  os\_printf("InnoServer address: %6pMR\n", inno\_server\_conn.ble\_addr);  /\* Scan for server \*/  bt\_scan\_handle.period = SCAN\_PERIOD;  bt\_scan\_handle.interval = SCAN\_INT;  bt\_scan\_handle.window = SCAN\_WIN;  bt\_scan\_handle.background\_interval = SCAN\_INT;  bt\_scan\_handle.background\_window = SCAN\_WIN;  bt\_scan\_handle.filter\_duplicates = 1;  .  .  .  } |

bt\_gap\_discovery\_mode puts the device into discovery mode. A pointer to a gap\_opts\_t instance is supplied to specify relevant callback functions; this is how the example specifies that the device\_discovery\_event function should be called when a new BLE device is discovered during scan:

|  |
| --- |
| bt\_gap\_discovery\_mode(GAP\_DISCOVERY\_MODE\_GENERAL, bt\_hci\_addr\_type\_random, addr\_type\_zero, address\_zero, &gap\_ops); |

In the device\_discovery\_event function, the client determines whether the identified device is the InnoServer based on a comparison of BLE addresses. If so, a copy of the server’s advertising report is saved and the main thread executing scan\_and\_connect is notified to turn off discovery and proceed with connection.

### Connecting

The client connects to the server using the following API calls: bt\_gap\_cfg\_conn\_set

|  |
| --- |
| /\* Configure connection \*/  bt\_conn\_handle.interval = CONN\_INTERVAL;  bt\_conn\_handle.latency = CONN\_LATENCY;  bt\_conn\_handle.timeout = CONN\_TIMEOUT;  bt\_conn\_handle.params\_int\_min = 0;  bt\_conn\_handle.params\_int\_max = CONN\_PARAMS\_INT\_MIN;  bt\_conn\_handle.params\_reject = CONN\_PARAMS\_INT\_MAX;  bt\_gap\_cfg\_conn\_set(&bt\_conn\_handle); |

bt\_gap\_connection\_mode puts the device into connecting mode. The client passes the server’s BLE address and address type to this function, along with a pointer to an instance of gap\_opts\_t. This GAP options struct instance specifies the callback functions that will be called when the connection is established or a disconnect occurs.

|  |
| --- |
| bt\_gap\_connection\_mode(GAP\_CONNECTION\_MODE\_DIRECT, bt\_hci\_addr\_type\_random,inno\_server\_conn.adv\_report->addr\_type,inno\_server\_conn.ble\_addr,&gap\_ops); |

In the sample, the connected\_event function will be called when the connection to the server is established. A connection handle is available from the argument to the connected callback. In connected\_event, this handle is saved and the main thread executing scan\_and\_connect is notified that the connection has been established. The following API call is then made to associate the GATT client with the connection:

|  |
| --- |
| inno\_server\_conn.gatt\_link = bt\_gap\_client\_link\_add(inno\_server\_conn.conn\_handle); |

### Service Discovery

The function discover\_services implements functionality for discovering the custom service and characteristic on the server. The results of discovery are handles:

1. Service is identified by a start handle and an end handle
2. Characteristic is identified by a single handle

Since the UUID of the service is known beforehand, bt\_gatt\_discover\_primary\_service\_by\_service\_uuid is used to identify the service on the server:

|  |
| --- |
| bt\_gatt\_discover\_primary\_service\_by\_service\_uuid(  inno\_server\_conn.gatt\_link,  inno\_server\_conn.service.uuid,  &service\_discovery\_event); |

The service\_discovery\_event function is supplied as a callback to record the start handle and end handle of the service.

Similarly, bt\_gatt\_discover\_characteristics\_by\_uuid is used to identify the custom characteristic of the custom service on the server:

|  |
| --- |
| bt\_gatt\_discover\_characteristics\_by\_uuid(  inno\_server\_conn.gatt\_link,  inno\_server\_conn.service.start\_handle,  inno\_server\_conn.service.end\_handle,  inno\_server\_conn.service.characteristic.uuid,  &characteristic\_discovery\_event); |

The start and end handles of the service are required for this function call. The function characteristic\_discovery\_event is supplied as a callback which records the handle of the characteristic.

### Exchanging MTU Size

The client exchanges MTU sizes with the server. This allows for an increase in the amount of payload data that can be sent in each BLE packet. The following API call is used to exchange MTU size:

|  |
| --- |
| bt\_gatt\_exchange\_mtu(inno\_server\_conn.gatt\_link, size, mtu\_set\_event); |

The mtu\_set\_event function is supplied as a callback and is called when the MTU size has been exchanged.

### Reading the Characteristic

With the connection to the server established and the handle of the characteristic identified, the client can read the value of the custom characteristic on the server. This is accomplished with the following API call:

|  |
| --- |
| bt\_gatt\_read\_characteristic\_value(  inno\_server\_conn.gatt\_link,  inno\_server\_conn.service.characteristic.handle,  rxbuf,  &data\_read\_event); |

A pointer to a data buffer, rxbuf, is supplied. This buffer will be filled with the data read. The supplied callback, data\_read\_event, will be called when the read is complete. In this sample, the received data is printed to the console from within the callback. The size argument to the callback function indicates the amount of data received, and the data argument provides a pointer to the data buffer.

## Running the Application

For ble\_client, there is a need for two Talaria TWO boards, with ble\_server.elf running on one and ble\_client.elf on the other.

Program the ELFs onto Talaria TWO boards using the Download tool (refer to steps in section 6.3 for programming the ELFs onto Talaria TWO).

## Expected Output

Console output - ble\_server.elf

|  |
| --- |
| UART:NWWWWWAE4 DWT comparators, range 0x8000  Build $Id: git-7e2fd6a94 $  app=gordon  flash: Gordon ready!  Y-BOOT 208ef13 2019-07-22 12:26:54 -0500 790da1-b-7  ROM yoda-h0-rom-16-0-gd5a8e586  FLASH:PNWWWAEBuild $Id: git-65f6c1f46 $  $App:git-e3ccdc7a  SDK Ver: sdk\_2.4  Ble Server Demo App  InnoServer started  [8.854,189] BT connect[0]: ia:58:1c:49:db:14:8e aa:05:04:03:02:01:00 phy2:0/0 phyC:00  Client connected  InnoServer: Hello from InnoServer  InnoServer: You can do anything, but not everything.  InnoServer: The richest man is not he who has the most, but he who needs the least.  InnoServer: You miss 100 percent of the shots you never take.  InnoServer: Courage is not the absence of fear, but rather the judgment that something else is more important than fear.  InnoServer: You must be the change you wish to see in the world.  InnoServer: To the man who only has a hammer, everything he encounters begins to look like a nail.  InnoServer: A wise man gets more use from his enemies than a fool from his friends.  InnoServer: The real voyage of discovery consists not in seeking new lands but seeing with new eyes.  InnoServer: Even if you’re on the right track, you’ll get run over if you just sit there.  InnoServer: People often say that motivation doesn’t last. Well,neither does bathing – thats why we recommend it daily.  InnoServer: Believe those who are seeking the truth. Doubt those who find it.  InnoServer: It is the mark of an educated mind to be able to entertain a thought without accepting it.  InnoServer: I’d rather live with a good question than a bad answer.  InnoServer: We learn something every day, and lots of times its that what we learned the day before was wrong.  InnoServer: I have made this letter longer than usual because I lack the time to make it shorter.  InnoServer: Don’t ever wrestle with a pig. You’ll both get dirty, but the pig will enjoy it.  InnoServer: An inventor is simply a fellow who doesn’t take his education too seriously.  InnoServer: Never be afraid to laugh at yourself, after all, you could be missing out on the joke of the century.  InnoServer: I am patient with stupidity but not with those who are proud of it.  InnoServer: The cure for boredom is curiosity. There is no cure for curiosity.  InnoServer: Advice is what we ask for when we already know the answer but wish we didn’t.  InnoServer: Some people like my advice so much that they frame it upon the wall instead of using it.  InnoServer: The trouble with the rat race is that even if you win,you’re still a rat.  InnoServer: Imagination was given to man to compensate him for what he is not,and a sense of humor was provided to console him for what he is.  InnoServer: When a person can no longer laugh at himself, it is time for others to laugh at him.  [33.064,574] BT disconnect[0]: st8  Client disconnected |

Console output - ble\_client.elf

|  |
| --- |
| Y-BOOT 208ef13 2019-07-22 12:26:54 -0500 790da1-b-7  ROM yoda-h0-rom-16-0-gd5a8e586  FLASH:PNWWWAEBuild $Id: git-65f6c1f46 $  $App:git-e3ccdc7a  SDK Ver: sdk\_2.4  Ble Client Demo App  InnoClient started  InnoServer address: 05:04:03:02:01:00  Scanning for InnoServer...  Discovered: 05:04:03:02:01:00 (InnoServer)  InnoServer 05:04:03:02:01:00 discovered!  Attempting to connect to InnoServer...  [1.278,267] BT connect[0]: ia:4f:ab:42:a5:b1:e7 aa:05:04:03:02:01:00 phy2:0/0 phyC:00  Connected to InnoServer!  Starting service discovery...  InnoServer custom service discovered!  InnoServer custom characteristic discovered!  Exchanging mtu size...  InnoServer says: Hello from InnoServer  InnoServer says: You can do anything, but not everything.  InnoServer says: The richest man is not he who has the most, but he who needs the least.  InnoServer says: You miss 100 percent of the shots you never take.  InnoServer says: Courage is not the absence of fear, but rather the judgment that something else is more important than fear.  InnoServer says: You must be the change you wish to see in the world.  InnoServer says: To the man who only has a hammer, everything he encounters begins to look like a nail.  InnoServer says: A wise man gets more use from his enemies than a fool from his friends.  InnoServer says: The real voyage of discovery consists not in seeking new lands but seeing with new eyes.  InnoServer says: Even if you’re on the right track, you’ll get run over if you just sit there.  InnoServer says: People often say that motivation doesn’t last. Well,neither does bathing – that’s why we recommend it daily.  InnoServer says: Believe those who are seeking the truth. Doubt those who find it.  InnoServer says: It is the mark of an educated mind to be able to entertain a thought without accepting it.  InnoServer says: I’d rather live with a good question than a bad answer.  InnoServer says: We learn something every day, and lots of times it’s that what we learned the day before was wrong.  InnoServer says: I have made this letter longer than usual because I lack the time to make it shorter.  InnoServer says: Don’t ever wrestle with a pig. You’ll both get dirty, but the pig will enjoy it.  InnoServer says: An inventor is simply a fellow who doesn’t take his education too seriously.  InnoServer says: Never be afraid to laugh at yourself, after all, you could be missing out on the joke of the century.  InnoServer says: I am patient with stupidity but not with those who are proud of it.  InnoServer says: The cure for boredom is curiosity. There is no cure for curiosity.  InnoServer says: Advice is what we ask for when we already know the answer but wish we didn’t.  InnoServer says: Some people like my advice so much that they frame it upon the wall instead of using it.  InnoServer says: The trouble with the rat race is that even if you win,you’re still a rat.  InnoServer says: Imagination was given to man to compensate him for what he is not,and a sense of humor was provided to console him for what he is.  InnoServer says: When a person can no longer laugh at himself, it is time for others to laugh at him.  InnoClient shutting down...  InnoClient stopped |

## Mobile Application and ble\_server.elf

If the mobile application is used with BLE scanner app, it serves as a client and ble\_server.elf is loaded on Talaria TWO, the following output is printed on the console:

|  |
| --- |
| Y-BOOT 208ef13 2019-07-22 12:26:54 -0500 790da1-b-7  ROM yoda-h0-rom-16-0-gd5a8e586  FLASH:PNWWWAEBuild $Id: git-65f6c1f46 $  $App:git-e3ccdc7a  SDK Ver: sdk\_2.4  Ble Server Demo App  InnoServer started  [5.349,848] BT connect[0]: ia:5b:6b:19:93:5d:31 aa:05:04:03:02:01:00 phy2:0/0 phyC:00  Client connected  InnoServer: Hello from InnoServer  InnoServer: You can do anything, but not everything.  InnoServer: The richest man is not he who has the most, but he who needs the least.  InnoServer: You miss 100 percent of the shots you never take.  InnoServer: Courage is not the absence of fear, but rather the judgment that something else is more important than fear.  InnoServer: You must be the change you wish to see in the world.  InnoServer: To the man who only has a hammer, everything he encounters begins to look like a nail.  InnoServer: A wise man gets more use from his enemies than a fool from his friends.  InnoServer: The real voyage of discovery consists not in seeking new lands but seeing with new eyes.  InnoServer: Even if you’re on the right track, you’ll get run over if you just sit there.  InnoServer: People often say that motivation doesn’t last. Well,neither does bathing – thats why we recommend it daily.  InnoServer: Believe those who are seeking the truth. Doubt those who find it.  InnoServer: It is the mark of an educated mind to be able to entertain a thought without accepting it.  InnoServer: I’d rather live with a good question than a bad answer.  InnoServer: We learn something every day, and lots of times its that what we learned the day before was wrong.  InnoServer: I have made this letter longer than usual because I lack the time to make it shorter.  InnoServer: Don’t ever wrestle with a pig. You’ll both get dirty, but the pig will enjoy it.  InnoServer: An inventor is simply a fellow who doesn’t take his education too seriously.  InnoServer: Never be afraid to laugh at yourself, after all, you could be missing out on the joke of the century.  InnoServer: I am patient with stupidity but not with those who are proud of it.  InnoServer: The cure for boredom is curiosity. There is no cure for curiosity.  InnoServer: Advice is what we ask for when we already know the answer but wish we didn’t.  InnoServer: Some people like my advice so much that they frame it upon the wall instead of using it.  InnoServer: The trouble with the rat race is that even if you win,you’re still a rat.  InnoServer: Imagination was given to man to compensate him for what he is not,and a sense of humor was provided to console him for what he is.  InnoServer: When a person can no longer laugh at himself, it is time for others to laugh at him.  [151.533,040] BT disconnect[0]: st13  Client disconnected |

Following are the screenshots from the mobile application:

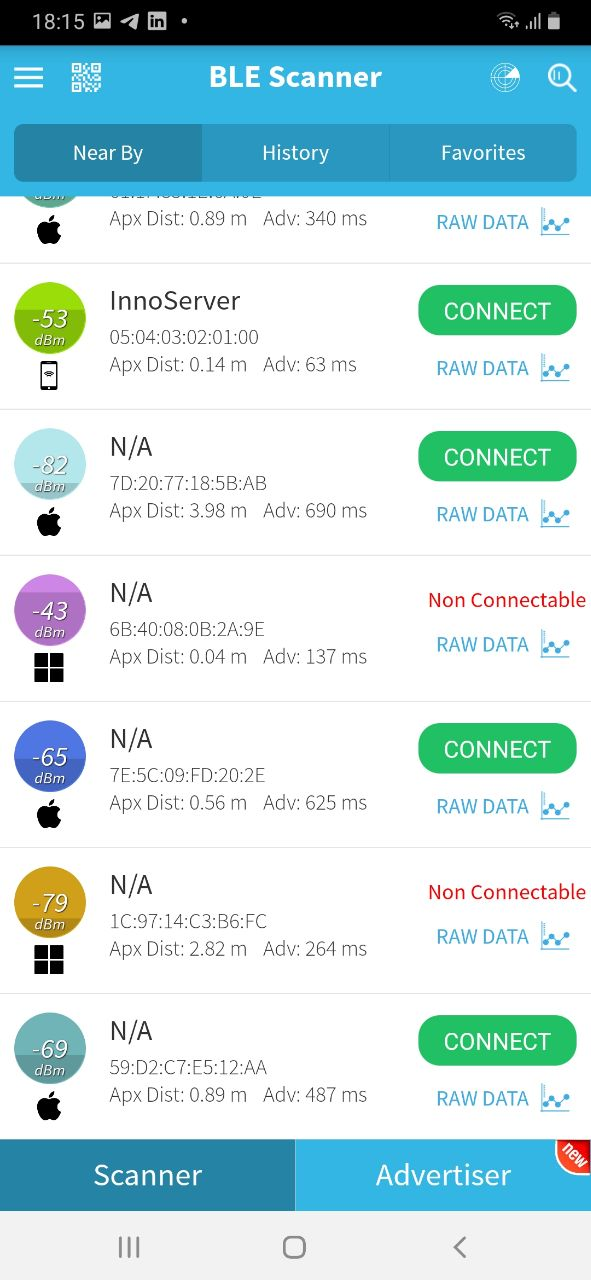


Figure Android application as BLE Client, Discovering InnoServer

BLE 1M Advertisement:

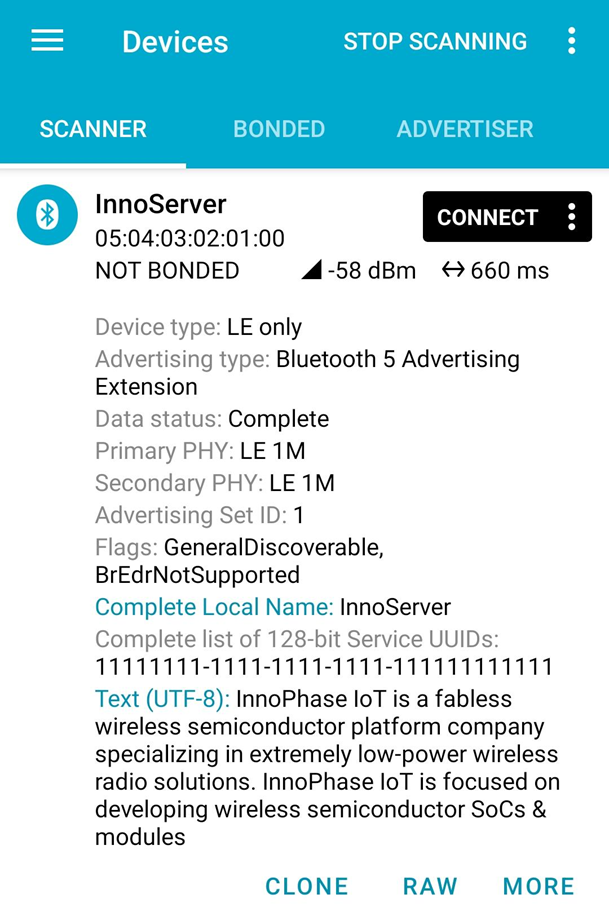


Figure : BLE 1M advertisement

BLE 2M Advertisement:

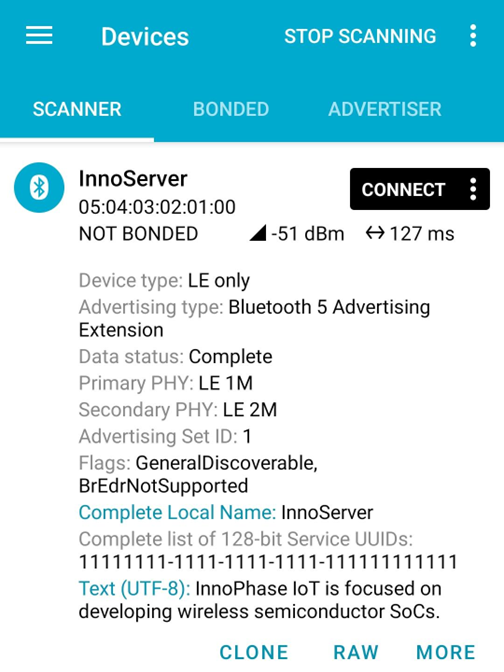


Figure : BLE 2M advertisement

A picture containing table

Description automatically generated

Figure : Successful connection and Read from Attribute

# Secure Server and Client Applications

Security Manager Protocol (SMP) APIs enable a GATT Server acting as a slave device to bond with a master and establish an encrypted link between them.

Server and Client applications described in earlier section, are extended here for incorporating security features supported by the SDK and the sample code is in the path examples/using\_ble/src/ble\_secure\_server.c and examples/using\_ble/src/ble\_secure\_client.c.

## Setting Security Parameters

SMP configuration is done using the bt\_smp\_cfg\_set() API, after the initialization.

It takes below fields as parameters input/output capabilities, OOB data present, bondable or not, man in the middle attack protection, secure connection support, generate keypress notifications, minimal key size (bytes) that is accepted, encrypt link automatically at connection setup if key exists, SMP callback functions.

In Server, SMP configuration is done before calling bt\_gap\_connectable\_mode().

|  |
| --- |
| /\* Starts our server \*/  static void start\_server(void)  {  bt\_gap\_cfg\_adv\_t bt\_adv\_handle;  bt\_smp\_cfg\_t bt\_smp\_handle;  /\* Configure advertisement \*/  bt\_adv\_handle.fast\_period = 10240;  bt\_adv\_handle.slow\_period = 0;  bt\_adv\_handle.fast\_interval = 160;  bt\_adv\_handle.slow\_interval = 1600;  bt\_adv\_handle.tx\_power = 0;  bt\_adv\_handle.channel\_map = BT\_HCI\_ADV\_CHANNEL\_ALL;  bt\_gap\_cfg\_adv\_set(&bt\_adv\_handle);  /\* Set our BLE address \*/  bt\_gap\_addr\_set(bt\_hci\_addr\_type\_random, SERVER\_ADDR);  /\* Set SMP Configuration \*/  #ifdef CLIENT\_ANDROID\_APP  bt\_smp\_handle.ops = &smp\_ops;  bt\_smp\_handle.io\_cap = bt\_smp\_io\_display\_only;  bt\_smp\_handle.oob = 0;  bt\_smp\_handle.bondable = 1;  bt\_smp\_handle.mitm = 0;  bt\_smp\_handle.sc = 1;  bt\_smp\_handle.keypress = 0;  bt\_smp\_handle.key\_size\_min = 16;  bt\_smp\_handle.encrypt = 1;  bt\_smp\_cfg\_set(&bt\_smp\_handle);  #else  bt\_smp\_handle.ops = &smp\_ops;  bt\_smp\_handle.io\_cap = bt\_smp\_io\_no\_input\_no\_output;  bt\_smp\_handle.oob = 0;  bt\_smp\_handle.bondable = 1;  bt\_smp\_handle.mitm = 0;  bt\_smp\_handle.sc = 1;  bt\_smp\_handle.keypress = 0;  bt\_smp\_handle.key\_size\_min = 16;  bt\_smp\_handle.encrypt = 1;  bt\_smp\_cfg\_set(&bt\_smp\_handle);  #endif  /\* Make server connectable (will enable advertisement) \*/  bt\_gap\_discoverable\_mode(GAP\_DISCOVERABLE\_MODE\_GENERAL, 1, 0,  address\_zero, &gap\_ops);  } |

In this example, bt\_smp\_io\_no\_input\_no\_output is configured as bt\_smp\_io\_capability\_t in both server and client as there is no scope of entering the PIN etc.

Therefore, the Just Works pairing method will be selected internally, which does not require the generation of a random 6-digit passkey.

|  |
| --- |
| /\* BLE SMP callback functions \*/  static void passkey\_input\_cb(uint8\_t handle)  {  uint8\_t passkey[16];  /\* Either 20-bits passkey or 128-bits oob \*/  os\_printf("Enter 20-bits passkey or 128-bits oob: ...\n");  /\* FIXME \*/  bt\_smp\_passkey\_set(handle, passkey);  }  static void passkey\_output\_cb(uint32\_t passkey)  {  os\_printf("Passkey (to be entered on remote device): %06d\n",  passkey);  } |

## Security Permissions for Attributes

When the Attributes are defined for GATT server, various security permissions can be set for those read and write operations. Those attributes will not be accessible if any of the security permission of the peer device trying to access it, doesn’t match. An error is thrown instead, indicating the peer that it does not have the required security clearance.

This is shown in secure server example code while making a custom characteristic in custom\_server\_create().

|  |
| --- |
| bt\_gatt\_add\_char\_128(srv.cust\_service, UUID\_CUSTOM\_CHARACTERISTIC, char\_access\_cb, (GATT\_PERM\_READ | GATT\_PERM\_ENCRYPTION | GATT\_PERM\_ENC\_KEY\_SIZE\_128 | GATT\_PERM\_AUTHORIZATION ), GATT\_CHAR\_PROP\_BIT\_READ); |

**Note**: Adding GATT\_PERM\_AUTHENTICATION will not allow the read access in this example as the pairing occurred through Just Works pairing method.

When pairing with Passkey Entry method is used, permission GATT\_PERM\_AUTHENTICATION will be applicable. This is shown in one of the next sections, where this same BLE secure server is enabled for Passkey Entry method to be used with an Android Phone App as BLE client.

## Requesting for Authentication

In this example, the authentication is requested by ble\_secure\_server once any remote peer BLE client connects to it.

It is achieved by calling API bt\_gap\_authenticate()from the connected\_cb, the callback function received by server when any client connects.

|  |
| --- |
| /\* Callback called when the client connects \*/  static void connected\_cb(bt\_hci\_event\_t \*hci\_event)  {  const bt\_hci\_evt\_le\_conn\_cmpl\_t \*param = (bt\_hci\_evt\_le\_conn\_cmpl\_t\*)&hci\_event->parameter;  os\_printf("Client connected\n");  // Add link for the connection  srv.gatt\_link = bt\_gap\_server\_link\_add(param->handle);  //smp authenticate  bt\_gap\_authenticate(param->handle, 0 /\*oob\*/, 1 /\*bondable\*/, 0 /\*mitm\*/, 0/\*sc\*/, 1 /\*key128\*/);  } |

This internally triggers the pairing request from BLE server side.

## Running Talaria TWO BLE Secure Server

The ble\_secure\_server can be tested in two ways:

1. Android mobile application acting as BLE Secure Client
2. Talaria TWO application acting as BLE Secure Client

### Running the Application

Program ble\_secure\_server.elf to Talaria TWO using the Download tool (refer section 6.3 for steps on programming the ELF onto Talaria TWO).

### Expected Output

|  |
| --- |
| UART:NWWWWWAE4 DWT comparators, range 0x8000  Build $Id: git-7e2fd6a94 $  app=gordon  flash: Gordon ready!  Y-BOOT 208ef13 2019-07-22 12:26:54 -0500 790da1-b-7  ROM yoda-h0-rom-16-0-gd5a8e586  FLASH:PNWWWAEBuild $Id: git-65f6c1f46 $  $App:git-e3ccdc7a  SDK Ver: sdk\_2.4  Ble Secure Server Demo App  InnoServer started  [44.583,194] BT connect[0]: ia:79:af:65:43:91:82 aa:05:04:03:02:01:00 phy2:0/0 phyC:00  Client connected  Authentication succeeded.  InnoServer: Hello from InnoServer  InnoServer: You can do anything, but not everything.  InnoServer: The richest man is not he who has the most, but he who needs the least.  InnoServer: You miss 100 percent of the shots you never take.  InnoServer: Courage is not the absence of fear, but rather the judgment that something else is more important than fear.  InnoServer: You must be the change you wish to see in the world.  InnoServer: To the man who only has a hammer, everything he encounters begins to look like a nail.  InnoServer: A wise man gets more use from his enemies than a fool from his friends.  InnoServer: The real voyage of discovery consists not in seeking new lands but seeing with new eyes.  InnoServer: Even if you’re on the right track, you’ll get run over if you just sit there.  InnoServer: People often say that motivation doesn’t last. Well, neither does bathing – that’s why we recommend it daily.  InnoServer: Believe those who are seeking the truth. Doubt those who find it.  InnoServer: It is the mark of an educated mind to be able to entertain a thought without accepting it.  InnoServer: I’d rather live with a good question than a bad answer.  InnoServer: We learn something every day, and lots of times its that what we learned the day before was wrong.  InnoServer: I have made this letter longer than usual because I lack the time to make it shorter.  InnoServer: Don’t ever wrestle with a pig. You’ll both get dirty, but the pig will enjoy it.  InnoServer: An inventor is simply a fellow who doesn’t take his education too seriously.  InnoServer: Never be afraid to laugh at yourself, after all, you could be missing out on the joke of the century.  InnoServer: I am patient with stupidity but not with those who are proud of it.  InnoServer: The cure for boredom is curiosity. There is no cure for curiosity.  InnoServer: Advice is what we ask for when we already know the answer but wish we didn’t.  InnoServer: Some people like my advice so much that they frame it upon the wall instead of using it.  InnoServer: The trouble with the rat race is that even if you win,you’re still a rat.  InnoServer: Imagination was given to man to compensate him for what he is not,and a sense of humor was provided to console him for what he is.  InnoServer: When a person can no longer laugh at himself, it is time for others to laugh at him.  [69.993,697] BT disconnect[0]: st8  Client disconnected |

### Running Android Mobile Application as BLE Client

To showcase the Passkey Entry method for pairing and attribute permission GATT\_PERM\_AUTHENTICATION (for attribute to be allowed access by a peer which is authenticated), the same BLE secure server code can be compiled with the option #define CLIENT\_ANDROID\_APP 1 (its commented by default).

|  |
| --- |
| #define CLIENT\_ANDROID\_APP 1  .  .  .  // Set SMP Configuration  #ifdef CLIENT\_ANDROID\_APP  bt\_smp\_handle.ops = &smp\_ops;  bt\_smp\_handle.io\_cap = bt\_smp\_io\_display\_only;  bt\_smp\_handle.oob = 0;  bt\_smp\_handle.bondable = 1;  bt\_smp\_handle.mitm = 0;  bt\_smp\_handle.sc = 1;  bt\_smp\_handle.keypress = 0;  bt\_smp\_handle.key\_size\_min = 16;  bt\_smp\_handle.encrypt = 1;  bt\_smp\_cfg\_set(&bt\_smp\_handle);  #else  bt\_smp\_handle.ops = &smp\_ops;  bt\_smp\_handle.io\_cap = bt\_smp\_io\_no\_input\_no\_output;  bt\_smp\_handle.oob = 0;  bt\_smp\_handle.bondable = 1;  bt\_smp\_handle.mitm = 0;  bt\_smp\_handle.sc = 1;  bt\_smp\_handle.keypress = 0;  bt\_smp\_handle.key\_size\_min = 16;  bt\_smp\_handle.encrypt = 1;  bt\_smp\_cfg\_set(&bt\_smp\_handle);  #endif  /\* Make server connectable (will enable advertisement) \*/  bt\_gap\_discoverable\_mode(GAP\_DISCOVERABLE\_MODE\_GENERAL, 1, 0,  address\_zero, &gap\_ops);  } |

Now bt\_smp\_io\_display\_only is configured as bt\_smp\_io\_capability\_t, and when Android Phone tries to connect to it, which has display as well as keyboard, internally Passkey Entry method is chosen for pairing.

A mobile application called BLE Scanner (which is developed by Bluepixel Technologies) is used for this example.

A random 6-digit passkey is generated and printed out to console for the user to enter on Android App, which prompts for the key.

Also, while making a custom characteristic in custom\_server\_create(), permission GATT\_PERM\_AUTHENTICATION is added, so only the authenticated client can successfully read this characteristic.

|  |
| --- |
| #define CLIENT\_ANDROID\_APP 1  .  .  .  #ifdef CLIENT\_ANDROID\_APP  bt\_gatt\_add\_char\_128(srv.cust\_service, UUID\_CUSTOM\_CHARACTERISTIC, char\_access\_cb, (GATT\_PERM\_READ | GATT\_PERM\_ENCRYPTION | GATT\_PERM\_ENC\_KEY\_SIZE\_128 | GATT\_PERM\_AUTHORIZATION | GATT\_PERM\_AUTHENTICATION ), GATT\_CHAR\_PROP\_BIT\_READ);  #else  bt\_gatt\_add\_char\_128(srv.cust\_service, UUID\_CUSTOM\_CHARACTERISTIC, char\_access\_cb, (GATT\_PERM\_READ | GATT\_PERM\_ENCRYPTION | GATT\_PERM\_ENC\_KEY\_SIZE\_128 | GATT\_PERM\_AUTHORIZATION ), GATT\_CHAR\_PROP\_BIT\_READ);  #endif |

### Talaria TWO application acting as BLE Secure Client

For ble\_secure\_client, there is a need for two Talaria TWO boards, with ble\_secure\_server.elf running on one and ble\_secure\_client.elf on the other.

Program the ELFs onto Talaria TWO boards using the Download tool (refer section 6.3 for steps on programming the ELFs onto Talaria TWO).

### Expected Output

ble\_secure\_server.elf

|  |
| --- |
| UART:NWWWWWAE4 DWT comparators, range 0x8000  Build $Id: git-7e2fd6a94 $  app=gordon  flash: Gordon ready!  Y-BOOT 208ef13 2019-07-22 12:26:54 -0500 790da1-b-7  ROM yoda-h0-rom-16-0-gd5a8e586  FLASH:PNWWWAEBuild $Id: git-65f6c1f46 $  $App:git-e3ccdc7a  SDK Ver: sdk\_2.4  Ble Secure Server Demo App  InnoServer started  [0.489,990] BT connect[0]: ia:45:a8:11:60:17:32 aa:05:04:03:02:01:00 phy2:0/0 phyC:00  Client connected  Authentication succeeded.  InnoServer: Hello from InnoServer  InnoServer: You can do anything, but not everything.  InnoServer: The richest man is not he who has the most, but he who needs the least.  InnoServer: You miss 100 percent of the shots you never take.  InnoServer: Courage is not the absence of fear, but rather the judgment that something else is more important than fear.  InnoServer: You must be the change you wish to see in the world.  InnoServer: To the man who only has a hammer, everything he encounters begins to look like a nail.  InnoServer: A wise man gets more use from his enemies than a fool from his friends.  InnoServer: The real voyage of discovery consists not in seeking new lands but seeing with new eyes.  InnoServer: Even if you’re on the right track, you’ll get run over if you just sit there.  InnoServer: People often say that motivation doesn’t last. Well, neither does bathing – that’s why we recommend it daily.  InnoServer: Believe those who are seeking the truth. Doubt those who find it.  InnoServer: It is the mark of an educated mind to be able to entertain a thought without accepting it.  InnoServer: I’d rather live with a good question than a bad answer.  InnoServer: We learn something every day, and lots of times its that what we learned the day before was wrong.  InnoServer: I have made this letter longer than usual because I lack the time to make it shorter.  InnoServer: Don’t ever wrestle with a pig. You’ll both get dirty, but the pig will enjoy it.  InnoServer: An inventor is simply a fellow who doesn’t take his education too seriously.  InnoServer: Never be afraid to laugh at yourself, after all, you could be missing out on the joke of the century.  InnoServer: I am patient with stupidity but not with those who are proud of it.  InnoServer: The cure for boredom is curiosity. There is no cure for curiosity.  InnoServer: Advice is what we ask for when we already know the answer but wish we didn’t.  InnoServer: Some people like my advice so much that they frame it upon the wall instead of using it.  InnoServer: The trouble with the rat race is that even if you win,you’re still a rat.  InnoServer: Imagination was given to man to compensate him for what he is not,and a sense of humor was provided to console him for what he is.  InnoServer: When a person can no longer laugh at himself, it is time for others to laugh at him.  [25.800,300] BT disconnect[0]: st8  Client disconnected |

ble\_secure\_client.elf

|  |
| --- |
| UART:NWWWWWAE4 DWT comparators, range 0x8000  Build $Id: git-7e2fd6a94 $  app=gordon  flash: Gordon ready!  Y-BOOT 208ef13 2019-07-22 12:26:54 -0500 790da1-b-7  ROM yoda-h0-rom-16-0-gd5a8e586  FLASH:PNWWWAEBuild $Id: git-65f6c1f46 $  $App:git-e3ccdc7a  SDK Ver: sdk\_2.4  Ble Secure Client Demo App  InnoClient started  InnoServer address: 05:04:03:02:01:00  Scanning for InnoServer...  Discovered: 05:04:03:02:01:00 (InnoServer)  InnoServer 05:04:03:02:01:00 discovered!  Attempting to connect to InnoServer...  [9.948,176] BT connect[0]: ia:5c:04:14:ba:da:10 aa:05:04:03:02:01:00 phy2:0/0 phyC:00  Connected to InnoServer!  Starting service discovery...  InnoServer custom service discovered!  InnoServer custom characteristic discovered!  Exchanging mtu size...  Authentication succeeded.  mtu\_set\_event  InnoServer says: Hello from InnoServer  InnoServer says: You can do anything, but not everything.  InnoServer says: The richest man is not he who has the most, but he who needs the least.  InnoServer says: You miss 100 percent of the shots you never take.  InnoServer says: Courage is not the absence of fear, but rather the judgment that something else is more important than fear.  InnoServer says: You must be the change you wish to see in the world.  InnoServer says: To the man who only has a hammer, everything he encounters begins to look like a nail.  InnoServer says: A wise man gets more use from his enemies than a fool from his friends.  InnoServer says: The real voyage of discovery consists not in seeking new lands but seeing with new eyes.  InnoServer says: Even if you’re on the right track, you’ll get run over if you just sit there.  InnoServer says: People often say that motivation doesn’t last. Well, neither does bathing – that’s why we recommend it daily.  InnoServer says: Believe those who are seeking the truth. Doubt those who find it.  InnoServer says: It is the mark of an educated mind to be able to entertain a thought without accepting it.  InnoServer says: I’d rather live with a good question than a bad answer.  InnoServer says: We learn something every day, and lots of times it’s that what we learned the day before was wrong.  InnoServer says: I have made this letter longer than usual because I lack the time to make it shorter.  InnoServer says: Don’t ever wrestle with a pig. You’ll both get dirty, but the pig will enjoy it.  InnoServer says: An inventor is simply a fellow who doesn’t take his education too seriously.  InnoServer says: Never be afraid to laugh at yourself, after all, you could be missing out on the joke of the century.  InnoServer says: I am patient with stupidity but not with those who are proud of it.  InnoServer says: The cure for boredom is curiosity. There is no cure for curiosity.  InnoServer says: Advice is what we ask for when we already know the answer but wish we didn’t.  InnoServer says: Some people like my advice so much that they frame it upon the wall instead of using it.  InnoServer says: The trouble with the rat race is that even if you win,you’re still a rat.  InnoServer says: Imagination was given to man to compensate him for what he is not,and a sense of humor was provided to console him for what he is.  InnoServer says: When a person can no longer laugh at himself, it is time for others to laugh at him.  InnoClient shutting down...  InnoClient stopped  [33.613,748] BT stopped |

## Conclusion

In secure BLE server and client section, its shown that various capabilities of the peer devices are exchanged and appropriate pairing method is selected by the BLE stack. Based on this, key generation, exchange and the encryption of the messages, is done. And when needed, attribute permission can be set to use only encrypted, authenticated and authorized read and write.