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# Application Note Developing a DA14580 Bluetooth Profile Using Sample128

### **AN-B-029**

### Abstract

This Application Note describes how to implement a custom Bluetooth profile on the DA14580 using the sample service, sample128, as a foundation.

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# Developing a DA14580 Bluetooth Profile Using Sample128

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### **1** Terms and definitions

BT SIG	Bluetooth <sup>®</sup> Special Interest Group
IDE	Integrated Development Environment
SDK	Software Development Kit
DVK	Development Kit (DA14580 Expert, Pro, or Basic)
UUID	Universally Unique Identity
GATT	Generic Attribute Profile
MDK	Microprocessor Development Kit
UUID	Universally Unique Identifier

### 2 References

1. UM-B-003, Software Development Guide



### 3 Introduction

The Bluetooth Special Interest group has adopted a rich list of profiles and services to cover a wide variety of use cases in which Bluetooth Smart plays a role. The beauty of these already specified profiles and services is that their specifications are very clear and pretty much guarantees interoperability between smartphones and tablets and all kinds of peripheral devices. Before you venture into creating your own service or profile, it is recommended that you visit the BT SIG website www.bluetooth.org to see if a service or profile that meets your requirements has already been adopted.

In some cases, however, it is necessary to implement your own services or profiles. Your application may require some new functionality that does not fit within the already-adopted profiles or services. This document functions as a guide/tutorial on how to implement such custom services on the Dialog Semiconductor SmartBond series DA1458x.

You should already be familiar with the hardware and the Keil µVision MDK IDE, and you should have all the tools and drivers installed and operational. You should also have some basic knowledge of Bluetooth Smart and the concept of peripheral and central devices.

This tutorial will only address custom service implementation on the peripheral device side.



### 4 Building a project that includes the sample128 service

The Dialog SDK contains a profile named sample128. The '128' part of the name relates to the fact that the sample service uses a 128-bit UUID. The BT SIG adopted services all use a 16-bit short form. Custom services must use the long 128-bit form. In this section, we will demonstrate how to include sample128 in your project.

### 4.1 Creating a new project based on the template\_fh sample application

Clone the template\_fh project as described in the Software Development Guide [1]. In the following, we will assume that you have called the project "custom", but you can use any name you like. Open the newly created project and apply the following steps.

### 4.2 Add the sample128 service to the project

Adding the sample128 service requires the following steps (detailed instructions will follow):

- 1. Adding the sample128 path to the project include paths
- 2. Adding the source code of sample128 to the project
- 3. Including sample128

#### 4.2.1 Adding the sample128 path to the project Include Paths

Click the "Options for Target" icon:

File	Edi	t V	/iew	Proj	ect	Flash	D	ebug	Pe	riphe	rals	Tool	s S	s٧
	2	H	Ø	*	Ea		4)	6	-	⇒	1	12	13	1
٨			0		LOAD	Ful	l_emł	o_cort	ex_M	0	•	s.	å	Ę
Projec	t												Ţ	(
<u> </u>	\$ Pr	oject	: fh_	projec	t_cu	stom								
G		Ful	l em	ib con	tex N	<b>/1</b> 0								

Figure 1: Options for target

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Open the "C/C++" tab and click on the button to the right of the Include Paths field:

	of contrast county i const	and them I make I needy I comes I	
heprocess	ior Symbola		
Define:	-		
Undefine	ſ		
Janguage	/ Code Generation		1.22532331
- Execut	e-only Code	F Strict ANSI C	Warnings:
plimization	Level 3 (-03) -	F Enum Container always int	Al Warnings 🔹
Optimiz	e for Time	F Plain Char is Signed	T Thundi Mode
Split Lo	ad and Store Multiple	F Read-Only Position Independent	T No Auto Includes
One El	.F Section per Function	F Read-Wite Postion Independent	F C99 Mode
include Paths		e;c:\Kel\ARM\CMSIS\Include:C.\Kel\ARM\	RV31\INC:\.\.\webp
Misc Controls	-c.99 -thumb -c -preinclude	da14580_config.h -baa_threshold=0	
Compiler control string	c -cpu Cotex-M0-D_EVA Vinclude -lc: \Kel/ARM\CMS	L-D_MICROLIB-4 g-03 -apcs=interwork - IS Unclude 4C \Kel/VRM\RV31\INC 4\\	(\_{\_\_\arc\dialog \arc\pf\wfp\arc\arch 4.

Figure 2: Opening include paths list

Click at the bottom of the Include Paths list and type in the path for sample128 (you can also use the button to the right to browse for the path):

Folder Setup	8 23
Setup Compiler Include Paths:	🖄 🗙 🗲
	*
.\\\src\modules\app\src\app_project\custom .\\\src\plf\refip\src\driver\adc .\\\src\modules\app\src\app_project\custom\system .\\\src\plf\refip\src\driver\wkupct .\\\src\plf\refip\src\driver\battery .\\\src\modules\app\src\app_utils\app_console .\\\src\ip ble\hl\src\profiles\sample128	
OK Cancel	

Figure 3: Adding an include path

Or, for the copy & paste fans out there:

 $\approx$ .\..\..\src\ip\ble\hl\src\profiles\sample128

Click "OK" to close the folder setup window and click "OK" to close the "Options for Target" window.





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#### 4.2.2 Adding the sample128 source code to the project

Expand the project folder so it shows the view below:



#### Figure 4: Adding source code

Right-click on the profiles folder and select "Add Existing Files to Group 'profiles'..." Navigate to the folder "dk\_apps/src/ip/ble/hl/src/profiles/sample128":

ook in: 📕 sample128				
ame Schola	Date modified	Туре	Size	
i sam sam Sam Scenstra වී Constra වී විදුසුවන්න වී දේ ප්රියේදී (දි) වී දි වී විද්යාන්ති වී දේ ප්රියේදී (දි) වී ද වී ද වී විද්යාන්ති වී විද්යාන්ත් වී විය වී විද්යාන්ත් වී විද්යාන්ත් වී විද්යාන්ත් වී විය වී විය වී විය වී විය වී විය වී විය වී විය වී විය වී වී විය වී විය වී විය වී විය වී විය වී විය වී විය වී විය වී විය වී වි වී විය වී වි වී විය වී වි වී වි වී විය වී වි වී වි ව ව ව ව ව ව ව ව ව ව ව ව ව ව ව ව ව ව	10/1/2014 3:57 PM 10/1/2014 3:57 PM	C Source C Source	5 KB 16 KB	
name in ame	les			Add
is of typ kGl_gnSeitss sateton	mple128		•	Close

Figure 5: Finding source files

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You should see the following two files:

Look in:	sample128	- 🗧 🔁 📥 -	
Name	*	Date modified	Т
sample1	128.c	12/19/2014 1:45 PM	C
sample]	<u>128 task.c</u>	12/19/2014 1:45 PM	
sample]	128_task.c	12/19/2014 1:45 PM	•
<pre>sample1 </pre>	"" "sample128_task.c" "sample128.c	12/19/2014 1:45 PM	•

Figure 6: Sample128 source files

Select the two C source files and click "Add", then "Close".

X Now, rebuild the project to get the compiler to map the header files (this simplifies navigation).

#### 4.2.3 Including sample128

Open the file "da14580\_config.h" file (expand the "app" folder and the "app.c" file, locate the file and double-click on it to open it).

Change #undef CFG PRF SAMPLE128 to #define CFG PRF SAMPLE128 as shown below:

100	/* Accelerometer Profile */
101	<pre>#undef CFG_PRF_ACCEL</pre>
102	<pre>/* Dialog's Software Patch Over The Air Profile */</pre>
103	<pre>#undef CFG_PRF_SPOTAR</pre>
104	<pre>/* Dialog's Sample 128 bit UUIDs Profile */</pre>
105	<pre>#define CFG_PRF_SAMPLE128</pre>
106	///////////////////////////////////////
107	

#### Figure 7: Configuration of the project

 $\approx$ #define CFG PRF SAMPLE128

The file sample128\_task header should also be added to the project header file "app\_custom\_proj.h":





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```
32 🗄 / *
    * INCLUDE FILES
33
    34
    */
35
36
37 #include "rwble config.h"
38
   #include "app_task.h"
                                    // application task
   #include "gapc_task.h"
39
                                     // gap functions and messages
40 #include "gapm_task.h"
                                     // gap functions and messages
41 #include "app.h"
                                     // application definitions
42 #include "co_error.h"
43 #include "smpc_task.h"
                                     // error code definitions
                                     // error code definitions
44
  #include "sample128 task.h"
45
46
```

Figure 8: Including the service

#include "sample128 task.h"

imesYou should be able to build the project at this time and only see the two standard warnings.



### 5 Interfacing your application with sample128

The sample128 service implementation provides two characteristics. The first characteristic is a simple, single-byte-sized characteristic, facilitating client-side read and write permissions. The other characteristic is also a single byte, but this one facilitates read and notify permissions.

The application controls initializing the service, creating the service database and enabling the service upon a remote client connection. The application might also update the value of the second characteristic, which causes a GATT notify to be sent to any connected client that has subscribed to notifications.

The application will receive a confirmation from the service task when the database has been created, and it will receive indications from the service when a remote client writes to a characteristic or a remote client device (a central) causes the service to be disabled. The message flow is illustrated below:



Figure 9: Message flow diagram

It is usually recommended to implement a task between the application task and the service task; this is also how the sample applications in the SDK are structured. For this tutorial, in order to minimize the number of files that need to be touched and in order to decrease complexity, we will flatten the structure by implementing all interfaces to the sample service in the application task itself. This approach is acceptable as long as we don't need a lot of custom services.

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### 5.1 Creating the service database

The database of a service must be created in the "app\_db\_init\_func()" of "app\_custom\_proj.c":

```
324 bool app_db_init_func(void)
325 🗄 {
326
328 Initialize next supported profile's Database.
    Check if all supported profiles' Databases are initialized and return status.
329
    330
331
332
333
       // Indicate if more services need to be added in the database
334
       bool end db create = false;
335
       dbg = APP PRF LIST STOP;
336
337
338
       // Check if another should be added in the database
339
       if (app env.next prf init < APP PRF LIST STOP)
340 🚊
       {
341
342 -
           switch (app_env.next_prf_init)
          - {
#if (BLE_DIS SERVER)
344
             case (APP DIS TASK):
345
346
              - {
347
                 app_dis_create_db_send();
348
              } break;
349
              #endif //BLE_DIS_SERVER
    350
351
352
              case (APP_SAMPLE128):
353 📥
              1
354
               app sample128 create db send();
              } break;
355
356
357
              default:
358
359 📥
              {
360
                 ASSERT ERR(0);
361
              } break;
362
363
          - }
364
365
          // Select following service to add
366
           app_env.next_prf_init++;
367
       }
368
       else
369 📥
       {
370
          end db create = true;
371
       }
372
373
       return end_db_create;
374 }
```

#### Figure 10: Creating the database

```
case (APP_SAMPLE128):
{
    app_sample128_create_db_send();
} break;
```



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APP\_SAMPLE128 must be enumerated among all other profiles in "app\_api.h". This allows the application to loop through all the required services and create their databases one by one:



Figure 11: Enumerating the service database



We must also implement the "app\_sample128\_create\_db\_send()" function. This can be done in the "app\_custom\_proj.c" file in the function definitions segment:

```
48 白/*
49
    * FUNCTION DEFINITIONS
    *************
50
                                 51
   */
52
53
   void app sample128 create db send(void)
54 🖯 {
55
       struct sample128 create db req *req = KE MSG ALLOC(
56
                                                     SAMPLE128 CREATE DB REQ,
                                                     TASK SAMPLE128, TASK APP,
57
                                                     sample128 create db req
58
59
                                                   );
60
       ke msg send(req);
61
```

#### Figure 12: Creating the service database



The function simply sends a message to the service task requesting the creation of the service database.





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### 5.2 Enabling the service

The sample128 service must be enabled after a remote client has connected to the device. This can be done in the "app\_connection\_func()" function of "app\_custom\_proj.c":

137	<pre>void app_connection_func(struct gapc_connection_req_ind const *param)</pre>
138 -	
139	<pre>if (app_env.conidx != GAP_INVALID_CONIDX)</pre>
140 🗄	] {
141	
142 -	/**************************************
143	Handle connection request event. Enable required profiles
144	
145	i.e.
146	<pre>#if (BLE_DIS_SERVER)</pre>
147	<pre>app_dis_enable_prf(app_env.conhdl);</pre>
148	#endif
149	***************************************
150	-
151	<pre>app_sample128_enable();</pre>
152	

Figure 13: Enabling the service

```
app_sample128_enable();
```

We will implement the "app\_sample128\_enable()" function in the function definition segment of "app\_custom\_proj.c" - just below the definition of "app\_sample128\_create\_db\_send()":

63	void app_sample128_enable(void)
64	
65	// Allocate the message
66	<pre>struct sample128_enable_req* req = KE_MSG_ALLOC(</pre>
67	SAMPLE128_ENABLE_REQ,
68	TASK_SAMPLE128,
69	TASK_APP,
70	sample128_enable_req
71	);
72	req->conhdl = app_env.conhdl;
73	req->sec_lvl = PERM(SVC, ENABLE);
74	<pre>req-&gt;sample128_1_val = 0x01; // default value for sample128 characteristic 1</pre>
75	<pre>req-&gt;sample128_2_val = 0xff; // default value for sample128 characteristic 2</pre>
76	req->feature = 0x00; // client CFG notify/indicate disabled
77	// Send the message
78	ke_msg_send(req);
79	}



```
×
 void app sample128 enable(void)
 {
   // Allocate the message
   struct sample128_enable_req* req = KE_MSG_ALLOC(
                                                       SAMPLE128 ENABLE REQ,
                                                       TASK SAMPLE128,
                                                       TASK APP,
                                                       sample128_enable_req
                                                   );
   req->conhdl = app env.conhdl;
   req->sec lvl = PERM(SVC, ENABLE);
   req->sample128_1_val = 0x01;
                                       //\ default value for sample128 characteristic 1
   req->sample128_2_val = 0xff;
                                       // default value for sample128 characteristic 2
   req -> feature = 0 \times 00;
                                       // client CFG notify/indicate disabled
   // Send the message
   ke_msg_send(req);
 }
```

#### Application Note





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### 5.3 Implementing message handlers

As mentioned earlier, the sample128 service task will send the following kernel messages to the application:

- 1. A confirmation when the service database has been created
- 2. An indication when a remote client writes to a characteristic value
- 3. An indication when the service database is disabled (due to a remote client disconnection)

Three event handlers need to be defined for these events. In "app\_task\_handlers.h", add the following code:



#### Figure 15: Definition of event handlers



Finally, these handlers must be implemented in the application. In the project header file, "app\_custom\_proj.h", add the following prototypes:





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```
100 -/*
    * FUNCTION DECLARATIONS
101
102
                          *****
    */
103
104
105
106
    ****
        107
    * @brief Handles sample128 profile database creation confirmation.
108
    * @return If the message was consumed or not.
109
    -----
                                   . . . . . . . . . . . . . . . . . .
110
    */
111
112
   int sample128_create_db_cfm_handler(ke_msg_id_t const msgid,
113
                             struct sample128_create_db_cfm const *param,
114
                             ke_task_id_t const dest_id,
115
                             ke_task_id_t const src_id);
116
117
118
    119
    \star @brief Handles disable indication from the sample128 profile.
    * @return If the message was consumed or not.
120
121
    122
    */
123
124
   int sample128_disable_ind_handler(ke_msg_id_t const msgid,
125
                             struct sample128_disable_ind const *param,
126
                             ke_task_id_t const dest_id,
127
                             ke_task_id_t const src_id);
128
129
130
    ****
        *****
    * @brief Handles write of 1st characteristic event indication from sample128 profile
131
132
    * @return If the message was consumed or not.
133
                                    */
134
135
136
   int sample128 val ind handler(ke msg id t const msgid,
137
                               struct sample128_val_ind const *param,
138
                               ke_task_id_t const dest_id,
139
                               ke_task_id_t const src_id);
140
```

Figure 16: Event handler prototypes

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```
⊁
/**
 * @brief Handles sample128 profile database creation confirmation.
 * @return If the message was consumed or not.
                               */
int sample128_create_db_cfm_handler(ke_msg_id_t const msgid,
                        struct sample128 create db cfm const *param,
                        ke task id t const dest id,
                        ke task id t const src id);
/**
 *****
 * @brief Handles disable indication from the sample128 profile.
 * @return If the message was consumed or not.
 */
int sample128_disable_ind_handler(ke_msg_id_t const msgid,
                        struct sample128 disable ind const *param,
                        ke task id t const dest id,
                        ke task id t const src id);
/**
 * @brief Handles write of 1st characteristic event indication from sample128 profile
 * @return If the message was consumed or not.
                             */
int sample128_val_ind_handler(ke_msg_id_t const msgid,
                          struct sample128_val_ind const *param,
                          ke_task_id_t const dest_id,
                          ke task id t const src id);
```

We will implement the tree handlers in the "app\_custom\_proj.c" file. Handling the "database created confirmation" is implemented as shown below:

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```
#endif //BLE_APP_SEC
776
777
778
779
      *****
780
      * @brief Handles Sample128 profile database creation confirmation.
781
782
     * @param[in] msgid
783
                            Id of the message received.
784
     * @param[in] param
                            Pointer to the parameters of the message.
     * % @param[in] dest_id ID of the receiving task instance .
% @param[in] src_id ID of the sending task instance.
785
786
787
788
      * @return If the message was consumed or not.
                                                  789
      -----
790
     */
791
     int sample128_create_db_cfm_handler(ke_msg_id_t const msgid,
792
                                         struct sample128_create_db_cfm const *param,
793
                                          ke_task_id_t const dest_id,
794
795
                                         ke_task_id_t const src_id)
    ŧi (
796
         // If state is not idle, ignore the message
797
         if (ke_state_get(dest_id) == APP_DB_INIT)
798
799
800
             // Inform the Application Manager
801
             struct app_module_init_cmp_evt *cfm = KE_MSG_ALLOC(APP_MODULE_INIT_CMP_EVT,
                                                              TASK_APP, TASK_APP,
app_module_init_cmp_evt);
802
803
804
805
            cfm->status = param->status;
806
807
            ke msg_send(cfm);
808
809
         }
810
         return (KE MSG CONSUMED);
811
812
```

Figure 17: Database created handler

```
×
            * @brief Handles Sample128 profile database creation confirmation.
                        Id of the message received.
  * @param[in] msgid
  * @param[in] param Pointer to the parameters of the message.
* @param[in] dest_id ID of the receiving task instance .
* @param[in] src_id ID of the sending task instance.
   @param[in] src_id
  * @return If the message was consumed or not.
                                               *****
  * *
  * /
 int sample128 create db cfm handler(ke msg id t const msgid,
                                       struct sample128_create_db_cfm const *param,
                                       ke_task_id_t const dest_id,
                                       ke task id t const src id)
 {
     // If state is not idle, ignore the message
    if (ke state get(dest id) == APP DB INIT)
        // Inform the Application Manager
        struct app module init cmp evt *cfm = KE MSG ALLOC (APP MODULE INIT CMP EVT,
                                                            TASK APP, TASK APP,
                                                            app module init cmp evt);
        cfm->status = param->status;
        ke msg send(cfm);
     }
     return (KE MSG CONSUMED);
 }
```





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The handler, as implemented above, sends another message to the application task, indicating that the database has been created.

We will leave the other two handlers empty for now. We will implement them just below the "sample128\_create\_db\_cfm\_handler()" function, near the end of "app\_custom\_proj.c":

```
815
      816
817
      * @brief Handles disable indication from Sample128 profile.
818
819
     * @param[in] msgid
                            Id of the message received.
                            Pointer to the parameters of the message.
820
     * @param[in] param
     * @param[in] dest_id
 ID of the receiving task instance.
* @param[in] src_id
 ID of the sending task instance.
821
822
823
     * @return If the message was consumed or not.
824
                                                   ******
825
     */
826
827
    int sample128_disable_ind_handler(ke_msg_id_t const msgid,
828
                                          struct sample128 disable ind const *param,
829
                                           ke task id t const dest id,
830
                                          ke_task_id_t const src_id)
831
832
      return (KE_MSG_CONSUMED);
    3
833
834
    <u>۱</u>
835
      ****
836
     * @brief Handles write of 1st characteristic event indication from sample128 profile
837
838
     * @param[in] msgid Id of the message received.
* @param[in] param Pointer to the parameters of
839
840
                            Pointer to the parameters of the message.
     * @param[in] param Forneer to the parameters of the mercers
* @param[in] dest_id ID of the receiving task instance (TASK_GAP).
* @param[in] src_id ID of the sending task instance.
841
842
843
     * @return If the message was consumed or not.
844
                                                  845
846
847
848
     int sample128_val_ind_handler(ke_msg_id_t const msgid,
849
                                          struct sample128_val_ind const *param,
850
                                          ke_task_id_t const dest_id,
851
                                          ke_task_id_t const src_id)
852
    1
      return (KE_MSG_CONSUMED);
853
854
```

Figure 18: Service disabled handler and Char1 value changed handler

Both handlers will simply return the fact that the kernel message has been consumed.

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# Developing a DA14580 Bluetooth Profile Using Sample128

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```
⊁
      * @brief Handles disable indication from Sample128 profile.
   @param[in] msgid Id of the message received.
@param[in] param Pointer to the parameters of the message.
   @param[in] dest_id ID of the receiving task instance.
  * @param[in] src id
                      ID of the sending task instance.
 * @return If the message was consumed or not.
                                          ****
 * /
 int sample128_disable_ind_handler(ke_msg_id_t const msgid,
                                   struct sample128 disable ind const *param,
                                   ke_task_id_t const dest_id,
                                   ke_task_id_t const src_id)
 {
  return (KE MSG CONSUMED);
 }
 /**
              * *
  * @brief Handles write of 1st characteristic event indication from sample128 profile
 * @param[in] msgid Id of the message received.
* @param[in] param Pointer to the parameters of the message.
  * @param[in] dest_id ID of the receiving task instance (TASK_GAP).
  * @param[in] src id ID of the sending task instance.
 * @return If the message was consumed or not.
                                           *****
  * /
 int sample128_val_ind_handler(ke_msg_id_t const msgid,
                                   struct sample128 val ind const *param,
                                   ke task id t const dest id,
                                   ke task id t const src id)
 {
  return (KE MSG CONSUMED);
```

S By this time, you should be able to build the application and load it onto your DVK.

### 5.4 Trying it out

Using LightBlue for iOS or BlueLoupe for Android (Version 4.3 or later) should allow you to connect to the DVK and confirm that the custom service is provided. You may have to turn Bluetooth on your smart device off and back on to force a fresh service discovery. Both Android and iOS have a tendency to suppress service discovery for devices that they have previously been connected to.

A screenshot from BlueLoupe is shown below. The DVK exposes the custom service and the two characteristics that the service consists of. You can write to the first characteristic and see that the value changes. If you disconnect from the device, the value of the characteristic defaults back to 0x01 as specified in the function "app\_sample128\_enable()". No other functionality is enabled at this point. We will add some simple functionality in the following section.



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ę		X 🗢 🖸 7:48
9	👰 DA1458x	
De	vice address: 80:EA:CA:00:00:DD	
Sta	ate: Connected, RSSI:-58, Avg:-60	
4	Generic Access Service 00001800-0000-1000-8000-0080579534fb	
×	Generic Attribute Service 00001801-0000-1000-8000-00805f9b34fb	
	Unknown service 0f0e0d0c-060a-0906-0706-050403020100	
	< <unknown characteristic="">&gt; UUID: 0x1d1c, Properties: Read/Write</unknown>	
	< <unknown characteristic="">&gt; UUID: 0x2d2c, Properties: Read/Notify</unknown>	

Figure 19: GATT discovery using BlueLoupe

0

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### 6 Using sample128

In the previous section, we implemented all the functionality required to expose the sample128 service. We were able to write to one of the two characteristics using a smartphone or tablet, but none of that was really tied to the application. In this section we will implement some code that allows us to use Bluetooth Notify to monitor when the application changes the value of characteristic 2. We will also make use of the value that a user writes to characteristic 1 via a smartphone or tablet. Here is an overview of what we will implement:



Figure 20: Sample128 tutorial functionality

We will implement and start a timer which will time out after 500 ms. The timer will be started when a central device connects. At timeout, we will increment the value of characteristic 2 and restart the timer. If a user writes to characteristic 1, we will set the value of characteristic 2 to match the new value of characteristic 1 and let the timer function increment it from there.

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### 6.1 Implementing a kernel timer

In order to use the kernel timer from the application, we will need to define a new primitive to reference the timer. The primitive can be defined in the APP\_MSG enumeration in "app\_api.h":

124 /// APP Task messages 125 enum APP MSG 126 🗄 { 127 APP\_MODULE\_INIT\_CMP\_EVT = KE\_FIRST\_MSG(TASK\_APP), 128 129 #if BLE SAMPLE128 APP SAMPLE128 TIMER, 130 #endif //BLE SAMPLE128 131 132 133 🛱 #if BLE ACCEL 124 ADD ACCET TIMED

Figure 21: Adding a message primitive



We will have to implement a handler function to handle the event of the timer timing out. In "app\_task\_handlers.h", add the following code:

```
184 -
185 =#if BLE_SAMPLE128
186 {SAMPLE128_CREATE_DB_CFM, (ke_msg_func_t)sample128_create_db_cfm_handler},
187 {SAMPLE128_VAL_IND, (ke_msg_func_t)sample128_val_ind_handler},
188 {SAMPLE128_DISABLE_IND, (ke_msg_func_t)sample128_disable_ind_handler},
189 {APP_SAMPLE128_TIMER, (ke_msg_func_t)sample128_timer_handler},
190 #endif
```

Figure 22: Adding a message handler

{APP SAMPLE128 TIMER, (ke msg func t)sample128 timer handler},

Finally, we will implement the timer handler in "app\_custom\_proj.c" and a reference to it in "app\_custom\_proj.h". First the reference:

141 🕂 7\*\* 142 143 \* @brief Handles timer timeout \* @return If the message was consumed or not. 144 \*\*\* \*\*\*\*\*\*\*\*\*\* 145 146 \*/ 147 148 int sample128\_timer\_handler(ke\_msg\_id\_t\_const\_msgid, 149 struct gapm\_cmp\_event const \*param, 150 ke task id t const dest id, 151 ke task id t const src id); 152 153 /// @} APP



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And in "app\_custom\_proj.c" we will implement the handler function:



Figure 24: Timer handler implementation







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We will start the timer whenever a central device connects. In the "app\_connection\_func()" function of "app\_custom\_proj.c", add the following:

```
135 void app connection func(struct gapc connection req ind const *param)
136 白 {
        if (app env.conidx != GAP INVALID CONIDX)
137
138 🖻
        {
139
    /****
140 🖻
141
    Handle connection request event. Enable required profiles
142
143
    i.e.
    #if (BLE_DIS_SERVER)
144
145
       app_dis_enable_prf(app_env.conhdl);
146
    #endif
     147
148
149
           app_sample128_enable();
150
151
           ke timer set(APP SAMPLE128 TIMER,TASK APP,50);
152
           ke_state_set(TASK_APP, APP_CONNECTED);
153
154
155
           // Retrieve the connection info from the parameters
           app_env.conhdl = param->conhdl;
156
157
```

#### Figure 25: Starting our kernel timer

```
ke_timer_set(APP_SAMPLE128_TIMER,TASK_APP,50);
```

### X

At this time you should be able to successfully build the code. The timer will start as soon as a central connects, but you still need to actually do something useful when the timer times out.

### 6.2 Adding some functionality

We are going to need a placeholder variable with a global scope. In this tutorial, we will simply declare a global variable. This works well as long as we don't implement deep sleep. If we were to actually use deep sleep, we would need to store the placeholder variable in retention memory in order for it to be retained.

In "app\_custom\_proj.c", declare the octet sample128\_placeholder just above the function definitions:

46 uint8\_t sample128\_placeholder = 0; 47 48 ⊟ /\* 49 \* FUNCTION DEFINITIONS

#### Figure 26: Declaring a global variable

wint8 t sample128 placeholder = 0;

When a user writes to characteristic 1 using a smartphone/tablet, we will load the written value into the placeholder variable. Every time the timer times out, we will increment the placeholder value and load it into characteristic 2.





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In the timer handler, add the following code:

```
855 日/**
     856
857
     · Sbrief Handles timer timeout
858
     * Breturn If the message was consumed or not.
     859
860
     +/
861
862
    int sample126_timer_handler(ke_msg_id_t const megid,
                                     struct gapm_cmp_evt const *param,
ke_task_id_t const dest_id,
863
864
                                     ke_task_id_t const src_id)
865
866 84
867
      ke timer set(APF SAMPLE128 TIMER, TASK AFF, 50);
      sample128_placeholder++;
868
869
      struct sample128 upd char2 reg *reg = KE MSG ALLOC(
870
                                                    SAMPLE128 UPD CHAR2 REO.
871
                                                    TASK SAMPLE120,
TASK AFP,
872
873
874
                                                    sample125 upd char2 req
875
                                                 3.7
876
      req->val = sample128_placeholder:
877
      req->conhdl = app_env.conhdl;
878
879
      ke_mag_send(req);
880
      return (KE_MSG_CONSUMED) ;
881
    3
882
```

#### Figure 27: Timer functionality implementation

The implementation above restarts the timer, increments the placeholder variable and sends a kernel message to the sample128 service task to update the value of characteristic 2. A Bluetooth Notify will automatically be sent to the smartphone/tablet every time the value is updated if Notify is enabled for characteristic 2 via the smartphone/tablet.

Finally, we wanted to use the value written to characteristic 1 to reload the value of characteristic 2. This is a simple implementation in "sample128-val\_ind\_handler()" of "app\_custom\_proj.c":

```
847 int sample128_val_ind_handler(ke_msg_id_t const msgid,
848 struct sample128_val_ind const *param,
849 ke_task_id_t const dest_id,
850 ke_task_id_t const src_id)
851 -{
852 sample128_placeholder = param->val;
853 return (KE_MSG_CONSUMED);
854 }
```

#### Figure 28: Write event implementation

sample128\_placeholder = param->val;

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You should be able to build and run the application at this time. Use LightBlue or BlueLoupe to verify that it all works. Set characteristic 2 to Notify in order to see the automatic updates.



### 7 Modifying sample128

In this section we will dig a little further into the sample128 service to see how it is constructed and to modify parts of it. The application implemented in the previous sections of this document will be used as a foundation upon which all further modifications will be based.

### 7.1 The basics of sample128

In the Bluetooth domain, a service consists of a collection of attributes or data chunks that are exposed to a connected client. These attributes are arranged in a database or table that is commonly referred to as the GATT database. A client device can explore (or discover) this database and determine the kind of attributes that are available and which methods can be used to interact with the database entries. A device will implement a GATT database which covers all the services that it provides.

The sample128 service contains just two characteristics. The first characteristic is one byte wide and facilitates read and write access to the client. The second characteristic, also one byte wide, facilitates read and notify access. When notification is activated for a characteristic, any change to the value data, will cause a Bluetooth Notify to be sent to the client device.

The database format is defined by the BT SIG. The database of Sample128, consisting of a total of 6 attributes, is structured as shown below:

Handle (16-bit)	Attribute Declaration Type	Attribute Declaration Type ID	Size of Declaration Attribute Type ID [Bits]	Data	Data size [Bytes]
Start	Primary Service Declaration	0x2800	16	0x0F0E0D0C0B0A0	16
Start+1	Characteristic Declaration	0x2803	16	0x <rd wr><start+2>1F1E1D</start+2></rd wr>	19
Start+2	Characteristic value declaration	0x1F1E1D	128	0x00	1
Start+3	Characteristic Declaration	0x2803	16	0x <rd ntfy><start+4>2F2E</start+4></rd ntfy>	19
Start+4	Characteristic value declaration	0x2F2E2D	128	0x00	1
Start+5	Client configuration declaration	0x2902	16	0x0000	2

### Table 1: The GATT database of sample128

As illustrated in the table above, there are a total of six attributes that each are associated with a 16bit (2 bytes) handle. Sample128 only contains 4 different declaration types (colour coded in the table above):

- One primary service declaration (sample128 service)
- Two characteristic declarations (one for each characteristic)

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- Two characteristic value declarations (one for each characteristic)
- One client configuration declaration (enables notifications for the second characteristic)

#### 7.1.1 The primary service declaration attribute

The primary service declaration attribute has a BT SIG assigned declaration type identifier of 0x2800 (16-bit) as shown in Table 1: The GATT database of sample128. The data component of a primary service is the UUID of the service, and because our service is custom (as in not specified by the BT SIG) it is 128-bit (16 bytes) wide. The value is specified in "sample128.c" as follows:

```
35 /// sample128_1 Service
36 const struct att_uuid_128 sample128_svc =
37 	= {{0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
38 0x08, 0x09, 0x0A, 0x0B, 0x0C, 0x0D, 0x0E, 0x0F
39 }};
```

#### Figure 29: UUID of sample128 service

This translates to a UUID of 0x0F0E0D0C0B0A09080706050403020100. This UUID was completely randomly selected, hoping that it wouldn't be used by somebody else. The only way to completely prevent this from happening would be to register a service UUID with the BT SIG – Note that such a UUID would be 16-bit; not 128-bit. There is a charge for BT SIG registration of a UUID.

#### 7.1.2 The characteristic declaration attribute

Each of the two characteristics of sample128 is declared with a characteristic declaration type of 0x2803. The data component of a characteristic declaration consists of three pieces of information:

- 1. The properties bit field, that specifies how a client can access the characteristic (Read, Write, Notify, Indicate, Write without response etc.). The properties bit field is 1 byte wide.
- 2. The 2-byte handle to the value declaration of the characteristic. This enables a client device to access the value of a characteristic by referencing the handle directly.
- 3. The UUID of the characteristic. Any BT SIG assigned characteristic UUID would be 2 bytes wide, a custom UUID is 16 bytes wide.

The total size of a custom characteristic declaration's data field is therefore 1 + 2 + 16 = 19 bytes.

The declaration of characteristic 1 can be found in "sample128.c":

#### Figure 30: Characteristic 1 declaration

Note: The handle {0,0} is a placeholder that will be populated when the service database is created at runtime.

#### 7.1.3 The characteristic value declaration attribute

Both characteristics of the sample128 service are custom types and therefore use UUIDs of 128 bits. The characteristics were defined as being able to contain data of only one byte each (we will modify the size of one of them later in this section.)

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#### 7.1.4 The client configuration declaration attribute

The final type is the client configuration attribute type. It is required only for characteristic 2 because only characteristic 2 enables notifications. A client device will write to the data component of this attribute in order to subscribe to notifications. A client configuration attribute is identified by the type number (Attribute type UUID) of 0x2902. The data component is a 2-byte wide bit field (one bit specifies whether notification is active or not)

#### 7.1.5 Summarizing the components of sample128

Table 1 can be used to detail some important information about sample128. We can deduce that there are 6 attributes in total. Two of the attributes use type IDs of 128 bits and the remaining four use only 16-bit type IDs. This information is used in "sample128\_task.c":

76	//Add Service Into Database
77	
78	<pre>nb_att_16 = 4; // 4 UUID16 Attribute declaration types</pre>
79	<pre>nb_att_32 = 0; // 0 UUID32 Attribute declaration types</pre>
80	<pre>nb_att_128 = 2; // 2 UUID128 Attribute declaration types</pre>
81	

#### Figure 31: Different sized declaration type IDs

We can also calculate the total required size of the service database (from "sample128\_task.c"):

90	// т	otal	Data portion of GATT database = 58 data bytes:
91	11	16	Primary service declaration
92	// +	19	Declaration of characteristic 1
93	// +	1	Value declaration of characteristic 1
94	// +	19	Declaration of characteristic 2
95	// +	1	Value declaration of characteristic 2
96	// +	2	Client configuration declaration of characteristic 2
97	// =	58	Data bytes total
98			

#### Figure 32: Adding service128 to the database

Understanding how we got to the numbers in the above code snippets (Figure 31 and Figure 32) based on the data in Table 1 allows us to start modifying sample128. Without this understanding, you could be in for a rough ride.

### 7.2 Modifying the data size of characteristic 1

In this section, we will modify the data size of characteristic 1 from one byte to an array of 8 bytes. To do this we will need to do the following:

- Define our new data type of 8-bytes and initialize a variable of this type
- Recalculate the size of the data in the GATT database
- Modify the value attribute to reflect the increased size
- Modify the messages that are sent between the application and sample128 and modify the functions that are involved.

#### 7.2.1 Defining our new data type of 8 bytes

Defining a new variable type for our 8-byte characteristic value allows us later to modify its size in a single step. "sample128.h" is an appropriate place to define this new type

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Figure 33: Defining a new type

$\times$		
typedef unsigned	<pre>char my_new_t[8];</pre>	

We then initialize a new global variable of this type in "app\_custom.proj.c", as follows:

45	-
46	<pre>my_new_t sample128_my_new = {0x31,0x32,0x33,0x34,0x35,0x36,0x37,0x38};</pre>
47	<pre>uint8_t sample128_placeholder = 0;</pre>
48	
<b>49</b> [	匀/*
50	* FUNCTION DEFINITIONS
51	***********************

#### Figure 34: Initialization of a global variable

my\_new\_t sample128\_my\_new = {0x31,0x32,0x33,0x34,0x35,0x36,0x37,0x38};

#### 7.2.2 Recalculating the size of the database

This is not really a challenge. The data chunk that previously was 1 byte wide is now 8 bytes, so we should simply adjust the total size upwards by 7. We can thus change the size of 58 to the new value of 65:

82 83	<pre>status = attmdb_add_service( &amp;(sample128_env.sample128_shdl), TASK SAMPLE128,</pre>
84	nb att 16,
85	nb att 32,
86	nb att 128,
87	65 // See calcualtion below
88	);
89	
90	<pre>// Total Data portion of GATT database = 58 data bytes:</pre>
91	<pre>// 16 Primary service declaration</pre>
92	<pre>// + 19 Declaration of characteristic 1</pre>
93	// + 8 Value declaration of characteristic 1
94	<pre>// + 19 Declaration of characteristic 2</pre>
95	<pre>// + 1 Value declaration of characteristic 2</pre>
96	// + 2 Client configuration declaration of characteristic 2
97	// = 65 Data bytes total
~~	

#### Figure 35: Changes to the database size

Just change the numbers in "sample128\_task.c"" as highlighted above.

#### 7.2.3 Modifying the value attribute

This is another simple fix. We need to accommodate 8 bytes or sizeof(my\_mew\_t) instead of just one byte of data. In "sample128\_task.c", make the highlighted changes:

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116	// Characterisitic 1: ///////////////////////////////////
119	
120	// Add characteristic declaration attribute to database
121	status = attndb add attribute( sample128 env.sample128 shd1,
122	ATT UUID 128 LEN + 3, // Data size = 19 (ATT UUID 128 LEN + 3)
123	ATT DUID 16 LEN, // Size of declaration type ID
124	(uint8 t*) Eatt decl char, // 0x2803 for a characteristic declaration
125	PERM(RD, ENABLE), // Permissions
126	<pre>4(char_hdl) // Handle to the characteristic declaration</pre>
127	12
128	
129	
130	// Add characteristic value declaration attribute to database
131	status = attmdb_add_attribute( _sample128_env.sample128_shd1,
132	sizeof(my_new_t), // Dete size = 5 Bytes
133	ATT_UVID_128_LEN,// Size of custom declaration type = 128bit
134	(uint8_t*)&sample128_1_val.uuid, // UUID of the characteristic value
135	PERM(RD, ENABLE)   PERM(WR, ENABLE),// Permissions
136	& (val_hdl) // handle to the value attribute
137	):

Figure 36: Changing the value attribute

sizeof(my\_new\_t), // Data size = 8 Bytes

### 7.2.4 Modifying messages between sample128 and the application

Two different structures, both carrying the value of characteristic 1, are used for sending messages between the application and the sample128 service. Both structures are defined in "sample128-task.h" and must be changed. The first structure, used when the service is enabled, should be changed as shown here:

91	/// Parameters of the @ref SAMPLE128_ENABLE_REQ message
92	struct sample128 enable req
93 E	3{
94	/// Connection Handle
95	uint16_t conhdl;
96	/// Security level
97	uint8_t sec_lvl;
98	
99	/// characteristic 1 value
100	<pre>my_new_t sample128_1_val;</pre>
.01	
.02	/// characteristic 2 value
103	uint8_t sample128_2_val;
104	
L05	/// char 2 Ntf property status
106	uint8_t feature;
107	};



The other structure, in the same file, is used to indicate to the application when a connected client device is changing the value of characteristic 1. Modify the type of the value as shown below:

```
116 /// Parameters of the @ref SAMPLE128_VAL_IND message
117 struct sample128_val_ind
118 -{
119 /// Connection handle
120 uint16_t conhdl;
121 /// Value
122 my_new_t_val;
123
124 };
```

#### Figure 38: The sample128\_val\_ind structure

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The value of characteristic 1 is used twice in the "app\_custom\_proj.c" file. The first time is when the sample128 service is enabled. Make the changes as highlighted below:

```
65 void app sample128 enable(void)
66 🖯 {
67
      // Allocate the message
68
      struct sample128 enable req* req = KE MSG ALLOC(
                                                         SAMPLE128 ENABLE REQ,
69
70
                                                         TASK SAMPLE128,
71
                                                         TASK APP,
72
                                                         sample128 enable req
73
                                                       );
74
      req->conhdl = app env.conhdl;
75
      req->sec lvl = PERM(SVC, ENABLE);
76
      memcpy(&req->sample128_1_val,&sample128_my_new,sizeof(my_new_t)); // default
77
      req->sample128 2 val = 0xff; // default value for sample128 characteristic 2
78
      req \rightarrow feature = 0x00;
                              // client CFG notify/indicate disabled
79
      // Send the message
      ke msg send(req);
80
81
   }
```

#### Figure 39: Setting the default value via memcpy

memcpy(&req->sample128\_1\_val,&sample128\_my\_new,sizeof(my\_new\_t)); // default

The second use of the characteristic 1 value in "app\_custom\_proj.c" is when we receive an indication that a remote client has changed the value. We load the new value into our global value as shown below:

```
843 int sample128_val_ind_handler(ke_msg_id_t const msgid,
844 struct sample128_val_ind const *param,
845 ke_task_id_t const dest_id,
846 ke_task_id_t const src_id)
847 = {
848 memcpy(&sample128_my_new,&param->val,sizeof(my_new_t));
849 return (KE_MSG_CONSUMED);
850 }
```

#### Figure 40: Retrieving the value of characteristic 1

memcpy(&sample128\_my\_new,&param->val,sizeof(my\_new\_t));

The function "sample128\_send\_val()" defined in "sample128.c" is responsible for sending the above indication to the application. This function must also be changed. In "sample128.h" we will change the prototype of the function:





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114 -	]/**
115	************************************
116	* @brief Send value change to application.
117	* @param val Value.
118	***************************************
119	*/
120	-
121	<pre>void sample128_send_val(my_new_t val);</pre>
122	



And in "sample128.c" we need to make the following changes:



#### Figure 42: Changes to sample128\_send\_val

```
memcpy(&ind->val,val,sizeof(my_new_t));
```

The above function is called by "gattc\_write\_cmd\_ind\_handler()" defined in "sample128\_task.c". In this function we will need to make the following change:

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```
318 static int gattc_write_cmd_ind_handler(ke_msg_id_t const msgid,
319
                                            struct gattc_write_cmd_ind const *param,
320
                                            ke_task_id_t const dest_id,
321
                                            ke_task_id_t const src_id)
322 🗄 {
         uint8_t char_code = SAMPLE128_ERR_CHAR;
323
324
         uint8_t status = PRF_APP_ERROR;
325
326
         if (KE_IDX_GET(src_id) == sample128_env.con_info.conidx)
327 🖨
         {
             if (param->handle == sample128_env.sample128_shdl + SAMPLE128_1_IDX_VAL)
328
329 🗄
             {
                 char code = SAMPLE128 1 CHAR;
330
             }
331
332
             if (param->handle == sample128_env.sample128_shdl + SAMPLE128_2_IDX_CFG)
333
334 🖨
             {
                 char_code = SAMPLE128_2_CFG;
335
336
             }
337
             if (char code == SAMPLE128 1 CHAR)
338
339 🖯
             ł
340
341
                 //Save value in DB
                 attmdb_att_set_value(param->handle, sizeof(my_new_t), (uint8_t *)&param->value[0]);
342
343
344
                 if(param->last)
345 🖨
                 ł
                     sample128_send_val((uint8_t *)&param->value[0]);
346
347
                 }
348
349
                 status = PRF_ERR_OK;
350
351
             }
```

Figure 43: Changes to gattc\_write\_cmd\_ind\_handler



And finally we have to make the same change in the "sample128\_enable\_req\_handler()" function, also defined in "sample128 task.c"





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```
212 static int sample128_enable_req_handler(ke_msg_id_t const msgid,
213
                                       struct sample128_enable_req const *param,
214
                                       ke_task_id_t const dest_id,
215
                                       ke_task_id_t const src_id)
216 🗄 {
217
218
        uint16_t temp = 1;
219
220
        // Keep source of message, to respond to it further on
221
        sample128_env.con_info.appid = src_id;
        // Store the connection handle for which this profile is enabled
222
223
        sample128_env.con_info.conidx = gapc_get_conidx(param->conhdl);
224
225
        // Check if the provided connection exist
        if (sample128_env.con_info.conidx == GAP_INVALID_CONIDX)
226
227
        {
            // The connection doesn't exist, request disallowed
228
            229
230
231
        }
232
        else
233 🗎
        {
            // Sample128 service permissions
234
            attmdb_svc_set_permission(sample128_env.sample128_shdl, param->sec lvl);
235
236
237
            // Set characteristic 1 to specified value
            attmdb_att_set_value(sample128_env.sample128_shdl + SAMPLE128 1 IDX VAL,
238
239
                                sizeof(my_new_t), (uint8_t *)&param->sample128_1_val);
240
241
            // Set characteristic 2 to specified value
242
            attmdb att set value(sample128 env.sample128 shdl + SAMPLE128 2 IDX VAL,
                                sizeof(uint8 t), (uint8 t *)&param->sample128 2 val);
243
244
```

Figure 44: Changes to sample128\_enable\_req\_handler

You should now be able to build and download the modified code.

### 7.3 Adding a new characteristic to the service

In this section, we will add a completely new custom characteristic to the service. We will enable read and notification access to the characteristic and allow it to carry a total of 10 bytes.

The tasks ahead of us are as follows:

- Make another type definition, to make it easier to change the size if we decide to do so at some point.
- Recalculate the number of 128-bit declaration type IDs and recalculate the size of the data in the GAP database.
- Build the new database.
- Implement new functionality in sample128 that allows us to change the value of the new characteristic.

#### 7.3.1 Defining our new data type of 10 bytes

As with our previously created data type, we will place our new type in "sample128.h"

16 -	]#ifndef	SAMPLE128_H_		
17	#define	SAMPLE128 H		
18				
19	typedef	unsigned	char my_new_t	t[8];
20	typedef	unsigned	<pre>char my_newes</pre>	r_t[10];

#### Figure 45: Defining a new data type in sample128.h

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8	
0	
typedef unsigned	<pre>char my_newer_t[10];</pre>

### 7.3.2 Calculating the size of the new database

The database table must be changed. We are going to need another 3 attributes for our new characteristic. Note that we have also changed the data size for characteristic 2, according to our modifications in the previous section.

#### Table 2: The new GATT table

Handle (16-bit)	Attribute Declaration Type	Attribute Declaration Type ID	Size of Declaration Attribute Type ID [Bits]	Data	Data size [Bytes]
Start	Primary Service Declaration	0x2800	16	0x0F0E0D0C0B0A0	16
Start+1	Characteristic Declaration	0x2803	16	0x <rd wr><start+2>1F1E1D</start+2></rd wr>	19
Start+2	Characteristic value declaration	0x1F1E1D	128	0x00	8!!!
Start+3	Characteristic Declaration	0x2803	16	0x <rd ntfy><start+4>2F2E</start+4></rd ntfy>	19
Start+4	Characteristic value declaration	0x2F2E2D	128	0x00	1
Start+5	Client configuration declaration	0x2902	16	0x0000	2
Start+6	Characteristic Declaration	0x2803	16	0x <rd ntfy><start+7>3F3E</start+7></rd ntfy>	19
Start+7	Characteristic value declaration	0x3F3E3D	128	0x00	10
Start+8	Client configuration declaration	0x2902	16	0x0000	2

As can be seen in Table 2, we are adding three attributes. Two of the attributes are referenced using a 16-bit type ID and one is referenced with a 128-bit type ID. We can also see that we are adding 19 + 10 + 2 = 31 data bytes to the database. This information allows us to make the following code changes to "sample128\_task.c":

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72 📥 /\*\_\_\_\_\_ -----\* 73 \* Sample128 Service Creation 74 ----\*/ \_\_\_\_\_ 75 76 //Add Service Into Database 77 78 nb\_att\_16 = 6; // 6 UUID16 Attribute declaration types nb\_att\_32 = 0; // 0 UUID32 Attribute declaration types nb\_att\_128 = 3; // 3 UUID128 Attribute declaration types 79 80 81 82 status = attmdb add service( &(sample128 env.sample128 shdl), 83 TASK SAMPLE128, nb att 16, 84 nb att\_32, 85 nb att 128, 86 96 // See calculation below 87 88 ): 89 // Total Data portion of GATT database = 96 data bytes: 90 91 11 16 Primary service declaration 92 11 + 19 Declaration of characteristic 1 93 11 + 8 Value declaration of characteristic 1 11 + 19 Declaration of characteristic 2 94 11 95 + 1 Value declaration of characteristic 2 96 11 + 2 Client configuration declaration of characteristic 2 // + 19 Declaration of characteristic 3 97 + 10 Value declaration of characteristic 3 98 // + 2 Client configuration declaration of characteristic 3 99 100 101 // = 96 Data bytes total

Figure 46: Database changes

#### 7.3.3 Building the new database

Adding the three new attributes to the database can be done by copying and slightly modifying the sequence from characteristic 2. In "sample128\_task.c", add the following:



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⊁ //Characteristic 3: // Add characteristic declaration attribute to database status = attmdb add attribute( sample128 env.sample128 shdl, ATT UUID 128 LEN + 3, //Data size = 19 ATT\_UUID\_16\_LEN,//Size of declaration type ID (uint8\_t\*) &att\_decl\_char, // 0x2803 PERM(RD, ENABLE),// Permissions &(char hdl) // Handle to the characteristic declaration );  $\ensuremath{//}\xspace$  Add characteristic value declaration attribute to database status = attmdb add attribute( sample128 env.sample128 shdl, sizeof(my\_newer\_t), //Data size = 10 Bytes
ATT\_UUID\_128\_LEN,// Size of custom type ID = 128-bit (uint8\_t\*)&sample128\_3\_val.uuid, // UUID PERM(RD, ENABLE) | PERM(NTF, ENABLE),// Permissions & (val hdl) // Handle to the value attribute ); // Store the value handle for characteristic 3  $\,$ memcpy(sample128 3 char.attr hdl, &val hdl, sizeof(uint16 t)); // Set initial value of characteristic 3  $\,$ status = attmdb\_att\_set\_value( char\_hdl, sizeof(sample128 3 char), (uint8 t \*)&sample128 3 char ); // Add client configuration declaration attribute to database ( Facilitates Notify ) status = attmdb add attribute( sample128 env.sample128 shdl, sizeof(uint16\_t), // Data size 2bytes (16-bit)
ATT\_UUID\_16\_LEN, // Size of client configuration type ID (uint8 t\*) &att decl cfg, // 0x2902 UUID PERM(RD, ENABLE) | PERM(WR, ENABLE), // Permissions &(val hdl) // Handle to value attribute );





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We need to define the attribute values of the new characteristic. This is done in "sample128.c" as follows:

```
31 * SAMPLE128 PROFILE ATTRIBUTES VALUES DEFINITION
                                                       *****
     *****
32
33
     */
34
35
    /// sample128 1 Service
36 const struct att_uuid_128 sample128_svc = {{0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07,
37
                                                    0x08, 0x09, 0x0A, 0x0B, 0x0C, 0x0D, 0x0E, 0x0F}};
38
39
    /// sample128 1 value attribute UUID
40
   const struct att_uuid_128 sample128_1_val = {{0x10, 0x11, 0x12, 0x13, 0x14, 0x15, 0x16, 0x17,
41
42
                                                      0x18, 0x19, 0x1A, 0x1B, 0x1C, 0x1D, 0x1E, 0x1F}};
43
44 struct att_char128_desc sample128_1_char = {ATT_CHAR_PROP_RD | ATT_CHAR_PROP_WR,
45
                                               {0,0},
46
                                               {0x10, 0x11, 0x12, 0x13, 0x14, 0x15, 0x16, 0x17,
47
                                                0x18, 0x19, 0x1A, 0x1B, 0x1C, 0x1D, 0x1E, 0x1F}};
48
                                               = {{0x20, 0x21, 0x22, 0x23, 0x24, 0x25, 0x26, 0x27,
0x28, 0x29, 0x2A, 0x2B, 0x2C, 0x2D, 0x2E, 0x2F}};
49 const struct att_uuid_128 sample128_2_val
50
51
52 struct att_char128_desc sample128_2_char = {ATT_CHAR_PROP_RD | ATT_CHAR_PROP_NTF,
                                                {0,0},
53
                                                {0x20, 0x21, 0x22, 0x23, 0x24, 0x25, 0x26, 0x27,
54
55
                                                0x28, 0x29, 0x2A, 0x2B, 0x2C, 0x2D, 0x2E, 0x2F}};
56
57 🗄
    const struct att_uuid_128 sample128_3_val = {{0x30, 0x31, 0x32, 0x33, 0x34, 0x35, 0x36, 0x37,
58
                                                       0x38, 0x39, 0x3A, 0x3B, 0x3C, 0x3D, 0x3E, 0x3F}};
59
60
    struct att_char128_desc sample128_3_char = {ATT_CHAR_PROP_RD | ATT_CHAR_PROP_NTF,
61
                                               {0,0},
62
                                                {0x30, 0x31, 0x32, 0x33, 0x34, 0x35, 0x36, 0x37,
                                                 0x38, 0x39, 0x3A, 0x3B, 0x3C, 0x3D, 0x3E, 0x3F}};
63
64
```

#### Figure 47: Defining attribute values

We need to be able to reference the three new attributes. This is achieved by enumerating them in "sample128.h":



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```
33 🗄 / *
     * ENUMERATIONS
34
     *****
35
     */
36
37
38
   /// Handles offsets
39
   enum
40 🗄 {
        SAMPLE128_1_IDX_SVC,
41
42
43
        SAMPLE128_1_IDX_CHAR,
44
        SAMPLE128 1 IDX VAL,
45
46
        SAMPLE128_2_IDX_CHAR,
        SAMPLE128_2_IDX_VAL,
47
48
        SAMPLE128_2_IDX_CFG,
49
        SAMPLE128_3_IDX_CHAR,
50
        SAMPLE128 3 IDX VAL,
51
52
        SAMPLE128 3 IDX CFG,
53
54
        SAMPLE128_1_IDX_NB,
55
    };
56
```

Figure 48: Indexing the 3 new attributes

```
SAMPLE128_3_IDX_CHAR,
SAMPLE128_3_IDX_VAL,
SAMPLE128_3_IDX_CFG,
```

In "sample128.h", we make the following changes to accommodate the new characteristic:

80 E	3/*
81	<ul> <li>* SAMPLE128 PROFILE ATTRIBUTES VALUES DECLARATION</li> </ul>
82	***************************************
83	*/
84	_
85	/// sample128 Service
86	<pre>extern const struct att_uuid_128 sample128_svc;</pre>
87	/// sample128 1 - Characteristic
88	<pre>extern struct att_char128_desc sample128_1_char;</pre>
89	/// sample128_1 - Value
90	<pre>extern const struct att_uuid_128 sample128_1_val;</pre>
91	/// sample128 2 - Characteristic
92	<pre>extern struct att_char128_desc sample128_2_char;</pre>
93	/// sample128 2 - Value
94	extern const struct att uuid 128 sample128 2 val;
95	// sample128 3 - Characteristic
96	<pre>extern struct att_char128_desc sample128_3_char;</pre>
97	/// sample128 3 - Value
98	<pre>extern const struct att_uuid_128 sample128_3_val;</pre>
99	

Figure 49: Changes to sample128.h

```
>>
// sample128_3 - Characteristic
extern struct att_char128_desc sample128_3_char;
/// sample128_3 - Value
extern const struct att_uuid_128 sample128_3_val;
```

**Application Note** 

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You should now be able to build the modified code. You can also load it to your DVK and use Light Blue (iOS) or BlueLoupe (Android) to see that the new characteristic shows up. Note: you may have to turn Bluetooth on your smart device off and back on to see the change:

69908				ene 🖬 🎔 🛊
( DA1458x				
Device address: 80:EA:CA:00	:00:DD			
State: Connected, RSSI:-47, /	Avg:-48			
Generic Access Ser	vice Rostsbaam			
Generic Attribute Se	rvice 80519634fb			
<ul> <li>Unknown service</li> <li>bibe0d0c-0b0e-0908-0708-050</li> </ul>	403020100			
< <unknown char<br="">UUID: 0x1d1c, Properties:</unknown>	acteristic>>			
< <unknown char<br="">UUID: 0x2d2c, Properties:</unknown>	acteristic>> Read/Notify			
<>Unknown char UUIO: 0x8d3c, Properties	acteristic>> Read/Notify			
	⊲	0	D	

Figure 50: The new characteristic is exposed (BlueLoupe)

### 7.3.4 Initializing the characteristic value

At this point we have successfully built the new and expanded GATT data base, and it is time to start actually using it. The first thing to do is to initialise the value of the new characteristic. In this tutorial, we will simply define a global variable in "app\_custom\_proj.c":

45	-
46	<pre>my_new_t sample128_my_new = {0x31,0x32,0x33,0x34,0x35,0x36,0x37,0x38};</pre>
47	<pre>my_newer_t sample128_my_newer = {0x41,0x42,0x43,0x44,0x45,0x46,0x47,0x48,0x49,0x4A};</pre>
48	
49	uint8_t sample128_placeholder = 0;

#### Figure 51: Initialization of a global variable

$\times$								
my_	_newer_	t	sample128	_my	_newer	=	{0x41,0x42,0x43,0x44,0x45,0x46,0x47,0x48,0x49,0x4A};	

Note: As mentioned earlier, these global variables will not be retained if deep sleep is enabled. Use retention RAM to store these types of variables if you plan to use deep sleep.

We need to modify the structure used when we enable the service, in order to allow us to initialize the database upon client connection. The structure, defined in "sample128\_task.h", must be modified as follows:





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```
86 📥 / *
     * API MESSAGES STRUCTURES
 87
     ******
 88
 89
     */
 90
 91
    /// Parameters of the @ref SAMPLE128_ENABLE_REQ message
 92 struct sample128_enable_req
93 🗄 {
        /// Connection Handle
 94
 95
        uint16_t conhdl;
 96
        /// Security level
        uint8_t sec_lvl;
97
98
 99
        /// characteristic 1 value
100
        my_new_t sample128_1_val;
101
102
        /// characteristic 2 value
103
        uint8_t sample128_2_val;
104
105
        /// char 2 Ntf property status
        uint8 t feature;
106
107
108
        /// characteristic 3 value
109
        my_newer_t sample128_3_val;
110
111
        /// char 3 Ntf property status
112
        uint8_t feature3;
113
114 };
```

#### Figure 52: Modifying the enable structure

```
/// characteristic 3 value
my_newer_t sample128_3_val;
/// char 3 Ntf property status
uint8_t feature3;
```

We are ready to initialize the new characteristic where we enable the service in "sample128\_task.c":





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```
251
252
253
                                                                                                                      ke_task_id_t const dest_id,
ke_task_id_t_const_src_id)
254
255 🗄 {
256
257
                           uint16_t temp = 1;
258
                           // Keep source of message, to respond to it further on
sample128_env.con_info.appid = src_id;
// Store the connection handle for which this profile is enabled
259
260
 261
262
                           sample128_env.con_info.conidx = gapc_get_conidx(param->conhdl);
 263
                           // Check if the provided connection exist
if (sample128_env.con_info.conidx == GAP_INVALID_CONIDX)
264
 265
266 =
267
                                       // The connection doesn't exist, request disallowed
                                      prf_server_error_ind_send((prf_env_struct *)&sample128_env, PRF_ERR_REQ_DISALLOWED,
SAMPLE128_ERROR_IND, SAMPLE128_ENABLE_REQ);
268
269
270
271
                           else
 272
273
                                      // Sample128 service permissions
 274
                                      attmdb_svc_set_permission(sample128_env.sample128_shdl, param->sec_lvl);
275
276
                                      // Set characteristic 1 to specified value
277
278
                                      attmdb_att_set_value(sample128_env.sample128_shdl + SAMPLE128_1_IDX_VAL,
                                                                                                  sizeof(my_new_t), (uint8_t *)&param->sample128_1_val);
 279
280
                                      // Set characteristic 2 to specified value
 281
                                      attmdb_att_set_value(sample128_env.sample128_shdl + SAMPLE128_2_IDX_VAL,
282
                                                                                                  sizeof(uint8_t), (uint8_t *)&param->sample128_2_val);
 283
284
                                       // Set characteristic 3 to specified value
                                      set chalacteristic s to specification and the sample set of the sample sam
285
286
287
```

#### Figure 53: Initialization of the characteristic value

### 7.3.5 Setting the default value of characteristic 3

We will have to set the default value of the new characteristic when the service is enabled. In "app\_custom\_proj.c", add the following line:

```
66 void app_sample128_enable(void)
67 🛱 {
68
       // Allocate the message
69
       struct sample128_enable_req* req = KE_MSG_ALLOC(
70
                                                                 SAMPLE128 ENABLE REQ,
71
                                                                 TASK SAMPLE128,
72
                                                                 TASK APP,
73
                                                                 sample128 enable req
74
                                                               ):
75
      req->conhdl = app env.conhdl;
76
      req->sec lvl = PERM(SVC, ENABLE);
      memcpy(&reg->sample128_1_val,&sample128_my_new,sizeof(my_new_t)); // default
memcpy(&reg->sample128_3_val,&sample128_my_newer,sizeof(my_newer_t)); // default
77
78
      req->sample128_2_val = 0xff; // default value for sample128 characteristic 2
79
      req \rightarrow feature = 0x00;
                                          // client CFG notify/indicate disabled
80
81
       // Send the message
82
       ke_msg_send(req);
83
    }
```

#### Figure 54: Default value of characteristic 3

memcpy(&req->sample128\_3\_val,&sample128\_my\_newer,sizeof(my\_newer\_t)); // default





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#### 7.3.6 Updating the characteristic value from the application

We also need a new structure for updating the value of our new characteristic from the application. We will define this structure in "sample128\_task.h":

147	/// Parameters of the @ref SAMPLE128_UPD_CHAR2_REQ message
148	struct sample128_upd_char2_req
149	
150	/// Connection handle
151	uint16_t conhdl;
152	/// Characteristic Value
153	uint8_t val;
154	};
155	-
156	/// Parameters of the @ref SAMPLE128_UPD_CHAR3_REQ message
157	<pre>struct sample128_upd_char3_req</pre>
158	自 (
159	/// Connection handle
160	uint16_t conhdl;
161	/// Characteristic Value
162	<pre>my_newer_t val;</pre>
163	};

Figure 55: New characteristic update structure

```
/// Parameters of the @ref SAMPLE128_UPD_CHAR3_REQ message
struct sample128_upd_char3_req
{
    /// Connection handle
    uint16_t conhdl;
    /// Characteristic Value
    my_newer_t val;
};
```

We will need a couple of new message primitives to be able to update the characteristic. In "sample128\_task.h" add these two primitives:



Figure 56: New message primitives

An	nli	oati	on	NI.	oto
AD	pili	Lau			υιε





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```
>>
///Update value of characteristic 3
SAMPLE128_UPD_CHAR3_REQ,
///Confirm the update of value of characteristic 3
SAMPLE128 UPD CHAR3 CFM,
```

We also need to implement a new handler for sample128 to manage the value update. The handler must be implemented among the connected state handlers of sample128 defined in "sample128\_task.c":

478	111	Connected State handler defi	inition.	
479	cons	st struct ke_msg_handler samp	le128_connected	[] =
480 🗄	- {			
481		{GATTC_WRITE_CMD_IND,	(ke_msg_func_t)	<pre>gattc_write_cmd_ind_handler},</pre>
482		{SAMPLE128 UPD CHAR2 REQ,	(ke msg func t)	sample128 upd char2 req handler},
483		{SAMPLE128_UPD_CHAR3_REQ,	(ke_msg_func_t)	<pre>sample128_upd_char3_reg_handler},</pre>
484	};			

Figure 57: Implementing a new handler

```
{SAMPLE128_UPD_CHAR3_REQ, (ke_msg_func_t) sample128_upd_char3_req_handler},
```

Finally, we must implement the handler function itself. We will just copy the handler function for characteristic 2, and make appropriate adjustments. Place this code in "sample128\_task.c" just below the "sample128\_upd\_char2\_req\_handler()" function.

```
⊁
 static int sample128_upd_char3_req_handler(ke_msg_id_t const msgid,
                                      struct sample128_upd_char3_req const *param,
                                      ke_task_id_t const dest_id,
                                      ke task id t const src id)
 {
     uint8 t status = PRF ERR OK;
     // Check provided values
     if(param->conhdl == gapc_get_conhdl(sample128_env.con_info.conidx))
         // Update value in database
         attmdb att set value(sample128 env.sample128 shdl + SAMPLE128 3 IDX VAL,
                              sizeof(my_newer_t), (uint8_t *)&param->val);
         if((sample128_env.feature3 & PRF_CLI_START_NTF))
             // Send notification through GATT
             prf server send event((prf env struct *)&sample128 env, false,
                     sample128 env.sample128 shdl + SAMPLE128 3 IDX VAL);
     }
     else
     {
         status = PRF ERR INVALID PARAM;
     }
     if (status != PRF_ERR_OK)
     {
         sample128 upd char2 cfm send(status);
     1
     return (KE MSG CONSUMED);
 }
```

Note: We are reusing the "sample128\_upd\_char2\_cfm\_send()" function. Our application doesn't act on the confirmation anyway.

At this time we are ready to change the value of characteristic 3 from the application. We will simple reuse our timer handler and change the first byte of the characteristic value every time the timer times out. Make the following changes to the timer handler function in "app\_custom\_proj.c":

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```
870
    int sample128_timer_handler(ke_msg_id_t const msgid,
871
                                             struct gapm_cmp_evt const *param,
872
                                             ke_task_id_t const dest_id,
873
                                             ke task id t const src id)
874 🗄 {
875
       ke timer set(APP SAMPLE128 TIMER, TASK APP, 50);
876
       sample128 placeholder++;
877
878
879
       struct sample128_upd_char2_req *req = KE_MSG_ALLOC(
                                                                SAMPLE128 UPD CHAR2 REQ,
880
881
                                                                TASK SAMPLE128,
882
                                                                TASK APP,
883
                                                                sample128 upd char2 req
884
                                                            );
885
       req->val = sample128 placeholder;
886
       req->conhdl = app env.conhdl;
887
888
       ke msg send(req);
889
890
       struct sample128 upd char3 req *req3 = KE MSG ALLOC(
891
                                                                SAMPLE128_UPD_CHAR3_REQ,
892
                                                                TASK SAMPLE128,
893
                                                                TASK APP,
894
                                                                sample128 upd char3 req
895
                                                            );
       memcpy(&req3->val,&sample128_my_newer,sizeof(my_newer_t));
896
897
       memcpy(&reg3->val,&sample128 placeholder,1);
       req3->conhdl = app_env.conhdl;
898
899
900
       ke msg send(reg3);
901
902
       return (KE MSG CONSUMED);
903
     }
904
```

#### Figure 58: Change the first byte of characteristic 3

```
$
$
struct sample128_upd_char3_req *req3 = KE_MSG_ALLOC(
SAMPLE128_UPD_CHAR3_REQ,
TASK_SAMPLE128,
TASK_APP,
sample128_upd_char3_req
);
memcpy(&req3->val,&sample128_my_newer,sizeof(my_newer_t));
memcpy(&req3->val,&sample128_placeholder,1);
req3->conhdl = app_env.conhdl;
ke_msg_send(req3);
```

### 7.3.7 Implementing support for GATT notify

A connected client subscribes to notification of changes to the characteristic value by writing to the client configuration attribute value of the characteristic. We will need a way to distinguish the different write actions from each other. An enumeration is used for this purpose, and we will have to add our new characteristic's client configuration to the enumeration in "sample128.h".





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```
57 ///Characteristics Code for Write Indications
58 enum
59 
{
60 SAMPLE128_ERR_CHAR,
61 SAMPLE128_1_CHAR,
62 SAMPLE128_2_CFG,
63 SAMPLE128_3_CFG,
64 };
```



SAMPLE128_3_CF	G,	
In order to keep tr add a parameter t	rack of w to the en	hether notifications are activated for the individual characteristic, we will vironment structure of the service. This must be done in "sample128.h":
	71 ///	sample128 environment variable
	72 str	uct sample128_env_tag
	73 🛱 {	
	74	/// Connection Information
	75	<pre>struct prf_con_info con_info;</pre>
	76	
	77	/// Sample128 svc Start Handle
	78	uint16_t sample128_shdl;
	79	
	80	//Notification property status
	81	uint8_t feature;
	82	
	83	<pre>//Notification property status characteristic 3</pre>
	84	uint8_t feature3;

Figure 60: Changing the service environment structure

```
// Notification property status characteristic 3
uint8_t feature3;
```

85 };

When we enable the service, we must remember to specify whether notifications are set for the characteristic. Near the bottom of the "sample128\_enable\_req\_handler()" function in "sample128\_task.c" add the following:

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```
293
              sample128_env.feature = param->feature;
294
295
              if (!sample128 env.feature)
296 🗄
              {
297
                     temp = 0;
298
              }
299
300
              attmdb att set value(sample128 env.sample128 shdl + SAMPLE128 2 IDX CFG,
301
                                   sizeof(uint16_t), (uint8_t *)&temp);
302
303
              sample128_env.feature3 = param->feature3;
304
305
              if (!sample128 env.feature3)
306 📄
              {
307
                     temp = 0;
308
              }
309
              else temp=1;
310
311
              attmdb att set value(sample128 env.sample128 shdl + SAMPLE128 3 IDX CFG,
312
                                   sizeof(uint16_t), (uint8_t *)&temp);
313
314
              // Go to Connected state
              ke_state_set(TASK_SAMPLE128, SAMPLE128_CONNECTED);
315
316
         }
317
318
         return (KE_MSG_CONSUMED);
319
     }
320
```

#### Figure 61: Initializing notification

Finally, we will have to set a flag when a connected client subscribes or unsubscribes to notifications. A client will write a 1 to our client configuration attribute to subscribe and a 0 to unsubscribe. In "sample128\_enable\_req\_handler" of "sample128\_task. c" add the following:





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```
420
     static int gattc_write_cmd_ind_handler(ke_msg_id_t const msgid,
421
                                            struct gattc_write_cmd_ind const *param,
422
                                            ke_task_id_t const dest_id,
423
                                            ke_task_id_t const src_id)
424 🛱 {
         uint8_t char_code = SAMPLE128_ERR_CHAR;
425
426
         uint8_t status = PRF_APP_ERROR;
427
         if (KE IDX GET(src id) == sample128 env.con info.conidx)
428
429 🖨
         {
              if (param->handle == sample128_env.sample128_shdl + SAMPLE128_1_IDX_VAL)
430
431 🗄
              {
432
                 char_code = SAMPLE128_1_CHAR;
433
             3
434
435
              if (param->handle == sample128_env.sample128_shdl + SAMPLE128_2_IDX_CFG)
436 📥
              {
                 char_code = SAMPLE128_2_CFG;
437
438
              3
439
440
             if (param->handle == sample128 env.sample128 shdl + SAMPLE128 3 IDX CFG)
441
             {
442
                  char_code = SAMPLE128_3_CFG;
443
              }
444
```

Figure 62: Handling notification subscriptions

And we must change the last "else if" statement in the same function so that it can also handle notification subscriptions to characteristic 3. Replace the entire "else if" block with the following:





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```
\sim
 else if ( (char code == SAMPLE128 2 CFG) || (char code == SAMPLE128 3 CFG))
 {
   // Written value
   uint16 t ntf cfg;
   //Extract value before check
   ntf_cfg = co_read16p(&param->value[0]);
   // Only update configuration if value for stop or notification enable
   if ((ntf cfg == PRF CLI STOP NTFIND) || (ntf cfg == PRF CLI START NTF))
   {
     //Save value in DB
     attmdb att set value(param->handle, sizeof(uint16 t), (uint8 t *)&param->value[0]);
     // Conserve information in environment
     if (ntf_cfg == PRF_CLI_START_NTF)
     {
        // Ntf cfg bit set to 1
       if(char code == SAMPLE128 2 CFG)
         sample128_env.feature |= PRF_CLI_START NTF;
       else
         sample128 env.feature3 |= PRF CLI START NTF;
     }
     else
        // Ntf cfg bit set to 0
       if (char code == SAMPLE128 2 CFG)
         sample128_env.feature &= ~PRF_CLI_START NTF;
       else
         sample128_env.feature3 &= ~PRF_CLI_START_NTF;
     }
     status = PRF ERR OK;
   }
 }
```

Ý

You should be able to build the project, download it to your DVK and run it. Using LightBlue or BlueLoupe should allow you to see the new characteristic, read the value and set up notifications to receive an updated value every 500ms.





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### 8 Revision history

Revision	Date	Description
1.1	19-Jan-2022	Updated logo, disclaimer, copyright.
1.0	25-April-2015	Initial version.



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#### **Status Definitions**

Status	Definition
DRAFT	The content of this document is under review and subject to formal approval, which may result in modifications or additions.
APPROVED or unmarked	The content of this document has been approved for publication.

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