

사물인터넷 디바이스 오픈소스 플랫폼 (Mbed OS) 프로그래밍

3. Peripheral IPs control practice

이동명
2020.07



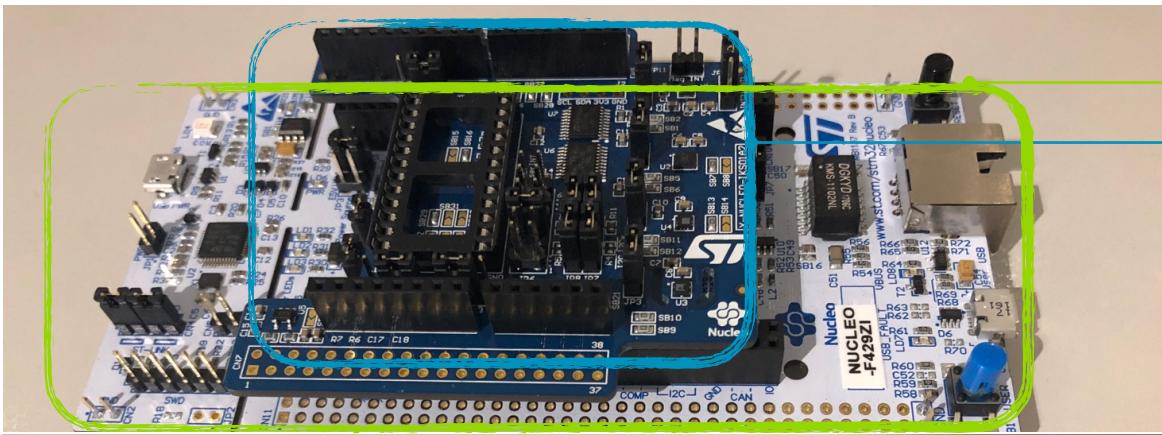
Agenda

1. Mbed Ecosystem
2. Setup develop environment
- 3. Peripheral IPs control practice**
4. Cloud / Web application with Mbed

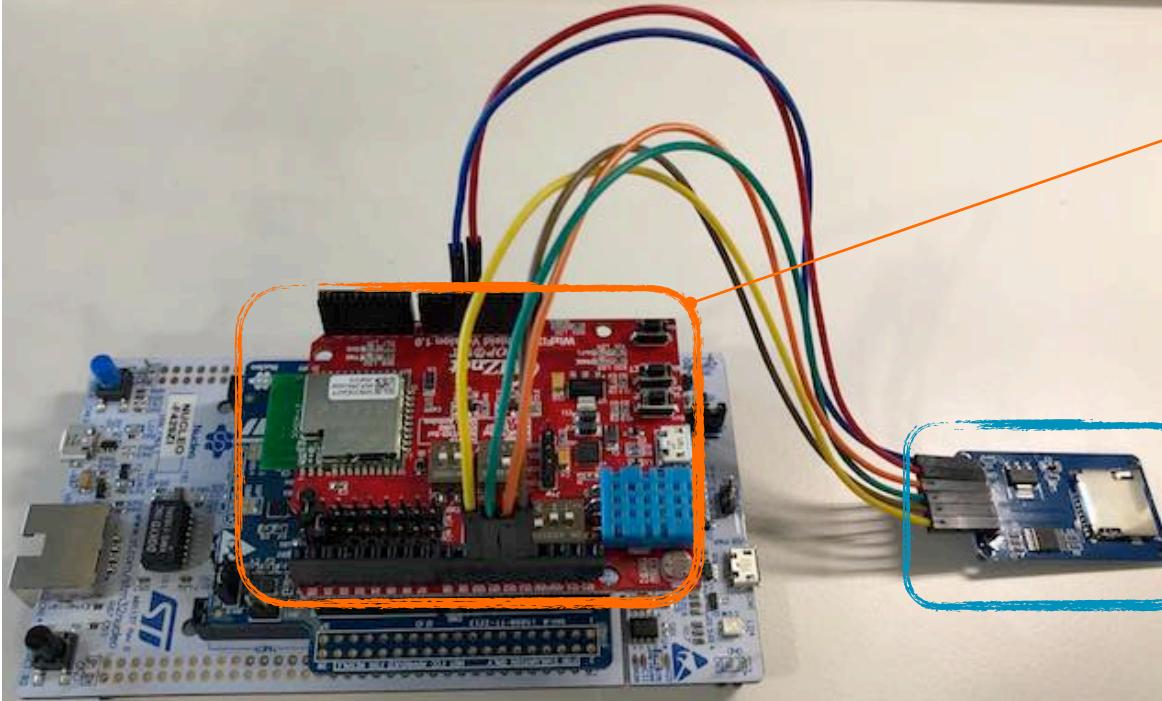


Prepare H/W

Prepare H/W

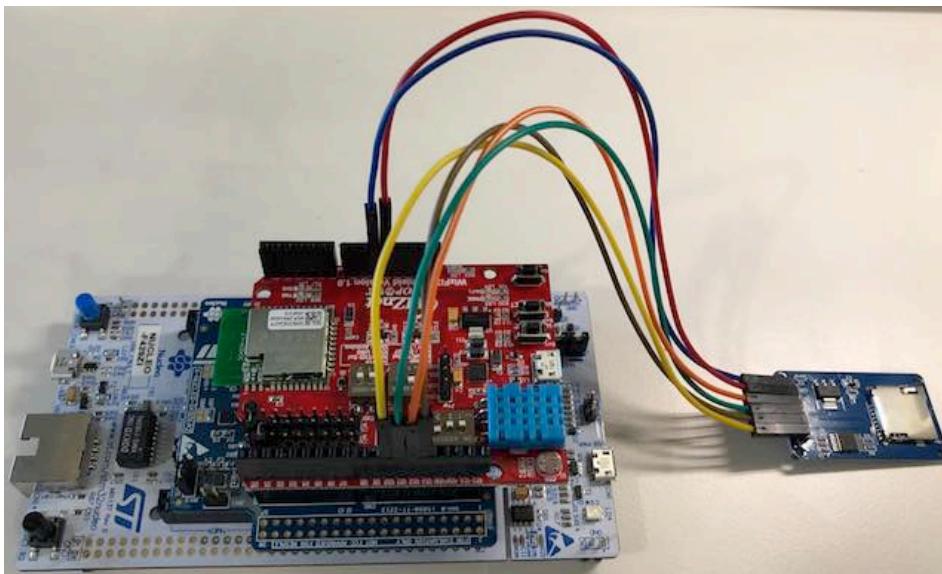


• Target board
• Sensor board

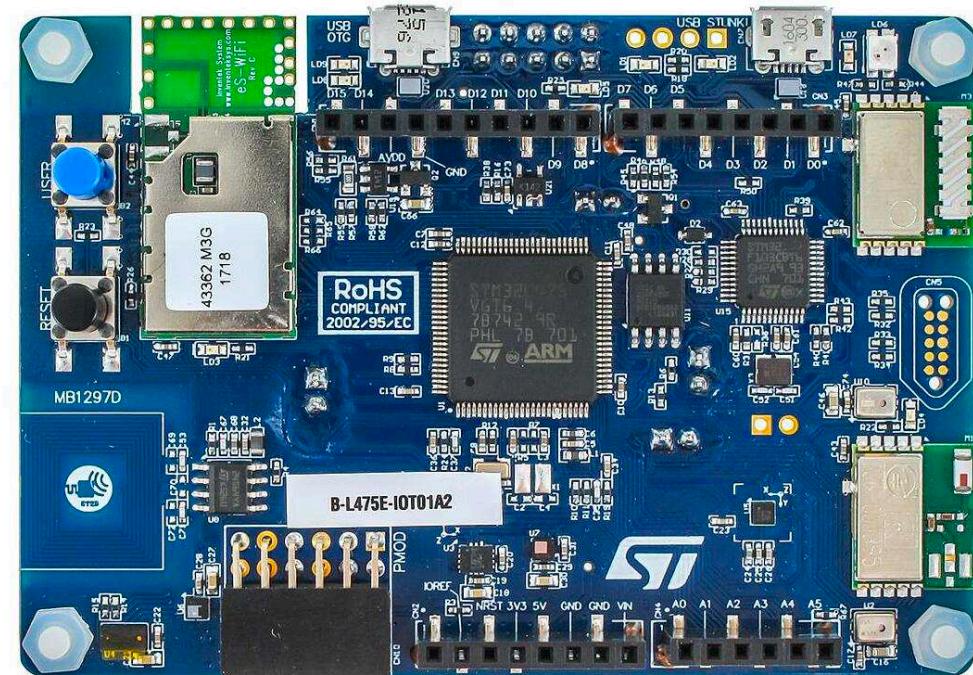


• Wifi board
• Storage(SD card) board

STM32L4 Discovery kit for IoT node



==



Prepare

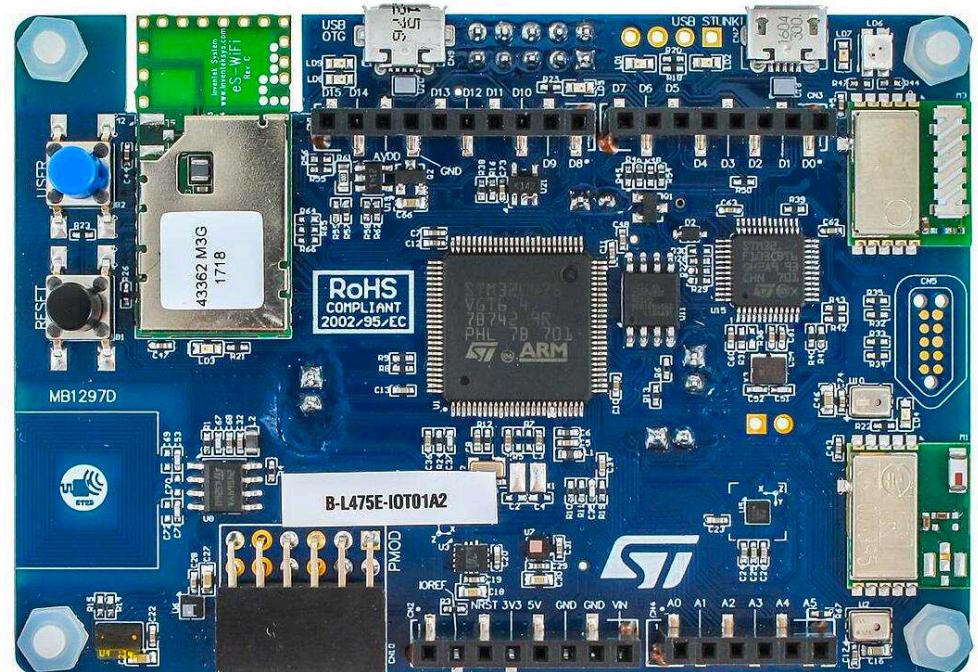
- 사용하고자 하는 Target Board의 성능/기능에 대한 이해
- 필요한 센서를 연결하기 위한 회로도, H/W Spec에 대한 이해

Spec & Board information

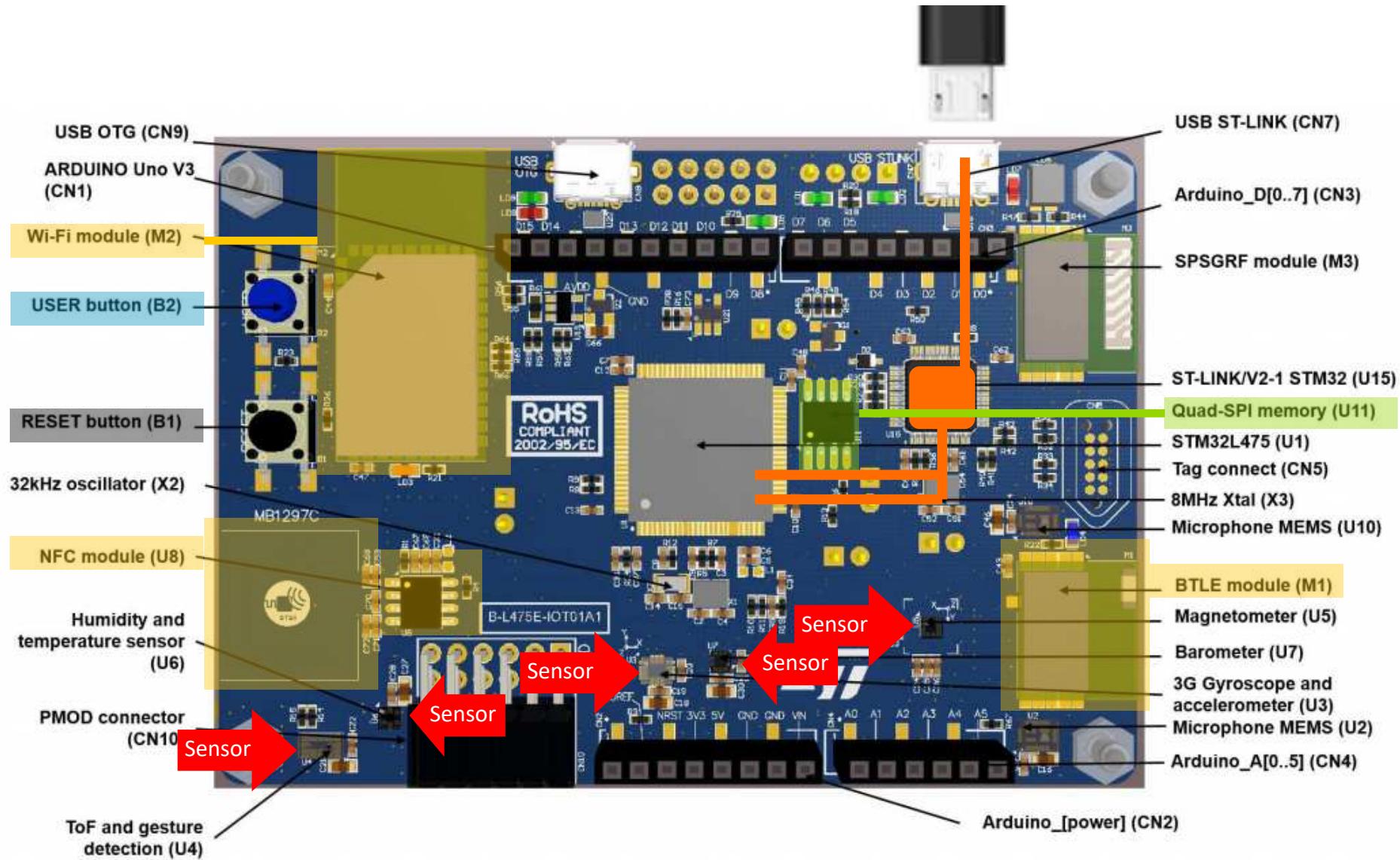
<https://os.mbed.com/platforms/ST-Discovery-L475E-IOT01A/>

User manual

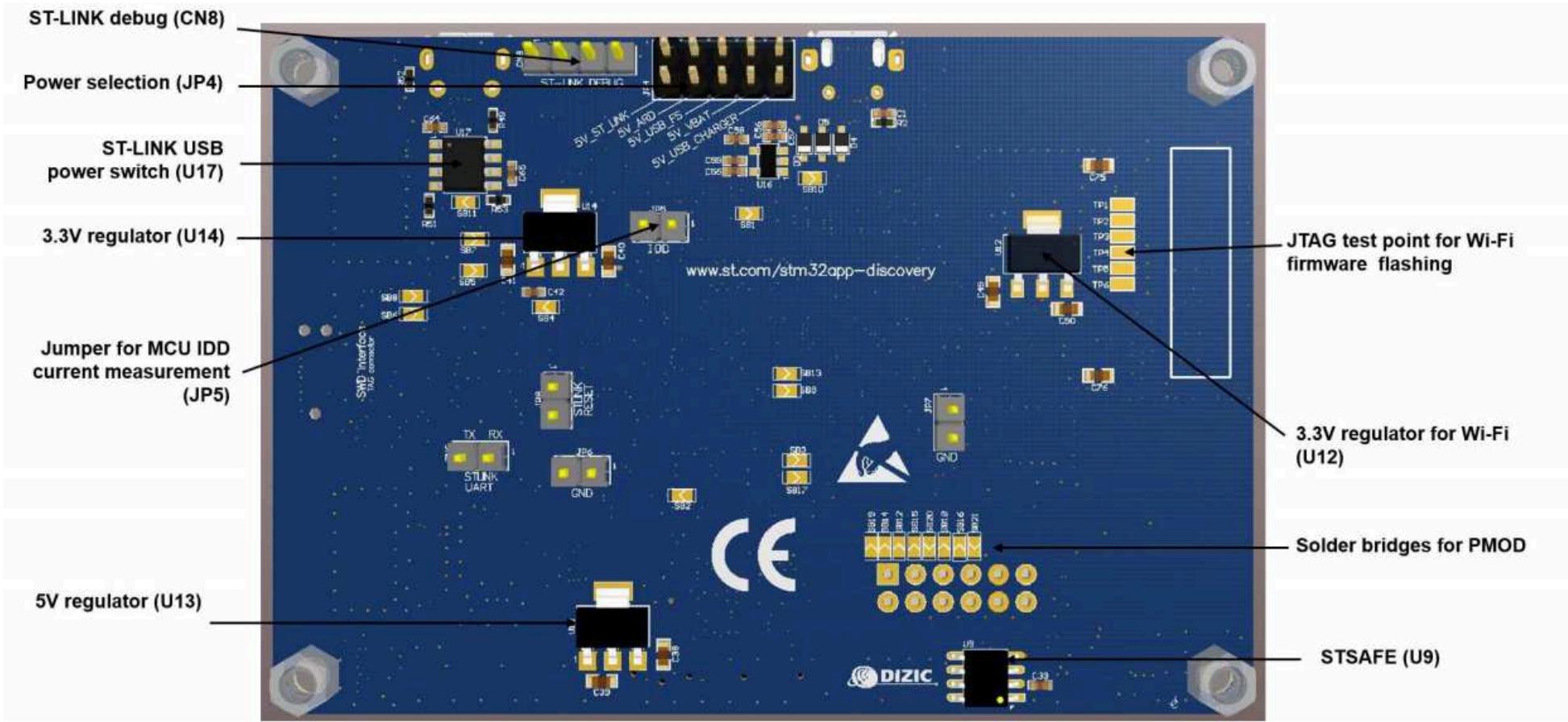
https://www.st.com/content/ccc/resource/technical/document/user_manual/group0/b1/b8/7a/f2/f7/8d/4b/6b/DM00347848/files/DM00347848.pdf/jcr:content/translations/en.DM00347848.pdf == <https://bit.ly/2Tywnsb>

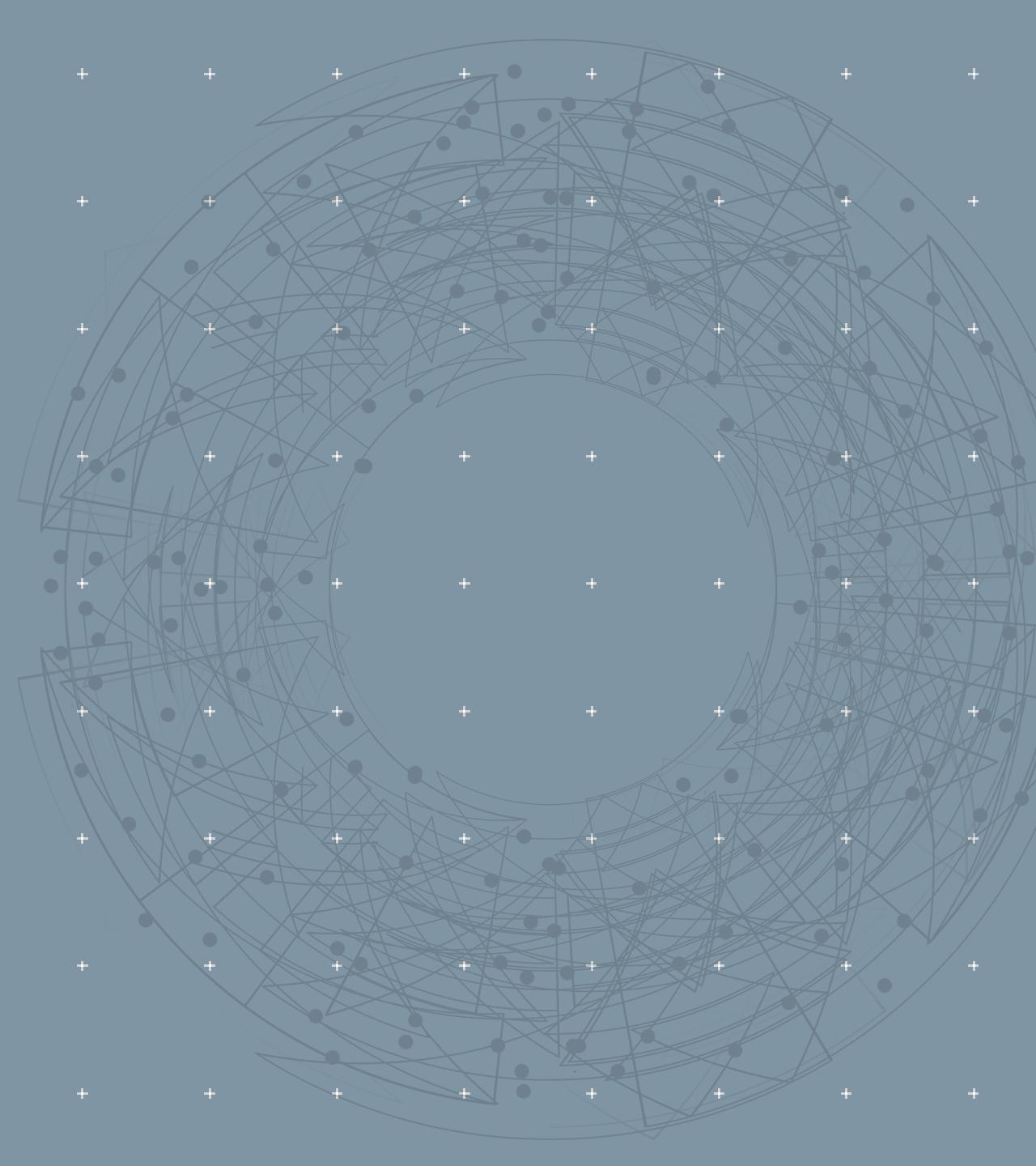


STM32L4 Discovery kit for IoT node (top view)



STM32L4 Discovery kit for IoT node (bottom view)





Mbed OS Source Code Structure

Recap..

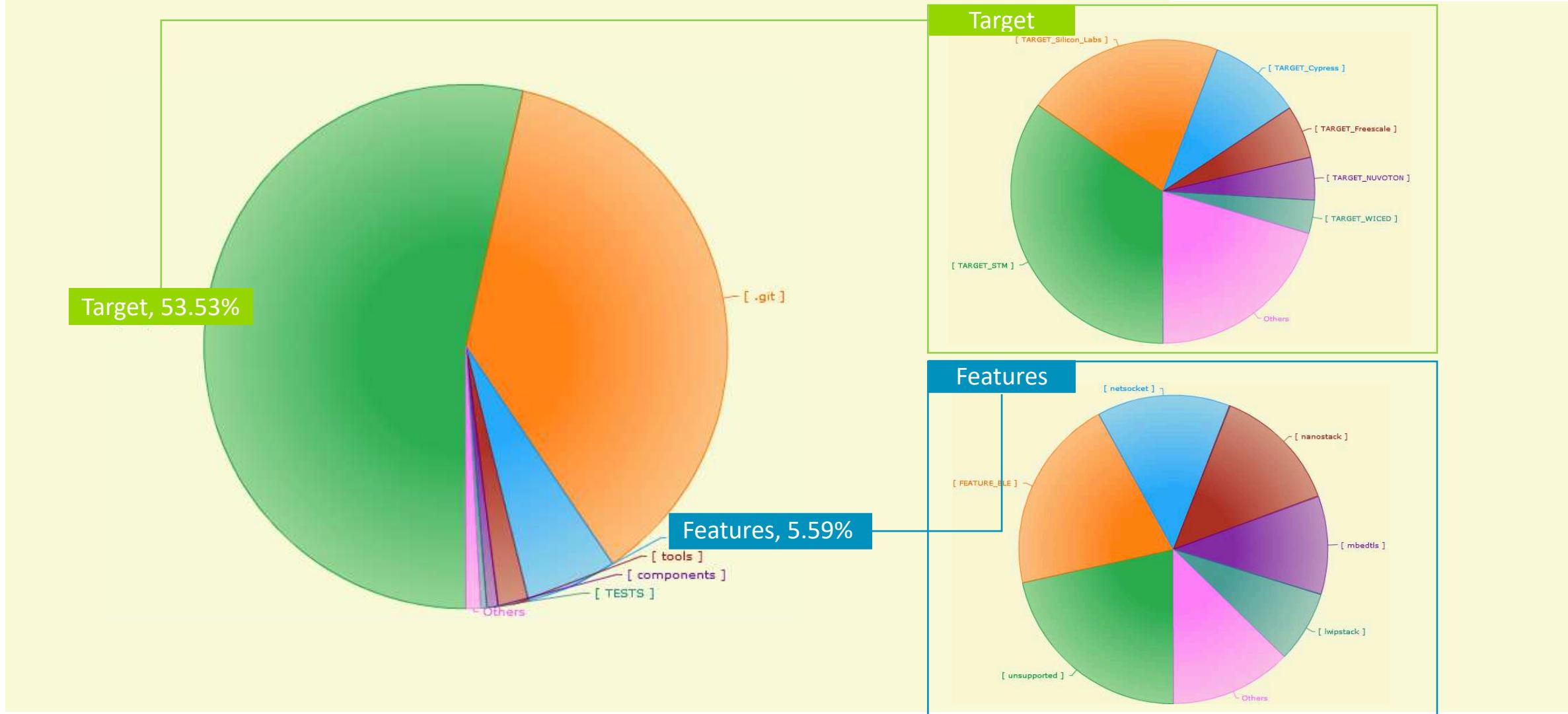
- Mbed ecosystem 소개
 - Online compiler
 - Mbed Studio
 - Mbed CLI
 - Board 설명

Recap..

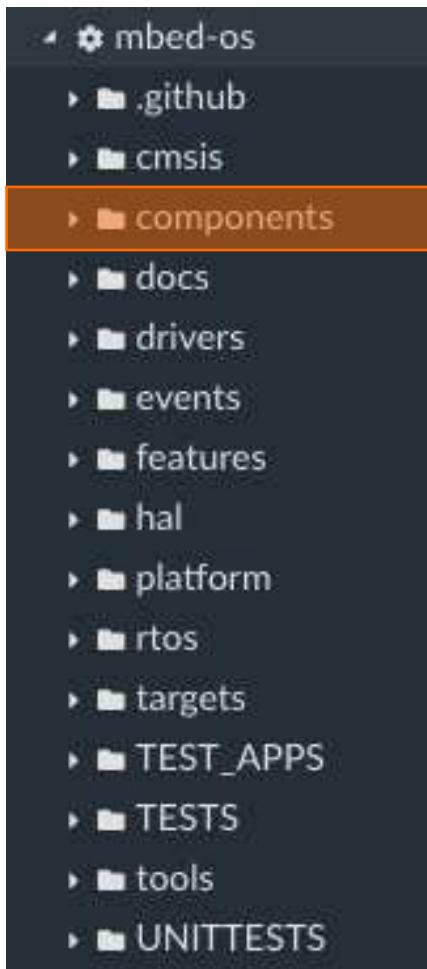
- Mbed-CLI 의 Issue...
 - <https://github.com/ARMmbed/mbed-cll/issues/980>
 - c:\mbed-os-example-blinky> pip uninstall mbed-cll
 - c:\mbed-os-example-blinky> pip install mbed-cll==1.8.3
 - c:\mbed-os-example-blinky> mbed -- version
 - c:\mbed-os-example-blinky> mbed compile -m auto -f -c

Source code size

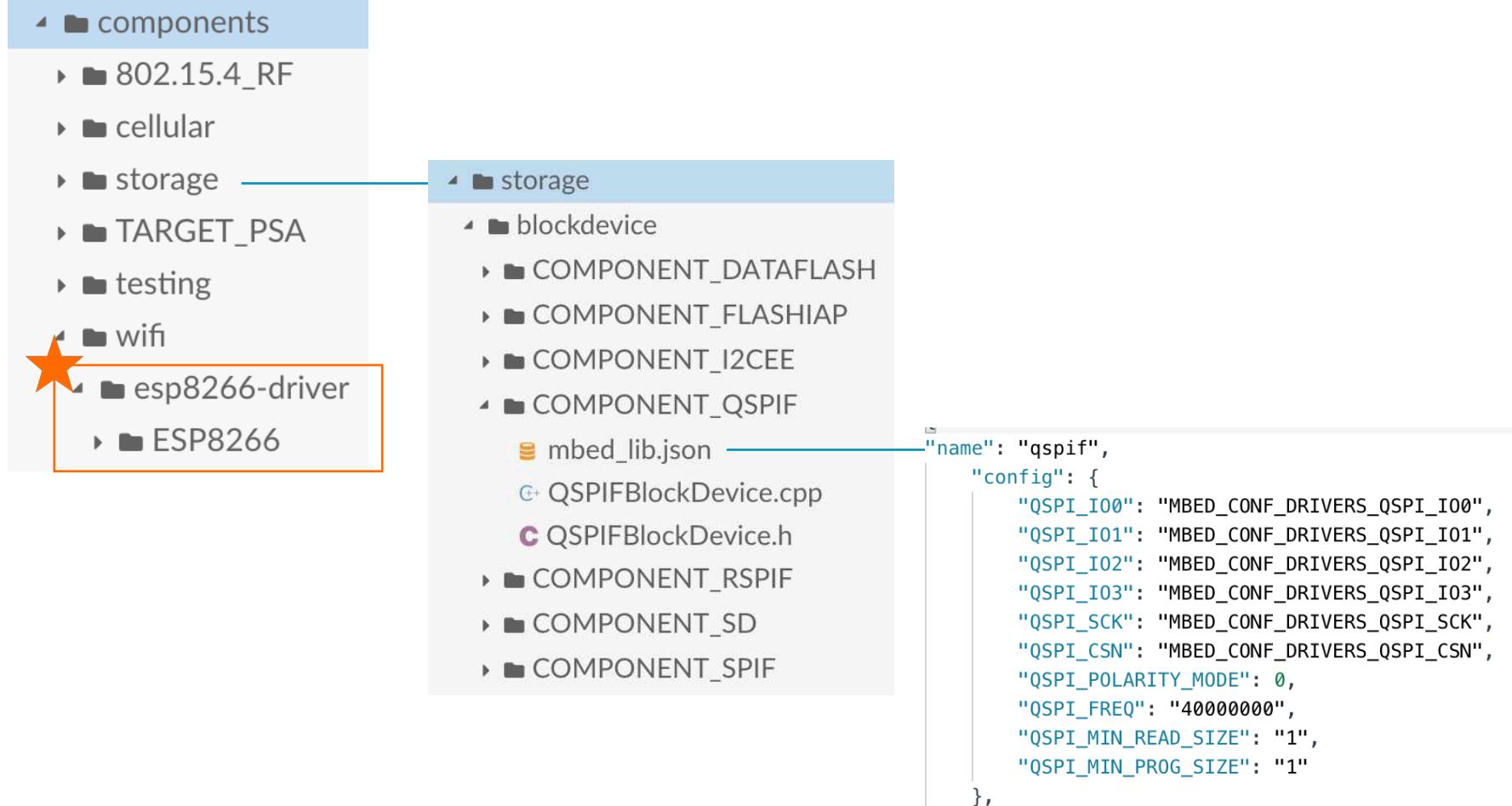
Based on mbed-os-5.15.0



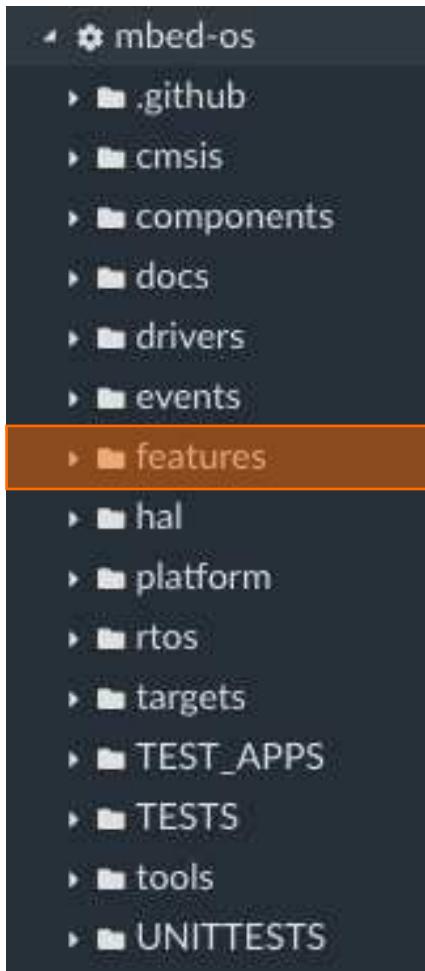
Code tree



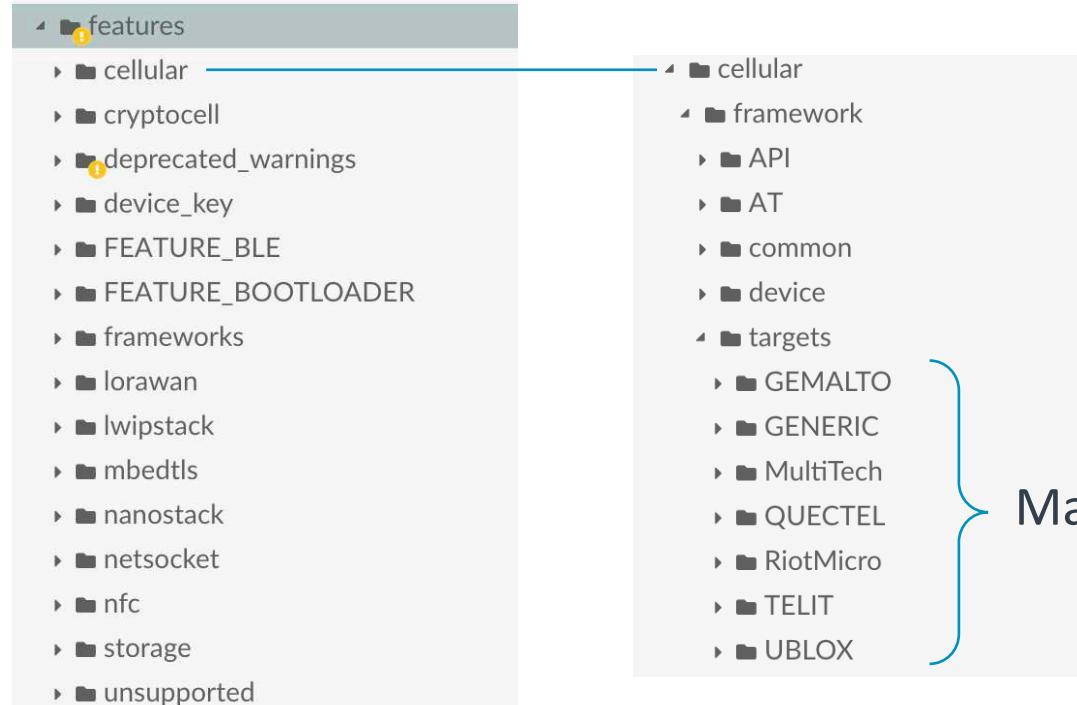
- CMSIS : RTOS V2
- Components : 가장 많이 사용하는 Components에 대한 드라이버



Code tree

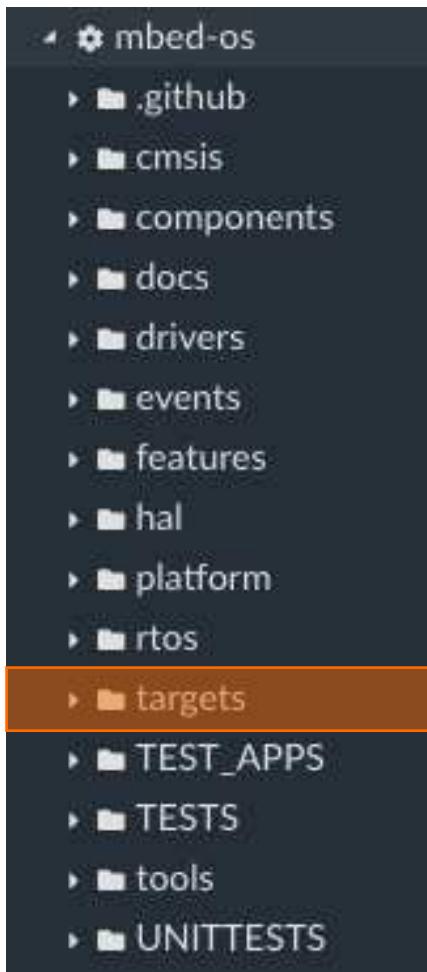


- CMSIS : RTOS V2
- Components : 가장 많이 사용하는 Components에 대한 드라이버
- Drivers : 각 Board의 Hal driver와 연결하기 위한 Wrapper
- Features : 통신/보안/저장장치 등의 공통 Stack

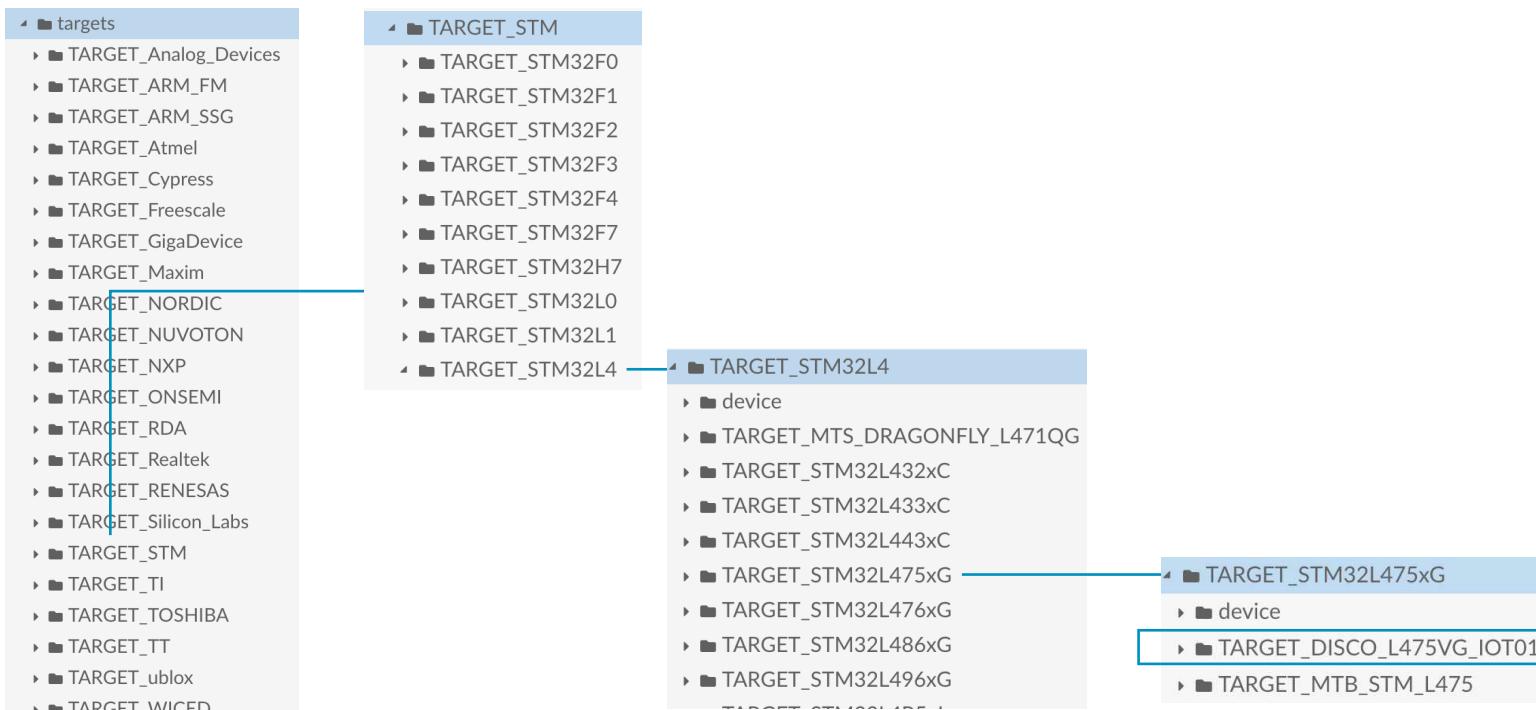


Major Cellular Modem Vendors

Code tree

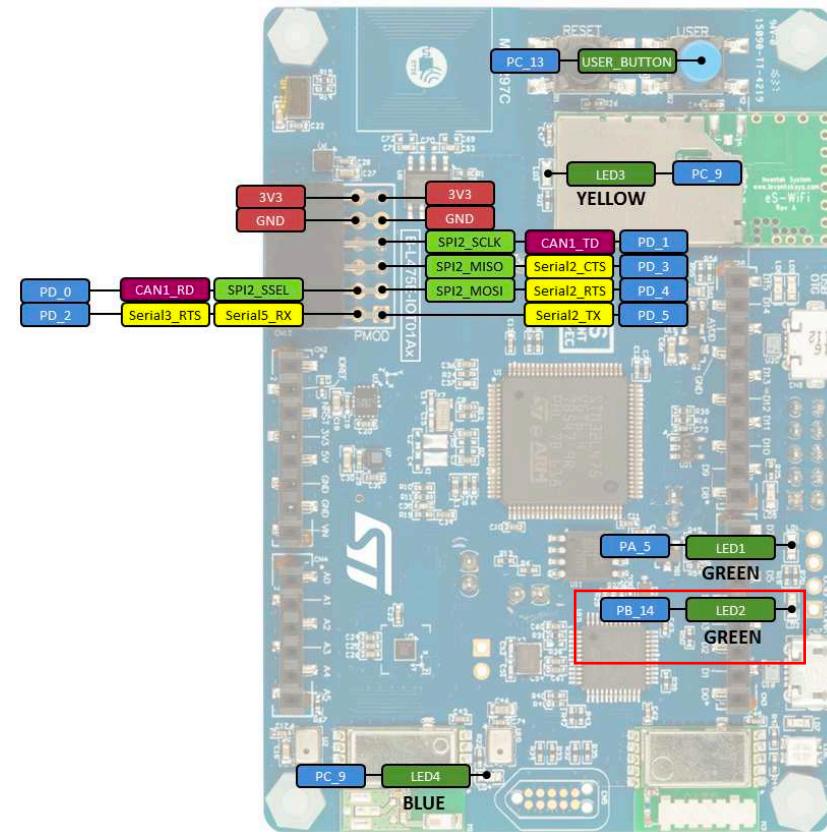


- CMSIS : RTOS V2
- Components : 가장 많이 사용하는 Components에 대한 드라이버
- Drivers : 각 Board의 Hal driver와 연결하기 위한 Wrapper
- Features : 통신/보안/저장장치 등의 공통 Stack
- Platform : Mbed OS platform 운영에 필요한 드라이버
- Target : Silicon/Module Maker의 Target board 정보/Hal Driver



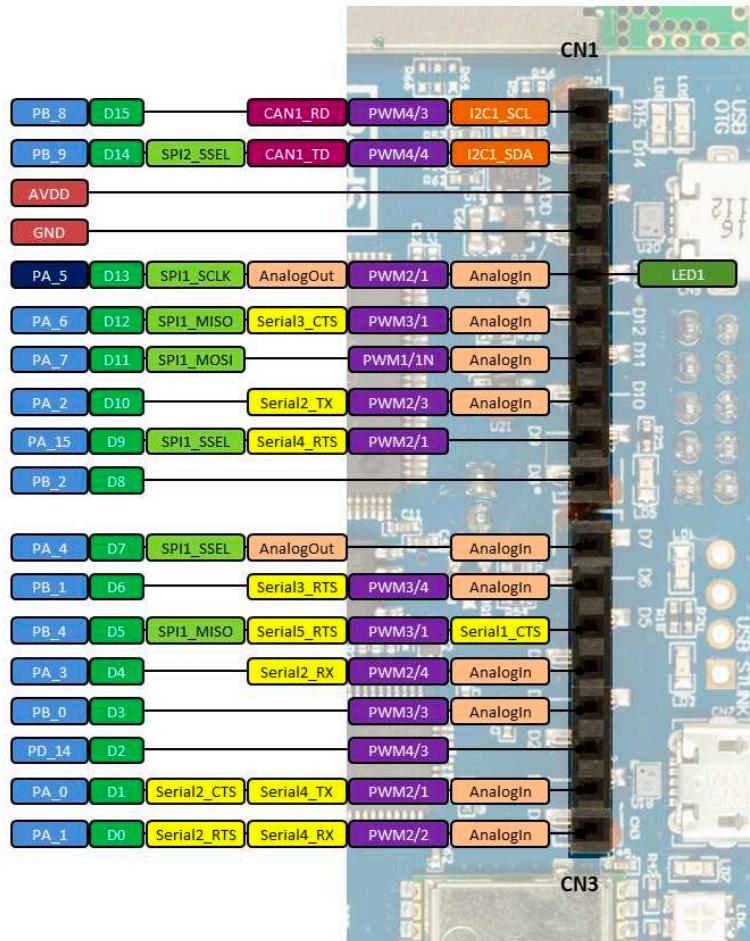
1. Example : LED 1 -> LED 2

- Mbed-os-example-blinky 를 이용해서 LED2 를 켜 봅시다.
- Arduino pin define 정보 혹은 Board의 Extension pin map 정보는 어디에서 찾을 수 있는가?



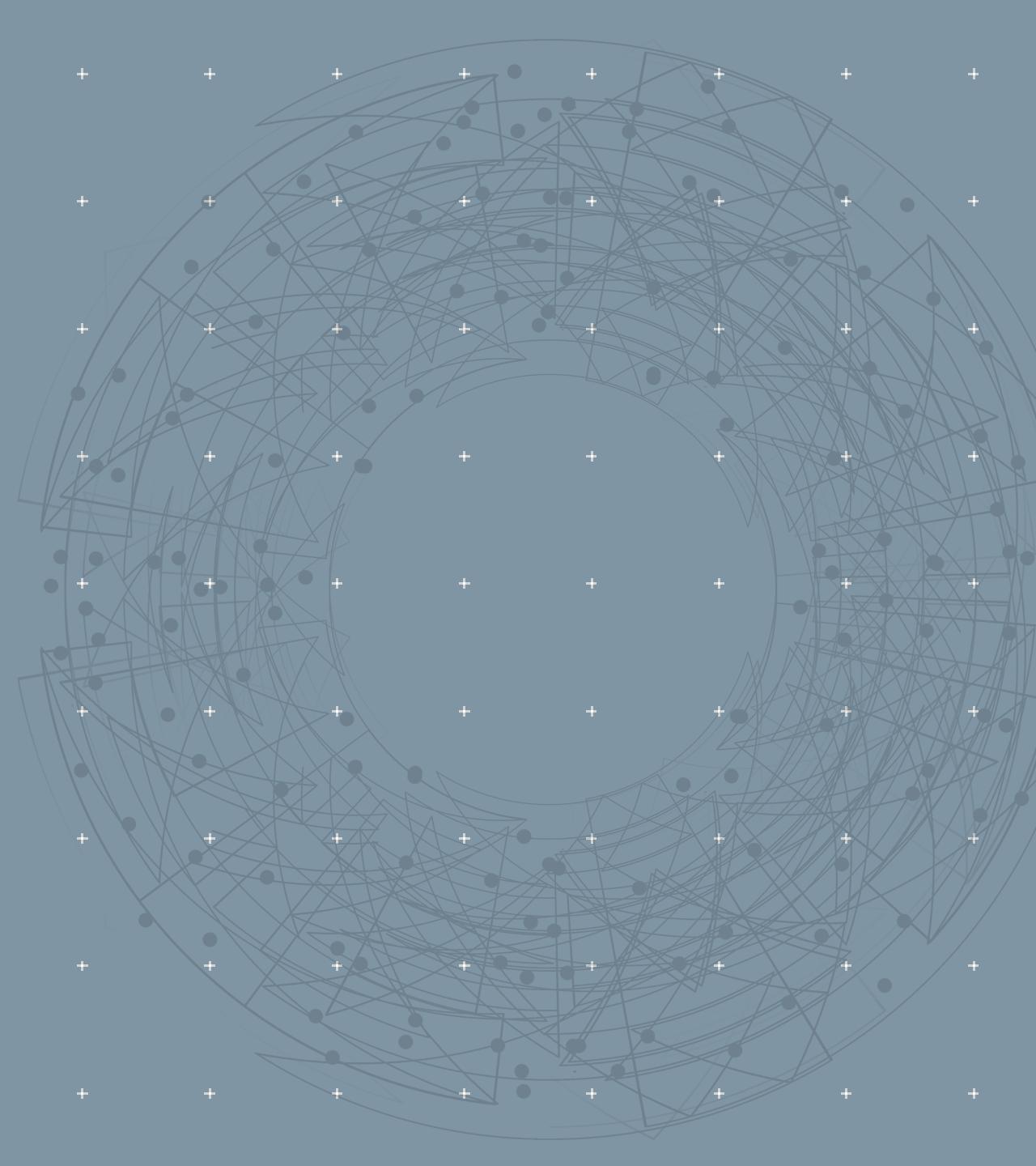
2. Example : Multiplexer(Mux) information?

- Mux pin 은 어디에서 확인할 수 있나?



3. Example : LED3 는 왜 2개가 켜질까요!?





Platform / RTOS / Driver APIs

Full API list

- <https://os.mbed.com/docs/mbed-os/v5.15/apis/index.html>

- Platform APIs

- Drivers APIs

- RTOS APIs

- USB APIs

- Network socket APIs

- Network interfaces APIs

- LoRa APIs

- NFC APIs

- Security APIs

- Storage APIs

Platform APIs

Platform APIs provide general purpose MCU management infrastructure, common data structures and a consistent user experience on top of different standard libraries and toolchains.

Wait	Time	NonCopyable	CircularBuffer
Callback	RTC	Shared pointer	ATCmdParser
DeepSleepLock	Debug	Span	Mbed statistics
Power management (sleep)	Memory tracing	FileHandle	MPU management
Idle loop	Error handling	Poll	ScopedRamExecutionLock
CriticalSectionLock	Assert	PlatformMutex	ScopedRomWriteLock

Drivers APIs

Driver APIs include analog and digital inputs and outputs on development boards, as well as digital interfaces, which allow your board to interface with a computer or external devices.

AnalogIn	BusInOut	Timeout	Flash IAP	I2CSlave
AnalogOut	PortIn	Timer	RawSerial	CAN
DigitalIn	PortOut	LowPowerTicker	Serial	MbedCRC
DigitalOut	PortInOut	LowPowerTimeout	SPI	
DigitalInOut	PwmOut	LowPowerTimer	SPISlave	
BusIn	InterruptIn	Watchdog	QuadSPI (QSPI)	
BusOut	Ticker	ResetReason	I2C	

RTOS APIs

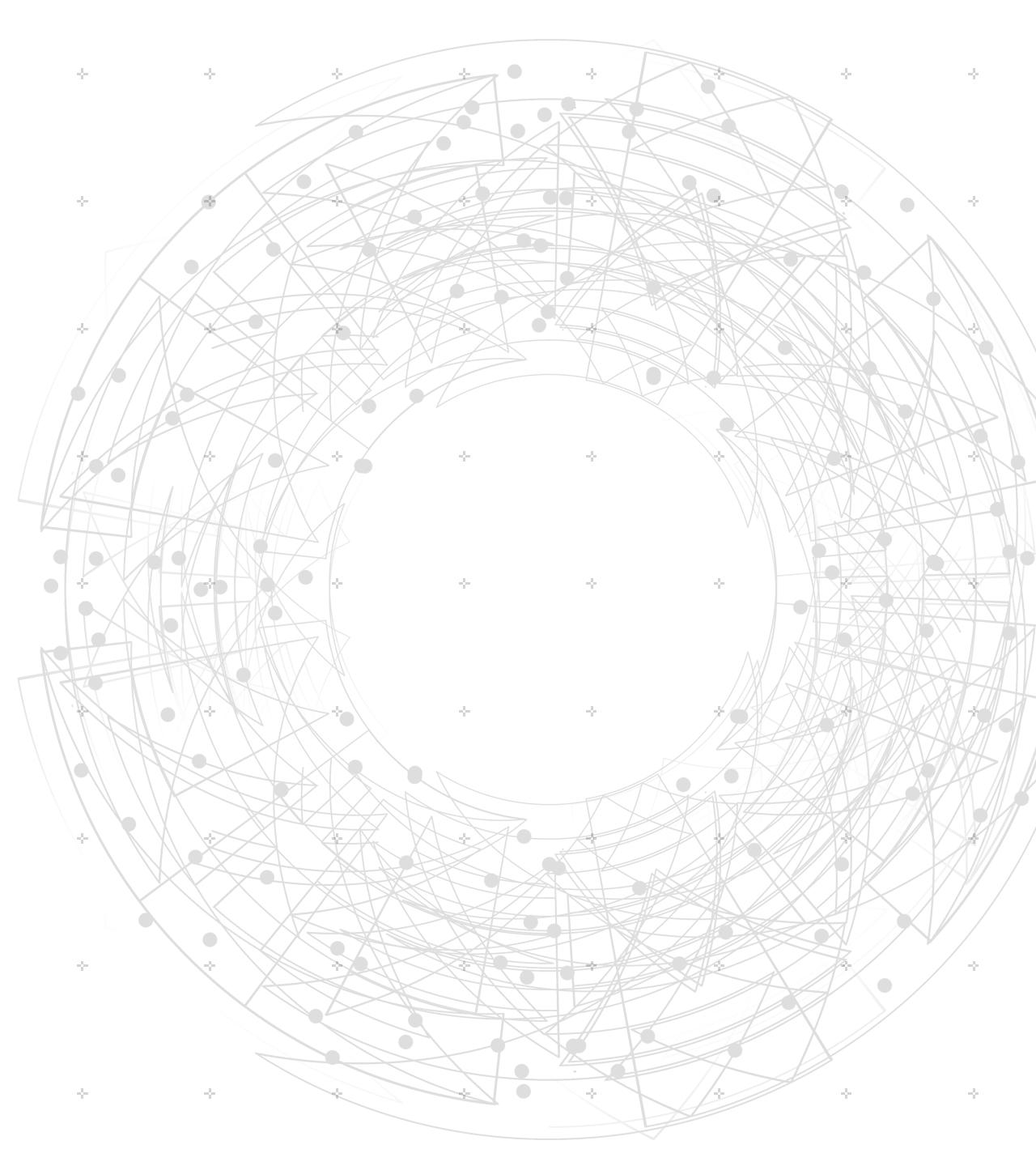
The Mbed OS RTOS capabilities include managing objects such as threads, synchronization objects and timers. It also provides interfaces for attaching an application-specific idle hook function, reads the OS tick count and implements functionality to report RTOS errors.

Thread	Semaphore	UserAllocatedEvent	EventFlags	Kernel interface functions
ThisThread	Queue	MemoryPool	Event	
Mutex	EventQueue	Mail	ConditionVariable	

Network interfaces APIs

Network interfaces are the application level APIs where users choose the driver, connectivity method and IP stack. These include ethernet, Wi-Fi, cellular and mesh interfaces.

Ethernet	Cellular	Network status
Wi-Fi	Mesh	



RTOS APIs

RTOS APIs

- 스레드, 동기화 객체 및 타이머와 같은 객체 관리가 포함됩니다. 또한 응용 프로그램 별 Idle hook (전원 전략을 위한) 기능을 연결하기 위한 인터페이스를 제공하고 OS 틱 수를 읽고 RTOS 오류를 보고하는 등의 기능을 가지고 있음

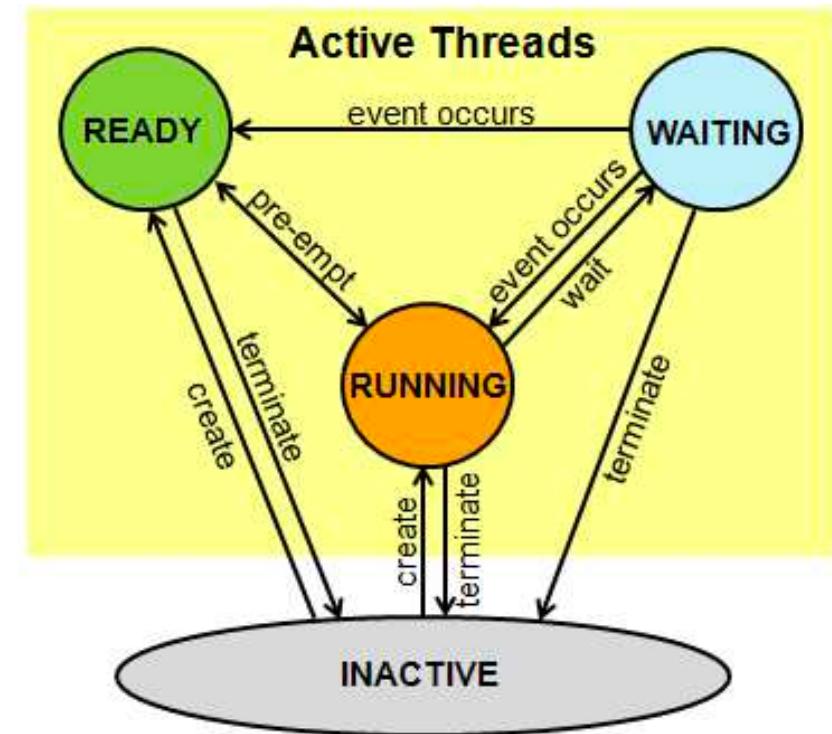
<https://os.mbed.com/docs/mbed-os/v5.15/apis/rtos.html>

Thread	Semaphore	UserAllocatedEvent	EventFlags	Kernel interface functions
ThisThread	Queue	MemoryPool	Event	
Mutex	EventQueue	Mail		

RTOS APIs – Thread

- 병렬 작업을 정의, 생성 및 제어 할 수 있다.
- 기본 스택 크기는 4K이나, THREAD_STACK_SIZE에서 필요한 크기로 옵션을 설정할 수 있다.

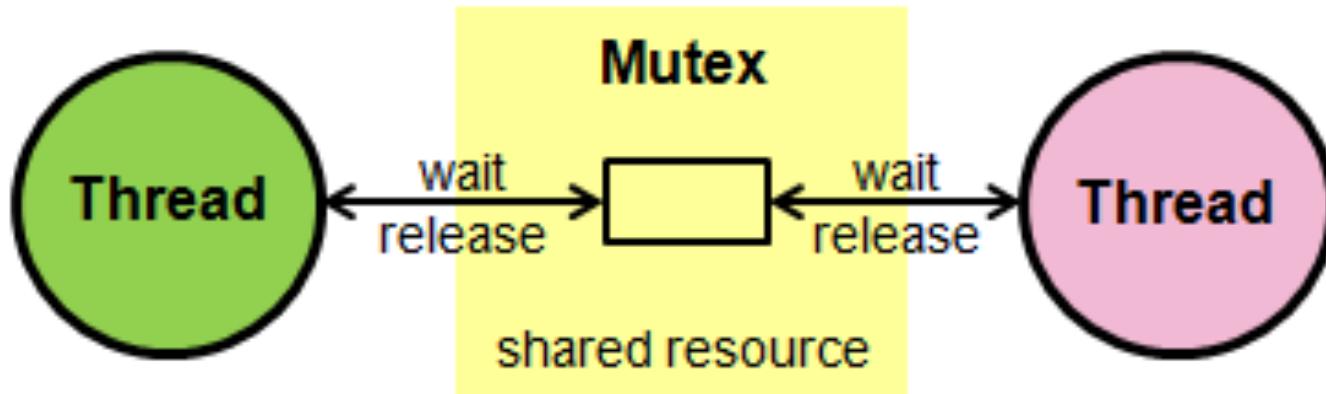
```
1 #include "mbed.h"
2
3 DigitalOut led1(LED1);
4 DigitalOut led2(LED2);
5 Thread thread;
6
7 void led2_thread() {
8     while (true) {
9         led2 = !led2;
10        wait(1);
11    }
12 }
13
14 int main() {
15     thread.start(led2_thread);
16
17     while (true) {
18         led1 = !led1;
19         wait(0.5);
20     }
21 }
```



[Warning] main.cpp@89,9: 'void wait(float)' is deprecated: 'wait' is deprecated in favor of explicit sleep functions. To sleep, 'wait' should be replaced by 'ThisThread::sleep_for' (C++) or 'thread_sleep_for' (C). If you wish to wait (without sleeping), call 'wait_us'. 'wait_us' is safe to call from ISR context. [since mbed-os-5.14] [-Wdeprecated-declarations]

RTOS APIs – Mutex

- Mutex는 공유 리소스에 대한 액세스를 보호하고 스레드 실행을 동기화하는 데 사용된다.
- Mbed OS는 모든 드라이버에 RTOS 뮤텍스 대신 [PlatformMutex](#) 클래스를 사용된다.

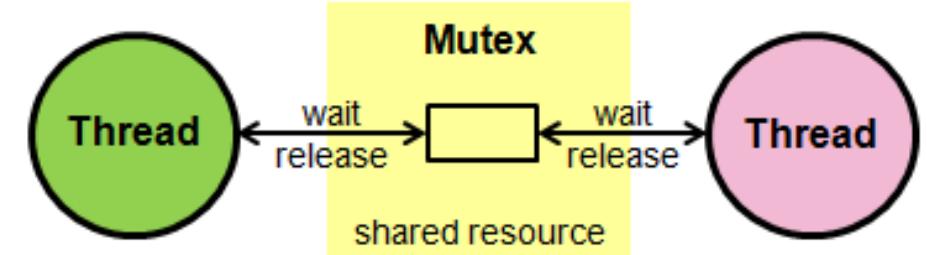


```
++ MbedOS Error Info ++
Error Status: 0x80020115 Code: 277 Module: 2
Error Message: Mutex lock failed
Location: 0x80026B3
Error Value: 0xFFFFFFFFFA
Current Thread: Id: 0x20004F54 Entry: 0x8002ABF StackSize: 0x1000 StackMem: 0x20004F98 SP: 0x2004FEF8
For more info, visit: https://armmbed.github.io/mbedos-error/?error=0x80020115
-- MbedOS Error Info --
```

RTOS APIs – Mutex

- Mutex는 공유 리소스에 대한 액세스를 보호하고 스레드 실행을 동기화하는 데 사용된다.
- Mbed OS는 모든 드라이버에 RTOS 뮤텍스 대신 [PlatformMutex](#) 클래스를 사용한다.

```
1 #include "mbed.h"
2
3 Mutex stdio_mutex;
4 Thread t2;
5 Thread t3;
6
7 void notify(const char* name, int state) {
8     stdio_mutex.lock();
9     printf("%s: %d\n\r", name, state);
10    stdio_mutex.unlock();
11 }
12
13 void test_thread(void const *args) {
14     while (true) {
15         notify((const char*)args, 0); wait(1);
16         notify((const char*)args, 1); wait(1);
17     }
18 }
19
20 int main() {
21     t2.start(callback(test_thread, (void *)"Th 2"));
22     t3.start(callback(test_thread, (void *)"Th 3"));
23
24     test_thread((void *)"Th 1");
25 }
```

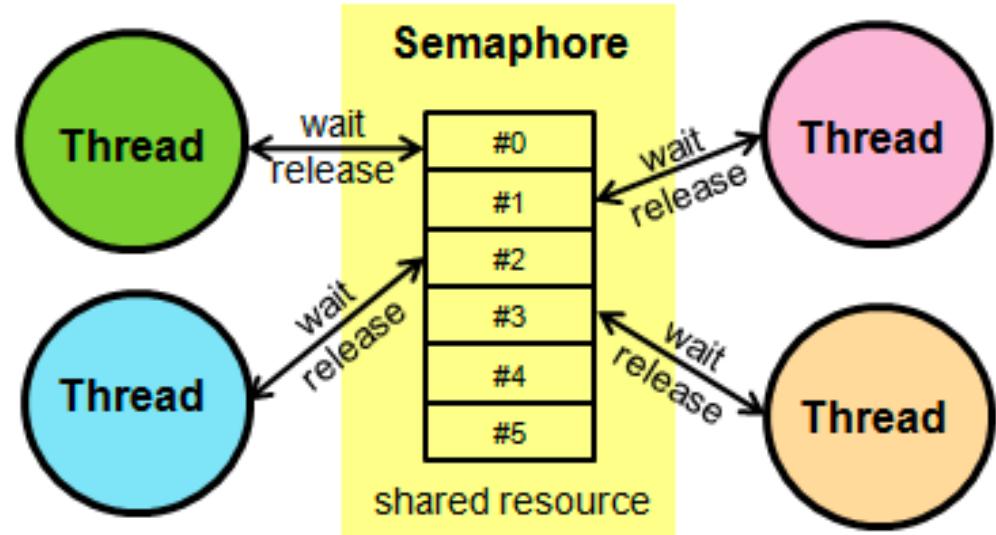


RTOS APIs – Semaphore

- Semaphore 공유 리소스 풀에 대한 스레드 액세스를 관리한다.
- N 개의 Key 를 가질 수 있다.

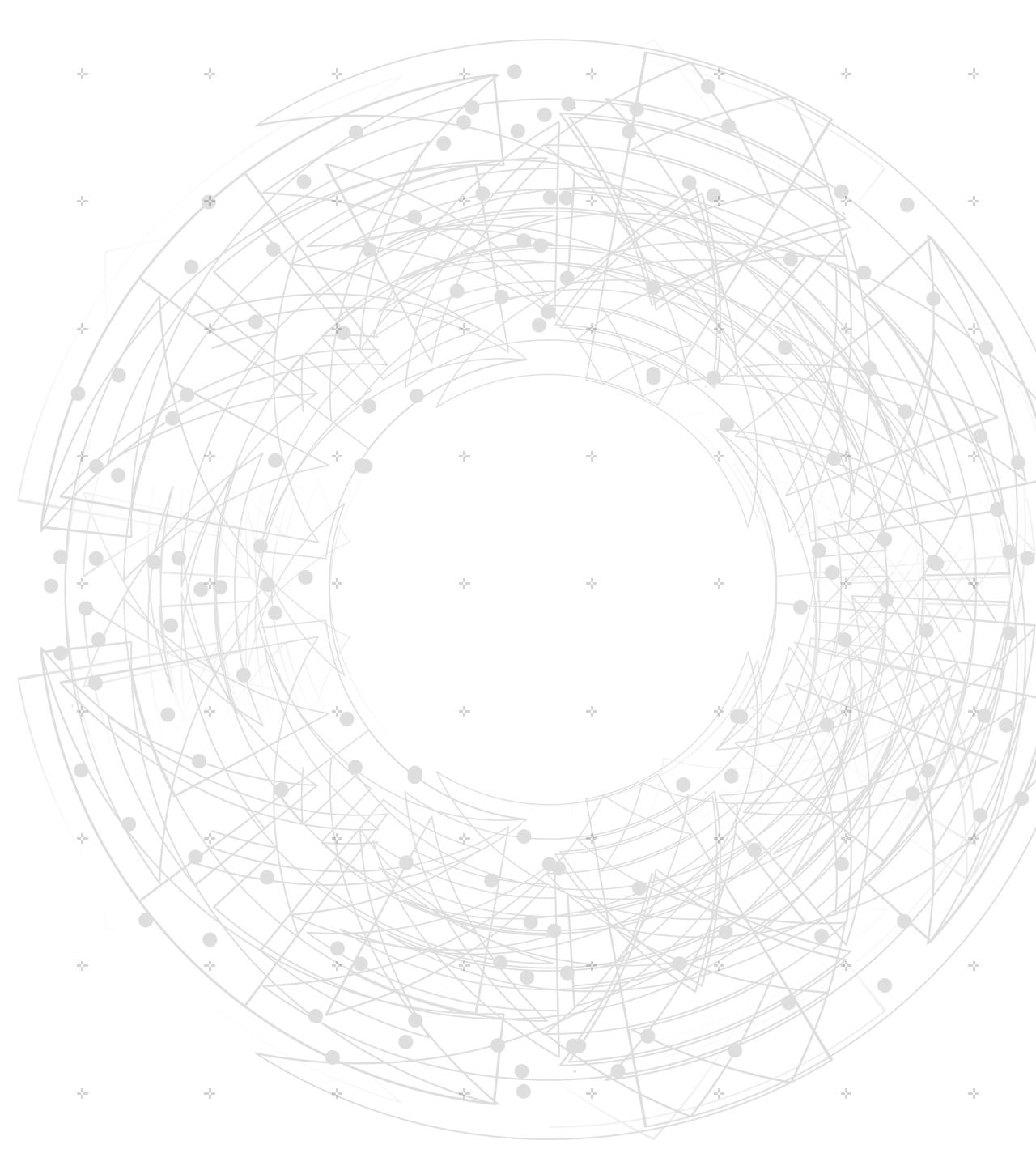
```
1 #include "mbed.h"
2
3 Semaphore one_slot(1);
4 Thread t2;
5 Thread t3;
6
7 void test_thread(void const *name) {
8     while (true) {
9         one_slot.wait();
10        printf("%s\n\r", (const char*)name);
11        wait(1);
12        one_slot.release();
13    }
14 }
15
16 int main (void) {
17     t2.start(callback(test_thread, (void *)"Th 2"));
18     t3.start(callback(test_thread, (void *)"Th 3"));
19
20     test_thread((void *)"Th 1");
21 }
22
23
24
25 }
```

<https://os.mbed.com/docs/mbed-os/v5.15/apis/semaphore.html>



Public Member Functions

	Semaphore (int32_t count=0)
	Create and Initialize a Semaphore object used for managing resources. More...
	Semaphore (int32_t count, uint16_t max_count)
	Create and Initialize a Semaphore object used for managing resources. More...
int32_t	wait (uint32_t millisec=osWaitForever)
	Wait until a Semaphore resource becomes available. More...
int32_t	wait_until (uint64_t millisec)
	Wait until a Semaphore resource becomes available. More...
void	acquire ()



Platform APIs

Platform APIs

<https://os.mbed.com/docs/mbed-os/v5.15/apis/platform.html>

- Platform API는 범용 MCU 관리 인프라, 공통 데이터 구조 및 다양한 표준 라이브러리, 그리고 툴 체인에서 필요 한 일관된 사용자 환경을 제공

Wait	Time	NonCopyable	CircularBuffer
Callback	RTC	Shared pointer	ATCmdParser
DeepSleepLock	Debug	Span	Mbed statistics
Power management (sleep)	Memory tracing	FileHandle	MPU management
Idle loop	Error handling	Poll	ScopedRamExecutionLock
CriticalSectionLock	Assert	PlatformMutex	ScopedRomWriteLock

Platform APIs – Mbed statistics

- 시스템 동작중에 메모리 및 스레드 통계를 확인하기 위한 기능 세트를 제공

Mbed_app.json

```
.mbed
CONTRIBUTING.md
main.cpp
mbed_app.json
README.md
```

```
1  {
2      "target_overrides": {
3          "*": {
4              "platform.all-stats-enabled": true
5          }
6      }
7 }
```

Main.cpp

```
#include "mbed.h"

#if !defined(MBED_THREAD_STATS_ENABLED) ???
#error "Stats not enabled"
#endif

#define MAX_THREAD_STATS    0x8

int main()
{
    mbed_stats_thread_t *stats = new mbed_stats_thread_t[MAX_THREAD_STATS];
    int count = mbed_stats_thread_get_each(stats, MAX_THREAD_STATS);

    for(int i = 0; i < count; i++) {
        printf("ID: 0x%x \n", stats[i].id);
        printf("Name: %s \n", stats[i].name);
        printf("State: %d \n", stats[i].state);
        printf("Priority: %d \n", stats[i].priority);
        printf("Stack Size: %d \n", stats[i].stack_size);
        printf("Stack Space: %d \n", stats[i].stack_space);
        printf("\n");
    }
    return 0;
}
```

Serial Terminal

```
ID: 0x20000254
Name: main
State: 2
Priority: 24
Stack Size: 4096
Stack Space: 3620
```

```
ID: 0x20000298
Name: rtx_idle
State: 1
Priority: 1
Stack Size: 896
Stack Space: 832
```

우선순위 낮음

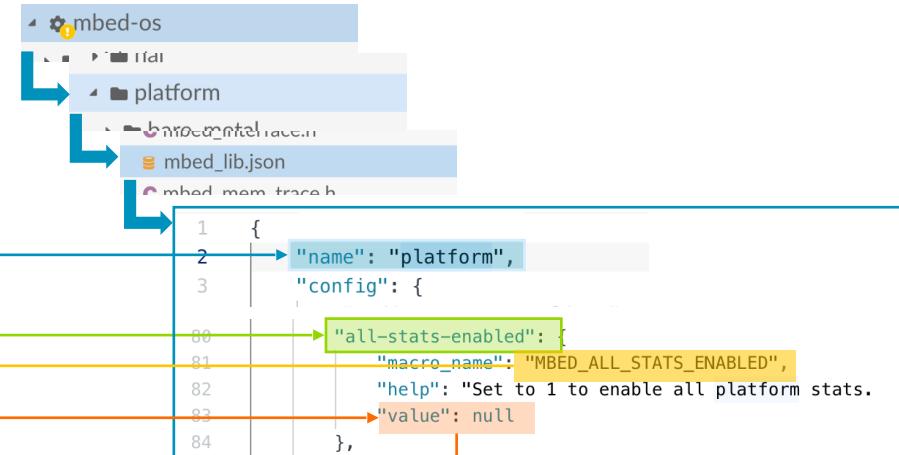
```
ID: 0x200002dc
Name: rtx_timer
State: 3
Priority: 40
Stack Size: 768
Stack Space: 672
```

우선순위 높음

Mbed_app.json 의 동작

Compile 전

```
1  {
2      "target_overrides": {
3          "*": {
4              "platform.all-stats-enabled": true
5          }
6      }
7  }
```



Compile 후

The screenshot shows the Eclipse IDE interface. On the left, the project structure includes `mbed-os-example-blinky`, `BUILD`, `DISCO_L475VG_IOT01A`, `ARMC6`, and `mbed-os`. Inside `mbed-os`, files like `.includes_6198900b7b5d275d118f068afe9c8``, `.includes_c8e0209a641bbf1be82910a74077e`, `.link_options.txt`, `.link_script.sct`, `.profile-asm`, `.profile-c`, `.profile-cxx`, `.profile-id`, `main.d`, and `main.o` are listed. The `mbed_config.h` file is currently selected.

The code in `mbed_config.h` is as follows:

```
13 * WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
14 * See the License for the specific language governing permissions and
15 * limitations under the License.
16 */
17 // Automatically generated configuration file.
18 // DO NOT EDIT, content will be overwritten.
19
20 #ifndef __MBED_CONFIG_DATA__
21 #define __MBED_CONFIG_DATA__
22
23 // Configuration parameters
24 #define CLOCK_SOURCE
25 #define LPTICKER_DELAY_TICKS
26 #define MBED_ALL_STATS_ENABLED
27 #define MBED_CONF_ALT1250_PPP_BAUDRATE
28 #define MBED_CONF_ALT1250_PPP_PROVIDE_DEFAULT
29 #define MBED_CONF_ATMEL_RF_ASSUME_SPACED_SPI
30 #define MRDN_CONF_ATMFI_RF_FIII_SPT_SFPEFD
31
```

A yellow arrow points from the `MBED_ALL_STATS_ENABLED` macro definition in the code to its definition in `mbed-lib.json`. Another yellow arrow points from the `USE_PLL_MSI` macro definition in the code to its definition in the build output. The build output shows the value `1` for `USE_PLL_MSI`, with `115200` and `75000000` also listed.

Build output (partial):

```
USE_PLL_MSI
0
1
115200
0
1
75000000
```

Platform APIs – Mbed statistics Example

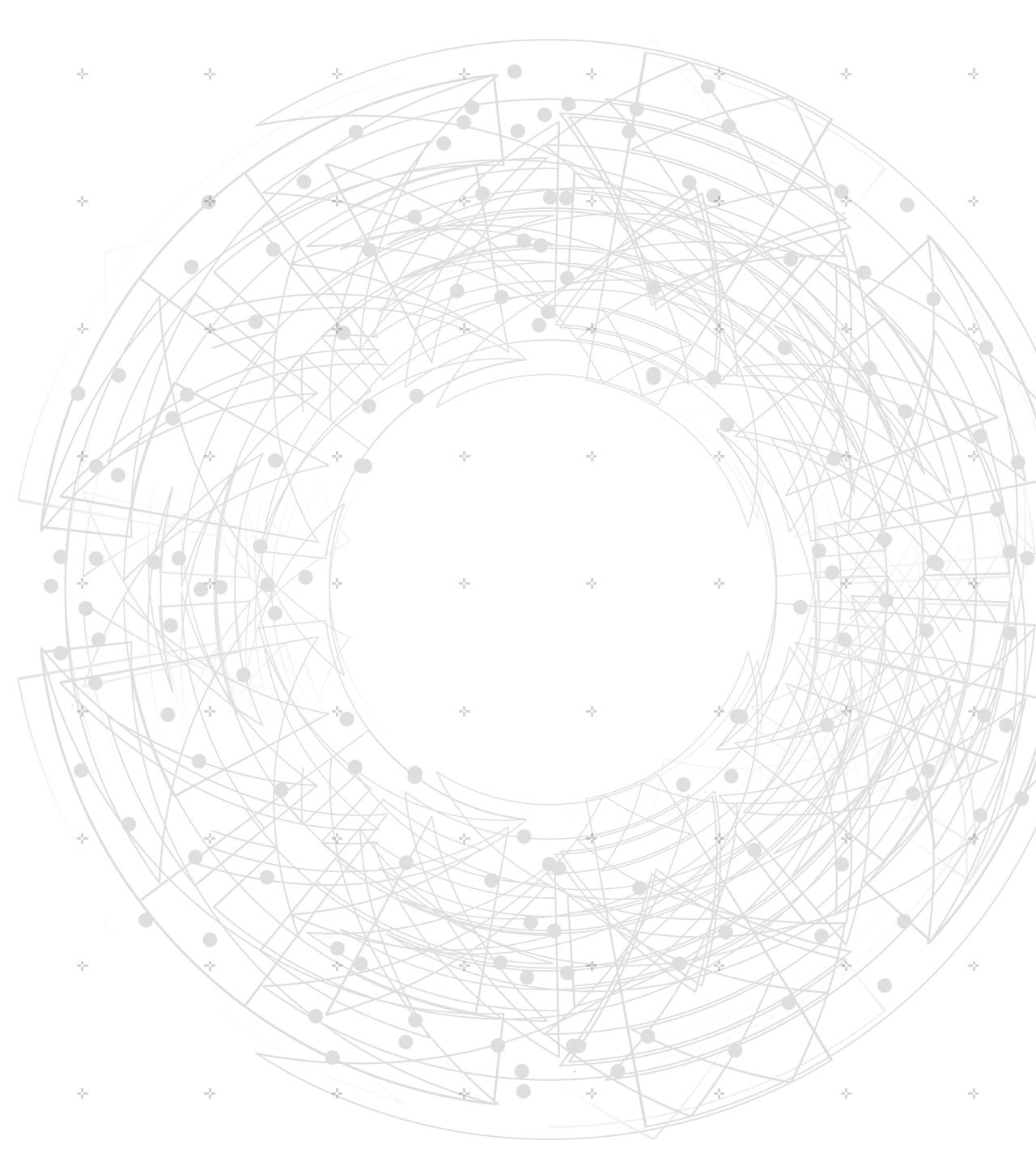
- 다른 Example도 실습 해봅시다!
 - Memory statistics example
 - System information example

```
Mbed OS Version: 51503
CPU ID: 0x410fc241
Compiler ID: 1
Compiler Version: 6130008
RAM0: Start 0x20000000 Size: 0x18000
RAM1: Start 0x10000000 Size: 0x8000
ROM0: Start 0x8000000 Size: 0x100000
```

- CPU statistics example

Uptime	Idle Time	Sleep time	DeepSleep time
1000122	916351	916351	0
2000061	1833588	1833588	0
3000122	2750947	2750947	0
4000061	3668093	3668093	0
5000122	4585452	4585452	0
6000061	5502598	5502598	0
7000122	6419866	6419866	0
8000061	7337103	7337103	0
9000122	8254462	8254462	0
10000061	9171577	9171577	0
11000122	10088936	10088936	0
12000061	11006173	11006173	0

```
This message is from debug function
This message is from debug_if fu
MemoryStats:
    Bytes allocated currently: 100
    Max bytes allocated at a given time: 100
    Cumulative sum of bytes ever allocated: 100
    Current number of bytes allocated for the heap: 96304
    Current number of allocations: 3
    Number of failed allocations: 0
Cumulative Stack Info:
    Maximum number of bytes used on the stack: 636
    Current number of bytes allocated for the stack: 5760
    Number of stacks stats accumulated in the structure: 3
Thread Stack Info:
    Thread: 0
        Thread Id: 0x100018B4
        Maximum number of bytes used on the stack: 476
        Current number of bytes allocated for the stack: 4096
        Number of stacks stats accumulated in the structure: 1
    Thread: 1
        Thread Id: 0x100018F8
        Maximum number of bytes used on the stack: 64
        Current number of bytes allocated for the stack: 896
        Number of stacks stats accumulated in the structure: 1
    Thread: 2
        Thread Id: 0x1000193C
        Maximum number of bytes used on the stack: 96
        Current number of bytes allocated for the stack: 768
        Number of stacks stats accumulated in the structure: 1
Done...
```

A circular network graph is positioned on the left side of the slide. It consists of numerous small, semi-transparent gray dots representing nodes, which are interconnected by a dense web of thin, light gray lines representing edges. The graph is contained within a circular frame with several concentric arcs.

Driver APIs

Drivers APIs

<https://os.mbed.com/docs/mbed-os/v5.15/apis/drivers.html>

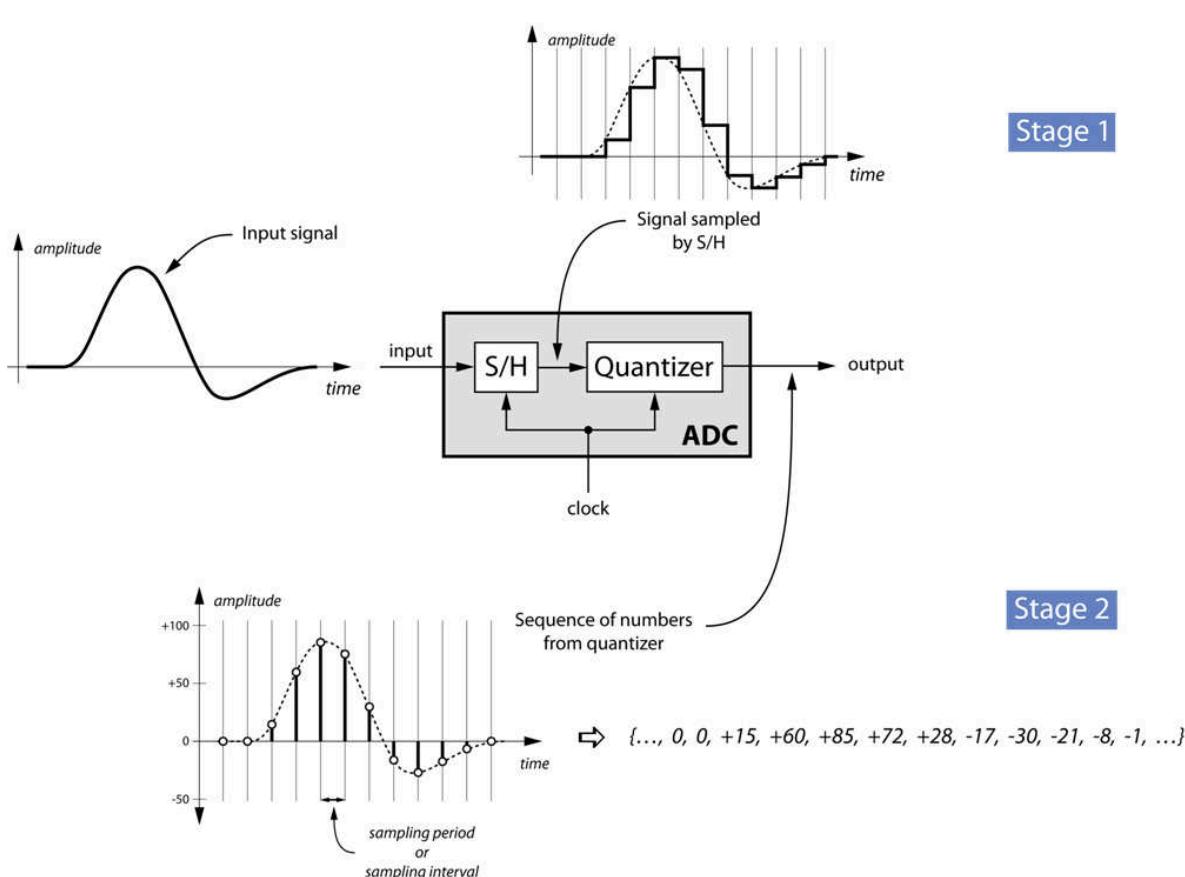
- 개발 보드의 아날로그 및 디지털 입력 및 출력과 디지털 인터페이스가 포함되어 있어 보드가 컴퓨터 또는 외부 장치와 인터페이스 할 수 있다.

<https://os.mbed.com/docs/mbed-os/v5.15/apis/drivers.html>

AnalogIn	BusInOut	Timeout	Flash IAP	I2CSlave
AnalogOut	PortIn	Timer	RawSerial	CAN
DigitalIn	PortOut	LowPowerTicker	Serial	MbedCRC
DigitalOut	PortInOut	LowPowerTimeout	SPI	
DigitalInOut	PwmOut	LowPowerTimer	SPISlave	
BusIn	InterruptIn	Watchdog	QuadSPI (QSPI)	
BusOut	Ticker	ResetReason	I2C	

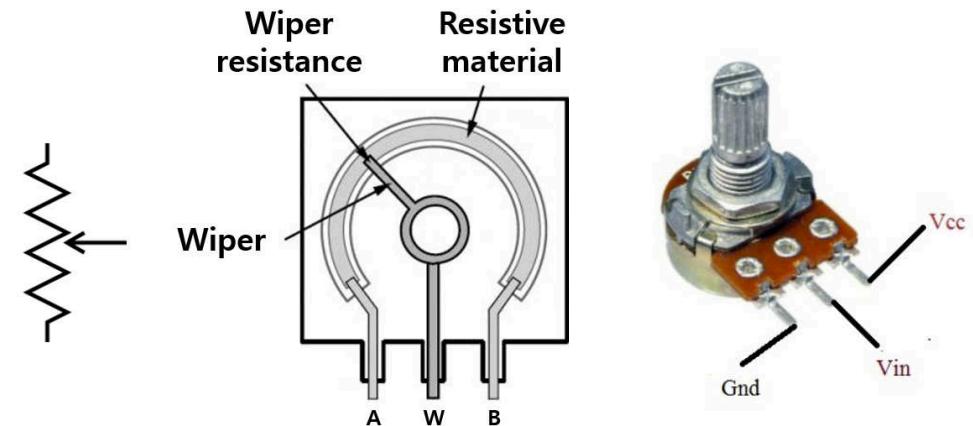
Drivers APIs – AnalogIn

- AnalogIn API를 사용하여 아날로그 입력 핀에 적용된 외부 전압을 읽는다.
- 값은 0.0(VSS)에서 1.0(VCC) 까지의 부동 소수점으로 예를 들어 3.3V 시스템을 사용하고 적용된 전압이 1.65V이면 AnalogIn 값은 0.5 가 된다.



Resolution (in bits)	Range
24	16,777,216
16	65,536
14	16,384
12	4,096
10	1,024
8	256
6	64

$$12\text{bit ADC의 분해능} = 3.3 / 4096 = 0.81\text{mV}$$



Drivers APIs – AnalogIn

```
1 #include "mbed.h"
2
3 // Initialize a pins to perform analog input and digital output
4 AnalogIn ain(A0);
5 DigitalOut dout(LED1);
6
7 int main(void)
8 {
9     while (1) {
10         // test the voltage on the initialized analog pin
11         // and if greater than 0.3 * VCC set the digital pin
12         // to a logic 1 otherwise a logic 0
13         if(ain > 0.3f) {
14             dout = 1;
15         } else {
16             dout = 0;
17         }
18
19         // print the percentage and 16 bit normalized values
20         printf("percentage: %3.3f%%\n", ain.read()*100.0f);
21         printf("normalized: 0x%04X \n", ain.read_u16());
22         wait(0.2f);
23     }
24 }
```

<https://os.mbed.com/docs/mbed-os/v5.15/apis/analogin.html>

AnalogIn Class Reference

Public Member Functions

AnalogIn (const PinMap &pinmap)

Create an [AnalogIn](#), connected to the specified pin.
[More...](#)

AnalogIn (PinName pin)

Create an [AnalogIn](#), connected to the specified pin.
[More...](#)

float [read \(\)](#)

Read the input voltage, represented as a float in the range [0.0, 1.0]. [More...](#)

unsigned short [read_u16 \(\)](#)

Read the input voltage, represented as an unsigned short in the range [0x0, 0xFFFF]. [More...](#)

[operator float \(\)](#)

An operator shorthand for [read\(\)](#) [More...](#)

Drivers APIs – DigitalIn / DigitalOut

- 핀(Digital in/output port)에 대한 상태를 읽고, 로직 레벨 0 또는 1로 설정하여 디지털 출력 핀을 구성하고 제어 한다.

DigitalOut

```
1 #include "mbed.h"
2
3 DigitalOut myled(LED1);
4
5 int main()
6 {
7     if(myled.is_connected()) {
8         printf("myled is initialized and connected!\n\r");
9     }
10
11     // Blink LED
12     while(1) {
13         myled = 1;          // set LED1 pin to high
14         printf("myled = %d \n\r", (uint8_t)myled );
15         wait(0.5);
16
17         myled.write(0);    // set LED1 pin to low
18         printf("myled = %d \n\r",myled.read() );
19         wait(0.5);
20     }
21 }
22 }
```

<https://os.mbed.com/docs/mbed-os/v5.15/apis/digitalout.html>

DigitalOut Class Reference

Public Member Functions

	DigitalOut(PinName pin)
	Create a DigitalOut connected to the specified pin. More...
	DigitalOut(PinName pin, int value)
	Create a DigitalOut connected to the specified pin. More...
void	write(int value)
	Set the output, specified as 0 or 1 (int) More...
int	read()
	Return the output setting, represented as 0 or 1 (int) More...
int	is_connected()
	Return the output setting, represented as 0 or 1 (int) More...
DigitalOut &	operator=(int value)
	A shorthand for write() More...
DigitalOut &	operator=(DigitalOut &rhs)
	A shorthand for write() using the assignment operator which copies the state from More...
	operator int()
	A shorthand for read() More...

Drivers APIs – DigitalIn / DigitalOut

- 핀(Digital in/output port)에 대한 상태를 읽고, 로직 레벨 0 또는 1로 설정하여 디지털 출력 핀을 구성하고 제어 한다.

DigitalIn

```
1 #include "mbed.h"
2
3 DigitalIn mypin(SW2); // change this to the button on your board
4 DigitalOut myled(LED1);
5
6 int main()
7 {
8     // check mypin object is initialized and connected to a pin
9     if(mypin.is_connected()) {
10         printf("mypin is connected and initialized! \n\r");
11     }
12
13     // Optional: set mode as PullUp/PullDown/PullNone/OpenDrain
14     mypin.mode(PullNone);
15
16     // press the button and see the console / led change
17     while(1) {
18         printf("mypin has value : %d \n\r", mypin.read());
19         myled = mypin; // toggle led based on value of button
20         ThisThread::sleep_for(0.25);
21     }
22 }
```

<https://os.mbed.com/docs/mbed-os/v5.15/apis/digitalin.html>

DigitalIn Class Reference

Public Member Functions

DigitalIn(PinName pin)

Create a DigitalIn connected to the specified pin. [More...](#)

DigitalIn(PinName pin, PinMode mode)

Create a DigitalIn connected to the specified pin. [More...](#)

int read()

Read the input, represented as 0 or 1 (int) [More...](#)

void mode(PinMode pull)

Set the input pin mode. [More...](#)

int is_connected()

Return the output setting, represented as 0 or 1 (int) [More...](#)

operator int()

An operator shorthand for read() [More...](#)

Drivers APIs – DigitalIn / DigitalOut Example

- SW 를 누를때마다 LED1~3 의 순서가 바뀌도록 만들어 봅시다.



Drivers APIs – InterruptIn

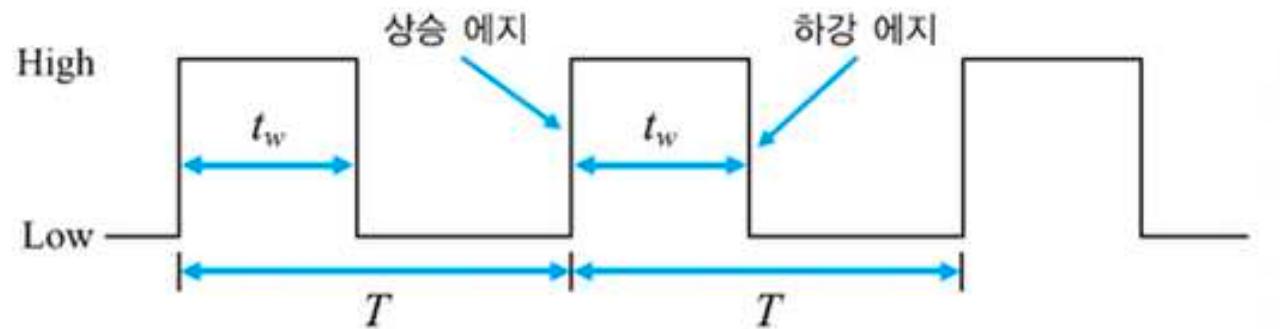
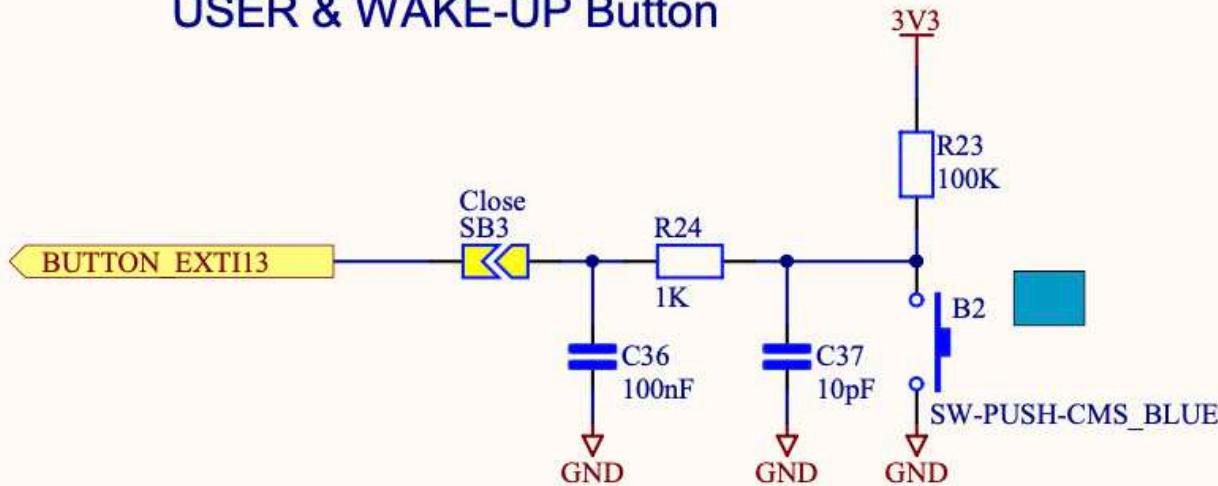
- 디지털 입력 핀(입력 신호)의 상승 에지 (Low -> High) 또는 하강 에지 (High -> Low)에서 인터럽트를 트리거 할 수 있다.

```
1 #include "mbed.h"
2
3 InterruptIn button(SW2);
4 DigitalOut led(LED1);
5 DigitalOut flash(LED4);
6
7 void flip() {
8     led = !led;
9 }
10
11 int main() {
12     button.rise(&flip); // attach the address of the flip function
13                     // to the rising edge
14     while(1) {        // wait around, interrupts will interrupt this!
15         flash = !flash;
16         ThisThread::sleep_for(0.25);
17     }
18 }
19
20
21
22
23
24
25
https://os.mbed.com/docs/mbed-os/v5.15/apis/interruptin.html
39
```

InterruptIn Class Reference	
Public Member Functions	
	InterruptIn (PinName pin)
	Create an InterruptIn connected to the specified pin. More...
	InterruptIn (PinName pin, PinMode mode)
	Create an InterruptIn connected to the specified pin, and the pin configured to the specified mode. More...
int	read ()
	Read the input, represented as 0 or 1 (int) More...
	operator int ()
	An operator shorthand for read() More...
void	rise (Callback< void()> func)
	Attach a function to call when a rising edge occurs on the input. More...
template<typename T , typename M >	
void	rise (T *obj, M method)
	Attach a member function to call when a rising edge occurs on the input. More...
void	fall (Callback< void()> func)
	Attach a function to call when a falling edge occurs on the input. More...
template<typename T , typename M >	
void	fall (T *obj, M method)
	Attach a member function to call when a falling edge occurs on the input. More...
void	mode (PinMode pull)

Drivers APIs – `InterruptIn`, `Button` 의 동작

USER & WAKE-UP Button



Drivers APIs – Ticker

- 지정한 주기로 Callback 을 실행한다.
- ISR(Interrupt Service Routine) 과 함께사용시 주의해야 한다.

```
1 #include "mbed.h"
2
3 Ticker flipper;
4 DigitalOut led1(LED1);
5 DigitalOut led2(LED2);
6
7 void flip() {
8     led2 = !led2;
9 }
10
11 int main() {
12     led2 = 1;
13     // the address of the function to be attached (flip) and the
14     // interval (2 seconds)
15
16     flipper.attach(&flip, 2.0);
17
18     // spin in a main loop. flipper will interrupt it to call flip
19     while(1) {
20         led1 = !led1;
21         wait(0.2);
22     }
23 }
24
25 
```

<https://os.mbed.com/docs/mbed-os/v5.15/apis/ticker.html>



Ticker Class Reference	
Public Member Functions	
template<typename F >	
MBED_FORCEINLINE void	attach (F &&func, float t)
Attach a function to be called by the Ticker , specifying the interval in seconds. More...	
template<typename T , typename M >	
void	attach (T *obj, M method, float t)
Attach a member function to be called by the Ticker , specifying the interval in seconds. More...	
void	attach_us (Callback< void()> func, us_timestamp_t t)
Attach a function to be called by the Ticker , specifying the interval in microseconds. More...	
template<typename T , typename M >	
void	attach_us (T *obj, M method, us_timestamp_t t)
Attach a member function to be called by the Ticker , specifying the interval in microseconds. More...	
void	detach ()
Detach the function. More...	

Drivers APIs – Timeout

- 지정한 시간후 1회 Callback 실행한다.
- ISR(Interrupt Service Routine) 과 함께사용시 주의해야 한다.

```
1 #include "mbed.h"
2
3 Timeout flipper;
4 DigitalOut led1(LED1);
5 DigitalOut led2(LED2);
6
7 void flip() {
8     led2 = !led2;
9 }
10
11 int main() {
12     led2 = 1;
13
14     // setup flipper to call flip after 2 seconds
15     flipper.attach(&flip, 2.0);
16
17     // spin in a main loop. flipper will interrupt it to call flip
18     while(1) {
19         led1 = !led1;
20         wait(0.2);
21     }
22 }
23
24
25
```

<https://os.mbed.com/docs/mbed-os/v5.15/apis/timeout.html>

Public Member Functions	
template<typename F >	
MBED_FORCEINLINE void	attach (F &&func, float t) Attach a function to be called by the Ticker , specifying the interval in seconds. More...
template<typename T , typename M >	
void	attach (T *obj, M method, float t) Attach a member function to be called by the Ticker , specifying the interval in seconds. More...
void	
void	attach_us (Callback< void()> func, us_timestamp_t t) Attach a function to be called by the Ticker , specifying the interval in microseconds. More...
template<typename T , typename M >	
void	attach_us (T *obj, M method, us_timestamp_t t) Attach a member function to be called by the Ticker , specifying the interval in microseconds. More...
void	
void	detach () Detach the function. More...

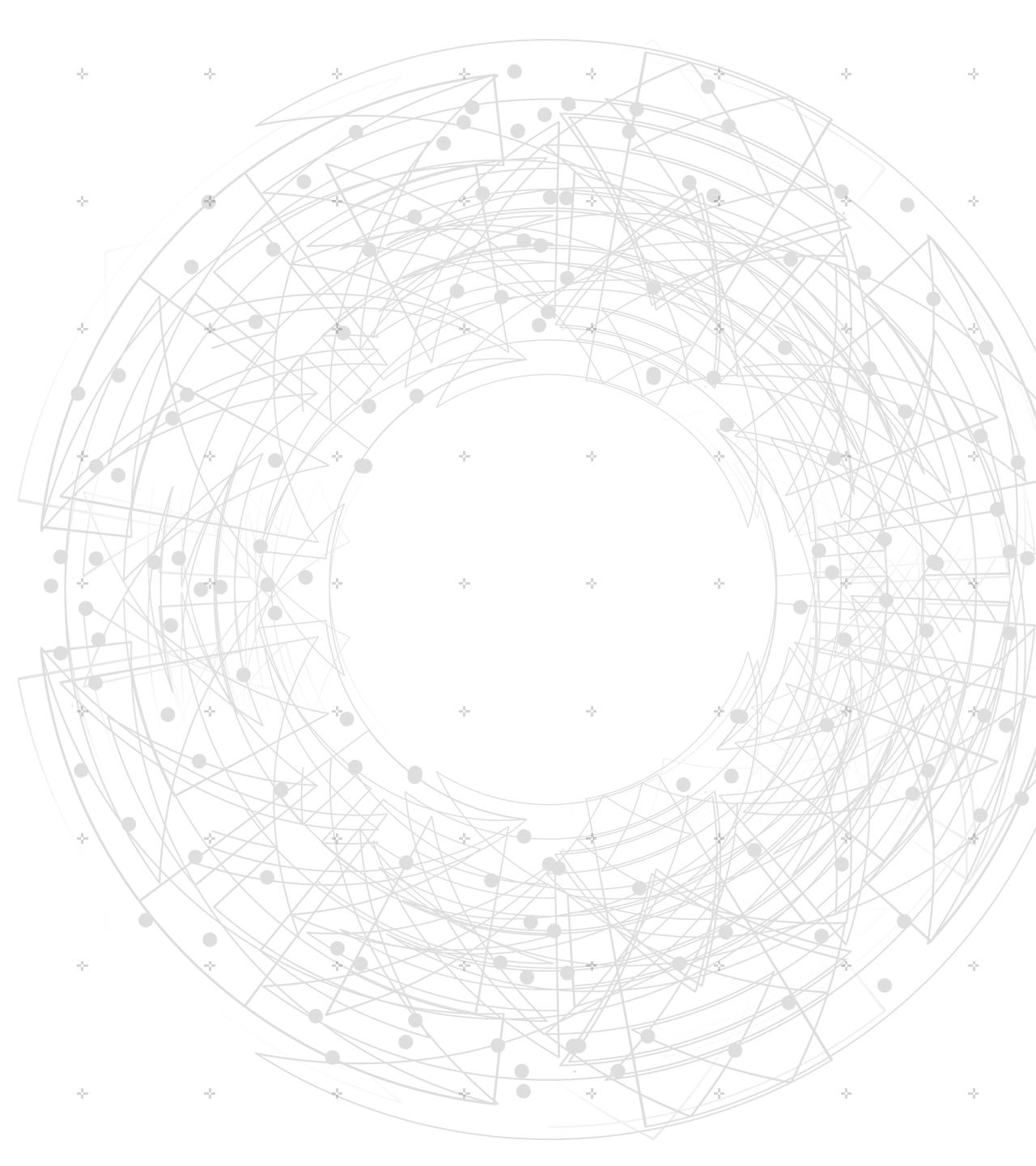
Drivers APIs – Timer

- 임의의 구간의 정확한 시간 (밀리 초보다 정확한)을 측정할 수 있음.
- 64bit timer 이나, OS의 하위 버전 API(read_ms(), read_us()) 사용을 위해 32bit 부호있는 정수로 리턴한다. 50 일 이상의 시간 카운트가 필요한 경우 read_high_resolution_us() 를 사용한다. 50만년의 시간 측정 가능..

```
1 #include "mbed.h"
2
3 Timer t;
4
5 int main() {
6     t.start();
7     printf("Hello World!\n");
8     t.stop();
9     /* 5.15 */
10    // printf("The time taken was %f seconds\n", t.read());
11    /* 5.16 */
12    printf("The time taken was %lld \n\r", t.elapsed_time().count()); //micro seconds
13 }
```



<https://os.mbed.com/docs/mbed-os/v5.15/apis/timer.html>



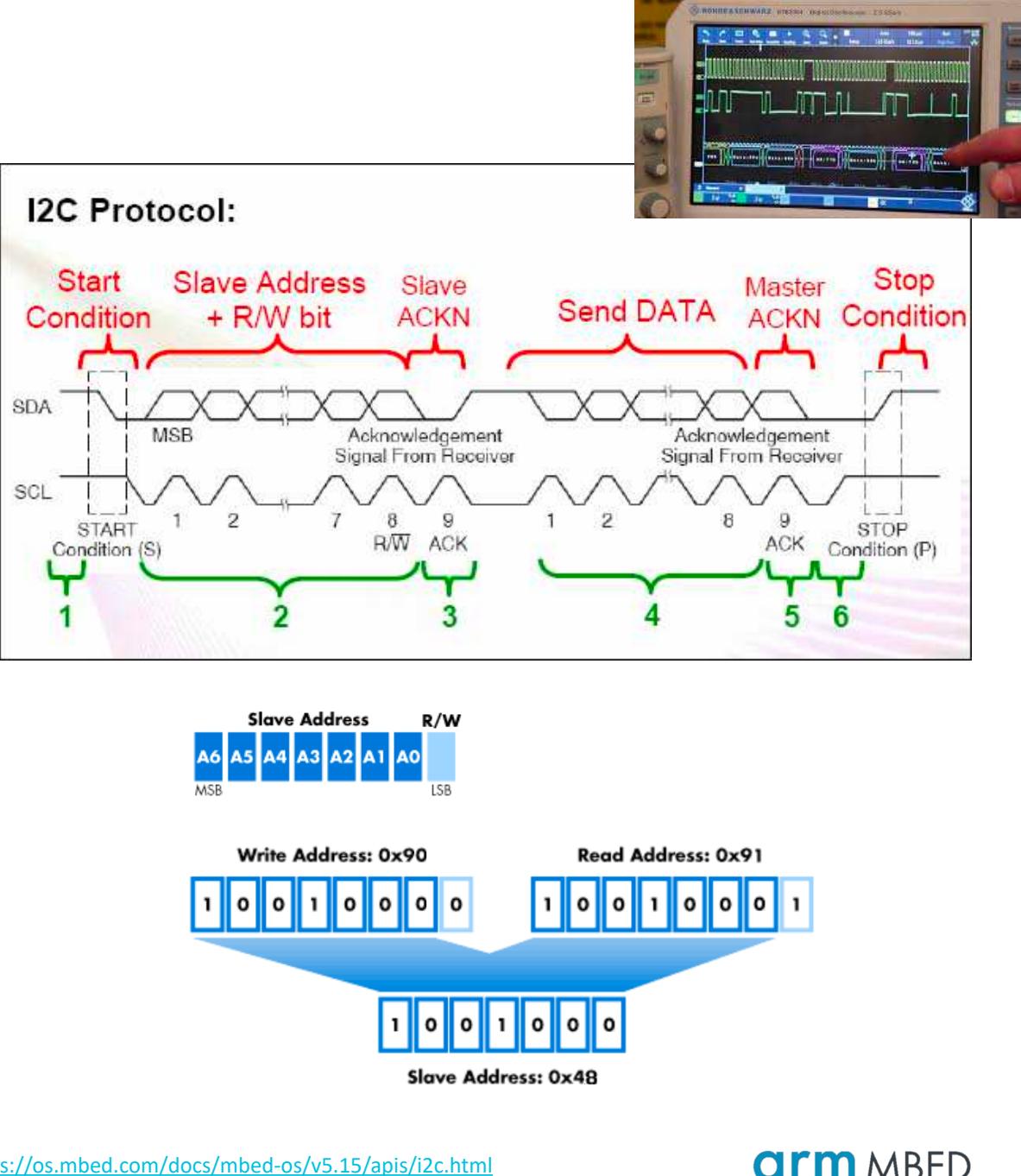
Drivers APIs

Peripheral IPs

Drivers APIs – I²C

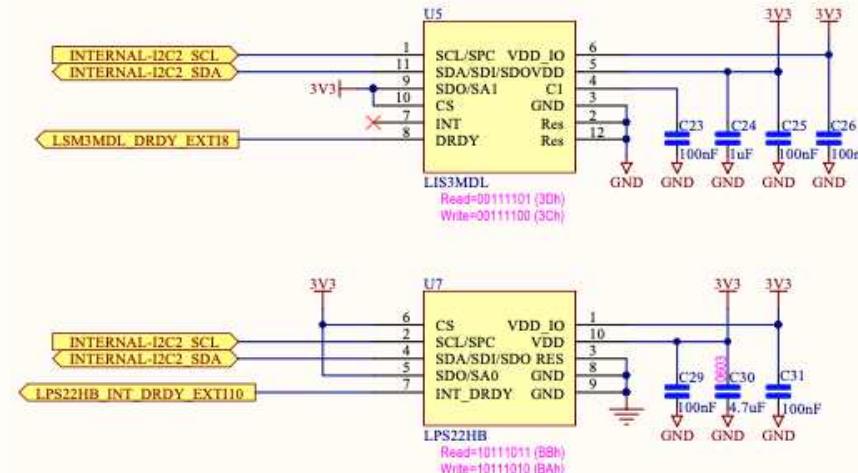
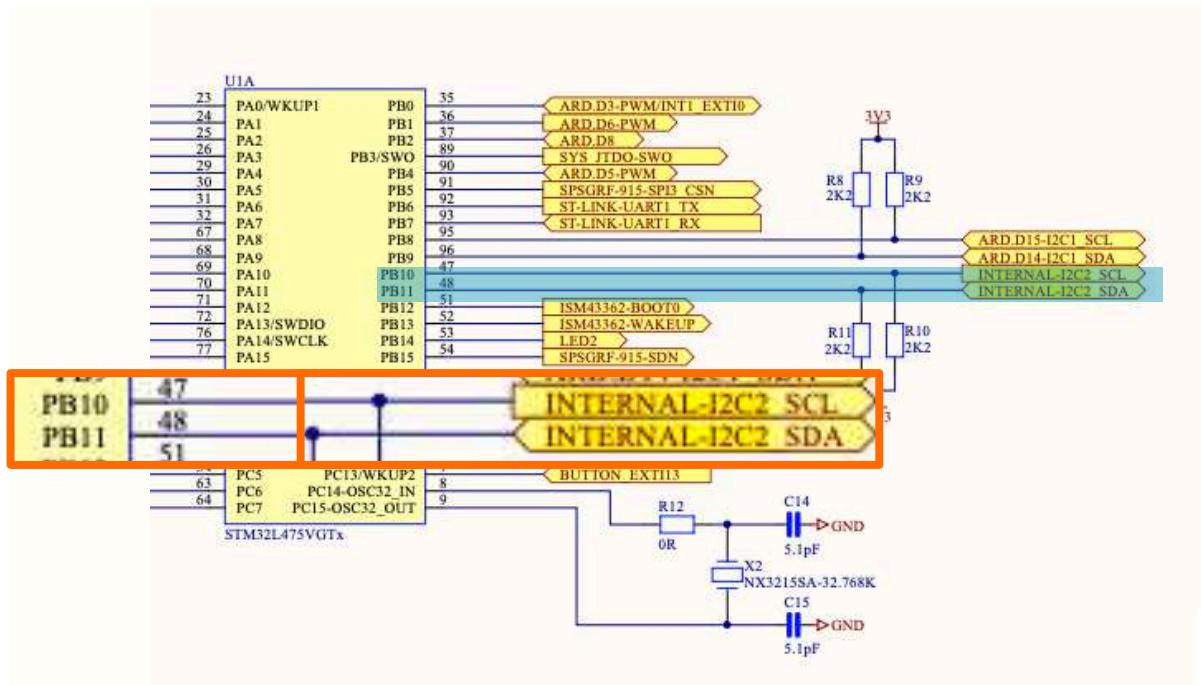
- LM75BD (temperature) 사용 example

```
1 #include "mbed.h"
2
3 // Read temperature from LM75BD
4
5 I2C i2c(I2C_SDA , I2C_SCL );
6
7 const int addr7bit = 0x48;           // 7 bit I2C address
8 const int addr8bit = 0x48 << 1; // 8bit I2C address, 0x90
9
10 int main() {
11     char cmd[2];
12     while (1) {
13         cmd[0] = 0x01;
14         cmd[1] = 0x00;
15         i2c.write(addr8bit, cmd, 2);
16
17         wait(0.5);
18
19         cmd[0] = 0x00;
20         i2c.write(addr8bit, cmd, 1);
21         i2c.read(addr8bit, cmd, 2);
22
23         float tmp = (float((cmd[0]<<8)|cmd[1])) / 256.0;
24         printf("Temp = %.2f\n", tmp);
25     }
26 }
```



Drivers APIs – I²C, Example #1 : Check I²C H/W

- DISCO-L475VG-IOT01 board에 있는 센서의 I²C Address 확인을 위해 I²C Scanner 코드를 만들어 봅시다.



PeripheralPinMaps.h

```

MSTD_CONSTEXPR_OBJ_11 PinMap PinMap_I2C_SDA[] = {
    {PB_7, I2C_1, STM_PIN_DATA(STM_MODE_AF_OD, GPIO_NOPULL, GPIO_AF4_I2C1)}, // Connected to STDIO_UART_RX
    {PB_9, I2C_1, STM_PIN_DATA(STM_MODE_AF_OD, GPIO_NOPULL, GPIO_AF4_I2C1)}, // Connected to ARD_D14 [I2C1_SDA]
    {PB_11, I2C_2, STM_PIN_DATA(STM_MODE_AF_OD, GPIO_NOPULL, GPIO_AF4_I2C2)}, // Connected to INTERNAL_I2C2_SDA [VL53L0X_SDA]
    {PB_14, I2C_2, STM_PIN_DATA(STM_MODE_AF_OD, GPIO_NOPULL, GPIO_AF4_I2C2)}, // Connected to LED2 [LED_GREEN]
    {PC_1, I2C_3, STM_PIN_DATA(STM_MODE_AF_OD, GPIO_NOPULL, GPIO_AF4_I2C3)}, // Connected to ARD_A4 [ADC]
    {NC, NC, 0}
};

MSTD_CONSTEXPR_OBJ_11 PinMap PinMap_I2C_SCL[] = {
    {PB_6, I2C_1, STM_PIN_DATA(STM_MODE_AF_OD, GPIO_NOPULL, GPIO_AF4_I2C1)}, // Connected to STDIO_UART_TX
    {PB_8, I2C_1, STM_PIN_DATA(STM_MODE_AF_OD, GPIO_NOPULL, GPIO_AF4_I2C1)}, // Connected to ARD_D15 [I2C1_SCL]
    {PB_10, I2C_2, STM_PIN_DATA(STM_MODE_AF_OD, GPIO_NOPULL, GPIO_AF4_I2C2)}, // Connected to INTERNAL_I2C2_SCL [VL53L0X_SCL]
    {PB_13, I2C_2, STM_PIN_DATA(STM_MODE_AF_OD, GPIO_NOPULL, GPIO_AF4_I2C2)}, // Connected to ISM43362_WAKEUP [ISM43362_WKUP]
    {PC_0, I2C_3, STM_PIN_DATA(STM_MODE_AF_OD, GPIO_NOPULL, GPIO_AF4_I2C3)}, // Connected to ARD_A5 [ADC]
    {NC, NC, 0}
};

```

Drivers APIs – I²C, Example #1 : Check I²C address

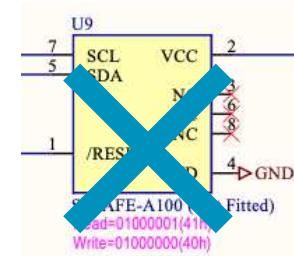
Code



Result

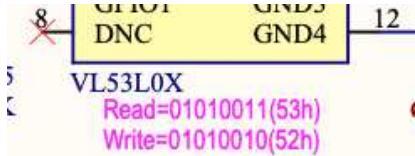
```
I2C scan test  
=> Found addr!  
> HEX(8bit):0x3c, HEX(7bit):0x1e  
> HEX(8bit):0x3d, HEX(7bit):0x1e  
> HEX(8bit):0x52, HEX(7bit):0x29  
> HEX(8bit):0x53, HEX(7bit):0x29  
> HEX(8bit):0x5a, HEX(7bit):0x2d  
> HEX(8bit):0x5b, HEX(7bit):0x2d  
> HEX(8bit):0xba, HEX(7bit):0x5d  
> HEX(8bit):0xbb, HEX(7bit):0x5d  
> HEX(8bit):0xbe, HEX(7bit):0x5f  
> HEX(8bit):0xbf, HEX(7bit):0x5f  
> HEX(8bit):0xd4, HEX(7bit):0x6a  
> HEX(8bit):0xd5, HEX(7bit):0x6a
```

Test done.....



LIS3MDL

Read=00111101 (3Dh)
Write=00111100 (3Ch)

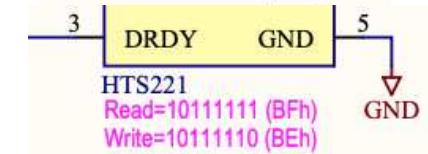


VL53L0X

Read=01010011(53h)
Write=01010010(52h)

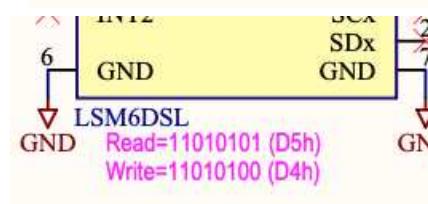
LPS22HB

Read=10111011(BBh)
Write=10111010(BAh)



HTS221

Read=10111111(BFh)
Write=10111110(BEh)



LSM6DSL

Read=11010101(D5h)
Write=11010100(D4h)

arm MBED

Drivers APIs – I²C, Example #2 : Sensor Read (Step 1)

- HTS221 (humidity + temperature)

Drivers APIs – I²C, Example #3 : Sensor Read (Step 1)

- LSM6DSL (3D accelerometer + 3D gyroscope)
- LIS3MDL (3D magnetometer)
- LPS22HB (pressure)
 - Sensor driver 를 찾아서 Mbed-os-example-blinky 예제에 병합
 - Sensor driver 와 Mbed OS example 이 함께 있는 예제
 - Target board 제조사의 Reference code 예제

Drivers APIs – I²C, Example #3 : Sensor Read (Step 1)

- Mbed Studio



<https://os.mbed.com/platforms/ST-Discovery-L475E-IOT01A/>

DISCO-L475VG-IOT01A
STM32L4 Discovery kit IoT node, low-power wireless, BLE, NFC, SubGHz, Wi-Fi

Overview
The B-L475E-IOT01A Discovery kit for IoT nodes allows users to develop applications with direct access to the cloud services. It enables the diversity of applications by exploiting low-power connectivity and memory management. The support for Arduino is provided with the addition of specialized add-on boards.

Microcontroller features
STM32L475VG76 in LQFP100 package

OS 5 DISCO_L475VG_IOT01-Sensors-BSP

To compile a program for this board using Mbed CLI, use DISCO_L475VG_IOT01A as the target name.

Board Partner ST life.augmented

Read board sensors (temperature, humidity, pressure, gyroscope, accelerometer, magnetometer) using ST BSP drivers. This example is superseded with the HelloWorld_ST_Sensors example.

Last updated: 24 Sep 2019

SP drivers. This

Import into Compiler Import with mbed CLI Import into Mbed Studio

Code 경로 복사

Import with Mbed Studio

Importing program with Mbed Studio
Use the following link in "File -> Import Program..."
http://os.mbed.com/teams/ST/code/DISCO_L475VG_IOT01-Sensors-BSP

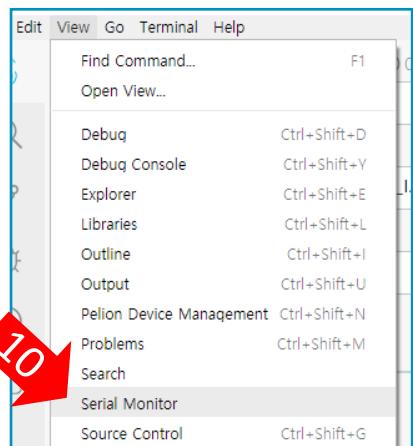
Download Mbed Studio



Sensor read 확인

```
Output >_ DISCO-L475VG-IOT01A (DISCO_L475VG_IOT01A)
New loop, LED1 should blink during sensor read
TEMPERATURE = 29.96 degC
HUMIDITY = 52.65 %
PRESSURE is 1009.16 mBar
MAGNETO_X = -88
MAGNETO_Y = -161
MAGNETO_Z = -508
GYRO_X = -630.00
GYRO_Y = -350.00
GYRO_Z = 1260.00
ACCELEROMERO_X = -3
ACCELEROMERO_Y = -20
ACCELEROMERO_Z = 1024
```

Serial Monitor 선택



컴파일

Code 경로 붙여넣기

Import program

Import Mbed Program to Workspace

URL
http://os.mbed.com/teams/ST/code/DISCO_L475VG_IOT01-Sensors-BSP

Program name
DISCO_L475VG_IOT01-Sensors-BSP

Make this the active program

Cancel Add Program

Mbed Programs — Mbed Studio

File Edit View Go Terminal Help

New Program... Alt+Ctrl+G

Import Program... Alt+Ctrl+M

New File

New Folder

arm MBED

Drivers APIs – I²C, Example #4 : Sensor Read (Step 1)

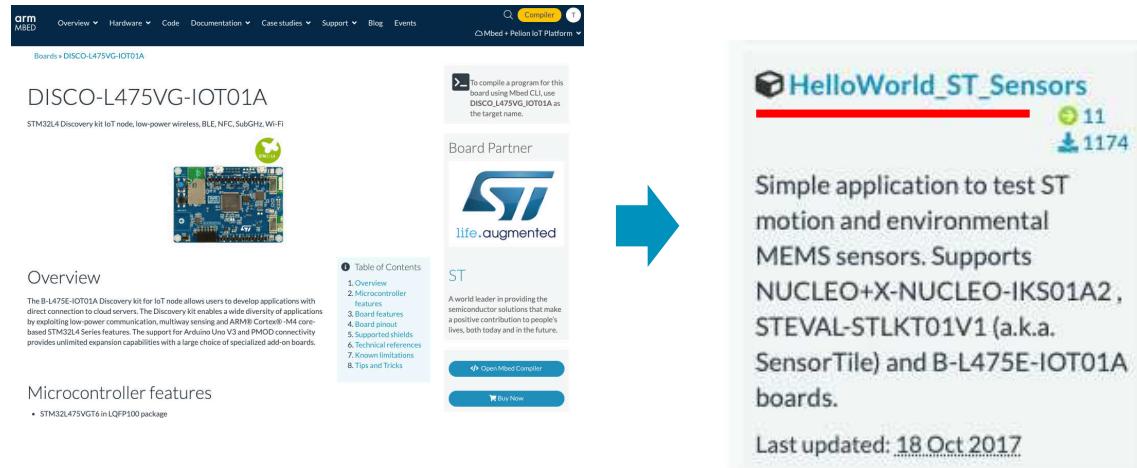
- Mbed CLI 환경에서 진행 해봅시다
 - Mbed-os-example-blink 에서 LIS3MDL (3D magnetometer) 센서를 동작
 - Hint! : <https://os.mbed.com/teams/ST/code/LIS3MDL/> 를 mbed add 명령어를 이용해서 추가하고 Application 을 작성



Your turn, let's try!

Drivers APIs – I²C, Example #4 : Sensor Read (Step 2)

- HelloWorld_ST_Sensors 를 실행 해봅시다



Mbed studio에서 컴파일?
Mbed CLI에서 컴파일?

Drivers APIs – I²C, Example #4 : Sensor Read (Step 3)

- HelloWorld_ST_Sensors 를 받아 Mbed OS 를 교체 합니다.

```
C:\Users\danlee02>mbed import http://os.mbed.com/teams/ST/code/HelloWorld_ST_Sensors/  
[mbed] Working path "C:\Users\danlee02" (directory)  
[mbed] Importing program "HelloWorld_ST_Sensors" from "https://os.mbed.com/teams/ST/code/HelloWorld_ST_Sensors" at latest revision in the current branch  
[mbed] Adding library "HTS221" from "https://developer.mbed.org/teams/ST/code/HTS221" at rev #312ee2694a77  
[mbed] Adding library "HTS221\ST_INTERFACES" from "https://developer.mbed.org/teams/ST/code/ST_INTERFACES" at rev #d3c9b33b992c  
[mbed] Adding library "VL53L0X" from "https://os.mbed.com/teams/ST/code/VL53L0X" at rev #5920911f624ed  
[mbed] Adding library "VL53L0X\ST_INTERFACES" from "https://developer.mbed.org/teams/ST/code/ST_INTERFACES" at rev #d3c9b33b992c  
[mbed] Adding library "VL53L0X\X_NUCLEO_COMMON" from "https://developer.mbed.org/teams/ST/code/X_NUCLEO_COMMON" at rev #21096473f63e  
[mbed] WARNING: Cannot find the mbed tools directory in "C:\Users\danlee02\HelloWorld_ST_Sensors"  
---  
C:\Users\danlee02>
```

- Application 에 따라 Mbed OS 를 최신버전으로 바꿔야 할 수 있습니다.. Mbed OS2 → Mbed OS5

```
C:\Users\danlee02>cd HelloWorld_ST_Sensors  
C:\Users\danlee02\HelloWorld_ST_Sensors>rmdir /s mbed  
mbed, Are you sure (Y/N)? Y  
C:\Users\danlee02\HelloWorld_ST_Sensors>del mbed.lib  
C:\Users\danlee02\HelloWorld_ST_Sensors>mbed add mbed-os  
[mbed] Working path "C:\Users\danlee02\HelloWorld_ST_Sensors" (program)  
[mbed] Adding library "mbed-os" from "https://github.com/ARMmbed/mbed-os" at latest revision in the current branch  
[mbed] Updating reference "mbed-os" -> "https://github.com/ARMmbed/mbed-os/#d128ff488235d806bbefb21ebb00aea0f55a4bb7"  
C:\Users\danlee02\HelloWorld_ST_Sensors>
```

Drivers APIs – I²C, Example #4 : Sensor Read (Step 4)

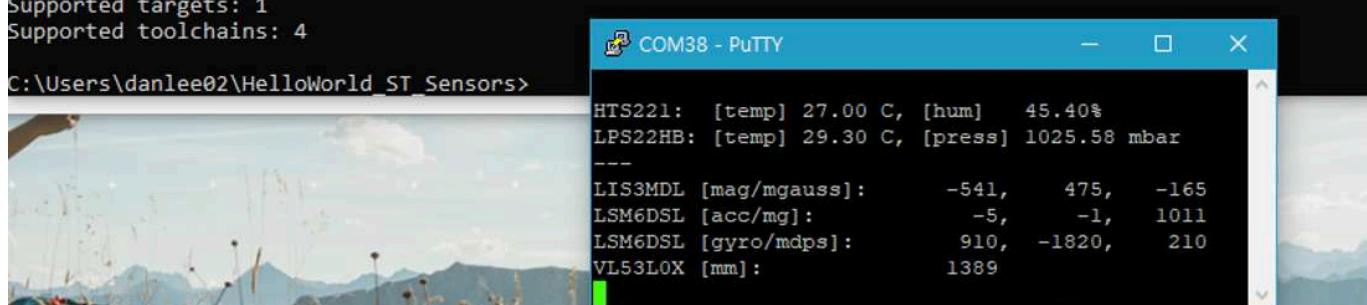
- HelloWorld_ST_Sensors 의 동작 확인

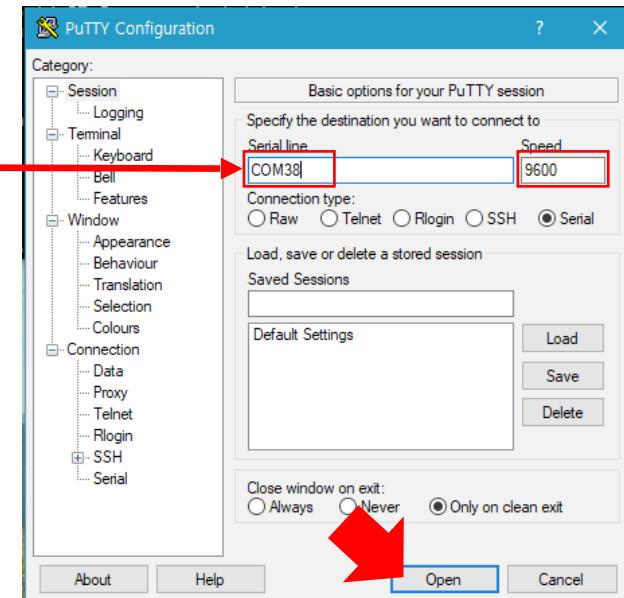
```
C:\Users\danlee02\HelloWorld_ST_Sensors>mbed compile -m auto -f
[mbed] Working path "C:\Users\danlee02\HelloWorld_ST_Sensors" (program)
[mbed] Detected "DISCO_L475VG_IOT01A" connected to "E:" and using com port "COM38"
[Warning] @,: Compiler version mismatch: Have 6.3.1; expected version >= 9.0.0 and < 10.0.0
Building project HelloWorld_ST_Sensors (DISCO_L475VG_IOT01A, GCC_ARM)
Scan: HelloWorld_ST_Sensors
Compile [ 0.1%]: HTS221_driver.c
Compile [ 0.2%]: HTS221Sensor.cpp
I Subtotals | 85250(+85250) | 3024(+3024) | 9052(+9052)
Total Static RAM memory (data + bss): 13256(+13256) bytes
Total Flash memory (text + data): 88860(+88860) bytes

Image: .\BUILD\DISCO_L475VG_IOT01A\GCC_ARM\HelloWorld_ST_Sensors.bin
  1 file(s) copied.

C:\Users\danlee02\HelloWorld_ST_Sensors>
C:\Users\danlee02\HelloWorld_ST_Sensors>mbed detect
[mbed] Working path "C:\Users\danlee02\HelloWorld_ST_Sensors" (program)

[mbed] Detected DISCO_L475VG_IOT01A, port COM38, mounted E:, interface version 0221.
[mbed] Supported toolchains for DISCO_L475VG_IOT01A
| Target | mbed OS 2 | mbed OS 5 | uARM | IAR | ARM | GCC_ARM | ARMC5 |
|-----|-----|-----|-----|-----|-----|-----|-----|
| DISCO_L475VG_IOT01A | Supported | Supported | Supported | Supported | Supported | Supported | - |
Supported targets: 1
Supported toolchains: 4

C:\Users\danlee02\HelloWorld_ST_Sensors>

```



CoolTerm for Mac
[CoolTerm](#)

Putty for Windows
32-bit: [putty-0.73-installer.msi](#)
64-bit: [putty-64bit-0.73-installer.msi](#)

주요 CLI 명령어 (Step 1)

- Mbed --help 를 통해 각 명령의 주요내용을 확인할 수 있습니다.

```
danlee02 > ~/work/00_blinky/mbed-os-example-blinky [master] ➤ mbed --help
usage: mbed [-h] [--version] ...
...
Command-line code management tool for ARM mbed OS - http://www.mbed.com
version 1.10.2

Use "mbed <command> -h|--help" for detailed help.
Online manual and guide available at https://github.com/ARMmbed/mbed-cl

optional arguments:
  -h, --help            show this help message and exit
  --version             print version number and exit

Commands:

  new                  Create new mbed program or library
  import               Import program from URL
  add                 Add library from URL
  remove              Remove library
  deploy              Find and add missing libraries
  publish             Publish program or library
  update              Update to branch, tag, revision or latest
  sync                Synchronize library references

  ls                  View dependency tree
  releases            Show release tags
  status              Show version control status

  compile             Compile code using the mbed build tools
  test                Find, build and run tests
  device-management   device management subcommand
  export              Generate an IDE project
  detect              Detect connected Mbed targets/boards

  sterm               Open serial terminal to connected target.

  config              Tool configuration
  target              Set or get default target
  toolchain           Set or get default toolchain
  cache               Repository cache management

  help                This help screen
```

- 코드 받기/추가 하기

- mbed import mbed-os-example-blinky
- mbed add <https://github.com/ARMmbed/wifi-ism43362>
- mbed deploy
- mbed sync

- Check Mbed OS version(package version)

- Mbed version 별 tag 정보로 Package 등의 관리에 사용하며, 원하는 버전은 update 명령을 사용
- Ex) Mbed releases 와 Mbed update

```
x danlee02 > ~/work/00_blinky/mbed-os-example-blinky [master] ➤ mbed releases
[mbed] Working path "/Users/danlee02/work/00_blinky/mbed-os-example-blinky" (program)
mbed-os-example-blinky (#b92624b31c3c)
  * mbed-os-5.1.0
  * mbed-os-5.1.1
  * mbed-os-5.14.0
  * mbed-os-5.14.1
  * mbed-os-5.15.0
```

```
danlee02 > ~/work/00_blinky/mbed-os-example-blinky [master] ➤ mbed update mbed-os-5.15.0
[mbed] Working path "/Users/danlee02/work/00_blinky/mbed-os-example-blinky" (program)
[mbed] Updating program "mbed-os-example-blinky" to branch/tag "mbed-os-5.15.0"
[mbed] Updating library "mbed-os" to rev #64853b354fa1 (tags: mbed-os-5.15.0, mbed-os-5.15.0-rc3)
danlee02 > ~/work/00_blinky/mbed-os-example-blinky [fe69e35] ➤ mbed releases
[mbed] Working path "/Users/danlee02/work/00_blinky/mbed-os-example-blinky" (program)
mbed-os-example-blinky (#fe69e35c520e, tag: mbed-os-5.15.0)
  * mbed-os-5.1.0
  * mbed-os-5.1.1
  * mbed-os-5.14.1
  * mbed-os-5.15.0 <- current
  * mbed-os-5.2.0
```

주요 CLI 명령어 (Step 2)

- Mbed Compile
- Mbed compile option 확인
 - Ex) mbed compile –help
- Mbed OS 가 지원하는 보드/컴파일러 정보 출력
 - Ex) mbed compile –S

```
danlee02 ~/work/00_blinky/mbed-os-example-blinky % master • mbed compile -S
[mbed] Working path "/Users/danlee02/work/00_blinky/mbed-os-example-blinky" (program)
+-----+
| Target | mbed OS 2 | mbed OS 5 | uARM | IAR | ARM | GCC_ARM | ARMCM5 |
+-----+
| ARCH_BLE | Supported | - | - | - | Supported | Supported | - |
| ARCH_BLE_BOOT | - | - | - | - | Supported | Supported | - |
| ARCH_BLE_OTA | - | - | - | - | Supported | Supported | - |
| ARCH_GPRS | Supported | - | Supported | Supported | Supported | Supported | - |
| ARCH_LINK | - | - | - | - | Supported | Supported | - |
| ARCH_LINK_BOOT | - | - | - | - | Supported | Supported | - |
```

- Ex) mbed compile --config

```
target.network-default-interface-type has no value
target.stdio_uart_rx has no value
target.stdio_uart_tx has no value
target.tickleless-from-us-ticker = 0 (macro name: "MBED_CONF_TARGET_TICKLESS_FROM_US_TICKER")
target.xip-enable = 0 (macro name: "MBED_CONF_TARGET_XIP_ENABLE")
```

• Simple serial terminal

- 컴파일후 Serial terminal 을 따로 실행할 필요없이 바로 mbed tool 의 자체 serial terminal 을 실행한다.
- Ex) Mbed compile –m auto –f **--stream**
- Baudrate 변경은??

```
danlee02 ~/work/00_blinky/mbed-os-example-blinky % fe69e35 ➜ mbed compile -m auto -f --stream
[mbed] Working path "/Users/danlee02/work/00_blinky/mbed-os-example-blinky" (program)
[mbed] Detected "DISCO_L475VG_IOT01A" connected to "/Volumes/DISCO_L4IOT" and using com port "/dev/tty.usbmodem4011403"
Building project mbed-os-example-blinky (DISCO_L475VG_IOT01A, GCC_ARM)
Scan: mbed-os-example-blinky
Link: mbed-os-example-blinky
Elf2Bin: mbed-os-example-blinky
Module | .text | .data | .bss |
+-----+
[fill] | 120(+0) | 8(+0) | 22(+0) |
[lib]/c.a | 28432(+0) | 2472(+0) | 89(+0) |
[lib]/gcc.a | 3104(+0) | 0(+0) | 0(+0) |
[lib]/misc | 180(+0) | 4(+0) | 28(+0) |
main.o | 60(+0) | 0(+0) | 0(+0) |
mbed-os/components | 36(+0) | 0(+0) | 4(+0) |
mbed-os/drivers | 174(+0) | 0(+0) | 0(+0) |
mbed-os/hal | 1538(+0) | 8(+0) | 130(+0) |
mbed-os/platform | 4592(+0) | 260(+0) | 221(+0) |
mbed-os/rtos | 6854(+0) | 168(+0) | 6228(+0) |
mbed-os/targets | 11014(+0) | 8(+0) | 966(+0) |
Subtotals | 56104(+0) | 2928(+0) | 7688(+0) |
Total Static RAM memory (data + bss): 10616(+0) bytes
Total Flash memory (text + data): 59032(+0) bytes
Image: ./BUILD/DISCO_L475VG_IOT01A/GCC_ARM/mbed-os-example-blinky.bin
--- Terminal on /dev/tty.usbmodem4011403 - 9600,8,N,1 ---
Simple terminal
Simple terminal
Simple terminal
Simple terminal
```

Drivers APIs – Serial

- 비동기 직렬 통신

```
16 #include "mbed.h"
17
18 Serial pc(USBTX, USBRX); // tx, rx
19
20 int main() {
21     pc.printf("Hello World!\n\r");
22     while(1) {
23         pc.putc(pc.getc() + 1); // echo input back to terminal
24     }
25 }
```

```
1 #include "mbed.h"
2
3 Serial device(USBTX, USBRX); // tx, rx
4
5 int main() {
6     device.baud(19200);
7     device.printf("Hello World\n");
8 }
```

```
1 #include "mbed.h"
2
3 I2C i2c(PB_11, PB_10);
4
5 int main()
6 {
7     printf("I2C scan test\r\n");
8 }
```

- Printf() 를 쓰면서 Boardrate 를 바꾸는 방법은?
- /r (carriage return) 을 계속 써야 하나?

- Printf() 는 Platform serial 설정에 따라 동작됨

- PinNames.h

```
212     // STUDIO for console print
213 #ifdef MBED_CONF_TARGET_STUDIO_UART_TX
214     STUDIO_UART_TX = MBED_CONF_TARGET_STUDIO_UART_TX,
215 #else
216     STUDIO_UART_TX = PB_6,
217 #endif
218 #ifdef MBED_CONF_TARGET_STUDIO_UART_RX
219     STUDIO_UART_RX = MBED_CONF_TARGET_STUDIO_UART_RX,
220 #else
221     STUDIO_UART_RX = PB_7,
222 #endif
223
224 // Generic signals namings
225 LED1      = D13, // Green LED (LD1)
226 LED2      = PB_14, // Green LED (LD2)
227 LED3      = PC_9, // Yellow LED (LD3 WIFI) / Blue LED (LD4 BLE)
228 LED4      = LED3,
229 USER_BUTTON = PC_13,
230 BUTTON1   = USER_BUTTON,
231 BUTTON2   = USER_BUTTON,
232 BUTTON3   = USER_BUTTON,
233 BUTTON4   = USER_BUTTON,
234 BUTTON5   = USER_BUTTON,
235 SERIAL_TX = STUDIO_UART_TX,
236 SERIAL_RX = STUDIO_UART_RX,
237 USBTX     = STUDIO_UART_TX,
238 USBRX     = STUDIO_UART_RX,
```

<https://os.mbed.com/docs/mbed-os/v5.15/apis/serial.html>

Mbed OS build rules - Json / .mbedignore

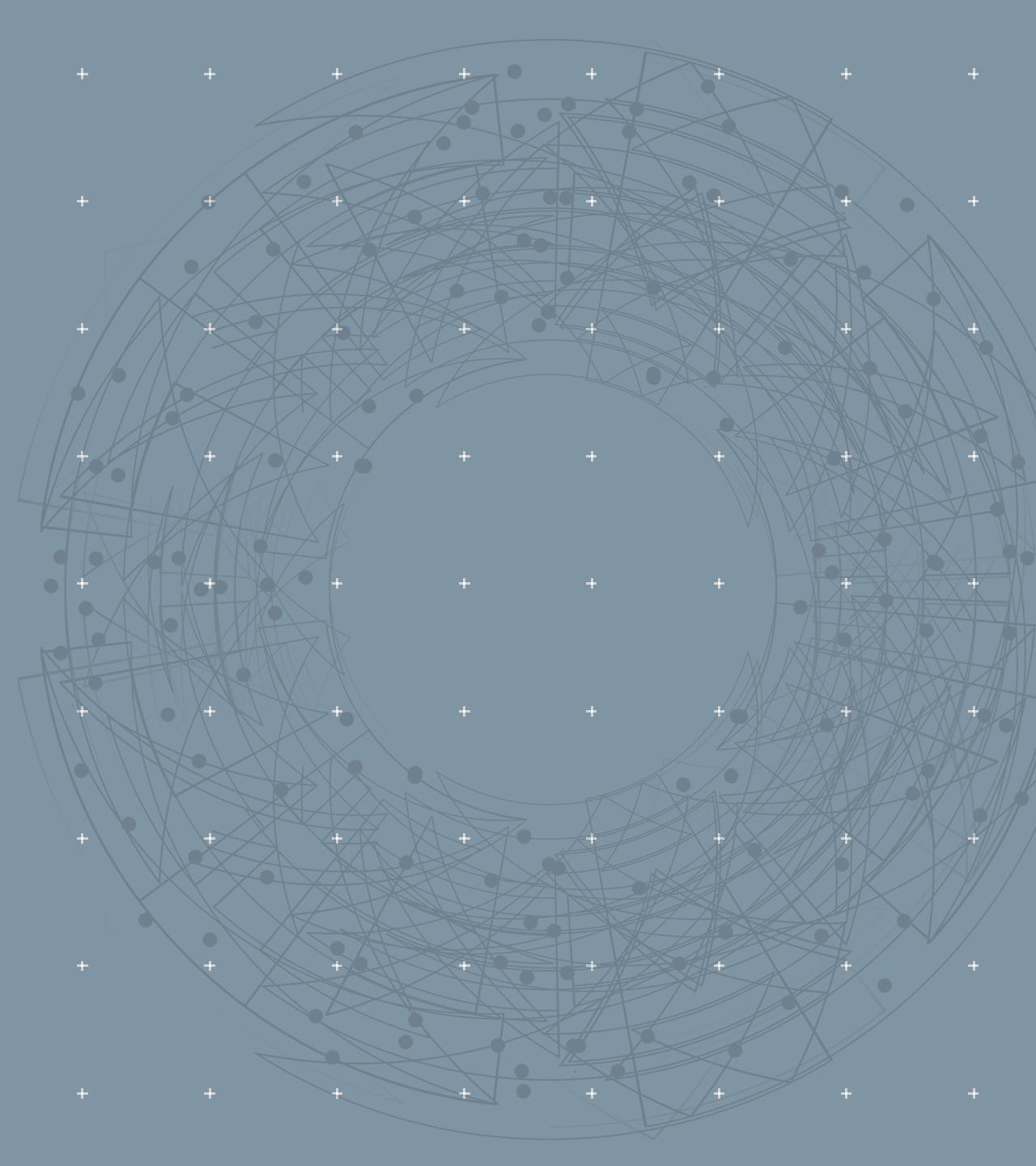
- Mbed OS 는 targets.json, mbed_app.json 그리고 mbed_lib.json과 같은 설정 파일의 규칙에 따라 운영됨
 - <https://os.mbed.com/docs/mbed-os/v5.15/reference/project-structures-and-configuration.html>
 - Ex) mbed_app.json



```
mbed_app.json x
1  {
2    "target_overrides": {
3      "*": {
4        "platform.stdio-convert-newlines": true,
5        "platform.stdio-baud-rate": 115200
6      }
7    }
8 }
```

- platform.stdio-convert-newlines : Enable conversion to standard newlines on stdin/stdout/stderr
 - platform.default-serial-baud-rate : Default baud rate for a Serial or RawSerial instance (if not specified in the constructor)

- 프로젝트를 진행하면서 사용하지 않는 Mbed-OS 코드는 mbedignore 를 통해 컴파일시간을 줄일 수 있음
 - <https://os.mbed.com/docs/mbed-os/v5.15/reference/mbed-os-build-rules.html#mbedignore>
 - Ex) .mbedignore 를 만들고 (Main.cpp 와 같은폴더) mbed-os/features/cellular/*.* 를 저장합니다. 이제, Cellular 폴더내의 모든 파일은 컴파일 되지 않음



Communication

WiFi

Network Socket APIs

<https://os.mbed.com/docs/mbed-os/v5.15/apis/network-socket.html>

- IP 네트워킹을 위한 응용프로그램 I/F API 를 제공하며 추상화된 Socket API는 네트워크를 위한 TCP, UDP 및 비 IP 데이터 전송과 같은 다양한 프로토콜을 지원합니다.

Socket	TCPSocket	Non-IP cellular socket	TLSSocket	SocketStats
UDPSocket	SocketAddress	DNS resolver	DTLSSocket	

Network Interface APIs

<https://os.mbed.com/docs/mbed-os/v5.15/apis/network-interfaces.html>

- NetworkInterface는 기본 소켓 작업을 구현하는 네트워크 스택을 제공합니다.

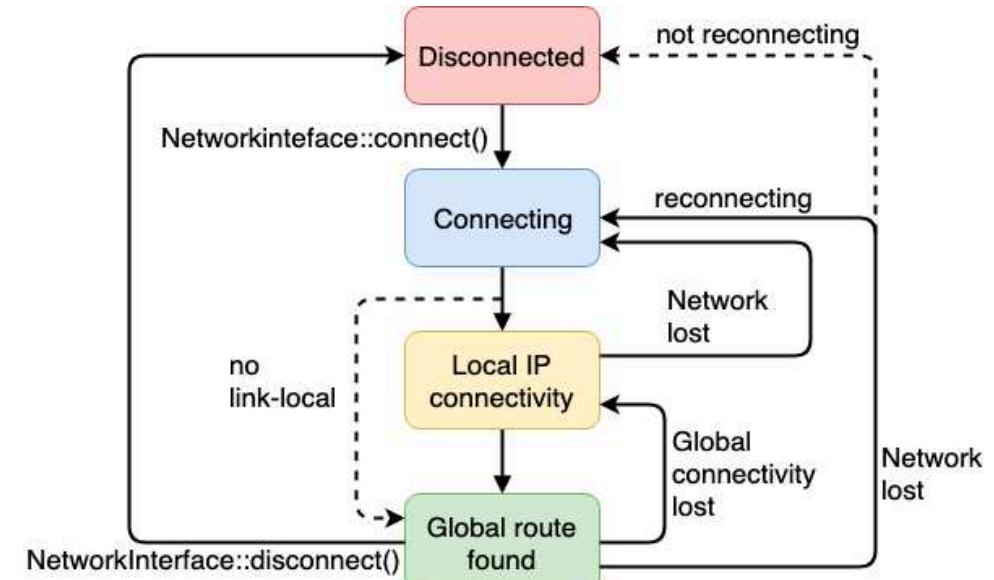
Ethernet	Cellular	Network status	Wi-Fi	Mesh
--------------------------	--------------------------	--------------------------------	-----------------------	----------------------

Network Socket/Interface APIs

Network Socket

OSI layer	API	Protocols
5 - 7	Application	
(4) transport	Socket API	TCP UDP
(3) network	Network stack	IPv4 IPv6
(2) Data link	Network driver	Ethernet WiFi Cellular IEEE 802.15.4

Network interface



Network I/F APIs : WiFi

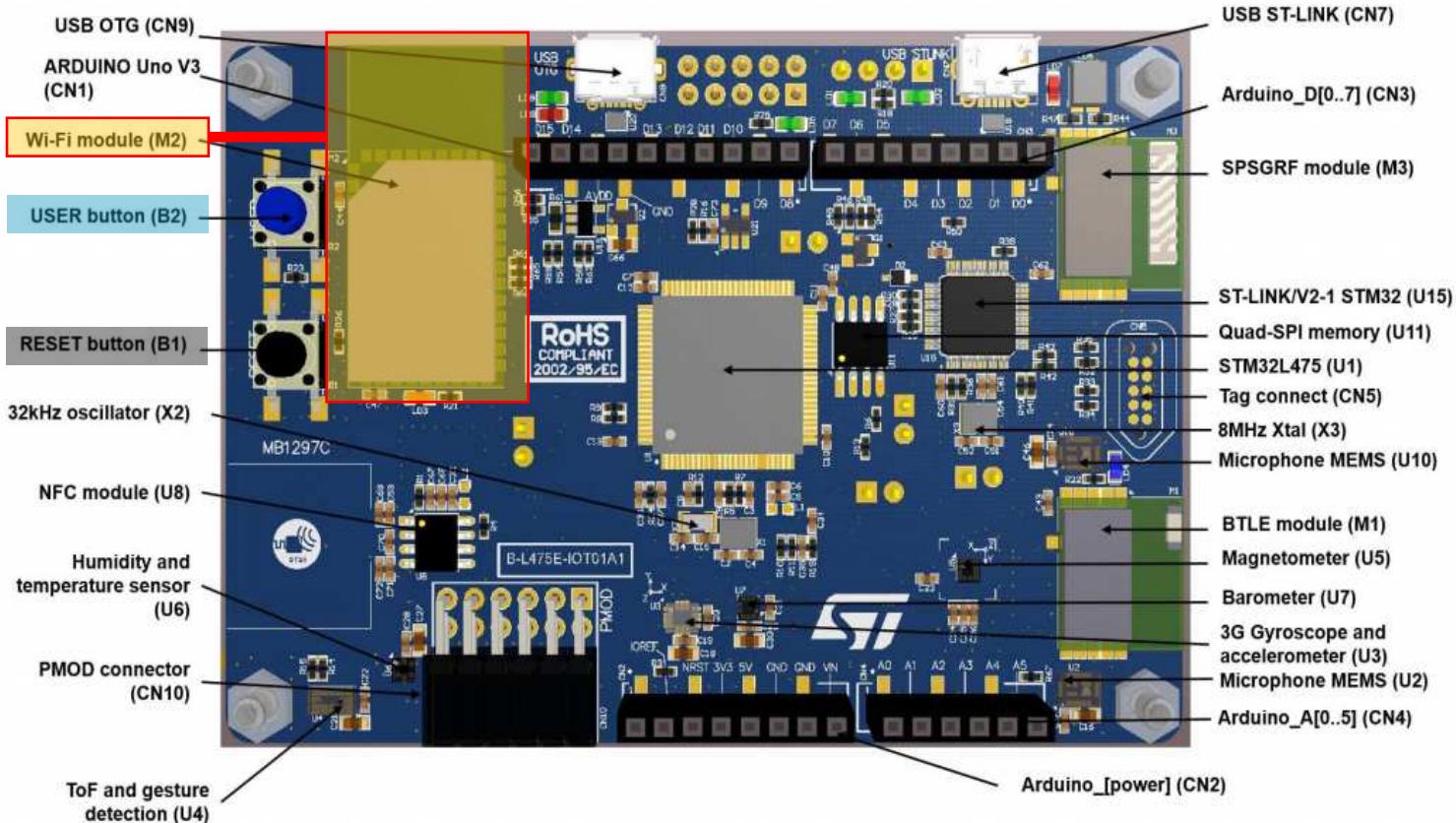
- DISCO-L475VG-IOT01A board의 WiFi(ISM43362) 를 돌려봅시다!
 - 주의!! L475 board의 ISM43362 는 2.4G AP 만 지원함



Your turn, let's try!

Network I/F APIs : WiFi - Example (Step 1)

- Board spec check - STM32L4 Discovery kit for IoT node (top view)

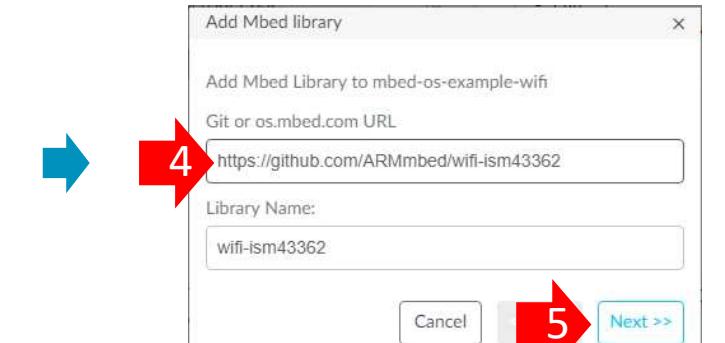
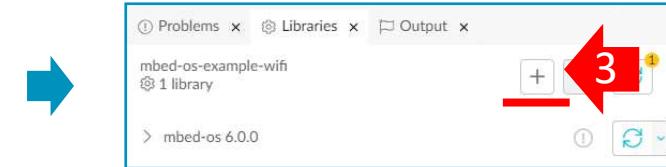
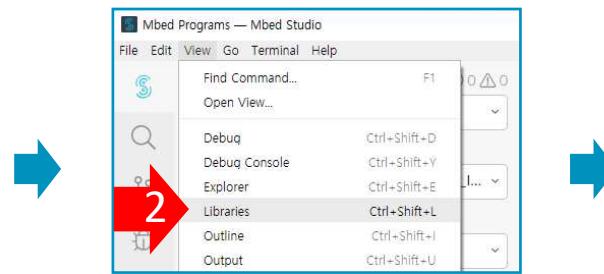
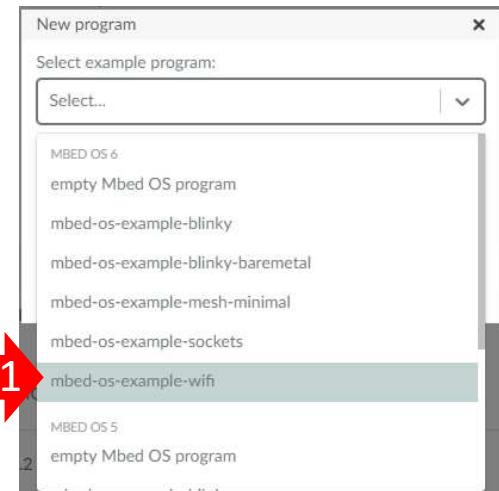


This example has been used on the following platforms

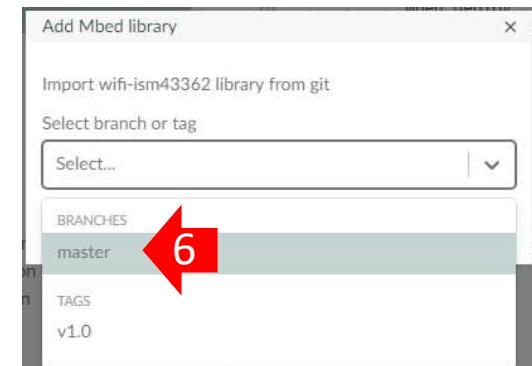
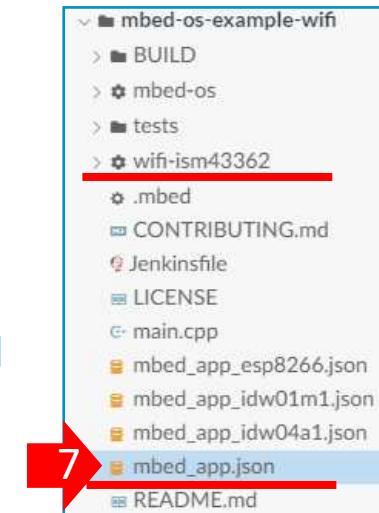
- [DISCO_L475VG_IOT01A](#) (embeds a [ISM43362 WiFi module](#))
- [DISCO_F413ZH](#) (embeds a [ISM43362 WiFi module](#))

Network I/F APIs : WiFi - Example (Step 2)

- Import ism43362 driver from <https://github.com/ARMmbed/wifi-ism43362>



SSID & PASSWORD 설정



Master 선택 -> Finish

Network I/F APIs : WiFi - Example (Step 3)

- Serial Monitor 상에 출력확인

```
WiFi example
Mbed OS version 5.12.0

Scan:
Network: U+Net42GDM secured: WPA2 BSSID: 70:4D:7B:e1:5:40 RSSI: -50 Ch: 2
Network: 105303_2G secured: WPA2 BSSID: 2C:4D:54:cd:31:e8 RSSI: -84 Ch: 6
Network: U+Net22B6 secured: WPA2 BSSID: 88:3C:1C:4e:22:b5 RSSI: -69 Ch: 11
Network: secured: WPA2 BSSID: 12:23:AA:4c:3c:6 RSSI: -77 Ch: 11
Network: SK_WiFiGIGA3C07 secured: WPA2 BSSID: 0:23:AA:4c:3c:6 RSSI: -77 Ch: 11
5 networks available.

Connecting to DM...
Success

MAC: C4:7F:51:07:B4:ED
IP: 172.20.10.2
Netmask: 255.255.255.240
Gateway: 172.20.10.1
RSSI: -45

Done
```

Network I/F APIs : How to use other WiFi module?

- ESP8266이나 Wizfi310를 사용하려면 어떻게 해야 할까요?
 - ESP8266은 Mbed OS -> Component -> wifi -> esp8266-driver에 위치합니다. Mbed_lib.json에서 다음과 같이 Tx, Rx, Provided-default를 설정해주면 됩니다!
 - <https://os.mbed.com/teams/mbed-os-examples/code/mbed-os-example-mbed5-wifi/>

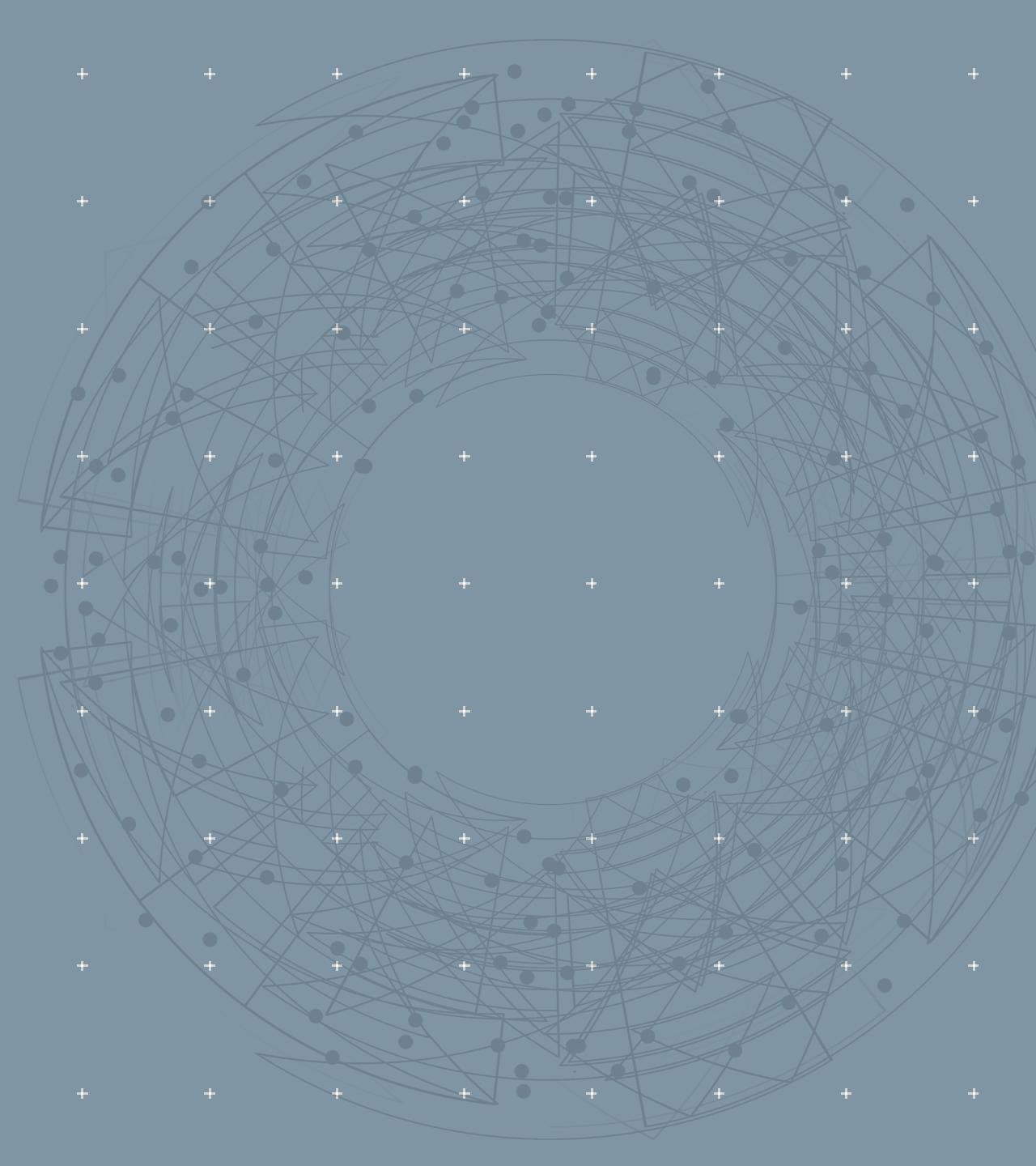
Example) Mbed_lib.json

```
{
  "name": "esp8266",
  "config": {
    "tx": {
      "help": "TX pin for serial connection",
      "value": null <- 'D1' by default if Arduino, adjust based on your board
    },
    "rx": {
      "help": "RX pin for serial connection",
      "value": null <- 'D0' by default if Arduino, adjust based on your board
    },
    "provide-default": {
      "help": "Provide default WifiInterface. [true/false]",
      "value": false <- Set to 'true' if this is the interface you are using
    },
    "socket-buflimit": {
      "help": "Max socket data heap usage",
      "value": 8192 <- Without HW flow control more is better. Once the limit is reached packets are dropped - does not matter is it TCP or UDP.
    }
  }
}
```

Example) mbed_app.json

```
{
  "config": {
    "wifi-ssid": {
      "help": "WiFi SSID",
      "value": "\"SSID\""
    },
    "wifi-password": {
      "help": "WiFi Password",
      "value": "\"PASSWORD\""
    }
  },
  "target_overrides": {
    "*": {
      "platform.stdio-convert-newlines": true,
      "esp8266.provide-default": true
    }
  }
}
```

- Wizfi310은 <https://github.com/ARMmbed/wizfi310-driver>를 통해 사용하실 수 있습니다.

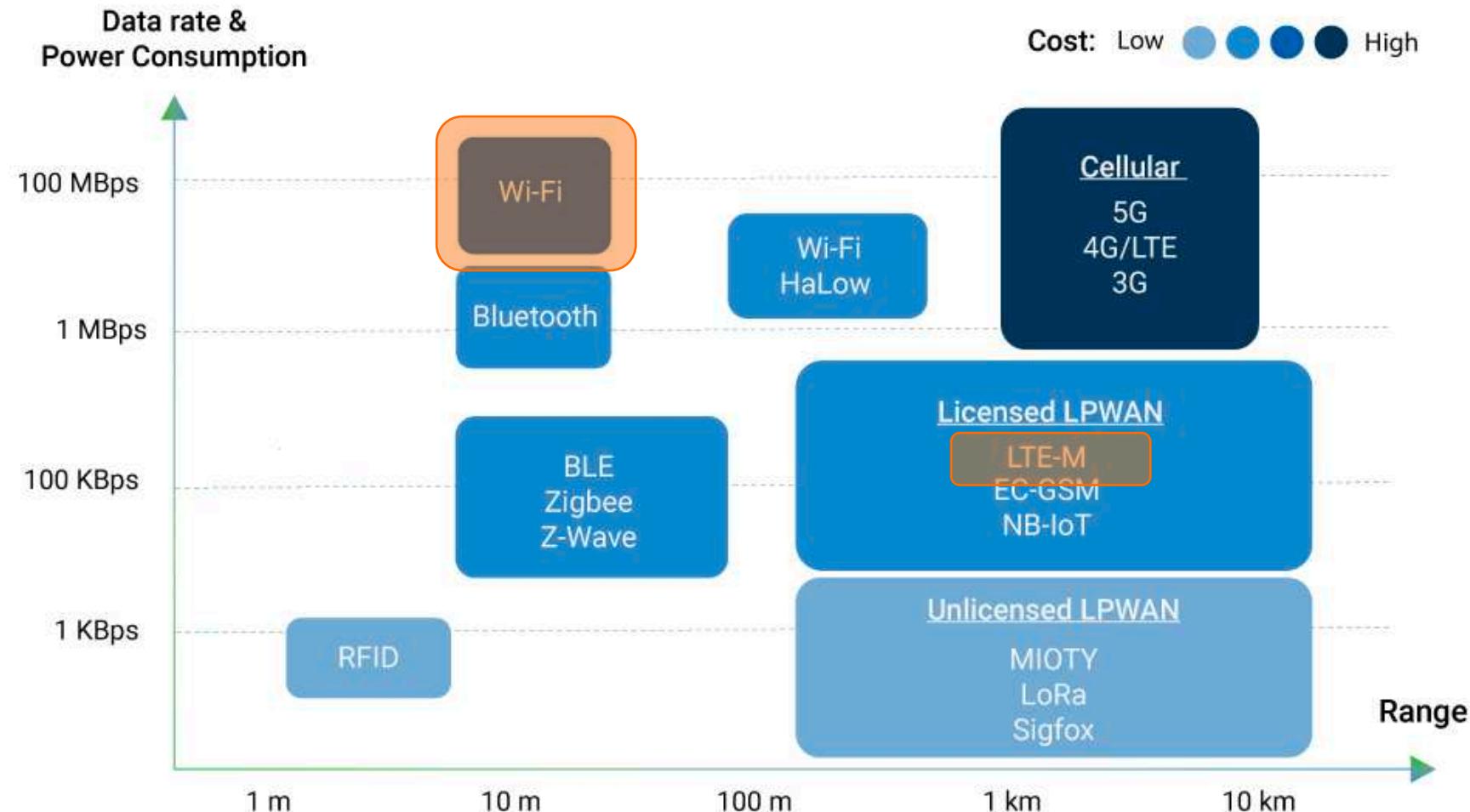


Communication

Cellular

무선 통신 방식

- IoT 시스템은 다양한 디바이스 애플리케이션을 위해 안전하고 비용 효율적인 연결을 필요로 합니다.



주요 통신 방식 비교

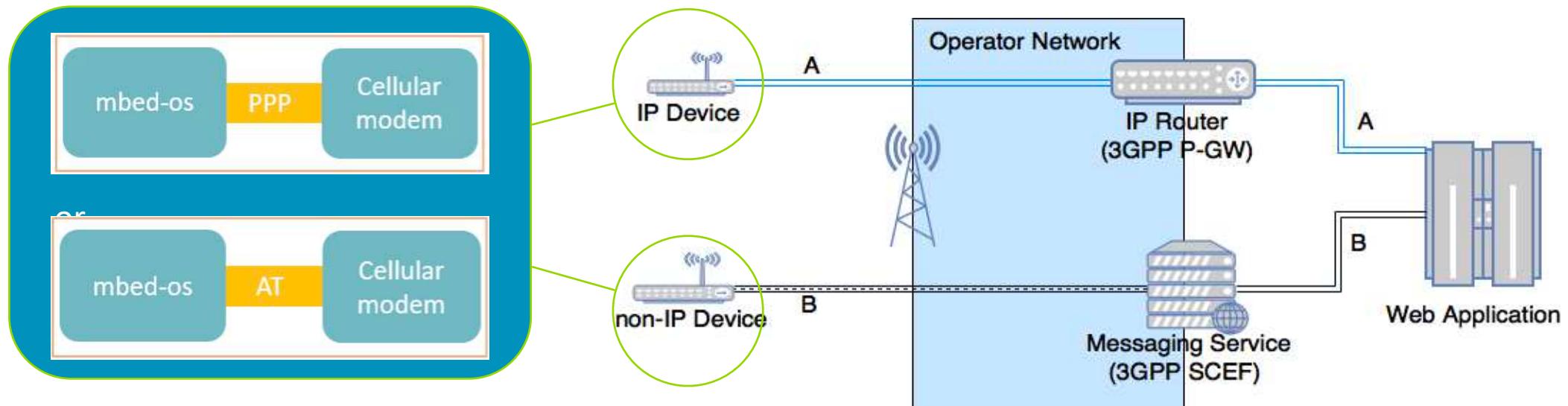
구분	Sigfox	LoRa	NB-IoT	LTE Cat.M1
표준화	ETSI	LoRa Alliance	3GPP	3GPP
Eco-system	Sigfox사 E2E 통합 솔루션 -통신모듈, 기지국, Core Cloud 등	LoRa 모뎀칩: Semtech 단말, 기지국, N/W Server 솔루션 누구나 개발 가능	기존 LTE Eco-system 기반	기존 LTE Eco-system 기반
주파수	비면허 Sub GHz 대역 (800~900MHz)	비면허 Sub GHz 대역 (800~900MHz)	면허 LTE 대역 (In-band, Guard-band)	면허 LTE 대역 (In-band)
RF B/W	DL:200KHz, UL:200KHz (단말당 UL B/W는 100Hz)	DL+UL: 7.8~500KHz, 125KHz*8채널 Main	DL,UL: 180KHz(1RB)	DL,UL: 180KHz*6(6RB)
전류소모		Idle(1~10uA) TX(20~30mA),RX(15~25mA)	Idle(10~20uA) TX&RX(50~100mA)	Idle(10~20uA) TX&RX(120~150mA) ※ 소모량, TX/RX속도 반비례
최대 전송 속도	DL/UL: 600/100bps Data Size: ~12Bytes	DL/UL:18~37,500bps 300~5,400bps@125KHz Data Size: ~240Bytes	Half Duplex DL/UL 27/63Kbps Full Duplex DL/UL 250Kbps	Half Duplex DL/UL 300/375Kbps Full Duplex DL/UL 1Mbps
기지국당 커버리지	LTE 대비 20dB 확장 수준	LTE 대비 20dB 확장 수준 (음영지역 존재: 지하)	LTE 대비 20dB 확장 수준	LTE 대비 20dB 확장 수준
Mobility		부분지원	부분지원	Mobility(Handover)지원
모듈 가격	\$5~\$10 수준	\$5~\$10 수준	\$20 예상	\$20 예상

Network Interface APIs - Cellular

<https://os.mbed.com/docs/mbed-os/v5.15/apis/cellular-api.html>

- CellularInterface Class는 휴대 기기를 통해 네트워크에 연결하기 위한 C++ API를 제공합니다.

- CellularInterface Class Reference abstract : https://os.mbed.com/docs/mbed-os/v5.15/mbed-os-api-doxy/class_cellular_interface.html
- 3GPP TS 27.007 및 27.005와 호환됩니다.

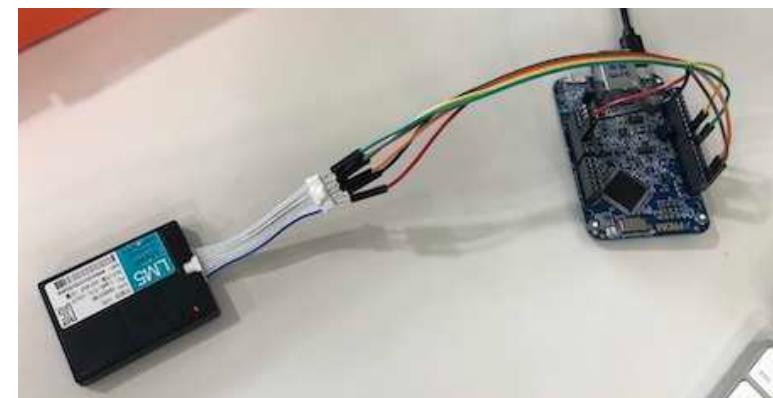
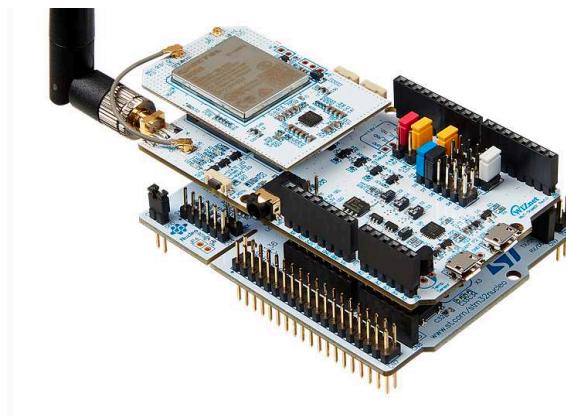


SKT – Cat.M1 Environment (Step 1)



1. SKT – Cat.M1

- B2B market only!
 - IoT open house(WIZnet) : <https://www.skтиot.com/iot/support/openhouse/reservation/openhouseMain>
 - 소재지 : 분당 수내역
 - 개발에 필요한 컨설팅/지원/개통 지원 등..
 - Cat1 Modem list : <https://www.skтиot.com/iot/product/catm1/catm1Modem>
 - M2M net : http://m2mnet.net/index/bbs/board.php?bo_table=inf05&wr_id=24
 - 모듈 & USIM & 소량 구매가능(사업자등록증 필요)



M2Mnet - LM5 module

SKT – Cat.M1 Environment (Step 2)



1. SKT – Cat.M1

- CatM1 모듈 : <https://www.skriot.com/iot/introduction/network/networkCatM1Main6>



Telit(LGA)_ME910C1-K1
Sibin.Yang@telit.com



M2Mnet(LGA)_BG96
tjkim@m2mnet.net

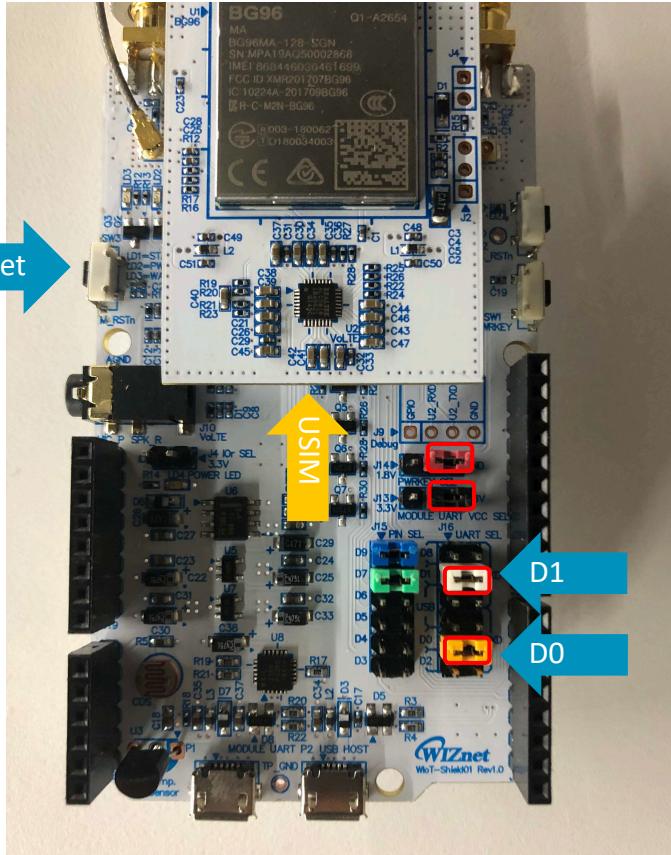
- [우리넷\(LGA\)](#)
- [우리넷\(Socket\)](#)
- [AM텔레콤\(PCIe M.2\)](#)

2. 요금제(SKT – Cat M1)

- <https://www.skriot.com/iot/introduction/paymentSystem/paymentSystemCatM1>

SKT – Cat.M1 Environment (Step 3) - Board Configure

Board stack type



<https://github.com/Wiznet/wiznet-iot-shield-mbed-kr>

Produced module type



		PIN	Signal Name
D0(or D2)	5V	1	VCC
D1(or D8)	GND	2	GND
		3	VBAT
		4	RXD
		5	TXD
		6	STATUS
D9		7	PWRKEY
		8	GND
		9	ONOFF_RESET
D7		10	GPS_TXD

SKT – Cat.M1 Environment (Step 4) - Operation Test

- Example source code(SKT - CatM1)
 - https://os.mbed.com/users/Daniel_Lee/code/mbed-os-example-cellular-BG96/
 - BG96 의 경우 5.12 이후 부터는 Patch 없이 Mbed_app.json 의 수정으로 사용이 가능하며, 5.12 이하의 Version 에서는 https://os.mbed.com/users/Daniel_Lee/code/mbed-os-example-cellular_BG96_os511/ 의 패치 내용을 통해 사용이 가능합니다.
 - 수정할 부분
 - Mbed_app.json

```
"lwip.ipv4-enabled": false,  
"lwip.ipv6-enabled": true,  
"lwip.ppp-enabled": true,  
"lwip.tcp-enabled": true,  
"nsapi.default-cellular-apn": "\"Ite-internet.sktelecom.com\""  
"QUECTEL_BG96.tx": "D1",  
"QUECTEL_BG96.rx": "D0",  
"QUECTEL_BG96.provide-default": true
```

LGU+T – Cat.M1 Environment

LG유플러스, LTE-Cat.M1 전국망 서비스 개시

발행일 : 2019.04.22



<LG유플러스는 사물인터넷(IoT) 통신 LTE Cat.M1 전국망 서비스를 개시한다고 22일 밝혔다.>



[http://mechasolution.com/shop/goods/goods_view.php?
goodsno=587303&category&fbclid=IwAR2dAhNkzHqi1G6cwGb_ErS7CaMA2CvBkWCLx6r5ki4fo3ddJTauIQaL6cI](http://mechasolution.com/shop/goods/goods_view.php?goodsno=587303&category&fbclid=IwAR2dAhNkzHqi1G6cwGb_ErS7CaMA2CvBkWCLx6r5ki4fo3ddJTauIQaL6cI)

LGU+T – NB.IoT Environment (Step 1)

1. LGU+'s NB-IoT

- 연구 개발목적으로 구매 및 사용가능 한 제품이 있습니다.
- 단말 & USIM & 요금제(선택 불가)
- http://mechasolution.com/shop/goods/goods_view.php?goodsno=583929&category=132030 == <https://bit.ly/2XIMLgR>
- [NB-IOT망 사용 가이드](#)



https://github.com/codezoo-ltd/NB-IoT_Hardware

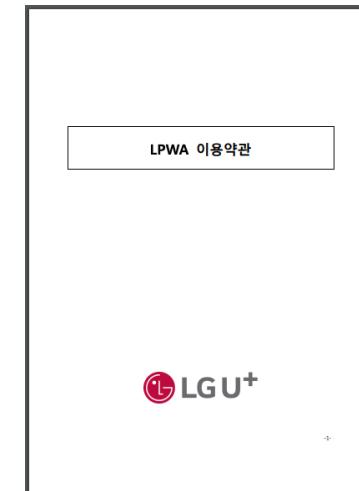


LGU+T – NB.IoT Environment (Step 2)

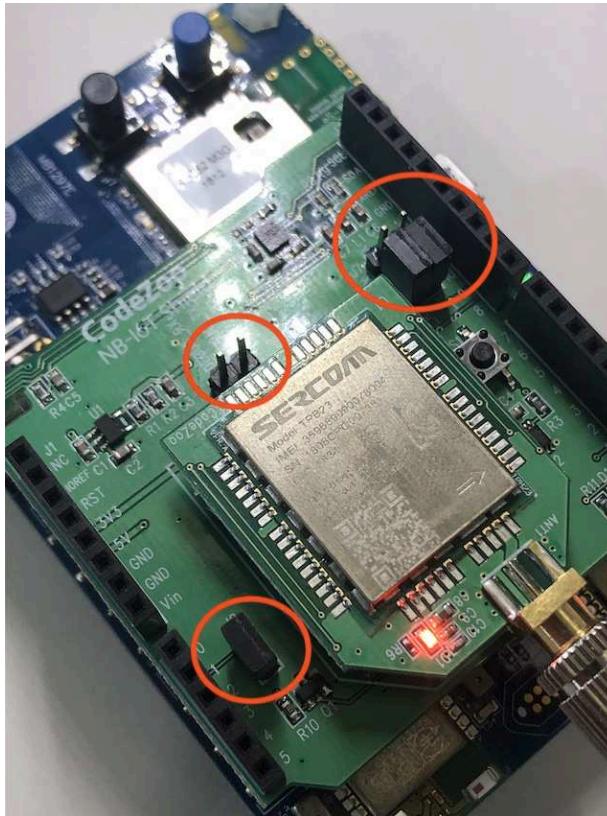
- B2B market
 - <https://innovationlab.uplus.co.kr/>
 - 사업 담당과 협의 후 기술/개통 등 지원
 - 요금제 (<http://www.uplus.co.kr/css/rfrm/prvs/RetrieveUbDnTerms.hpi>)

The screenshot shows a web browser window with the URL <http://www.uplus.co.kr/css/rfrm/prvs/RetrieveUbDnTerms.hpi>. The page title is "기업 서비스 이용약관". A dropdown menu labeled "제목" has "LPWA" selected, highlighted with a red circle labeled "1". Below the dropdown, a table lists services under the heading "서비스군". The first row shows "IoT" with "LPWA 이용약관" highlighted with a red circle labeled "2".

번호	서비스군	이용약관
1	IoT	LPWA 이용약관



LGU+T – NB.IoT Environment (Step 3) - Board Configure



https://github.com/codezoo-ltd/NB-IoT_Hardware

LGU+ NB.IoT Environment (Step 4) – Operation Test

- Example source code(**LGU+ NB IoT**)
 - https://os.mbed.com/users/Daniel_Lee/code/mbed-os-example-cellular-TPB23/
- 추가할 부분
 - Mbed_app.json

```
"SERCOMM_TPB23.tx" : "D1",
"SERCOMM_TPB23.rx" : "D0",
"SERCOMM_TPB23.provide-default" : true
```

Global MVNO - Environment

- 글로벌 모바일 MVNO(Mobile Virtual Network Operator, 가상 이동 통신망 사업자) 업체를 이용하여 통신하면, Prototype 개발시 개통 절차의 까다로움을 비교적 쉽게 해결할 수 있습니다.



<https://hologram.io/>

Support : 3G, 4G, Cat.M1

Target : B2B, B2C



<https://stream.iot-x.com/>

Arm Pelion Connectivity

Support : 3G, 4G,

Target : B2B,



<https://simsquare.kr/global/?idx=28>

Global IoT SIM (default 10Mbyte)

Support : Cat.M1,

Target : B2B, B2C

Cellular 통신을 위한 설정

- https://github.com/ARMmbed/mbed-os-example-cellular/blob/master/mbed_app.json
 - SIM card PIN(비밀번호) 설정
"nsapi.default-cellular-sim-pin": "\"1234\"",
 - Socket type (TCP, UDP or NONIP) 선택
"sock-type": "TCP",
 - 모뎀과 MCU 간 AT 명령의 디버깅을 위한 옵션
"cellular.debug-at": true
 - 디버깅을 위한 Tracing 과 Trace 레벨 선택
"mbed-trace.enable": true,
"value": "TRACE_LEVEL_INFO"

Wi-Fi로 개발하고 Cellular를 최종 선택할 수 있을까?



제약 사항이 WiFi에 비해 매우 많음

개발의 시작이 매우 용이함

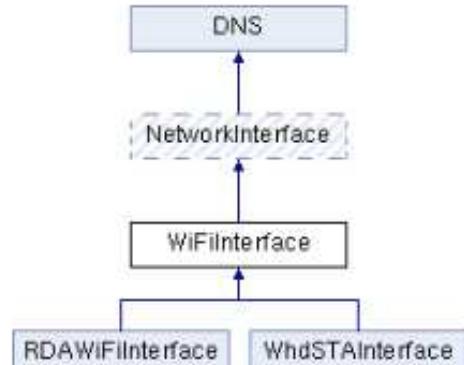


Free to start!

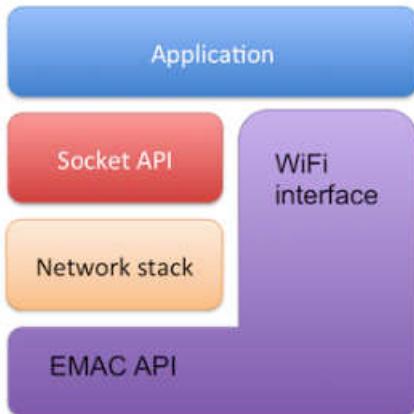
Wi-Fi 와 Cellular 의 자료 구조 (Step 1) – Hierarchy

<https://os.mbed.com/docs/mbed-os/v5.15/reference/ip-networking.html>

Wi-Fi

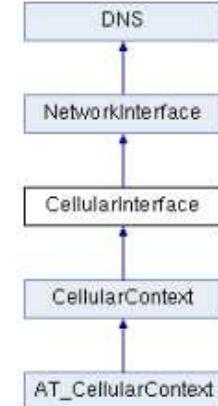


WiFiInterface class hierarchy

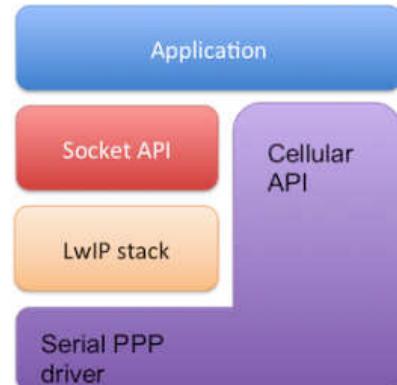


Wi-Fi driver

Cellular



CellularInterface class hierarchy



Cellular driver

Wi-Fi 와 Cellular 의 자료 구조 (Step 2) – Source code

<https://os.mbed.com/docs/mbed-os/v5.15/apis/network-interfaces.html>

<https://github.com/ARMmbed/mbed-os-example-wifi>

```
83     wifi = WiFiInterface::get_default_instance();
84     if (!wifi) {
85         printf("ERROR: No WiFiInterface found.\n");
86         return -1;
87     }
88
89     /* Common interface between Wi-Fi devices.
90      */
91     class WiFiInterface: public virtual NetworkInterface {
92     public:
93         /* Get the default Wi-Fi interface.
```

<https://github.com/ARMmbed/mbed-os-example-cellular>

```
255     #else
256     |     iface = CellularContext::get_default_instance();
257     | #endif
258     |
259     | MBED_ASSERT(iface);
260
261     /* CellularContext is CellularInterface/NetworkInterface
262      | with extensions for cellular connectivity
263      */
264     class CellularContext : public CellularInterface {
265
266         /* Common interface that is shared between cellular
267          | interfaces.
268          */
269         class CellularInterface: public NetworkInterface {
```

<https://github.com/ARMmbed/mbed-os-example-wifi>

```
175     // Connect with NetworkInterface
176     printf("Connect to network\n");
177     network = NetworkInterface::get_default_instance();
178     if (network == NULL) {
```

Wi-Fi 와 Cellular 의 자료 구조 (Step 3) – Mbed_app.json

Easy to change from Wi-Fi to Cellular!

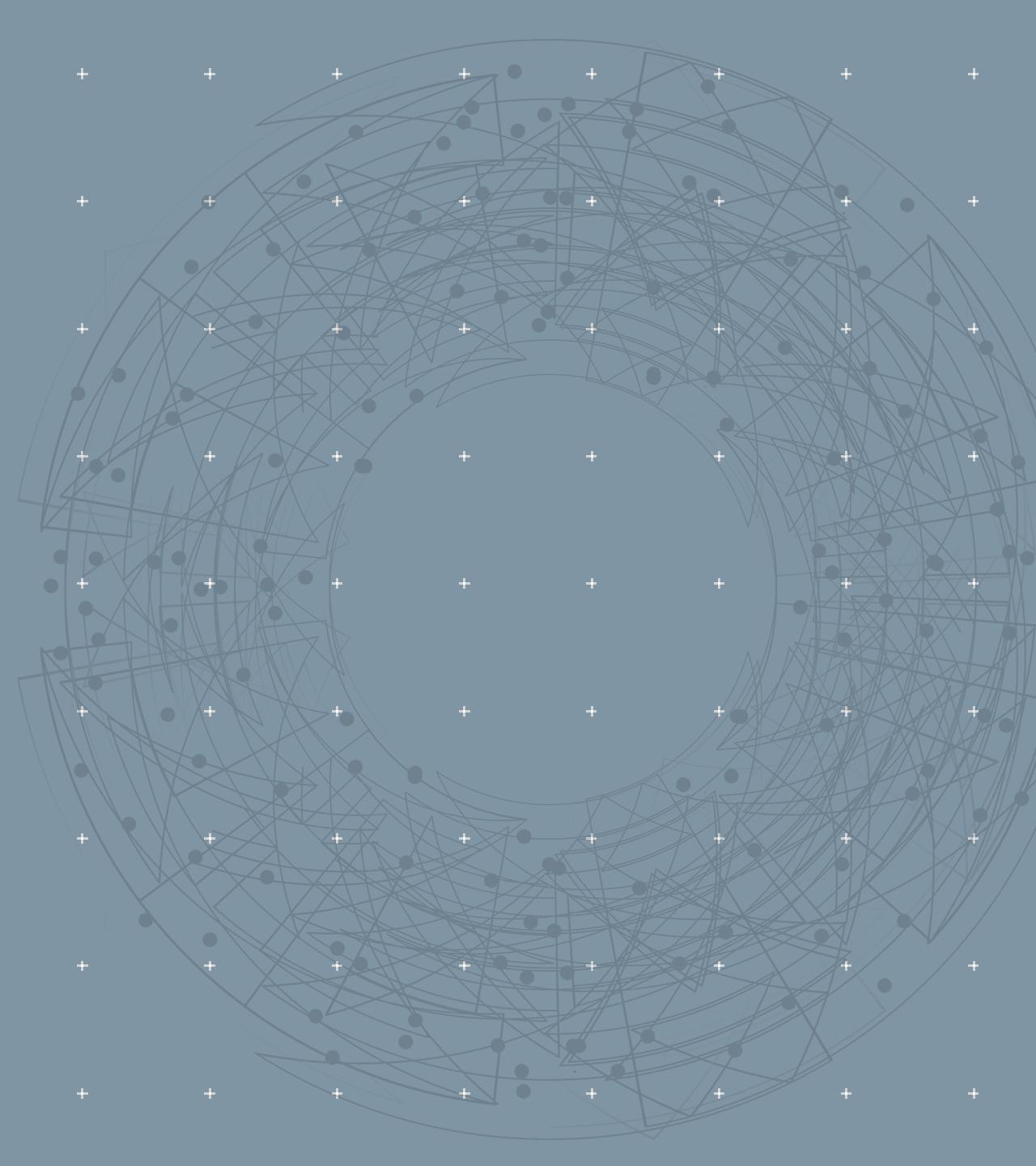
WiFi

```
"events.shared-stacksize" : 2048,  
"nsapi.default-wifi-security" : "WPA_WPA2",  
"nsapi.default-wifi-ssid" : "\"SSID\"",  
"nsapi.default-wifi-password" : "\"PASSWORD\"",  
"nsapi.default-cellular-apn" : "\"APN\"",  
"nsapi.default-cellular-sim-pin" : null,  
"nsapi.default-cellular-username" : null,  
"nsapi.default-cellular-password" : null  
  
"DISCO_L475VG_IOT01A": {  
    "target.macros_add" : ["MBEDTLS_USER_CONFIG_FILE=\\\"mbedtls\\\""],  
    "target.network-default-interface-type" : "WIFI",  
    "target.bootloader_img" : "bootloader/mbed-bootloader-disco_l475v",  
    "target.header_offset" : "0x11000",  
    "target.app_offset" : "0x11400",  
    "target.components_add" : ["QSPIF", "WIFI_ISM43362"],  
    "bootloader-size" : "(36*1024),  
    "ism43362.read-thread-stack-size" : 1024,  
  
    "update-client.firmware-header-version" : "2",  
    "update-client.storage-address" : "(MBED_CONF_STORAGE_FILESYSTEM_EXTERNAL)  
    "update-client.storage-locations" : 1,  
    "update-client.storage-size" : "((MBED_ROM_START + MBED_ROM_SIZE - APP)  
  
},  
"EP_AGORA": {
```

Cellular(For Cat.M1 of SKT)

```
"events.shared-stacksize" : 2048,  
"nsapi.default-wifi-security" : "WPA_WPA2",  
"nsapi.default-wifi-ssid" : "\"SSID\"",  
"nsapi.default-wifi-password" : "\"PASSWORD\"",  
"nsapi.default-cellular-apn" : "\"lte-internet.sktelecom.com\"",  
"nsapi.default-cellular-sim-pin" : null,  
"nsapi.default-cellular-username" : null,  
"nsapi.default-cellular-password" : null  
  
"DISCO_L475VG_IOT01A": {  
    "target.macros_add" : ["MBEDTLS_USER_COI"],  
    "target.network-default-interface-type" : "CELLULAR",  
    "target.bootloader_img" : "bootloader/mbed-l",  
    "target.header_offset" : "0x11000",  
    "target.app_offset" : "0x11400",  
    "target.components_add" : ["QSPIF", "WIFI_I"],  
    "bootloader-size" : "(36*1024)",  
    "ism43362.read-thread-stack-size" : 1024,  
  
    "update-client.firmware-header-version" : "2",  
    "update-client.storage-address" : "(MBED_CONF_STORAGE)",  
    "update-client.storage-locations" : 1,  
    "update-client.storage-size" : "((MBED_ROM_START -  
        "lwip.ipv4-enabled" : false,  
        "lwip.ipv6-enabled" : true,  
        "lwip.ethernet-enabled" : false,  
        "lwip.ppp-enabled" : false,  
        "lwip.tcp-enabled" : true,  
        "cellular.debug-at" : false,  
        "QUECTEL_BG96.tx" : "D1",  
        "QUECTEL_BG96.rx" : "D0",  
        "QUECTEL_BG96.provide-default" : true  
    ),  
    "EP_AGORA": {
```

Base mbed app.json : https://github.com/ARMmbed/mbed-os-example-pelion/blob/master/mbed_app.json



Power Management

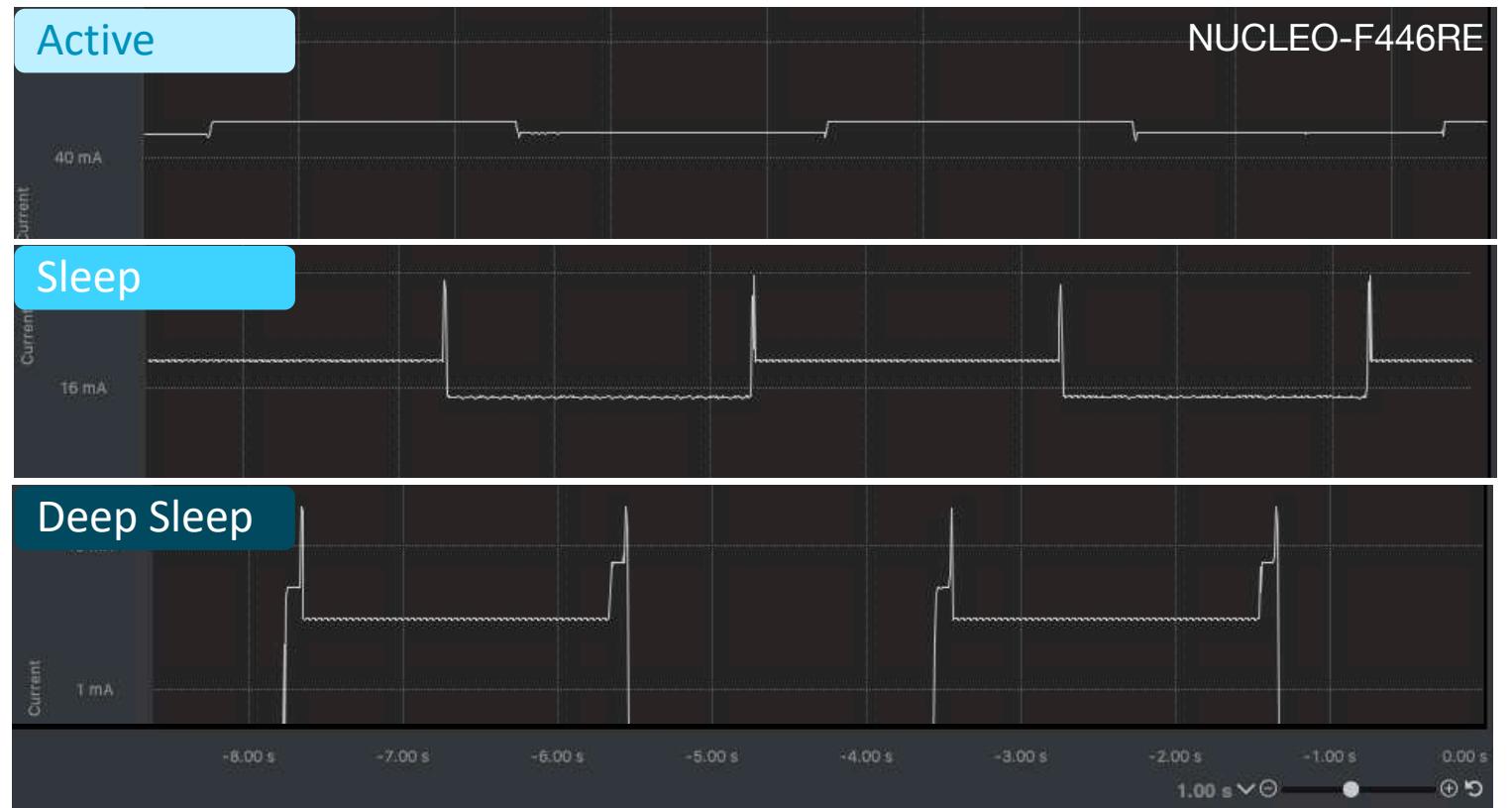
Power Management

- Mbed OS 의 절전 모드
 - Active - 활성화 상태, MCU 및 모든 클럭이 공급되는 상태
 - Sleep - 프로세서, 메모리 시스템 및 버스가 사용하는 동적 전력을 제거하는 모드
 - Deep Sleep - 코어 시스템 클럭 외에도 모든 고 주파수 클럭이 비활성화되고 SysTick 까지 비활성화 하여 최대 저전력으로 동작합니다.

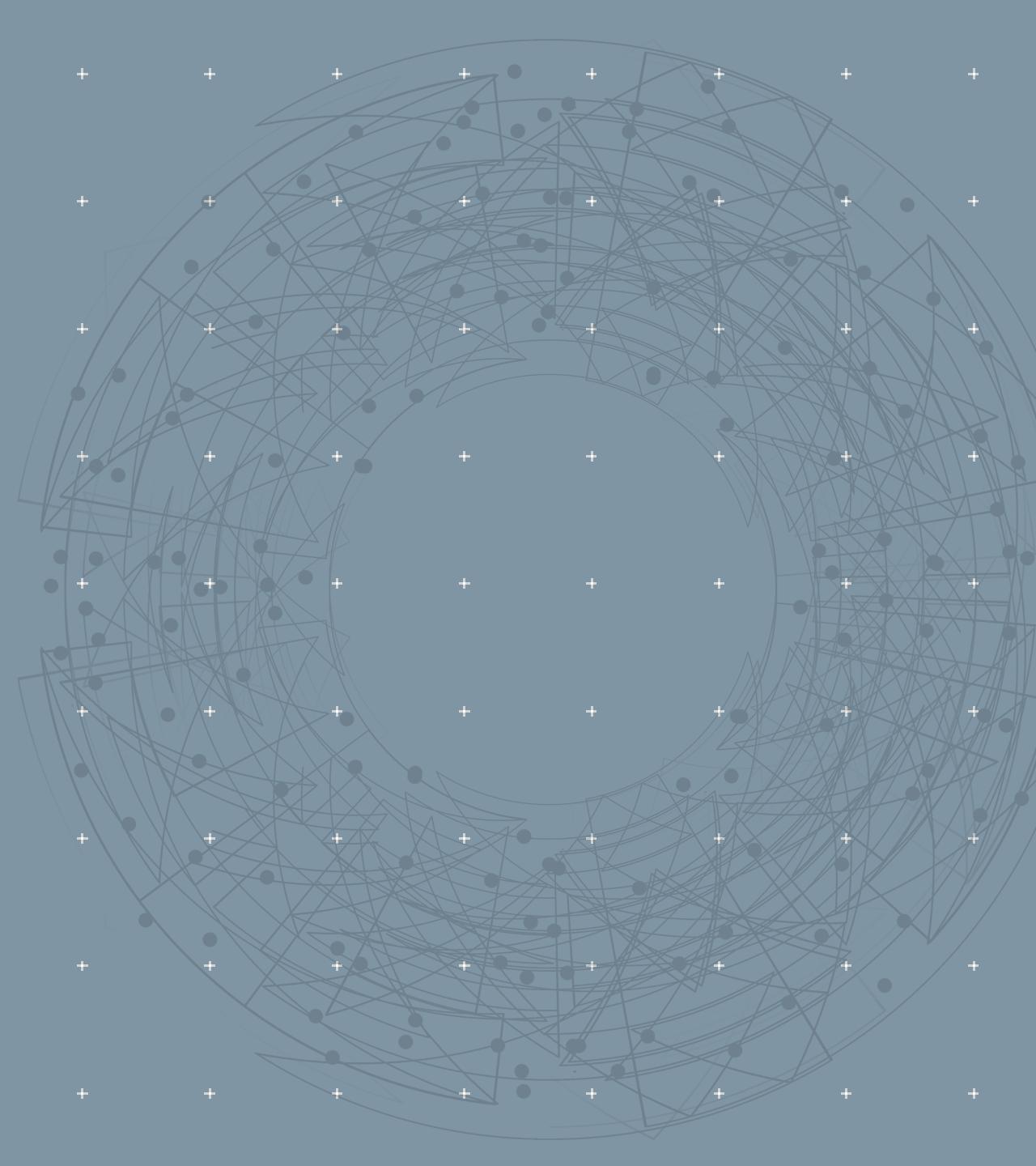
```
#include "mbed.h"

DigitalOut led(LED1);

int main() {
    while (1) {
        // blink the LED
        led = !led;
        // sleep for two seconds
        wait_ms(2000);
    }
}
```



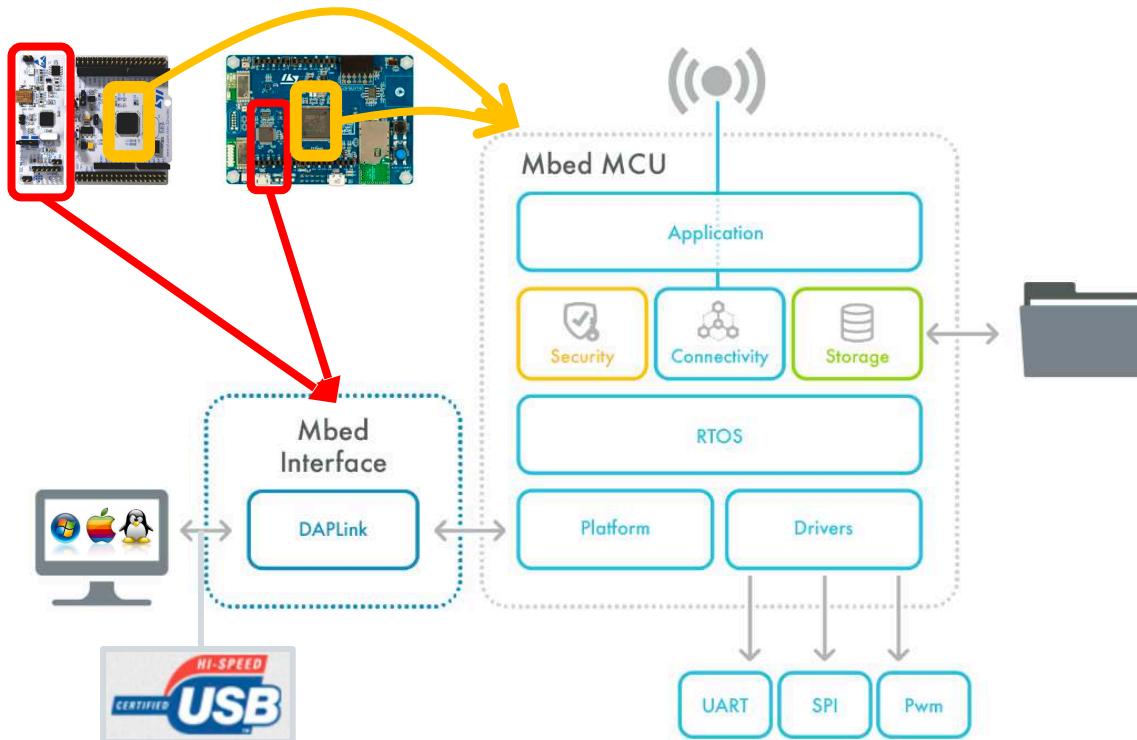
L475VG == 60uA



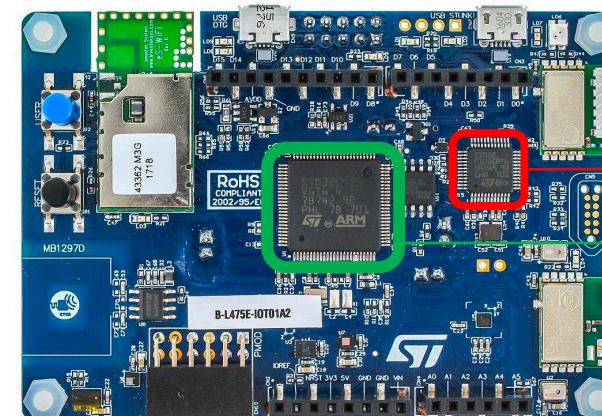
Mbed OS DAPLink

DAPLink #1

- Firmware for the CoreSight Debug Access Port (CMSIS-DAP)
- Interface Firmware 라고 하며 Main MCU의 SWD/JTAG 포트에 연결된 보조 MCU임
 - MSC – Drag & Drop 프로그래밍 플래시 메모리
 - CDC - 로그, 추적 및 터미널 에뮬레이션을 위한 가상 COM 포트
 - HID-CMSIS-DAP 호환 디버그 채널
 - WEBUSB HID-CMSIS-DAP 호환 디버그 채널



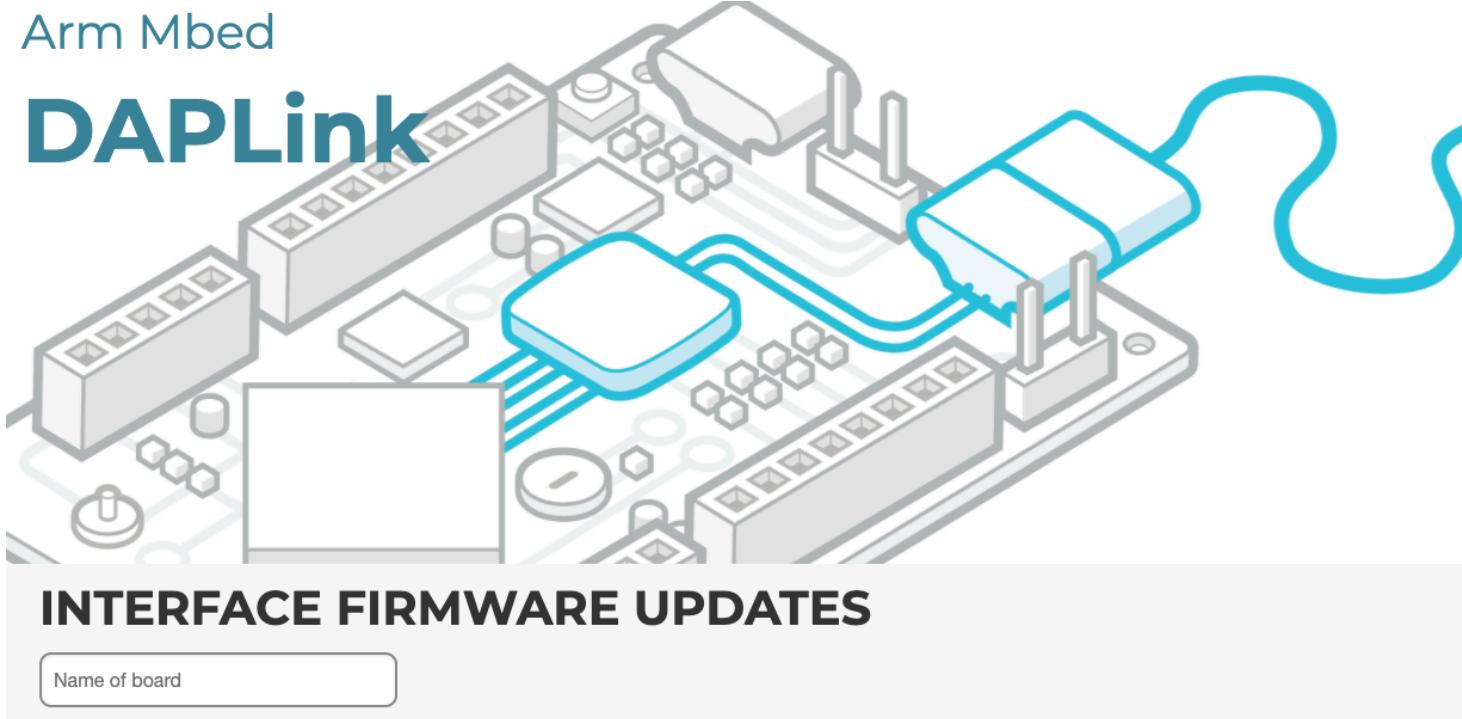
- [K20, K22 및 KL26 기반 NXP OpenSDA](#)
- [LPC11U35 또는 LPC4322 기반 NXP LPC-Link2](#)
- [Atmel SAM3U 기반의 Segger J-Link OB](#)
- [STM32F103 기반의 ST-LINK/V2](#)



arm MBED

DAPLink #2

- Source code : <https://github.com/ARMmbed/DAPLink>
- DAPLink public releases : <https://armmbed.github.io/DAPLink/>
- mbed Hardware Development Kit (mbed-HDK) : <https://github.com/armmbed/mbed-HDK>



Platform Name의 변경 방법 2가지

#1

1. Mbedls 기존

platform_name	platform_name_unique	mount_point	serial_port	target_id	daplink_version
MTS_MDOT_F411RE	MTS_MDOT_F411RE[0]	/Volumes/MULTITECH	/dev/tty.usbmodem145203	031502210158636D3E1CF145	0221

2. Mbedls.json 아래와 같이 설정

```
{  
    "031502210158636D3E1CF145": {  
        "platform_name": "MTS_DRAGONFLY_F411RE"  
    }  
}
```

3. Mbedls 변경 후

platform_name	platform_name_unique	mount_point	serial_port	target_id	daplink_version
MTS_DRAGONFLY_F411RE	MTS_MDOT_F411RE[0]	/Volumes/MULTITECH	/dev/tty.usbmodem145203	031502210158636D3E1CF145	0221

#2

1. Mbedls 기존

```
WARNING:mbedls.lstools_base:daplink entry: "2600" not found in platform database
```

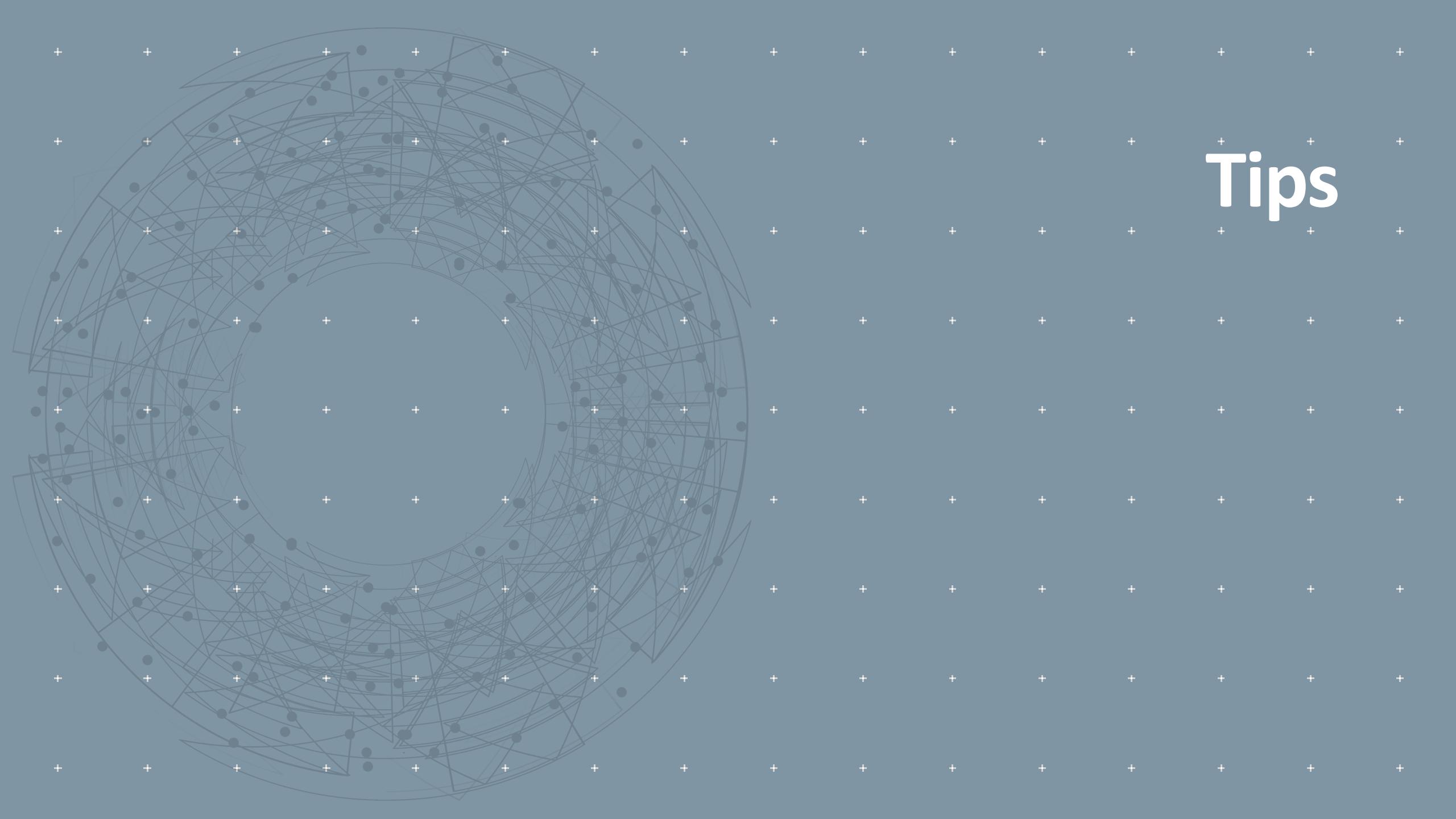
platform_name	platform_name_unique	mount_point	serial_port	target_id	daplink_version
unknown	None[0]	/Volumes/DAPLINK	/dev/tty.usbmodem14302	2600360248824e4500257008dd89000f8761000097969900	0254

2. 아래의 명령으로 2600에 대한 Platform name 추가

```
mbedls --mock 2600:EP_AGORA
```

3. Mbedls 변경 후

platform_name	platform_name_unique	mount_point	serial_port	target_id	daplink_version
EP_AGORA	EP_AGORA[0]	/Volumes/DAPLINK	/dev/tty.usbmodem14302	2600360248824e4500257008dd89000f8761000097969900	0254



Tips

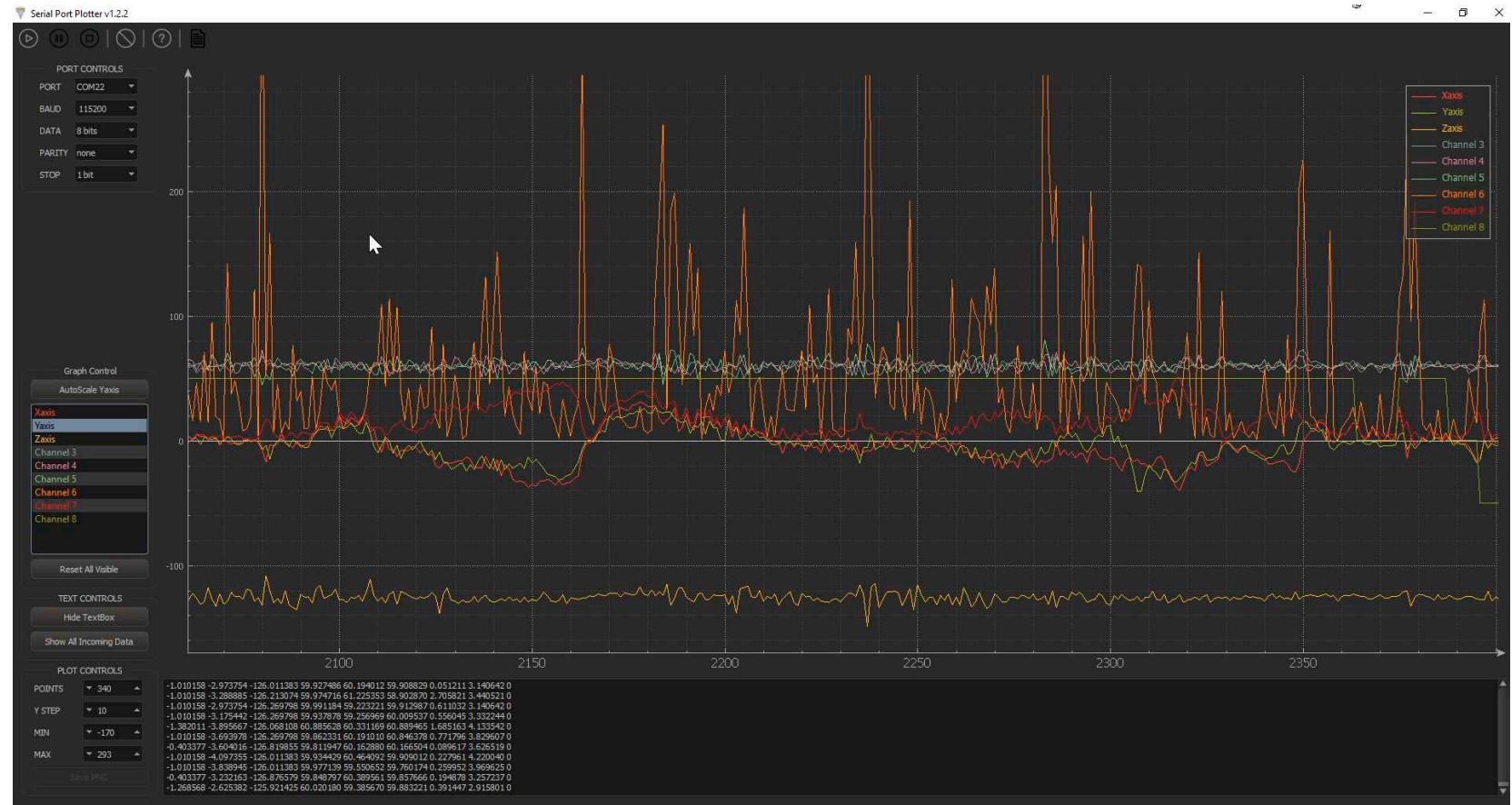
Tips #1 – 개발시 필요한 자료들

- Arm 공식 **example code** 들은..
 - <https://os.mbed.com/teams/mbed-os-examples/code/>
- Git 동영상 강좌
 - <https://www.seoulworkshop.org/tag/Github2019?page=1>

Tips #2 – Serial port plotter

- https://github.com/CieNTi/serial_port_plotter
 - Download : https://github.com/Eriobis/serial_port_plotter/releases/tag/v1.3.0

```
/* Example: Plot two values */  
printf ("%d %d;", data1, data2);
```





Thank You
Danke
Merci

谢谢
ありがとう
Gracias
Kiitos
감사합니다