ARM® mbed™ introduction

Development Platform for Devices

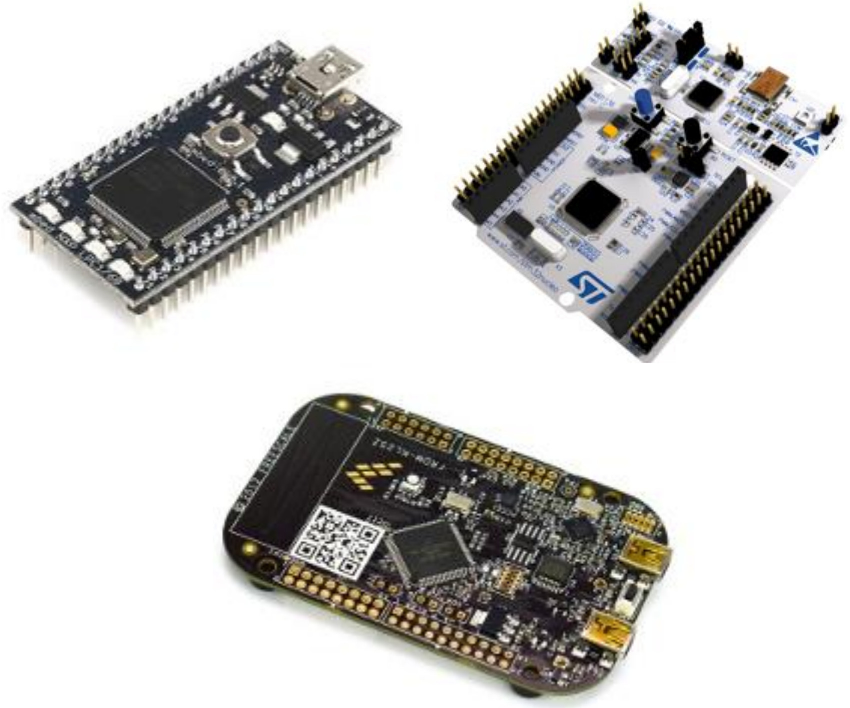
ARM K.K.
Toyomasa Watarai

mbed Overview

About mbed…

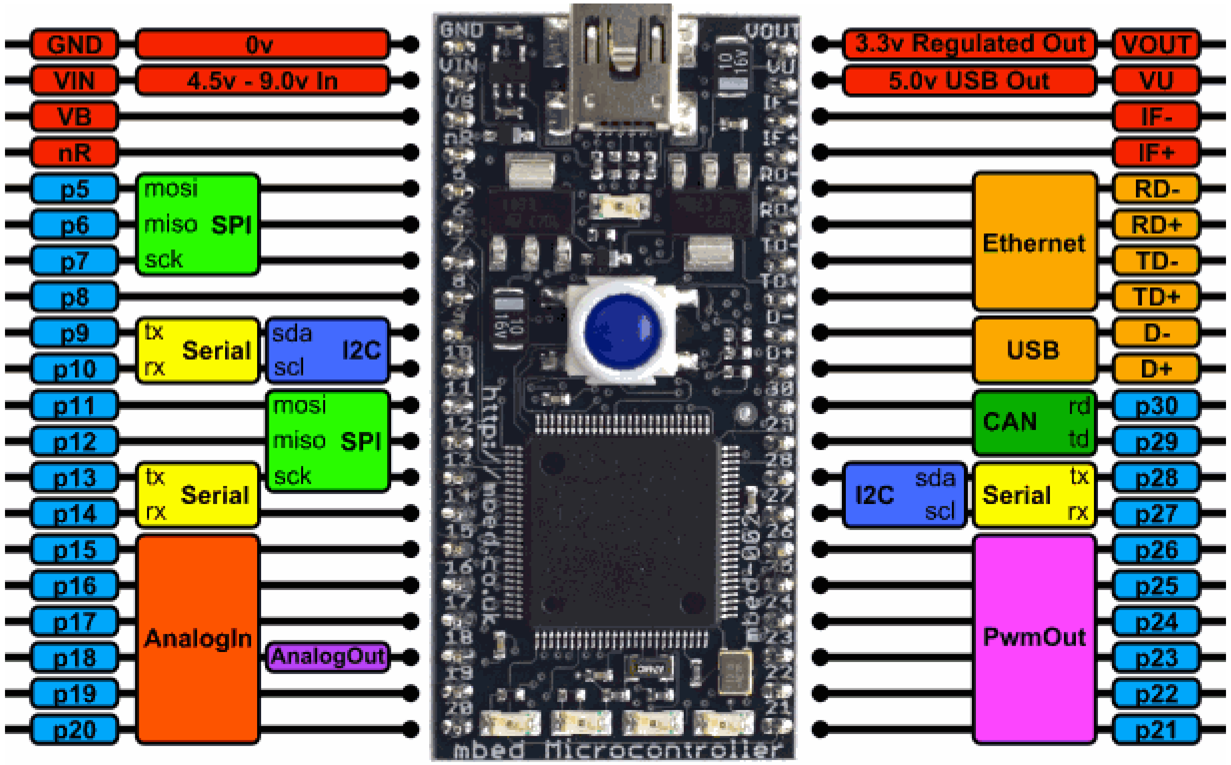
- IoT device development platform
- ARM® Cortex®-M based MCU
- Online compiler

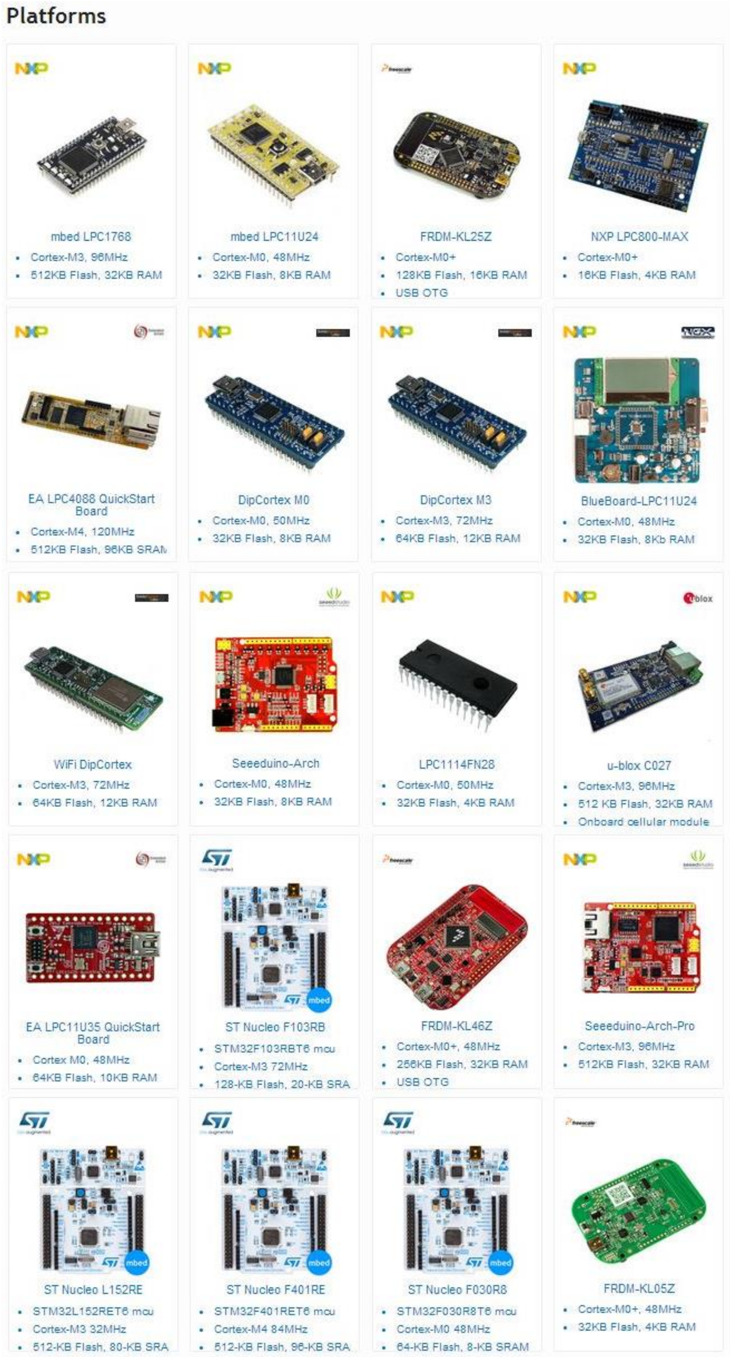
- Concept
  - Rapid prototyping tool
  - Connect to component (sensors and network modules)
  - Great portability using common APIs



mbed-enabled platforms

- 60 mbed-enabled platforms
  - NXP, Freescale, STMicroelectronics, Nordic Renesas, SiliconLab Maxim Integrated




Platforms

mbed LPC1768
- Cortex-M3, 96MHz
- 512KB Flash, 32KB RAM

mbed LPC11U24
- Cortex-M0, 48MHz
- 32KB Flash, 8KB RAM

FRDM-KL25Z
- Cortex-M0+
- 128KB Flash, 16KB RAM
- USB OTG

NXP LPC800-MAX
- Cortex-M0+
- 16KB Flash, 4KB RAM

EA LPC4088 QuickStart Board
- Cortex-M4, 120MHz
- 512KB Flash, 96KB SRAM

DipCortex M0
- Cortex-M0, 50MHz
- 32KB Flash, 8KB RAM

DipCortex M3
- Cortex-M3, 72MHz
- 64KB Flash, 12KB RAM

BlueBoard-LPC11U24
- Cortex-M0, 48MHz
- 32KB Flash, 8Kb RAM

WiFi DipCortex
- Cortex-M3, 72MHz
- 64KB Flash, 12KB RAM

Seeeduino-Arch
- Cortex-M0, 48MHz
- 32KB Flash, 8KB RAM

LPC1114FN28
- Cortex-M0, 50MHz
- 32KB Flash, 4KB RAM

u-blox C027
- Cortex-M3, 96MHz
- 512 KB Flash, 32KB RAM
- Onboard cellular module

EA LPC11U35 QuickStart Board
- Cortex M0, 48MHz
- 64KB Flash, 10KB RAM

ST Nucleo F103RB
- STM32F103RBT6 mcu
- Cortex-M3 72MHz
- 128-KB Flash, 20-KB SRA

FRDM-KL46Z
- Cortex-M0+, 48MHz
- 256KB Flash, 32KB RAM
- USB OTG

Seeeduino-Arch-Pro
- Cortex-M3, 96MHz
- 512KB Flash, 32KB RAM

ST Nucleo L152RE
- STM32L152RET6 mcu
- Cortex-M3 32MHz
- 512-KB Flash, 80-KB SRA

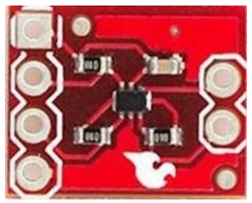
ST Nucleo F401RE
- STM32F401RET6 mcu
- Cortex-M4 84MHz
- 512-KB Flash, 96-KB SRA

ST Nucleo F030R8
- STM32F030R8T6 mcu
- Cortex-M0 48MHz
- 64-KB Flash, 8-KB SRAM

FRDM-KL05Z
- Cortex-M0+, 48MHz
- 32KB Flash, 4KB RAM

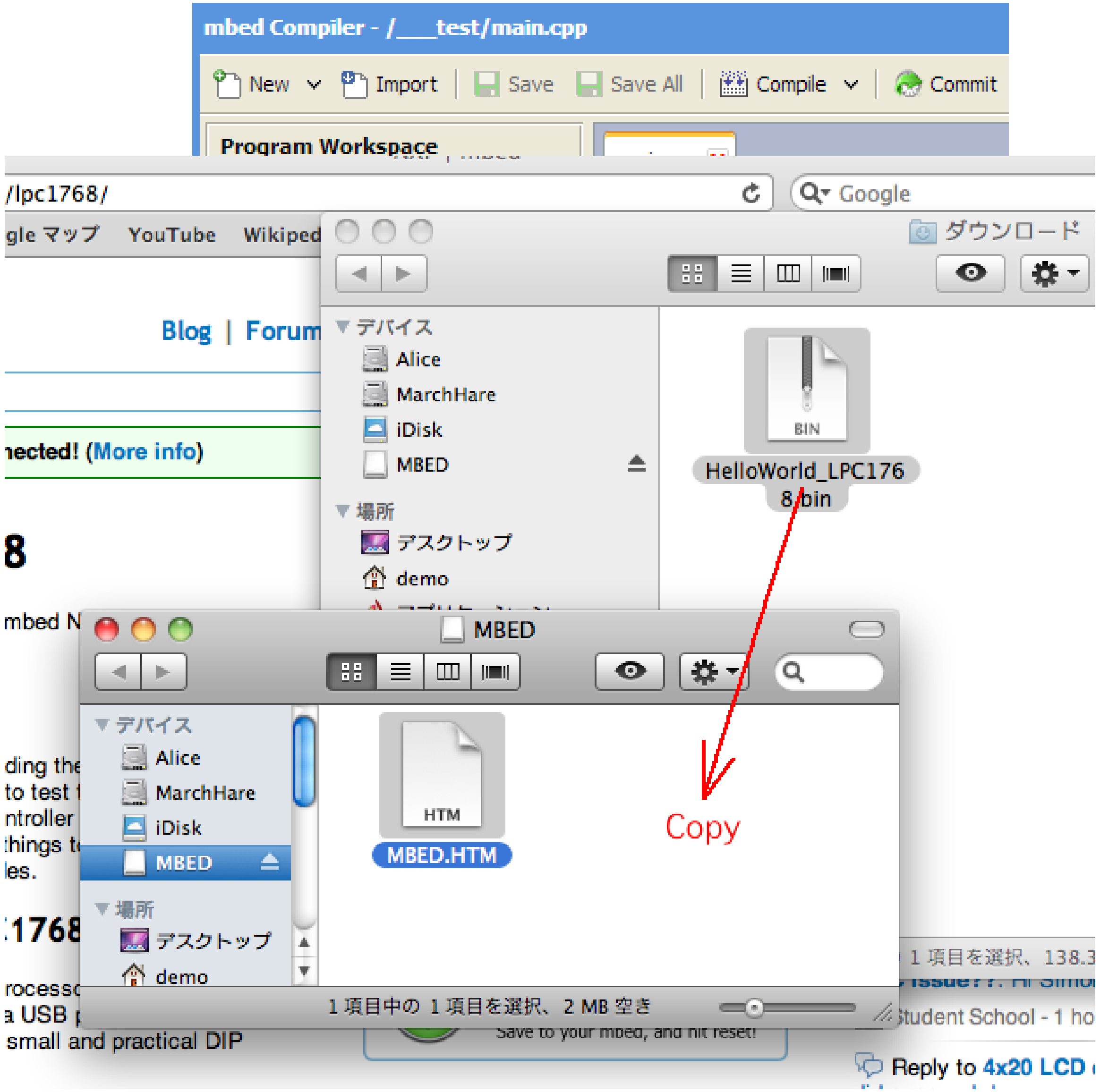
How you can use

- Common APIs by official mbed SDK (C++ class library)
  - Digital In/Out, Analog In/Out, Network, Serial, Timer Interrupt, file system, RTOS
- Re-use libraries by mbed community
  - USB, Display, Audio
  - 2,000+ and more
- Component database
  - Sensors
  - Communication modules
  - Display modules
  - Import and re-use



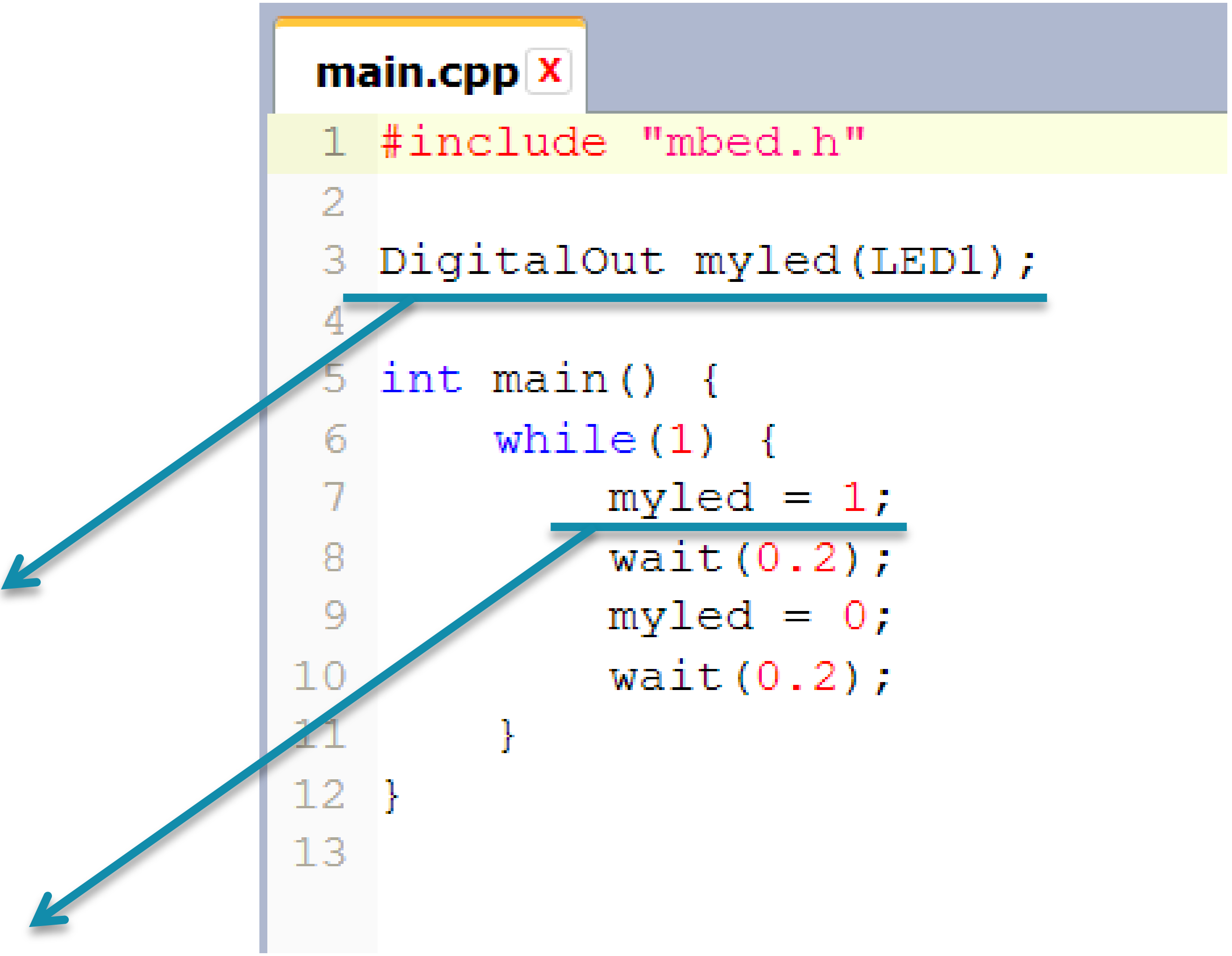
How you can develop

- Development site
  - Internet access and web browser
  - https://developer.mbed.org/
- Online IDE
  - You can get binary by pressing [Compile] button
- Flash to the target device
  - USB drag&drop



Hello mbed world! … Blink LED

1. Connect mbed and PC by USB cable
2. Create new project
3. Build
4. Drag&Drop the binary



```
#include "mbed.h"

DigitalOut myled(LED1);

int main() {
    while(1) {
        myled = 1;
        wait(0.2);
        myled = 0;
        wait(0.2);
    }
}

```

Constructor of the DigitalOut

Write specified GPIO port

Example of API（DigitalOut Class）

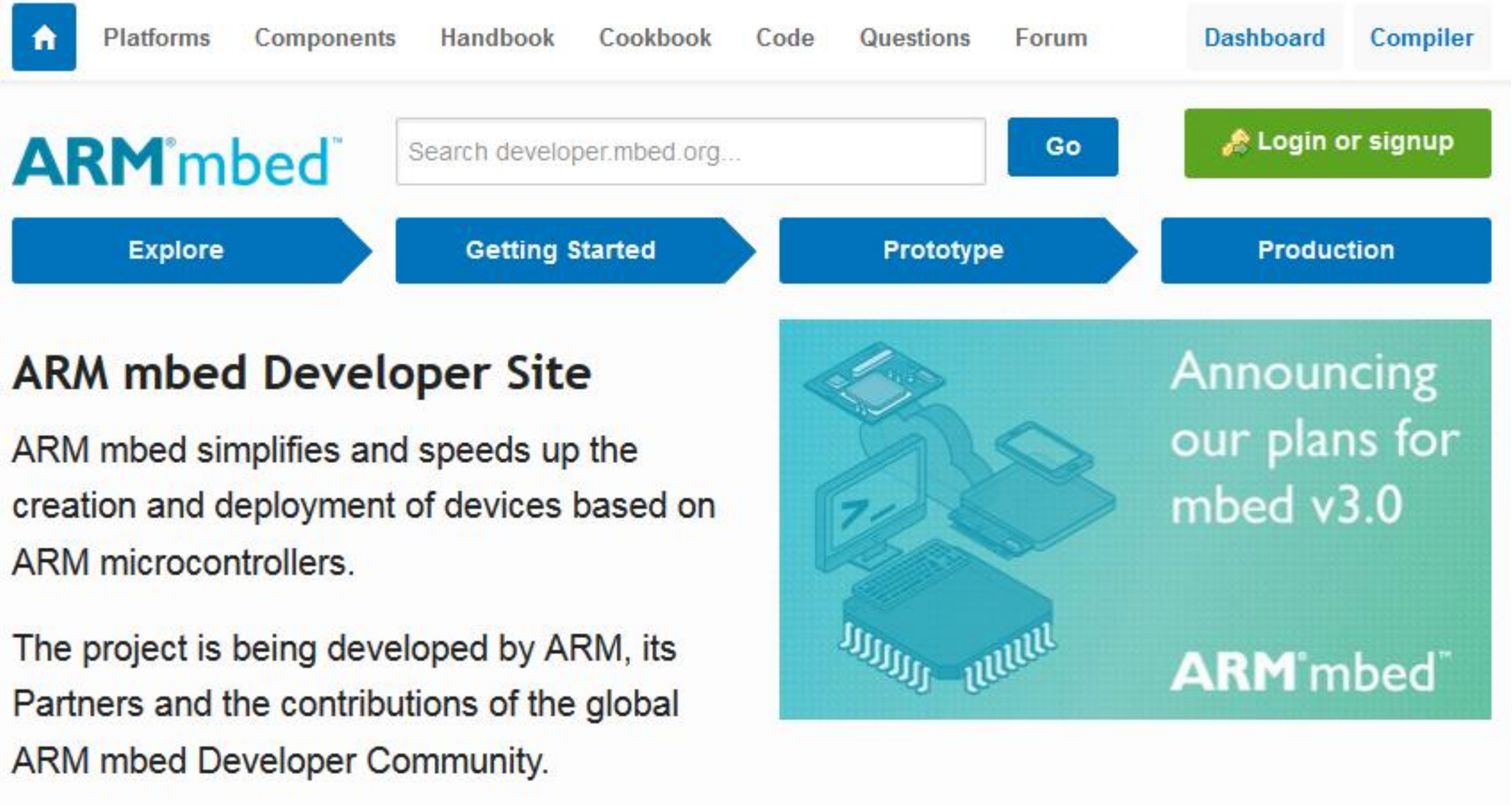
mbed - DigitalOut Class Reference

Public Member Functions

	DigitalOut (PinName pin) Create a **DigitalOut** connected to the specified pin.
	DigitalOut (PinName pin, int value) Create a **DigitalOut** connected to the specified pin.
void	**write** (int value) Set the output, specified as 0 or 1 (int)
int	**read** () Return the output setting, represented as 0 or 1 (int)
DigitalOut &	**operator=** (int value) A shorthand for **write()**
	operator int () A shorthand for **read()**

http://developer.mbed.org

- Platforms
- Components
- Handbook
- Cookbook
- Code
- Questions
- Forum



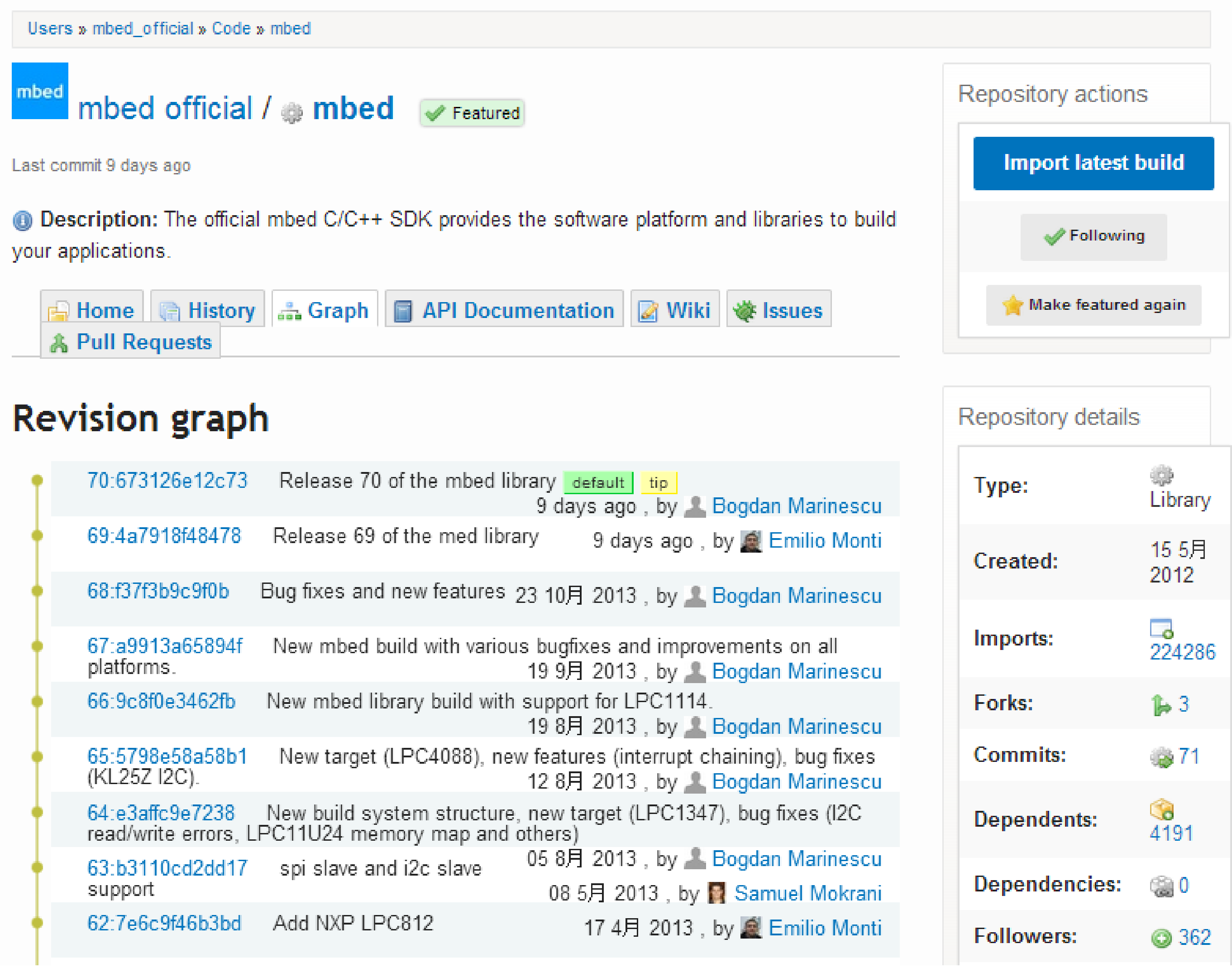
ARM mbed Developer Site

ARM mbed simplifies and speeds up the creation and deployment of devices based on ARM microcontrollers.

The project is being developed by ARM, its Partners and the contributions of the global ARM mbed Developer Community.

Source code management

- Code repository
  - Corroboration work flow
  - Integrated by online
- Support offline tool
  - Mercurial



Users » mbed_official » Code » mbed

mbed

mbed official / mbed ✓ Featured

Last commit 9 days ago

Description: The official mbed C/C++ SDK provides the software platform and libraries to build your applications.

Revision graph

70:673126e12c73 Release 70 of the mbed library default tip
9 days ago , by Bogdan Marinescu

69:4a7918f48478 Release 69 of the med library 9 days ago , by Emilio Monti

68:f37f3b9c9f0b Bug fixes and new features 23 10月 2013 , by Bogdan Marinescu

67:a9913a65894f New mbed build with various bugfixes and improvements on all platforms.
19 9月 2013 , by Bogdan Marinescu

66:9c8f0e3462fb New mbed library build with support for LPC1114.
19 8月 2013 , by Bogdan Marinescu

65:5798e58a58b1 New target (LPC4088), new features (interrupt chaining), bug fixes (KL25Z I2C).
12 8月 2013 , by Bogdan Marinescu

64:e3affc9e7238 New build system structure, new target (LPC1347), bug fixes (I2C read/write errors, LPC11U24 memory map and others)
05 8月 2013 , by Bogdan Marinescu

63:b3110cd2dd17 spi slave and i2c slave support
08 5月 2013 , by Samuel Mokrani

62:7e6c9f46b3bd Add NXP LPC812 17 4月 2013 , by Emilio Monti

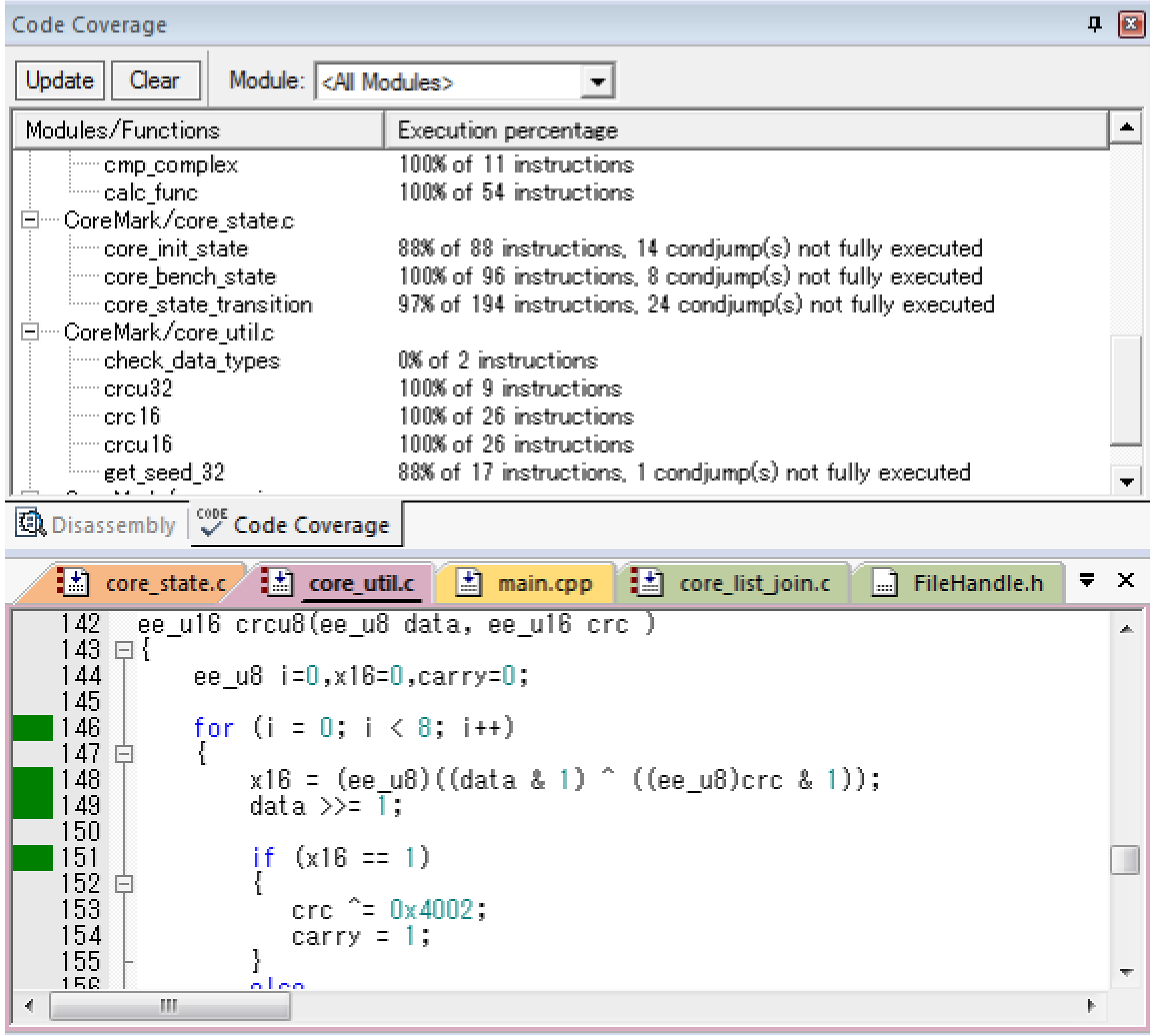
Repository actions

Repository details

Type:	Library
Created:	15 5月 2012
Imports:	224286
Forks:	3
Commits:	71
Dependents:	4191
Dependencies:	0
Followers:	362

Off-line IDEs and debug

- printf() debugging
- Off-line IDEs can be used by export your project
  - Keil uVision4 (MDK-ARM), DS-5
  - NXP LPCXpresso IDE
  - IAR EWARM
- Debug functions by CMSIS-DAP
  - C/C++ source level debug, disassenble
  - Write to flash memory
  - Hardware breakpoints (4 or 8)
  - Watchpoints (2 or 4)
  - Access to CPU and peripheral registers



Module: <All Modules>

Modules/Functions	Execution percentage
cmp_complex	100% of 11 instructions
calc_func	100% of 54 instructions
CoreMark/core_state.c	
core_init_state	88% of 88 instructions, 14 condjump(s) not fully executed
core_bench_state	100% of 96 instructions, 8 condjump(s) not fully executed
core_state_transition	97% of 194 instructions, 24 condjump(s) not fully executed
CoreMark/core_util.c	
check_data_types	0% of 2 instructions
crcu32	100% of 9 instructions
crc16	100% of 26 instructions
crcu16	100% of 26 instructions
get_seed_32	88% of 17 instructions, 1 condjump(s) not fully executed

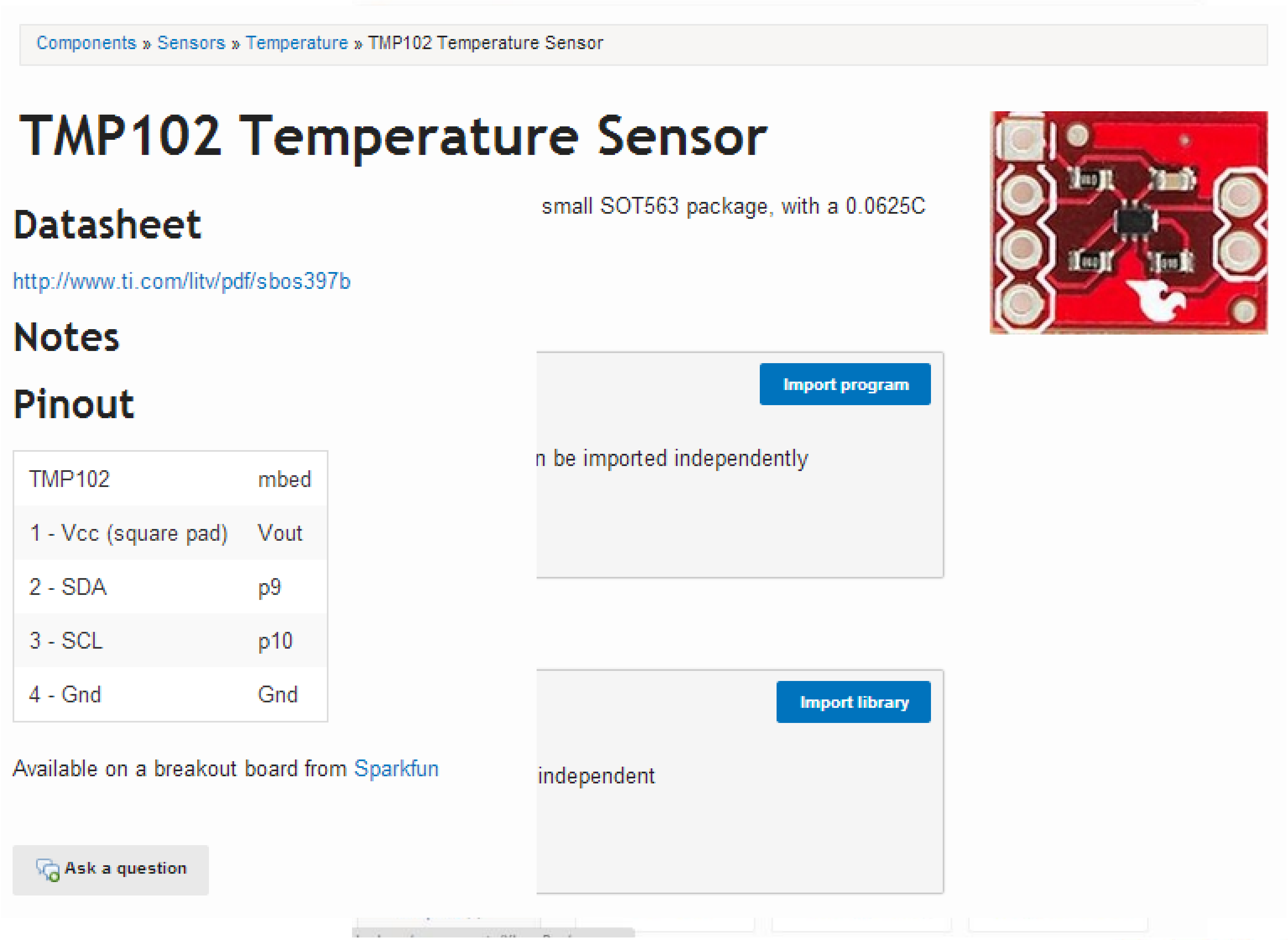
```
ee_u16 crcu8(ee_u8 data, ee_u16 crc )
{
    ee_u8 i=0,x16=0,carry=0;

    for (i = 0; i < 8; i++)
    {
        x16 = (ee_u8)((data & 1) ^ ((ee_u8)crc & 1));
        data >>= 1;

        if (x16 == 1)
        {
            crc ^= 0x4002;
            carry = 1;
        }
        else
```

Component library

- Components
  - Actuators
  - Communication
  - Display
  - Expansion boards
  - Internet of Things
  - Robotics
  - Sensors
  - Storage
  - Other



Components » Sensors » Temperature » TMP102 Temperature Sensor

TMP102 Temperature Sensor

small SOT563 package, with a 0.0625C

Datasheet

http://www.ti.com/litv/pdf/sbos397b

Notes

Pinout

TMP102	mbed
1 - Vcc (square pad)	Vout
2 - SDA	p9
3 - SCL	p10
4 - Gnd	Gnd

Available on a breakout board from Sparkfun

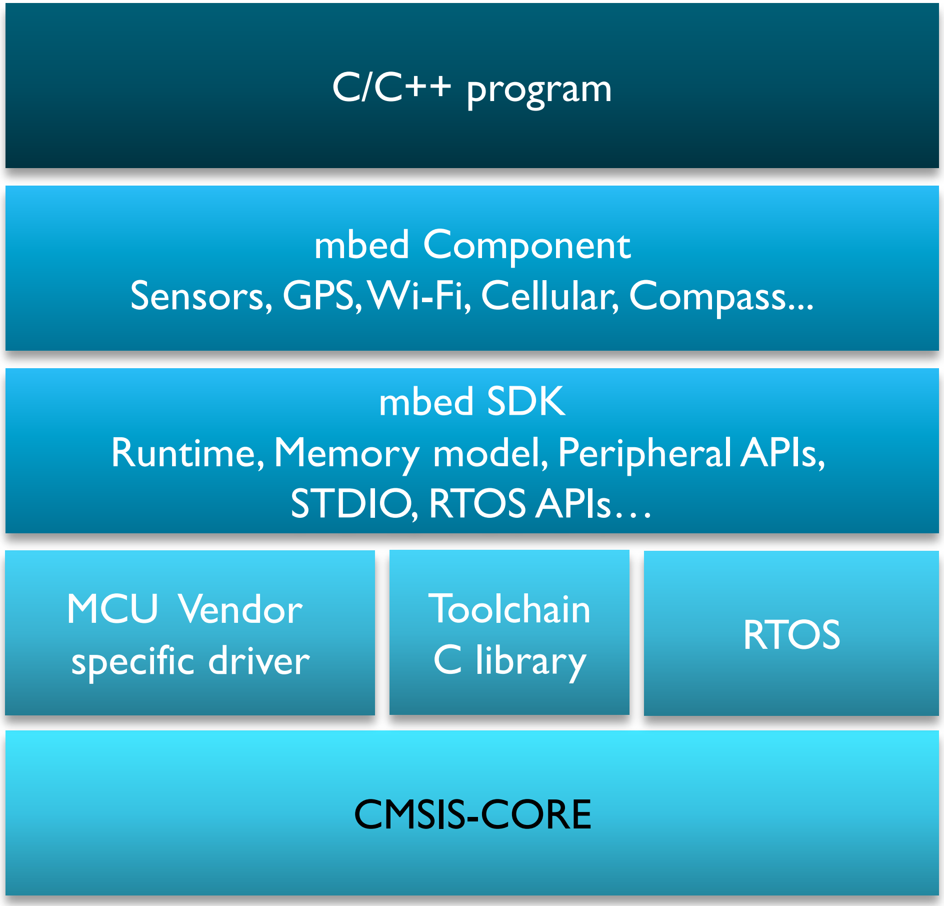
n be imported independently

independent

mbed SDK

mbed SDK

- C/C++ SDK for ARM Microcontrollers
  - High-level APIs and standard environment
  - Low level control as needed
  - Portable across different ARM silicon vendor MCUs
- Built on industry standard technology
  - ANSI/ISO C/C++
  - CMSIS Compliant
  - Compatible with all major professional MCU tools
- Open Source
  - Released under permissive Apache 2.0 license
  - Suitable for commercial and non-commercial use
  - Managed, maintained and tested by ARM



C/C++ program

mbed Component
Sensors, GPS, Wi-Fi, Cellular, Compass...

mbed SDK
Runtime, Memory model, Peripheral APIs, STDIO, RTOS APIs…

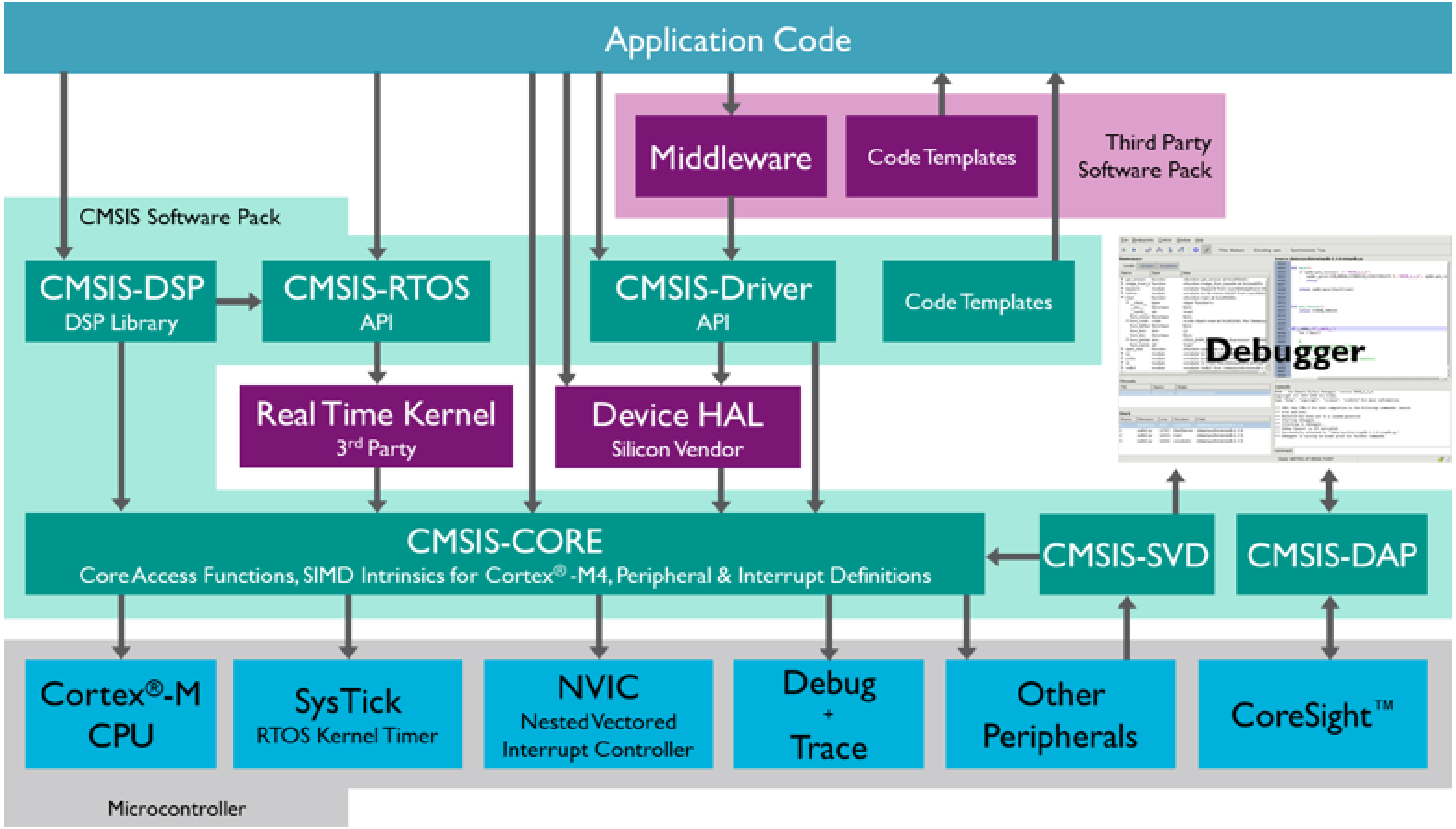
MCU Vendor specific driver

Toolchain C library

RTOS

CMSIS-CORE

CMSIS : Cortex Microcontroller Software Interface Standard

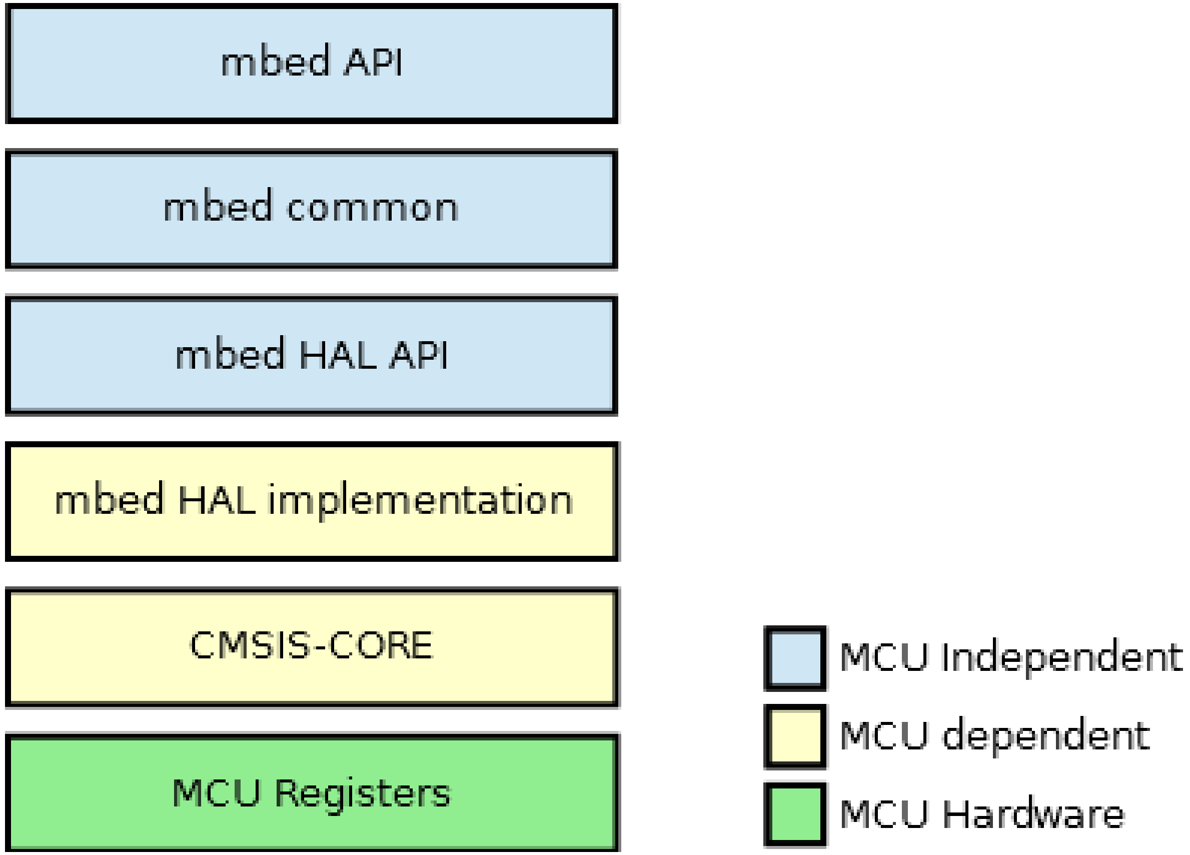


CMSIS on mbed platform

- CMSIS-CORE
  - API for the Cortex-M processor core and peripherals
- CMSIS-RTOS API
  - ‘mbed-rtos’ library uses this API
- CMSIS-DAP
  - Debug Access Port, HDK provide interface firmware (USB D&D, Virtual Com port, Debug)
- CMSIS-DSP
  - DSP library correction, ‘mbed-dsp’ library support this

SDK porting for MCU platform

- HAL implementation
  - Semiconductor partner implement this
  - Support Cortex-M target devices
  - Implement on the CMSIS-CORE layer



mbed API

mbed common

mbed HAL API

mbed HAL implementation

CMSIS-CORE

MCU Registers

🟦 MCU Independent

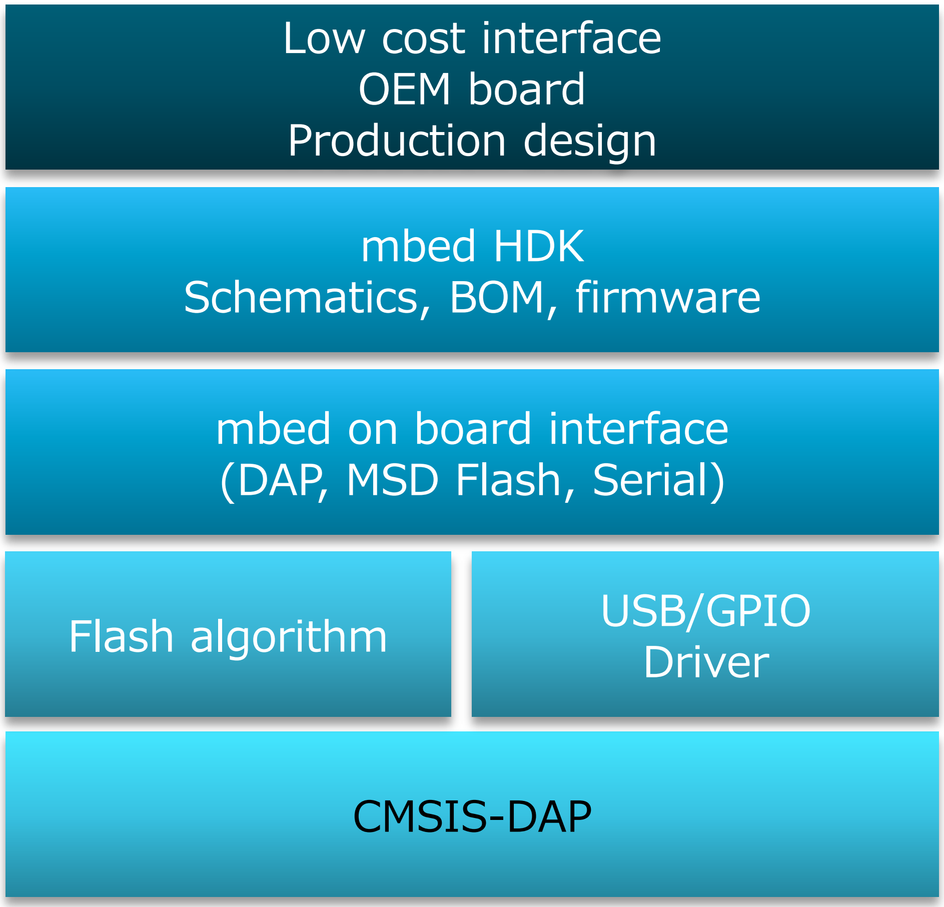
🟨 MCU dependent

🟩 MCU Hardware

mbed HDK

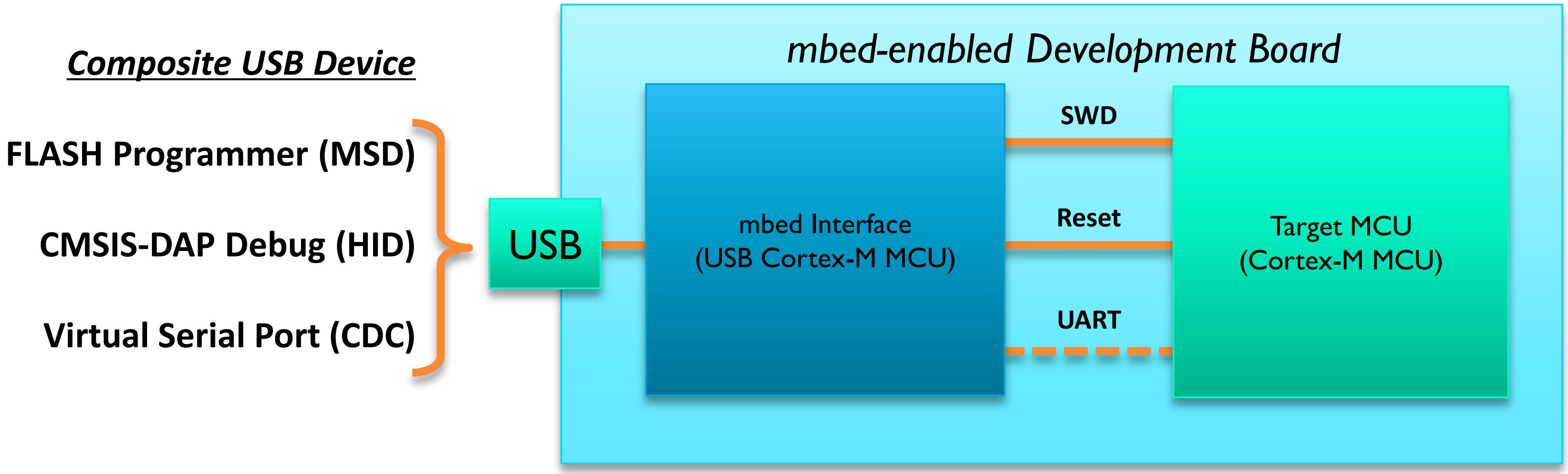
mbed HDK

- Recipes for creating low cost hardware that can leverage mbed platform
  - Open Source CMSIS-DAP Interface Firmware
  - Schematic reference designs
  - USB D&D programing
  - USB virtual serial port
  - Debugger connection



CMSIS-DAP interface firmware

- On-board USB interface for low-cost development boards
  - Supports driverless MSD Programming and CMSIS-DAP Debug
  - Interface implemented as firmware on selected Cortex-M MCUs



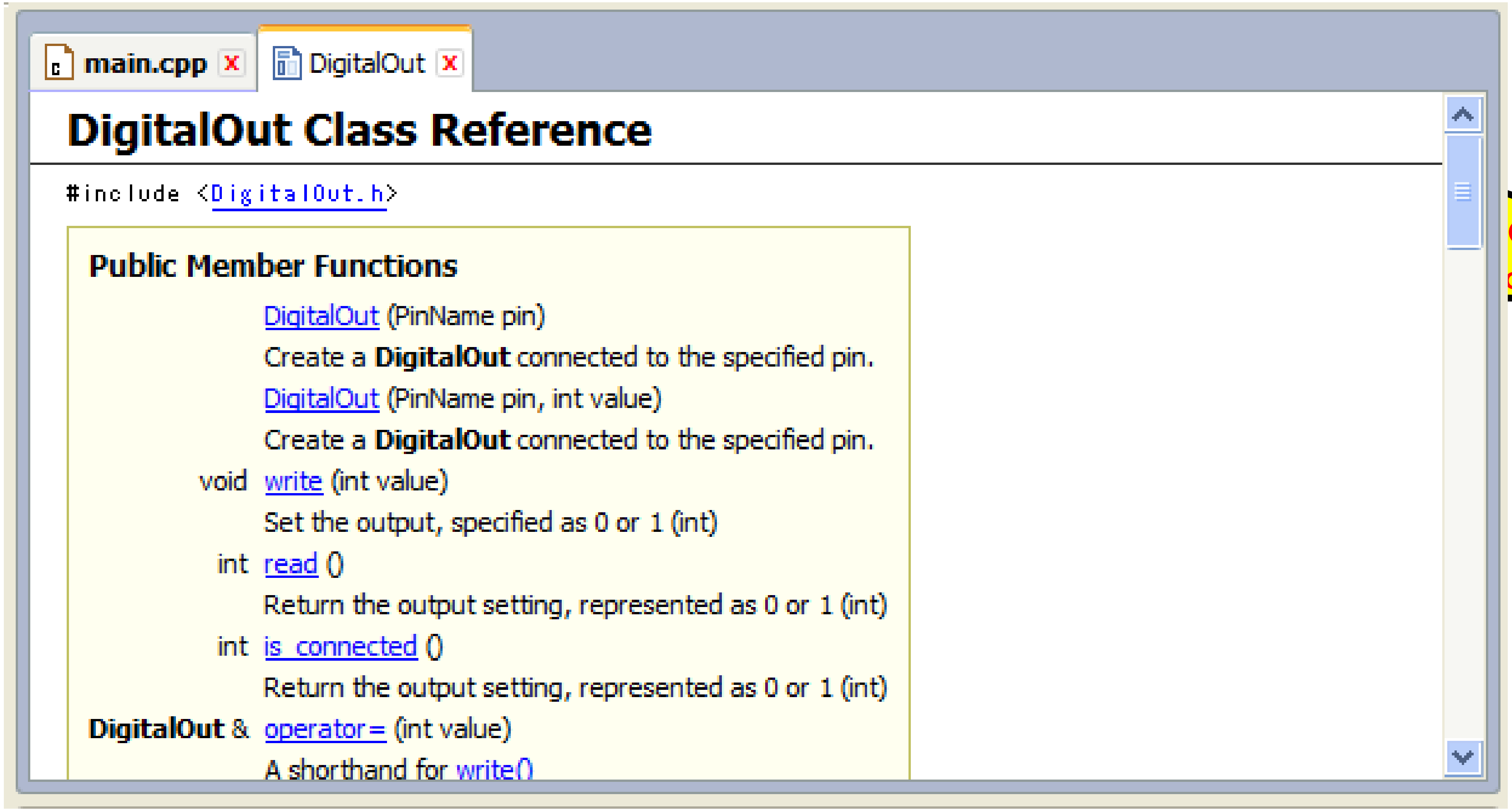
Enables simple USB drag-n-drop reprogramming of demo code through to full debug connection to ARM toolchains

mbed APIs and libraries

List of mbed official APIs

Digital input	**DigitalIn**
Digital output	**DigitalOut**
Digital input/output	**DigitalInOut**
Analog input	AnalogIn
Analog output	AnalogOut
GPIO Interrupt	InterruptIn
PWM output	PwmOut
Serial bus	Serial, SPI, SPISlave
I^2C bus	I2C, I2CSlave
Interval event	**Ticker**
USB	USBDevice, USBHost
Wait	**wait**

API Class reference



DigitalOut Class Reference

```
#include <DigitalOut.h>
```

Public Member Functions

	DigitalOut (PinName pin)
	Create a **DigitalOut** connected to the specified pin.
	DigitalOut (PinName pin, int value)
	Create a **DigitalOut** connected to the specified pin.
void	write (int value)
	Set the output, specified as 0 or 1 (int)
int	read ()
	Return the output setting, represented as 0 or 1 (int)
int	is_connected ()
	Return the output setting, represented as 0 or 1 (int)
DigitalOut &	operator= (int value)
	A shorthand for write()

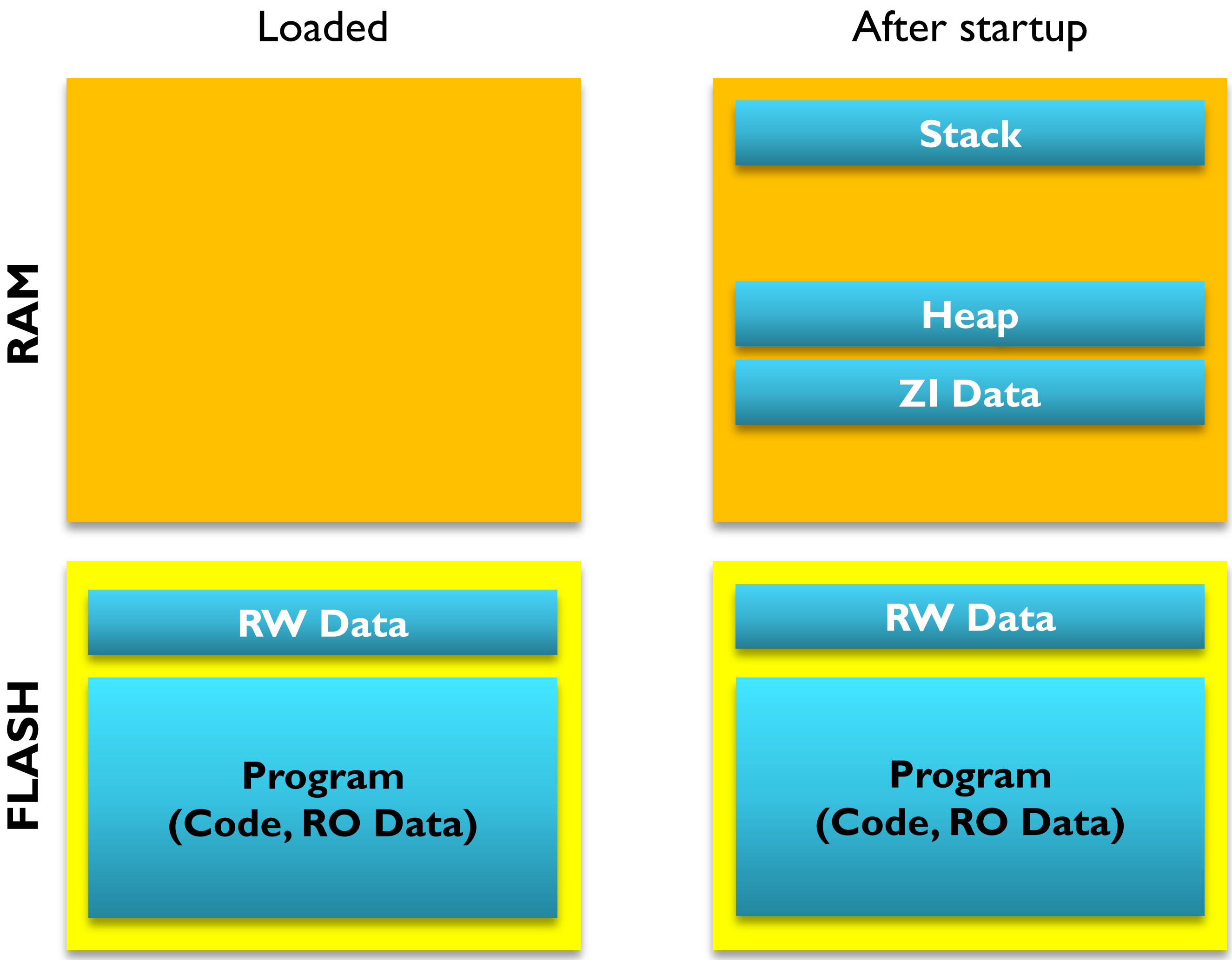
Click this
cument icon

Memory model

- FLASH
  - Stores program, unchanged data
- RAM
  - Stores data, stack and heap

- Stack
  - Stores fixed lifetime variables
- Heap
  - Dynamic memory allocation

- More detail
  - https://developer.mbed.org/handbook/Memory-Model
  - https://developer.mbed.org/handbook/RTOS-Memory-Model



Interrupts

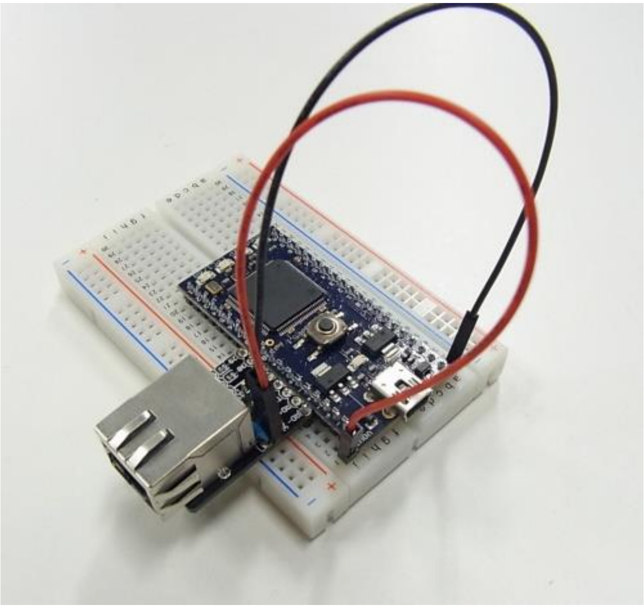
- GPIO interrupt (InterruptIn class)
  - InterruptIn::rise() and fall()
- Ticker (Timer) interrupt
  - Ticker::attach() and detach()
- UART interrupt
  - Serial::attach() and detach()
- SysTick interrupt
  - Used by mbed-rtos library

File System

- LocalFileSystem
  - 2MB flash memory as USB mass storage
  - Can be accessed by mbed microcontroller and host PC
  - Support only mbed NXP LPC1768 and LPC11U24
- SDCardFileSystem
  - Based on SPI
  - FAT12, FAT16 and FAT32
  - SD and SDHC cards up to 32GBytes
  - Long filename suport
  - Time stamp (if target has RTC support)

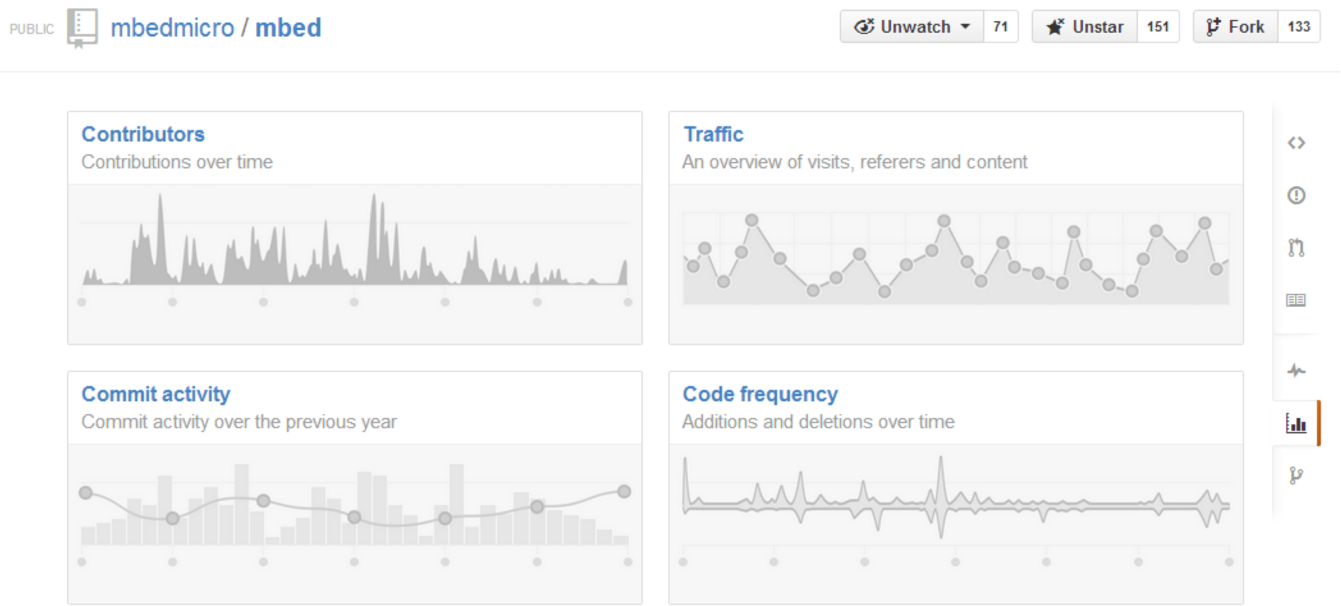
Communication libraries

- EthernetInterface library
  - Simple API to connect to the internet
  - lwIP and Socket library
  - https://developer.mbed.org/components/cat/ethernet/
- WiFiInterface library
  - Compatible with EthernetInterface APIs
  - https://developer.mbed.org/components/cat/wifi/
- Bluetooth Low Energy
  - BLE_API, BLE_Device and a lot of GATT Service examples
  - https://developer.mbed.org/teams/Bluetooth-Low-Energy/



Open source projects

- GitHub code repository
  - https://github.com/mbedmicro/
- mbed SDK/HDK
  - mbed (mbed SDK)
  - CMSIS-DAP (mbed HDK firmware)
  - PyOCD (Python library for HDK)
- mbed SDK repositry
  - 4,000+ commits
  - 120+ contributors
  - 430+ forks



Contributors
Contributions over time

Traffic
An overview of visits, referers and content

Commit activity
Commit activity over the previous year

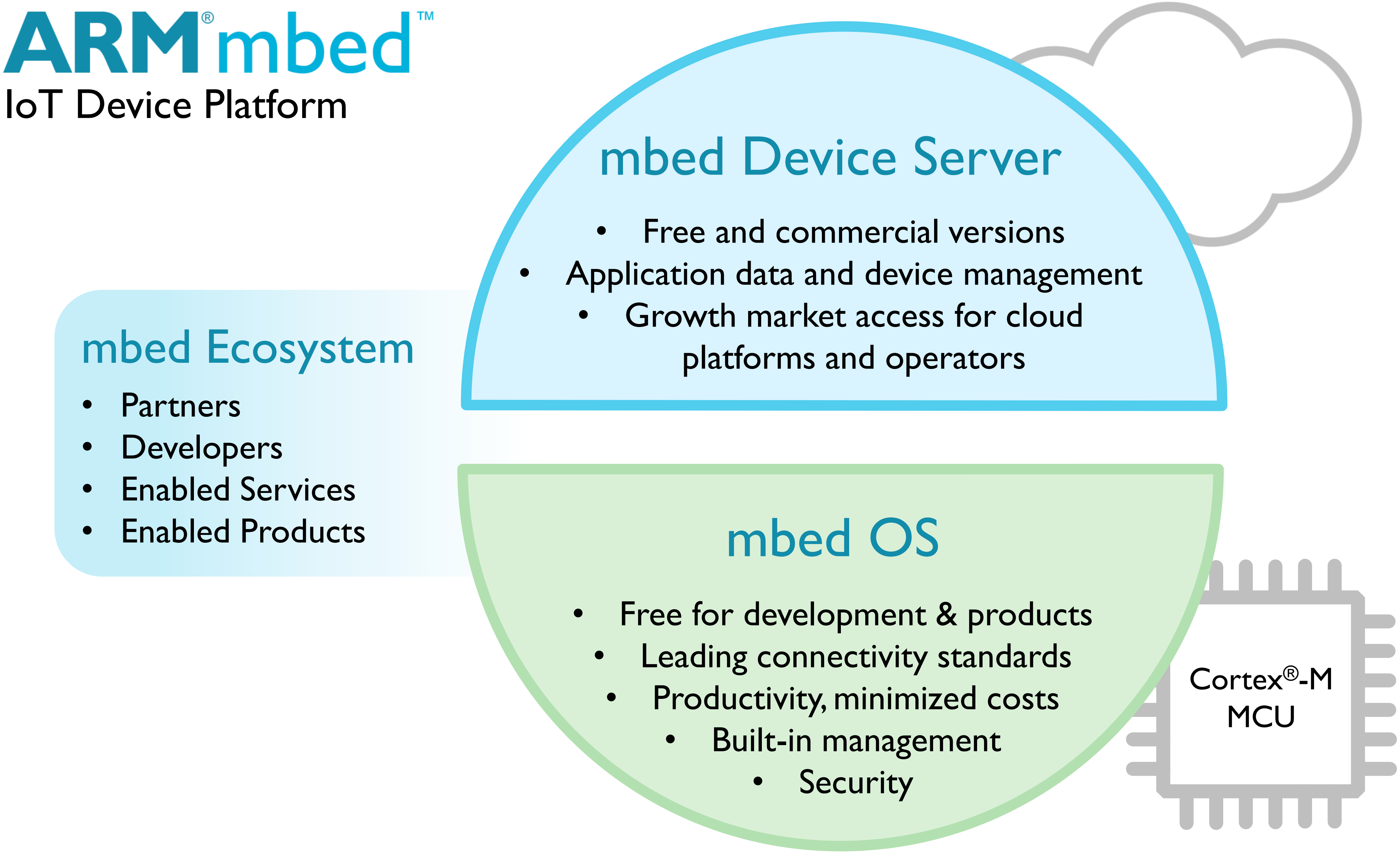
Code frequency
Additions and deletions over time

mbed developer site walkthrough

mbed OS

ARM® mbed™

IoT Device Platform



mbed Device Server

- Free and commercial versions
- Application data and device management
- Growth market access for cloud platforms and operators

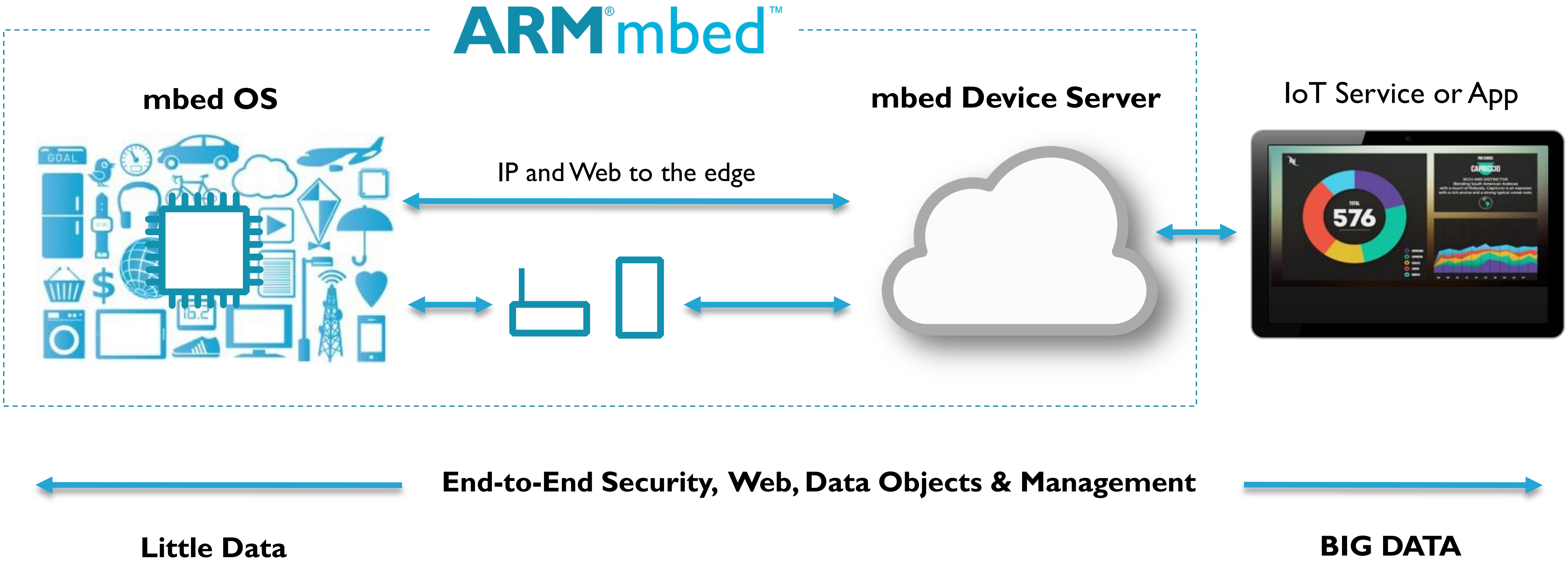
mbed Ecosystem

- Partners
- Developers
- Enabled Services
- Enabled Products

mbed OS

- Free for development & products
- Leading connectivity standards
- Productivity, minimized costs
- Built-in management
- Security

Little Data Enables Big Data



ARM® mbed™

mbed OS

IP and Web to the edge

mbed Device Server

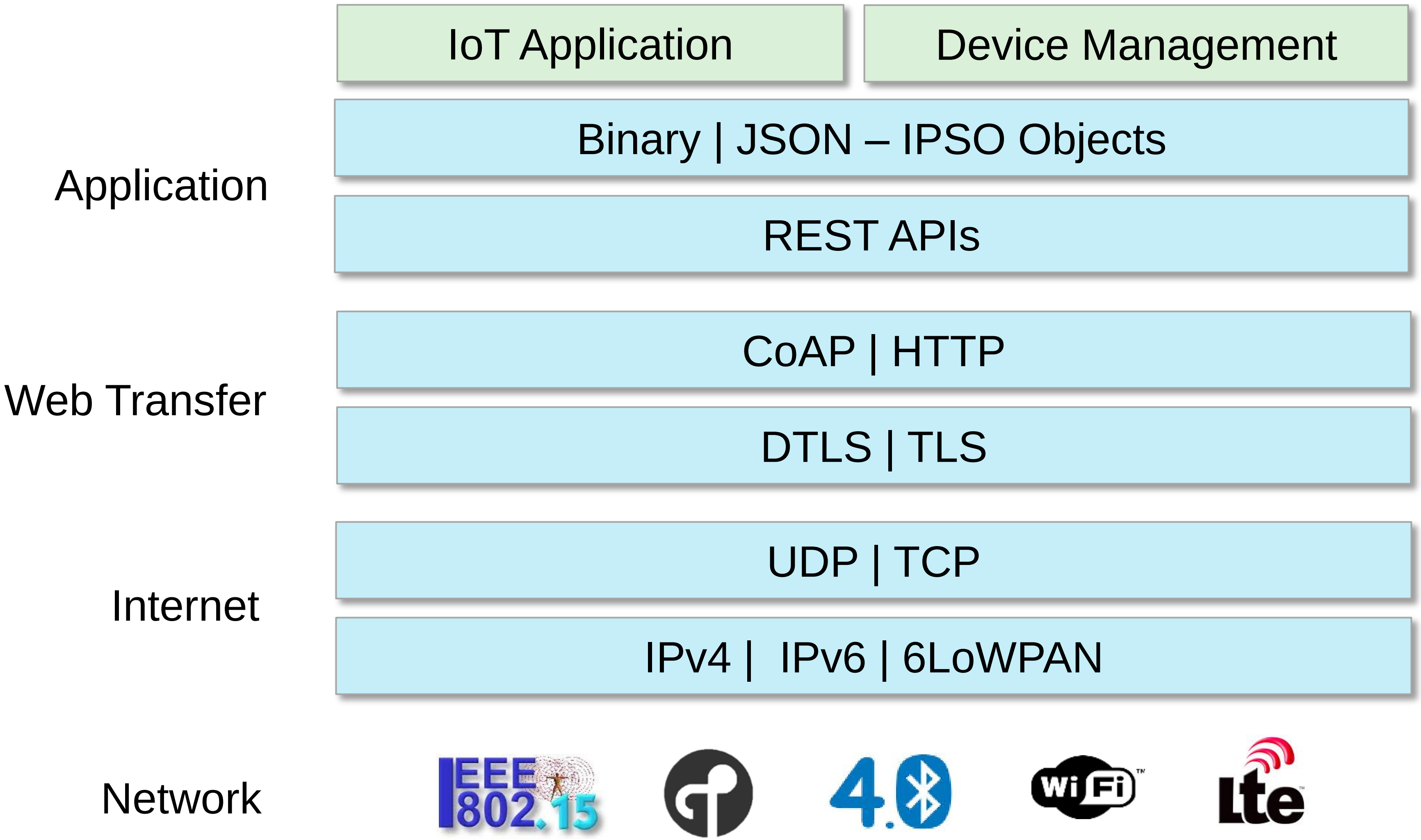
IoT Service or App

End-to-End Security, Web, Data Objects & Management

Little Data

BIG DATA

The I in IoT: web (and IP) protocols to the edge



Application

IoT Application | Device Management

Binary | JSON – IPSO Objects

REST APIs

Web Transfer

CoAP | HTTP

DTLS | TLS

Internet

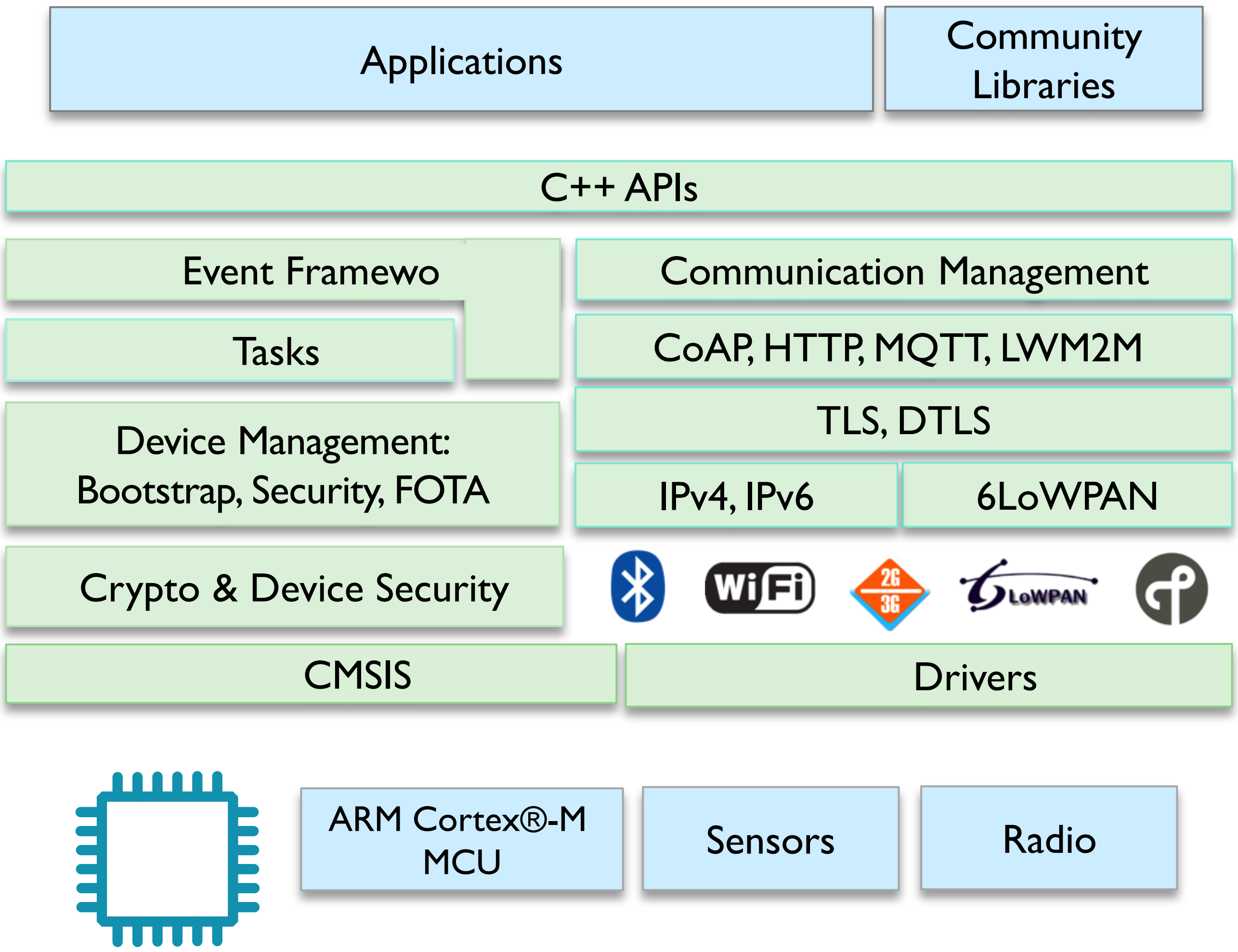
UDP | TCP

IPv4 | IPv6 | 6LoWPAN

Network

mbed OS Roadmap 2015

- Minimize time-to-market
- Low-power by design
- Complete security solution
- Top connectivity standards
- Built-in device management



Applications

Community Libraries

C++ APIs

Event Framewo

Tasks

Communication Management

CoAP, HTTP, MQTT, LWM2M

TLS, DTLS

Device Management: Bootstrap, Security, FOTA

IPv4, IPv6

6LoWPAN

Crypto & Device Security

CMSIS

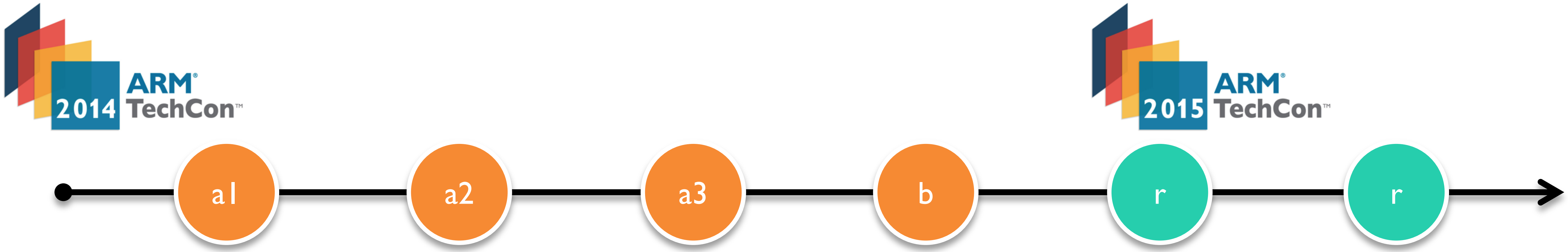
Drivers

ARM Cortex®-M MCU

Sensors

Radio

mbed OS Release Schedule



Release	Alpha 1	Alpha 2	Alpha 3	Beta	Stable 3.0	Stable 3.1
When	Dec ‘14	Mar ‘15	June ‘15	Aug ‘15	Nov ‘15	Feb ‘16
Community				✔	✔	✔
Partner	✔ (on request)	✔	✔	✔	✔	✔

Questions?