

ARTIK Gateway Modules

Wei Xiao

June 18, 2018

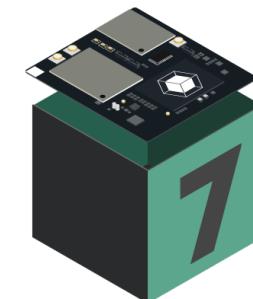
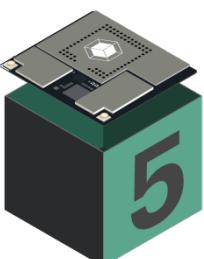
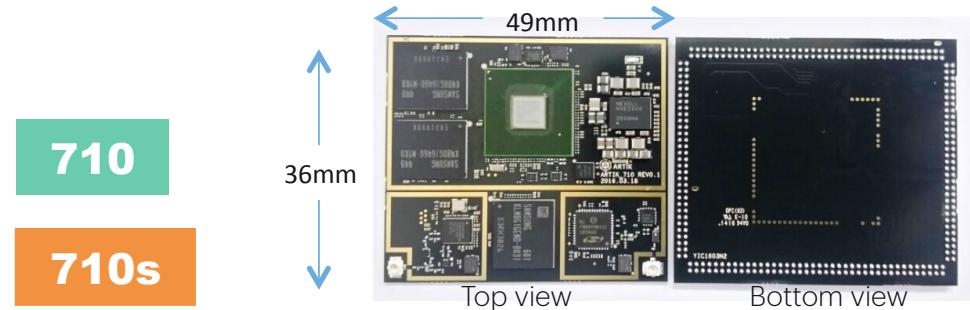
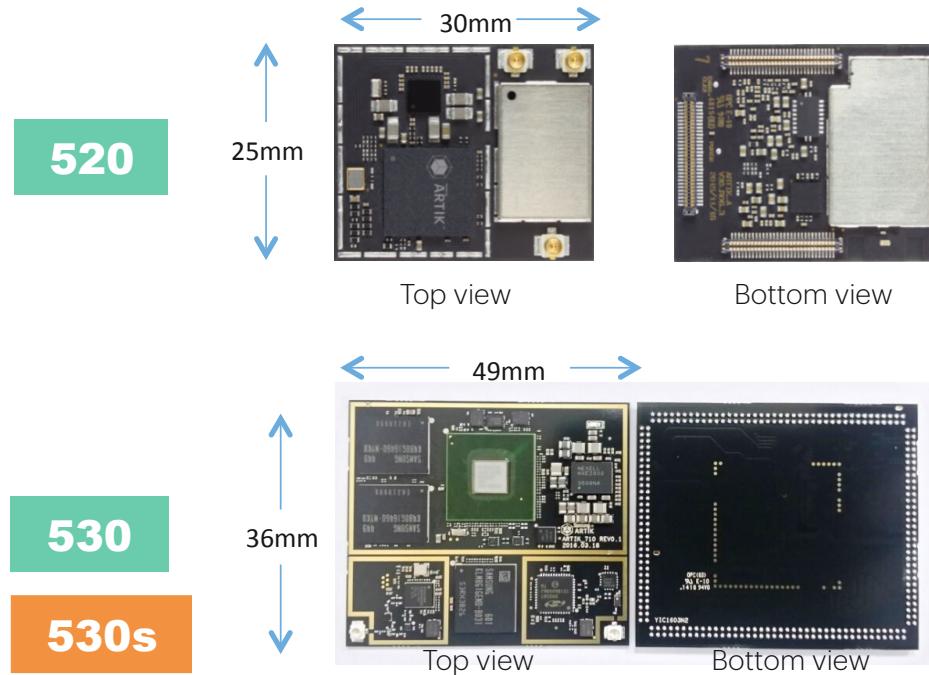


Agenda

- ARTIK Gateway Module Overview
- ARTIK Gateway Module Software Stack
- ARTIK End-to-end Solution
- ARTIK Gateway Module Development
- ARTIK Gateway Module Use Cases

ARTIK Gateway Module Overview

ARTIK High-end module



Samsung ARTIK™ 530/530s (512 MB, 1 GB) mid-range gateway

Secure, fully-integrated IoT solution



- Industrial and home gateways
- Voice-controlled speakers
- Building zone controllers
- Display-based healthcare monitors



Processor	CPU: 4x ARM® Cortex® A9 @ 1.2 GHz GPU: 3D graphics accelerator
Memory	DRAM: 512 MB/1 GB DDR3 Flash: 4 GB eMMC v4.5
Multimedia	Camera I/F: 4-lane MIPI CSI up to 5MP Display: 4-lane MIPI DSI, HDMI 1.4 a or LVDS (1280 x 720 @ 60 fps) Audio: 2x I2S audio input/output
Connectivity	WLAN (Wi-Fi): IEEE 802.11 b/g/n single-band SISO Bluetooth: 4.2+ Smart 802.15.4: Zigbee, Thread Ethernet: 10/100/1000 Base-T MAC (external PHY required)
Security	Secure element, EAL Level 5, unique device certificate and keys, PKI with mutual authentication to cloud, hardware crypto engine; secure boot*, KMS*, TEE*, *S-modules
I/O	GPIO, UART, I2C, SPI, USB Host, USB OTG, HSIC, ADC, PWM, I2S, JTAG
Temperature range	-25° to 85° (°C)
Size	36 mm W x 49 mm H x 3.4 mm D

Samsung ARTIK™ 710/710s high-end gateway

Secure, fully-integrated IoT solution

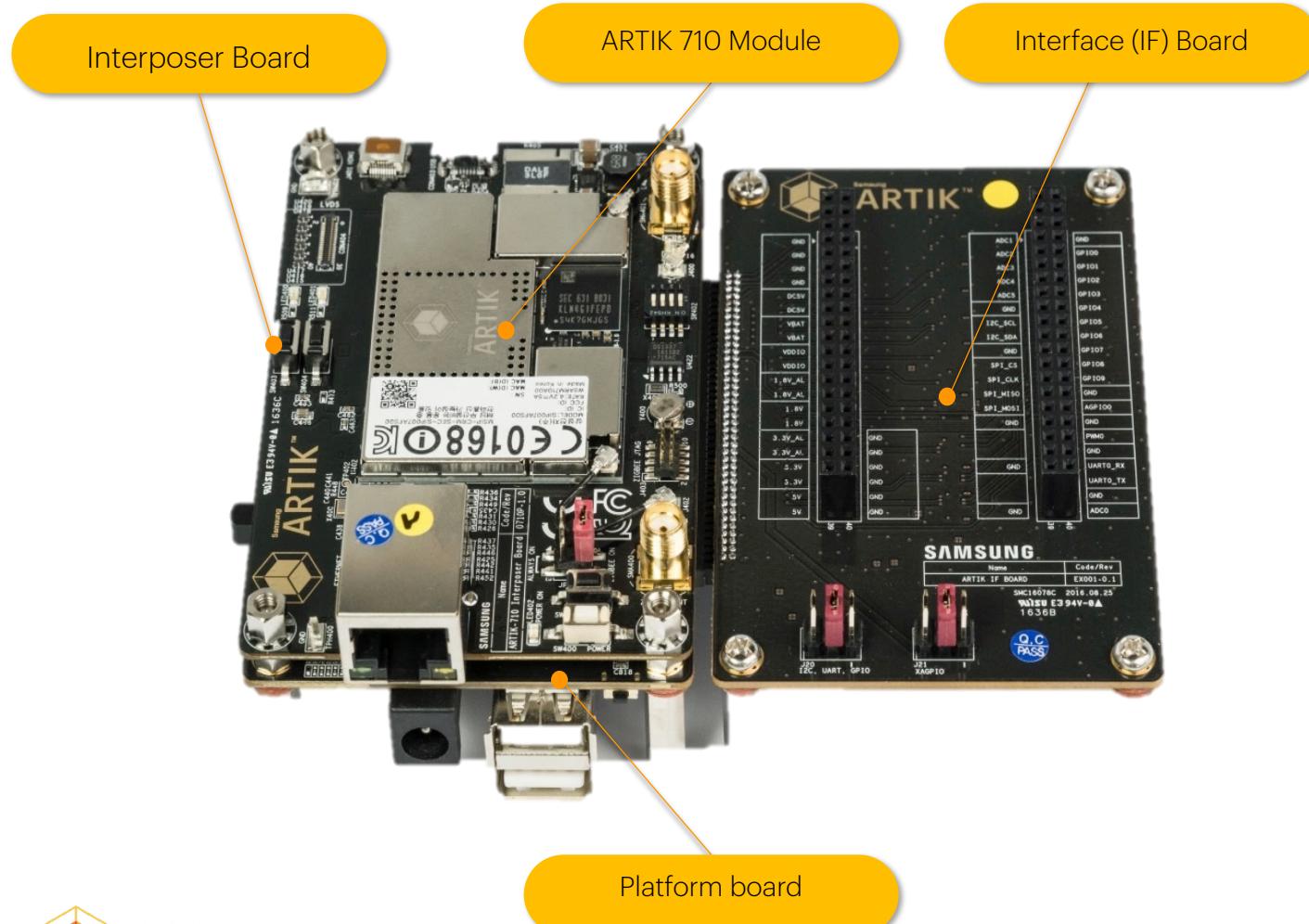


- High-end gateways
- Cameras
- Human-machine interface
- Machine learning

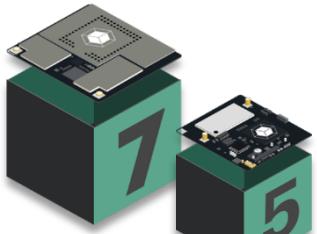
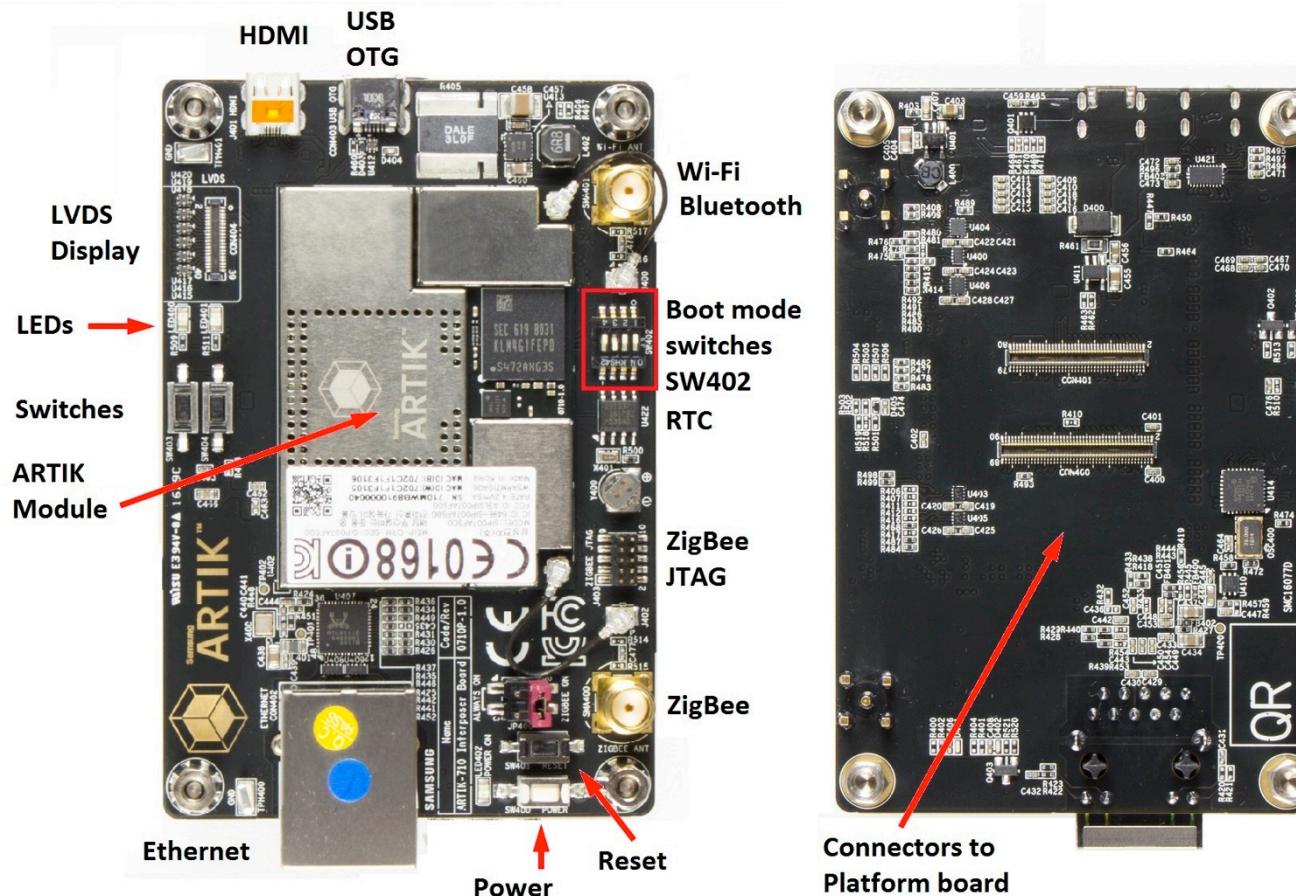


Processor	CPU: 8x ARM® Cortex® A53 @ 1.4 GHz GPU: 3D graphics accelerator
Memory	DRAM: 1 GB DDR3 @ 800 MHz Flash: 4 GB eMMC v4.5
Multimedia	Camera I/F: 4-lane MIPI CSI Display: 4-lane MIPI DSI up to FHD@24 bpp, LVDS, HDMI v1.4 Audio: I²S audio interface
Connectivity	WLAN (Wi-Fi): IEEE 802.11 b/g/n/ac Bluetooth: 4.1+ Smart 802.15.4: Zigbee, Thread Ethernet: 10/100/1000 Base-T MAC (external PHY required)
Security	Secure element, EAL Level 5, unique device certificate and keys, PKI with mutual authentication to cloud, hardware crypto engine; secure boot*, KMS*, TEE*, <small>*S-modules</small>
I/O	GPIO, I²C, I²S, SPI, UART, PWM, SDIO, USB 2.0, JTAG, analog input
Temperature range	0° to 70° (°C)
Size	36 mm W x 49 mm H x 3.4 mm D

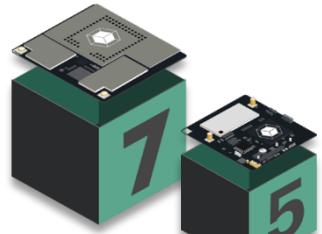
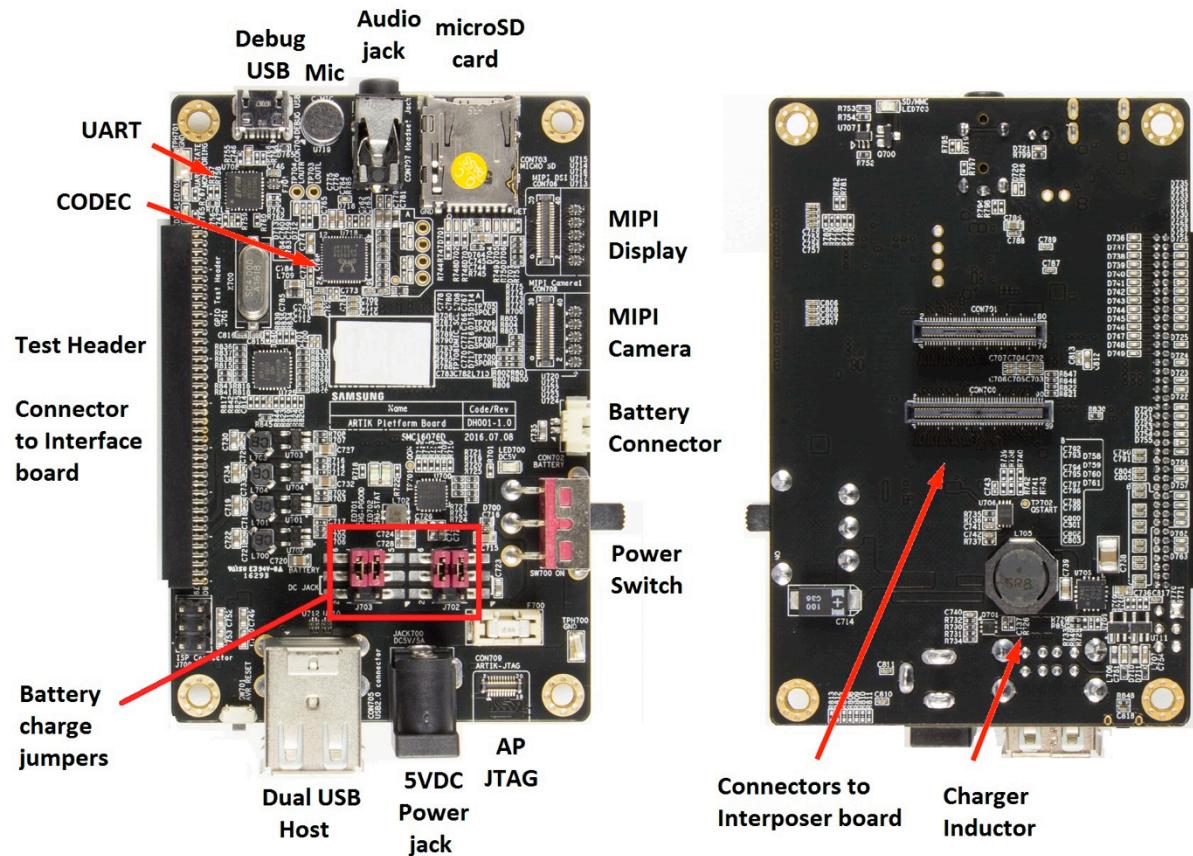
ARTIK High-end module development board



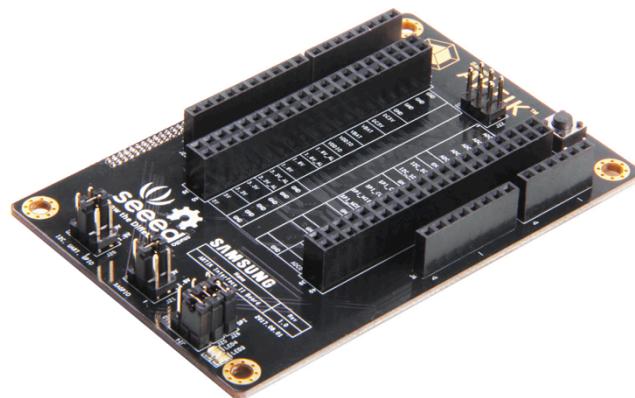
ARTIK High-End Module Interposer Board



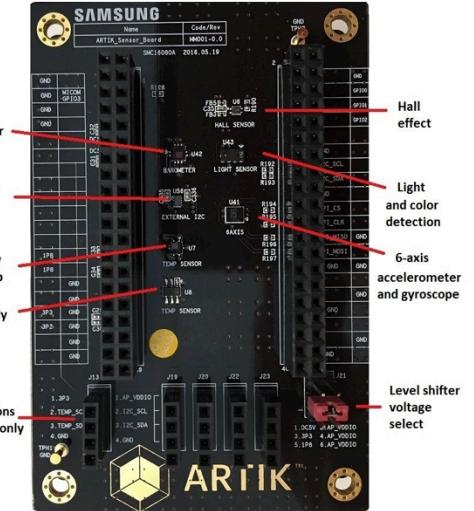
ARTIK Gateway Module Platform Board



ARTIK Gateway Module Expansion Boards



Interface Board II

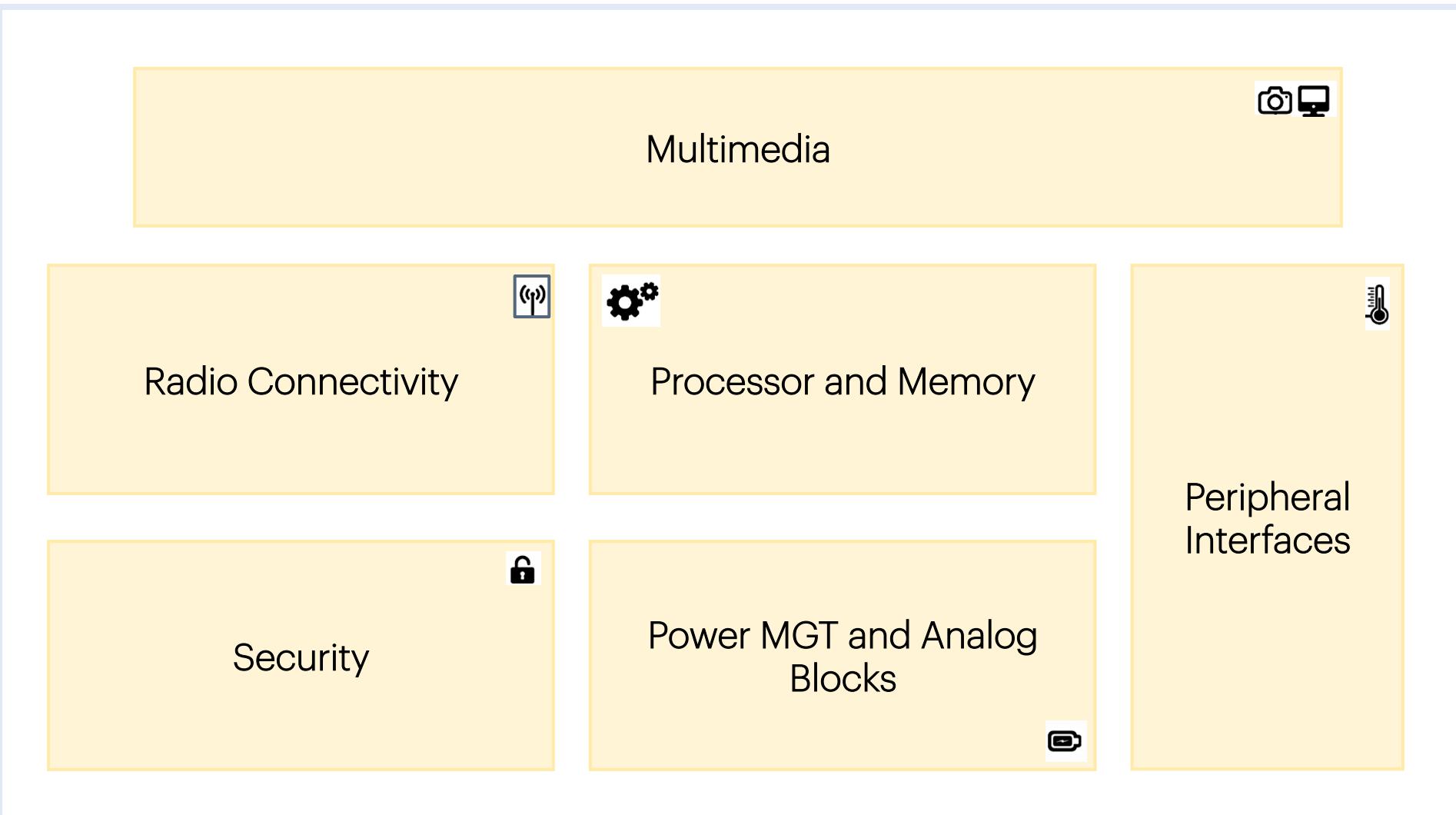


Sensor Board

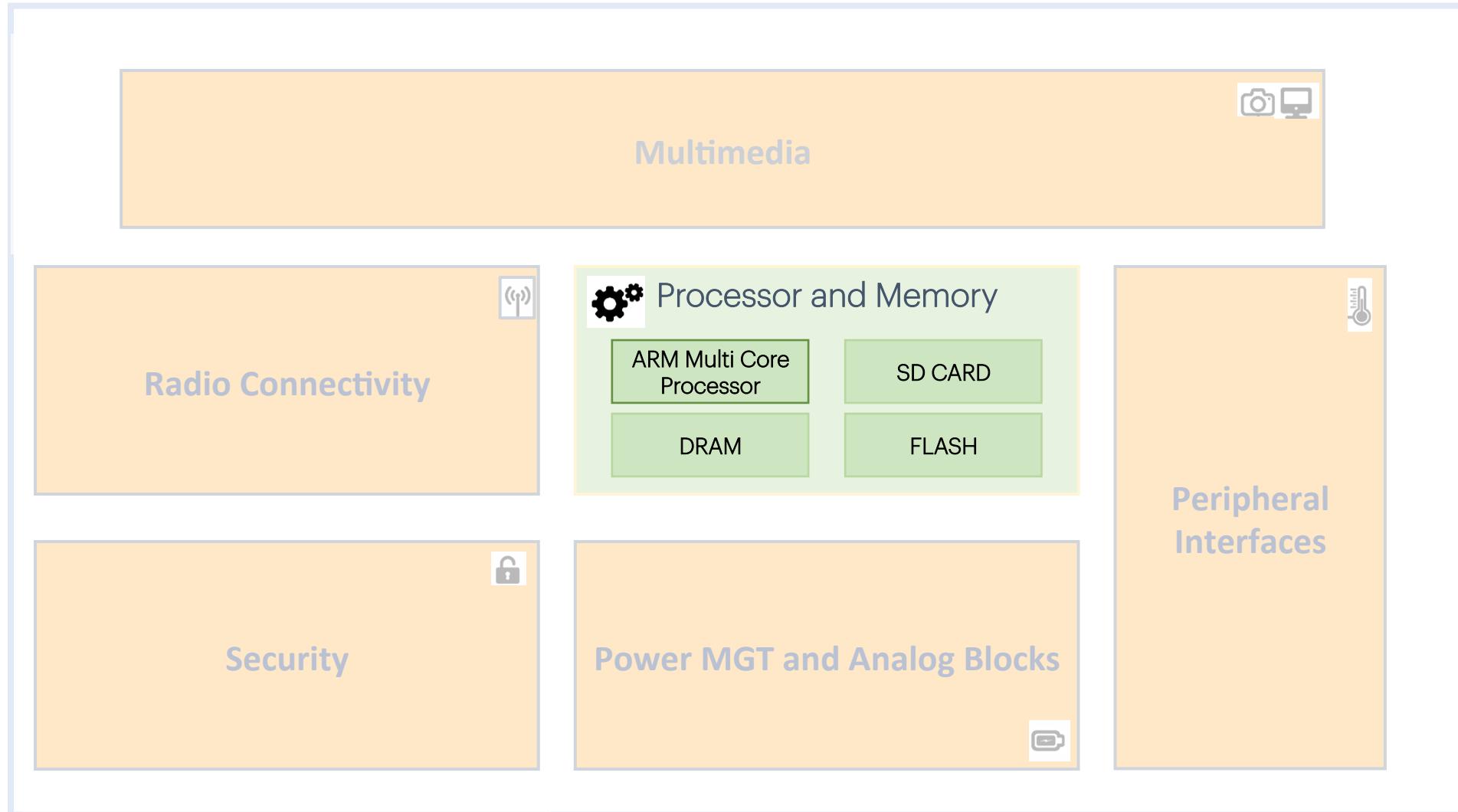
ARTIK Gateway Module

Product Details

Product Details



Product Details – Processor and Memory

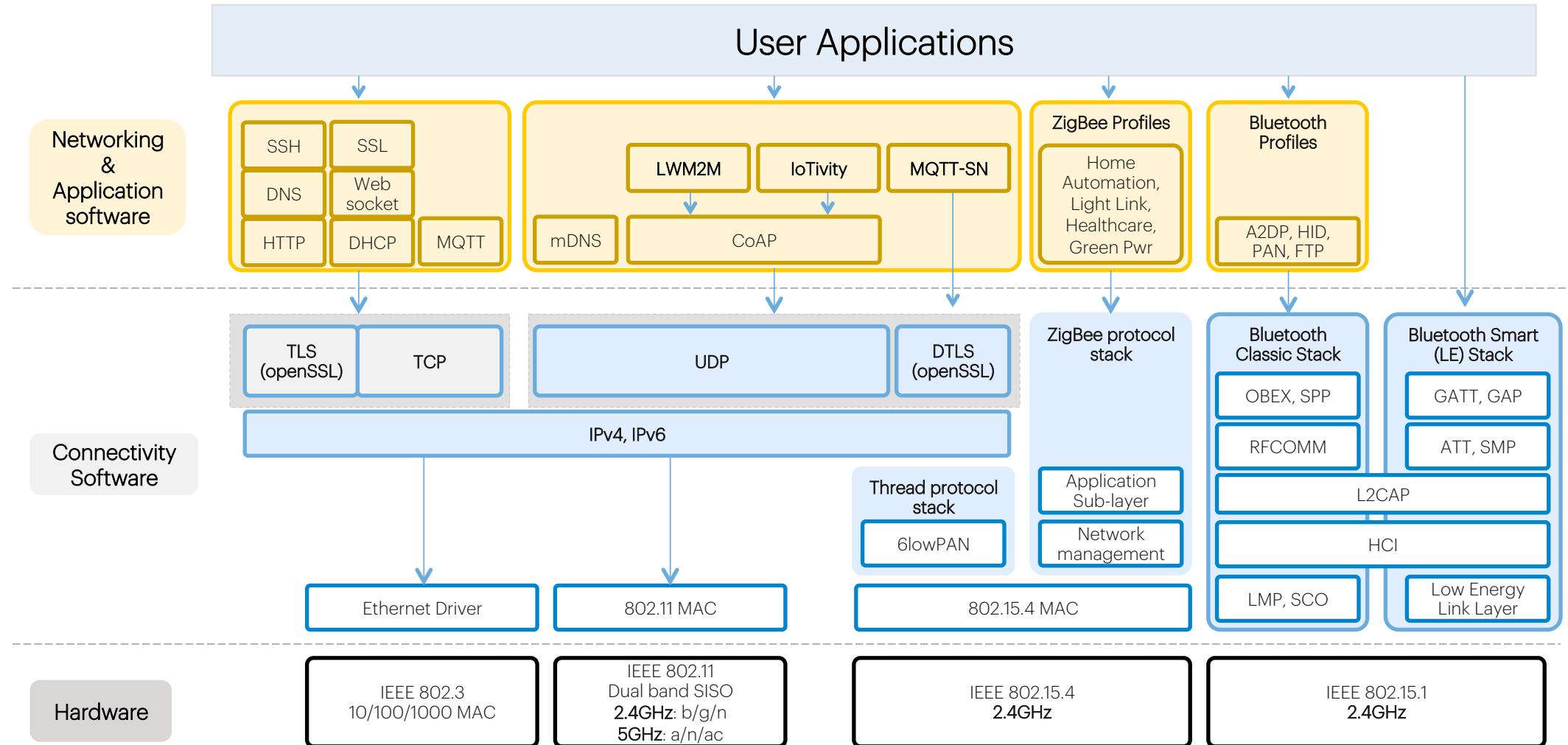


Radio Connectivity

Radio	Range	Data Rate	520	530	710
BLE	50m	<1Mbps	✓	✓	✓
BT	30m	1-3Mbps	✓	✓	✓
ZigBee	10-100m	10-100Kbps	✓	✓	✓
Thread	N/A	10-100Kbps	✓	✓	✓
Wi-Fi	~50m	10-100Mbps	✓	✓	✓
Ethernet			✓	✓	✓

*Z-wave and Sigfox chip set is on 520 development boards

Network Stack



Peripheral Interfaces + Power MGT & Analog blocks

	520	530	710	
Peripheral Interfaces	I2C	6	3	3
	SPI	2	2	2
	GPIO	100	107	108
	UART	2	3	3
	USB	USB 2.0*	USB 2.0	USB 2.0
Analog and Power MGT	ADC	2	6	6
	PWM	2	2	2
	PMIC	✓	✓	✓

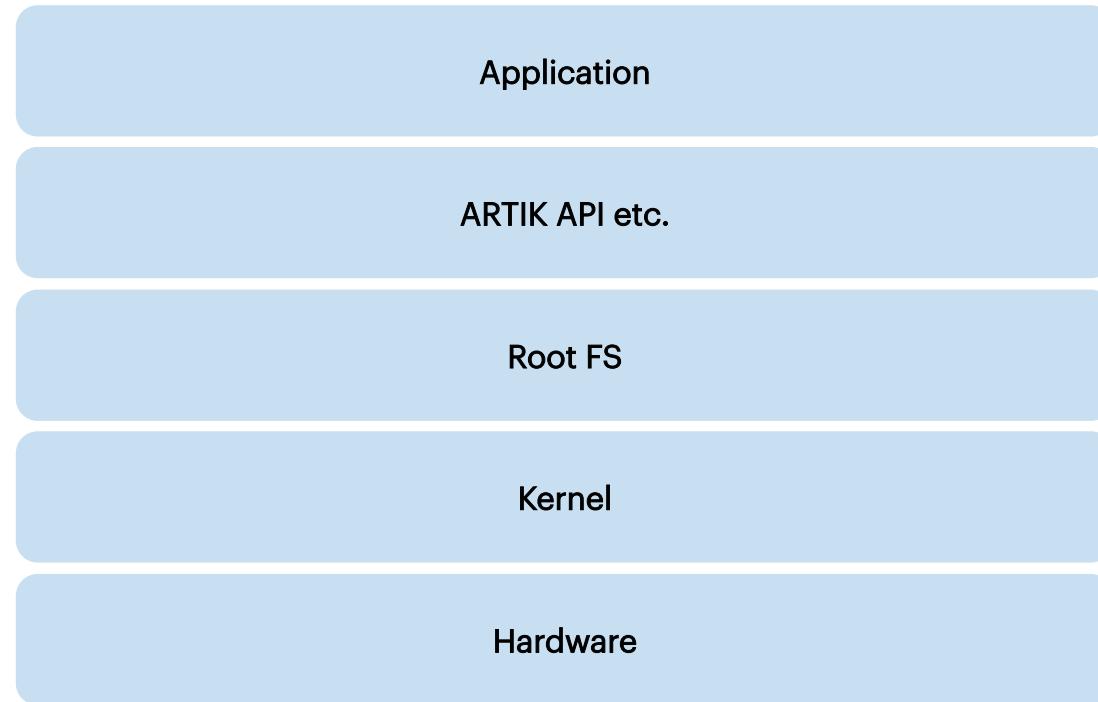
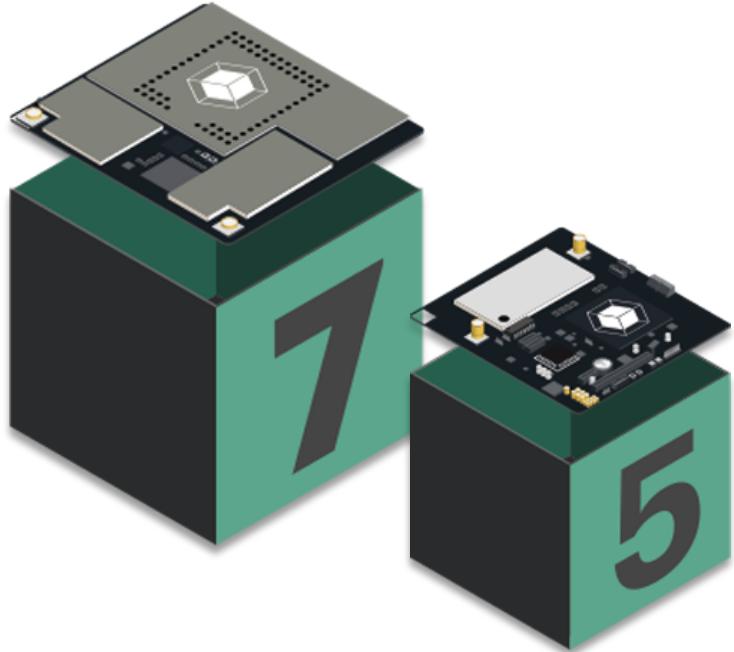
*USB device mode only for 520, rest of the module is both device and host mode.

Product Details - Multimedia

	520	530	710
I2S	1x	2x	2x
HDMI + audio	n/a	1080p @ 60fps	1080p @ 60fps
MIPI – DSI	2-lane 540p @ 24bpp	4-lane 1080p @ 60fps	4-lane 1200p @ 24bpp
MIPI – CSI	2-lane 3MP @ 30fps	4-lane 1080p @ 30fps	4-lane 1080p @ 30fps
LVDS	n/a	720p @ 60fps	720p @ 60fps

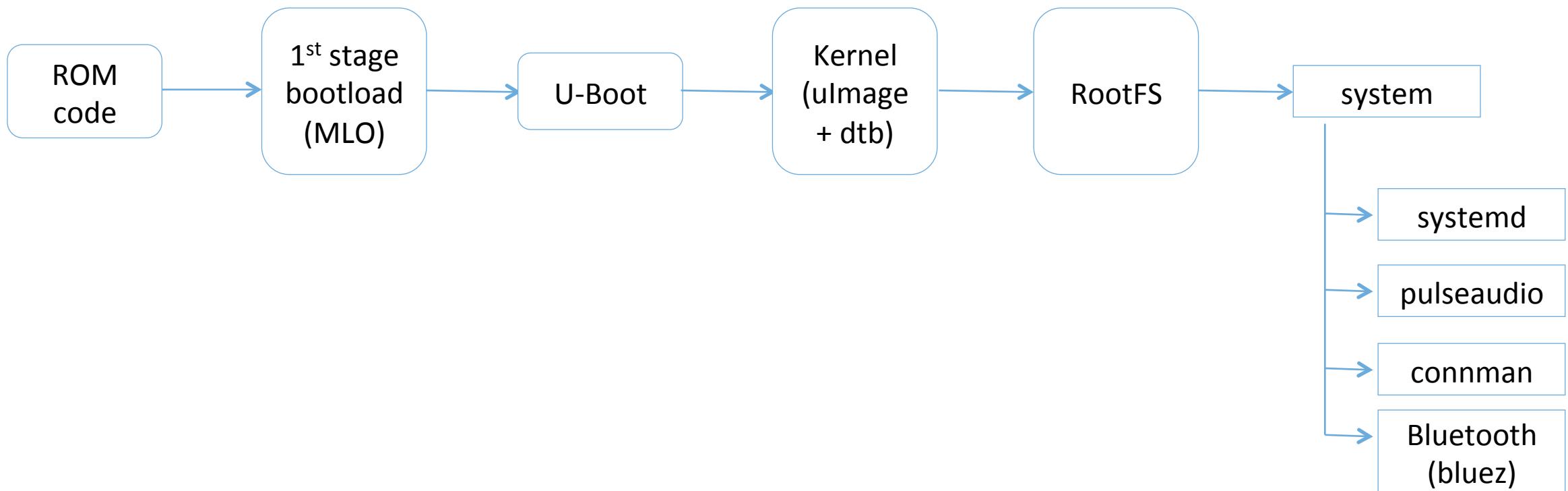
ARTIK Gateway Module Software Stack

ARTIK Gateway Software Stack

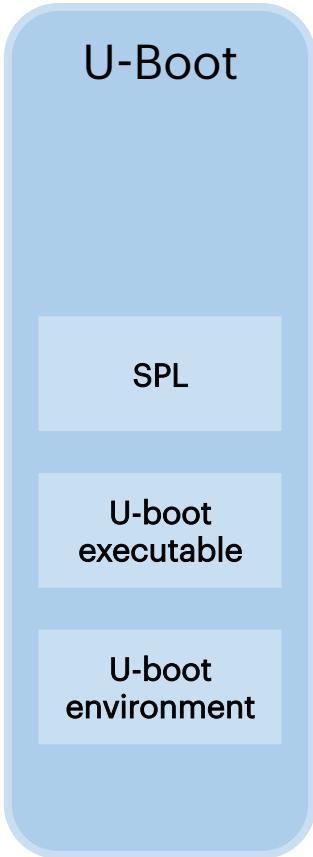


Boot Modes and Sequence

eMMC Boot Sequence

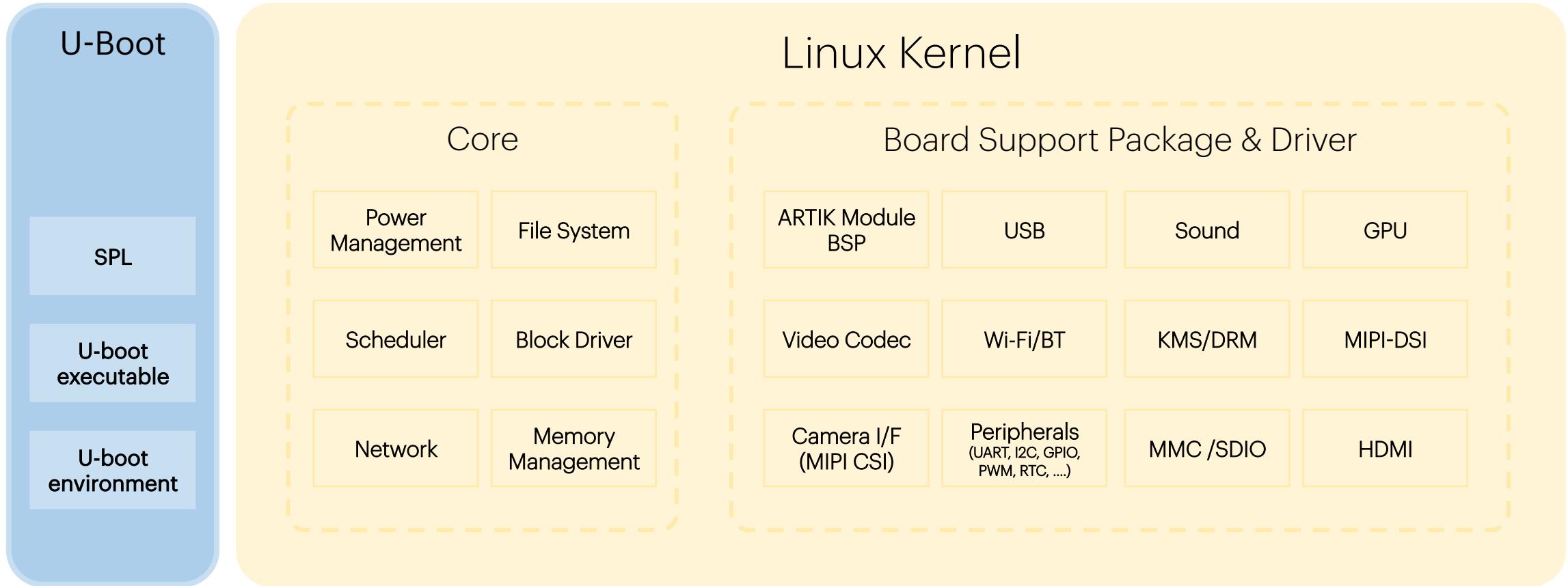


U-Boot



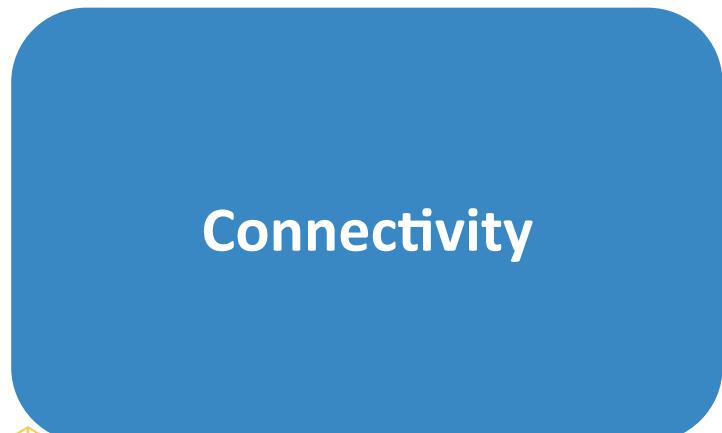
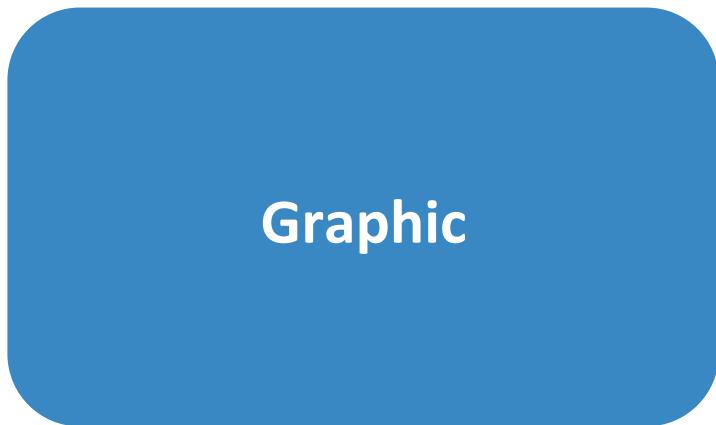
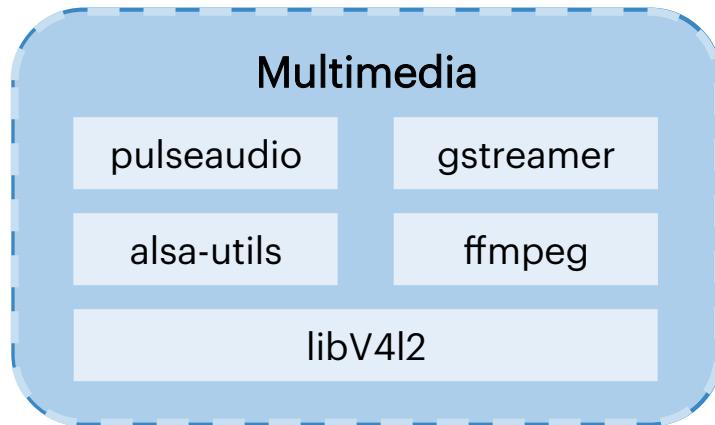
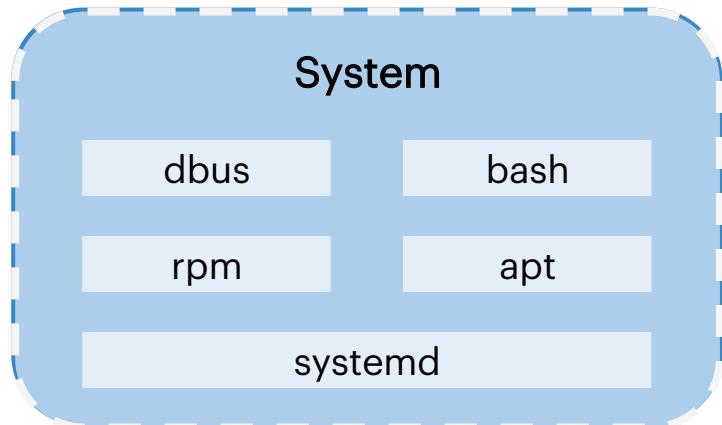
Boot Stage#	Terminology #1	Terminology#2	Program Name
1	Primary Program Loader	-	ROM Code
2	Secondary Program Loader(SPL)	1 st stage bootloader	U-boot SPL
3		2 nd stage bootloader	U-boot
4			kernel

U-Boot and Linux Kernel Architecture

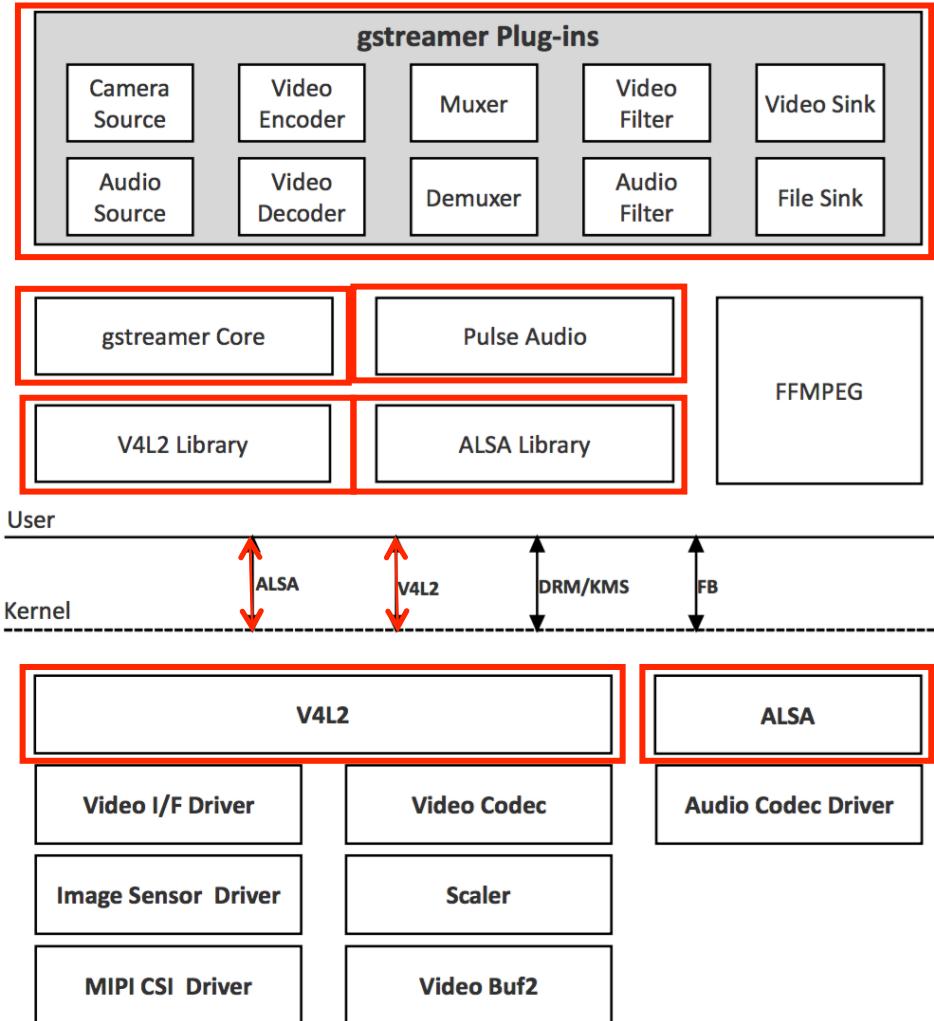


Architecture of Rootfs

Rootfs



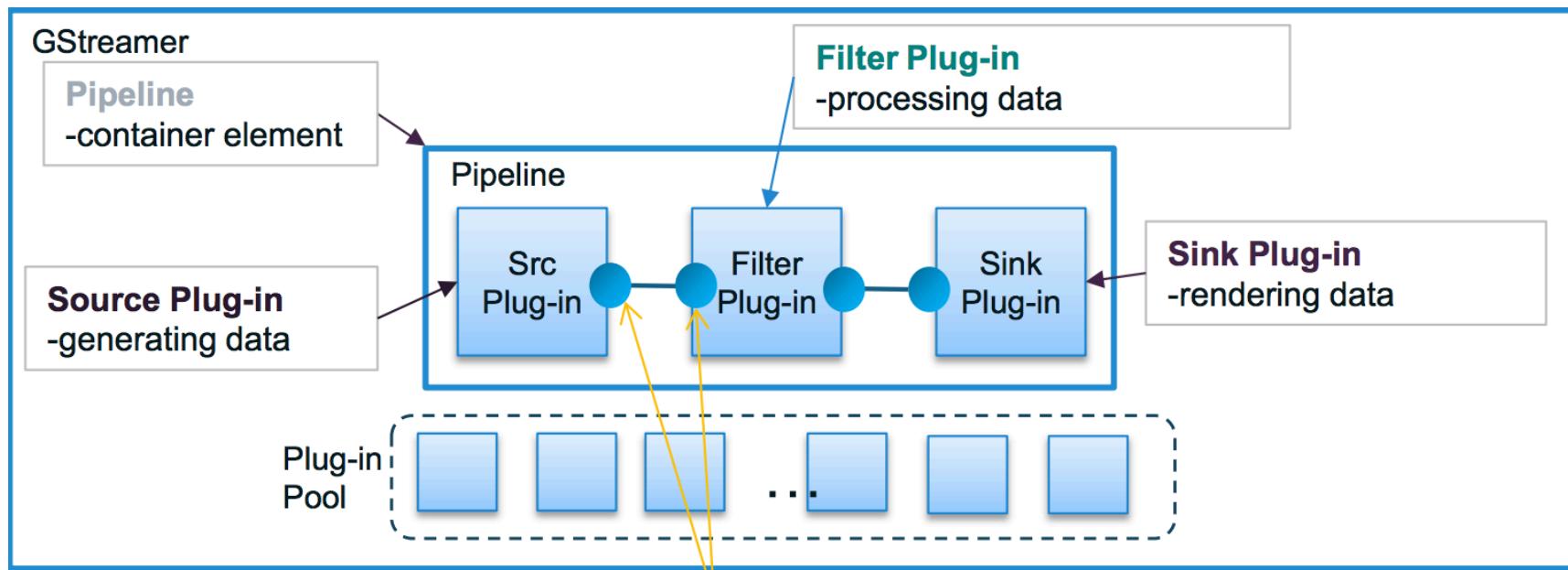
Multimedia Architecture



- ALSA lib is a framework that provides a software API for audio device drivers
- Pulse Audio is based on ALSA lib for supporting sound. It runs a sound server.
- Video for Linux Version 2 (V4L2) is collection of device drivers and API for supporting real-time video capture on Linux systems

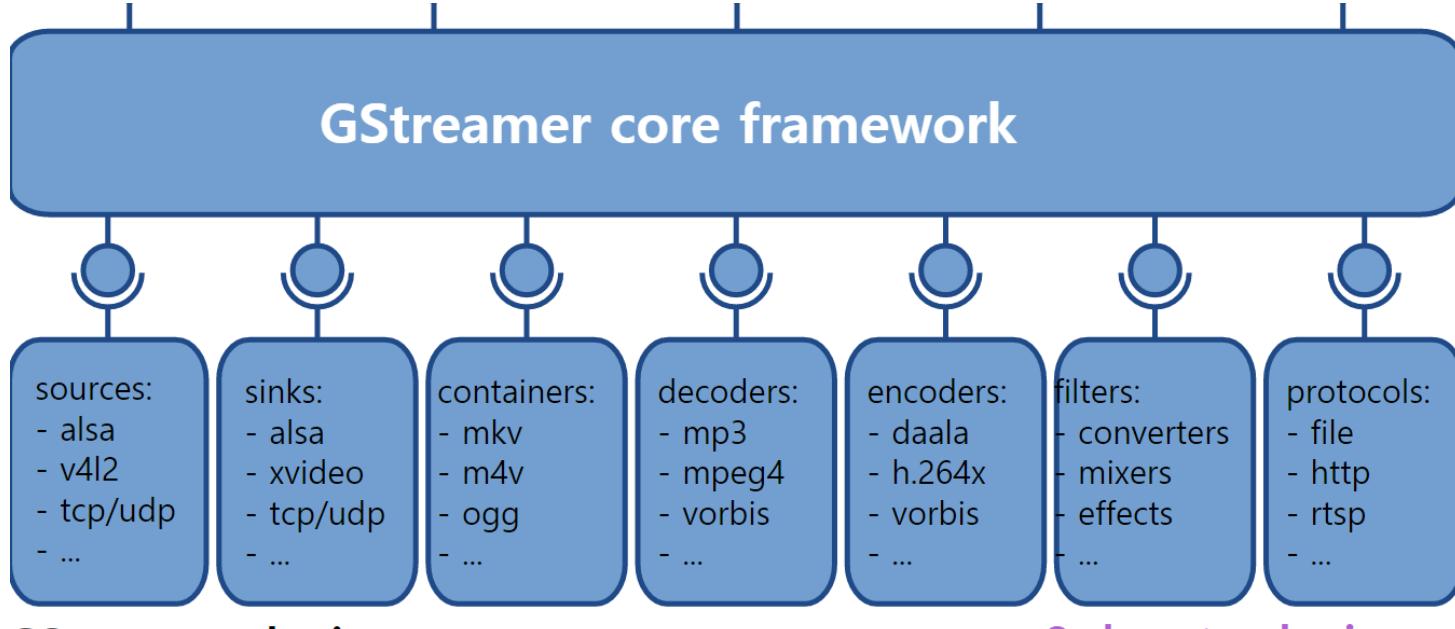
GStreamer

- Pipeline-based multimedia framework that links together a wide variety of media processing system to complete complex workflows (<https://gstreamer.freedesktop.org/>)



GStreamer Plugins

- GStreamer uses a plug-in architecture which makes the most of Gstreamer's functionality implemented as shared libraries.
- Various types including source, sinks, filters, etc.



GStreamer plugins

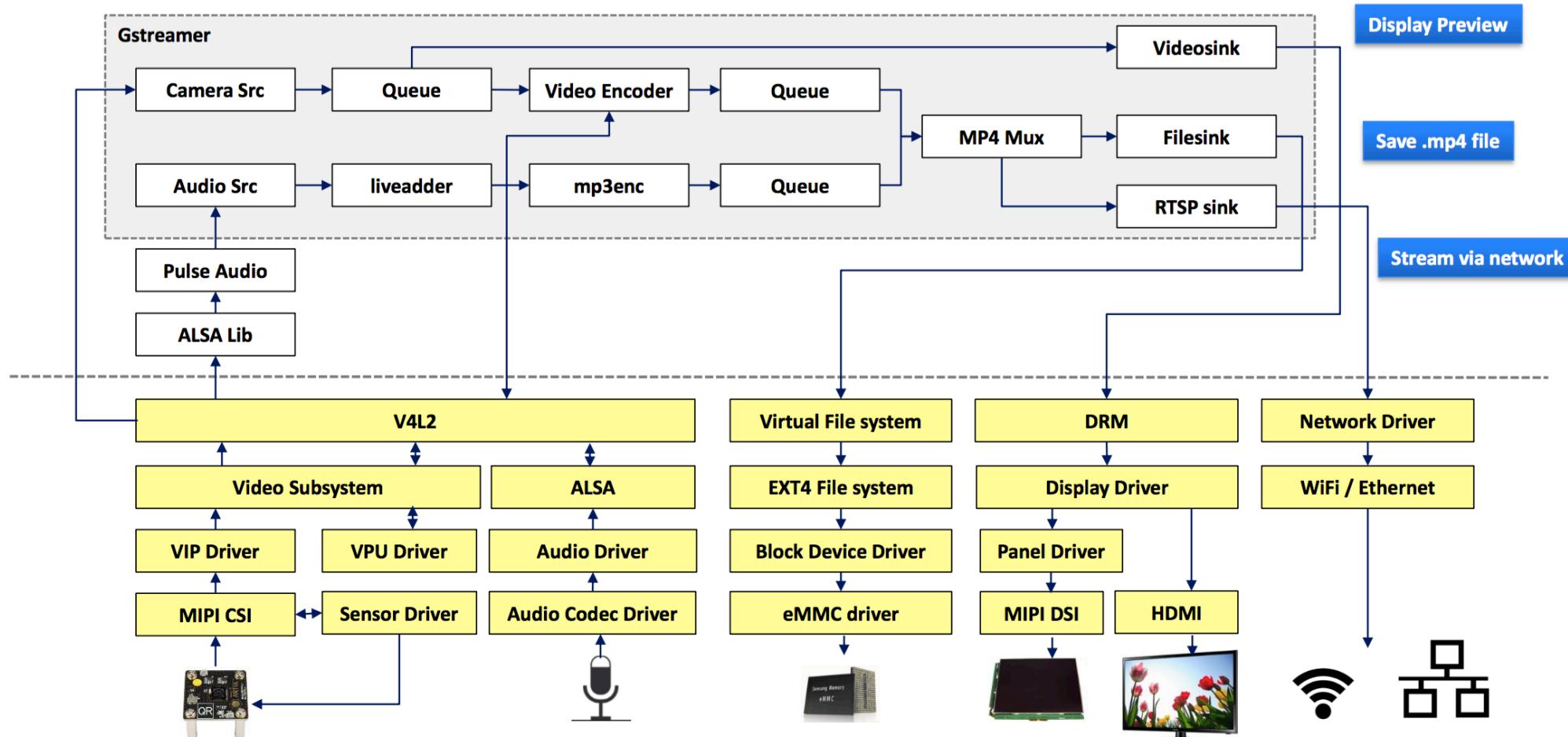
GStreamer includes over 150 plugins
software plugins are executed on the host CPU
hw accelerated plugins shunt execution to acceleration DSPs and the result back

3rd party plugins

Texas Instruments, Motorola,
et al.

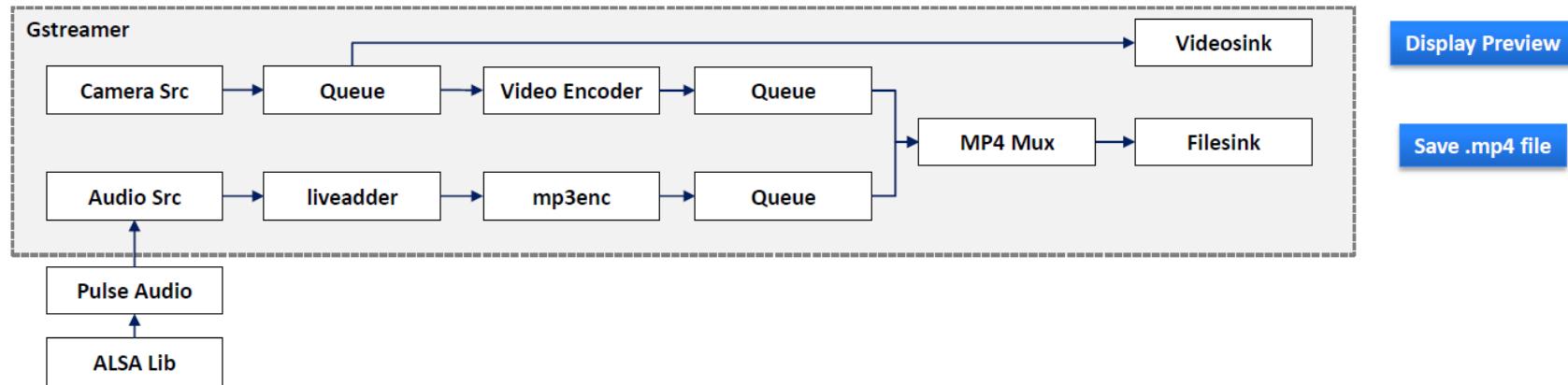
ARTIK Multimedia Example

Record a HD MP4 movie with sound and simultaneous preview on display, stream via network



GStreamer Pipeline Example for ARTIK 5x/7x

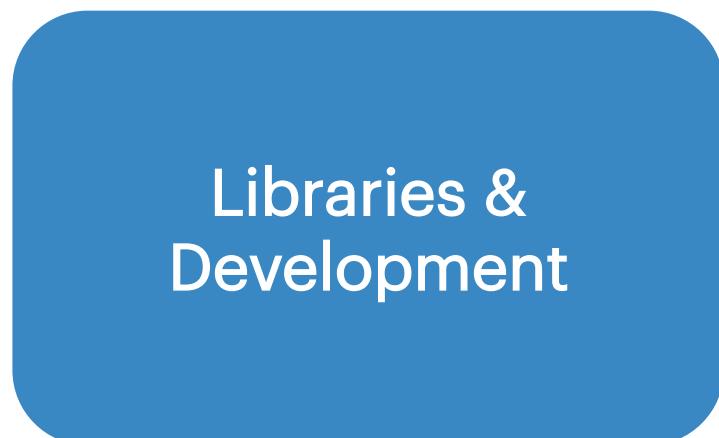
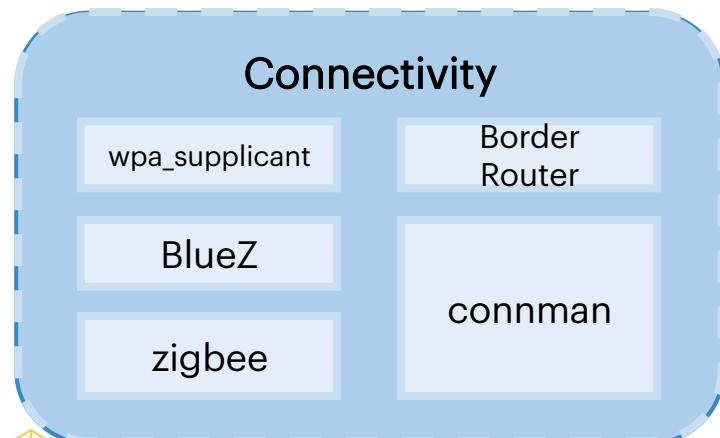
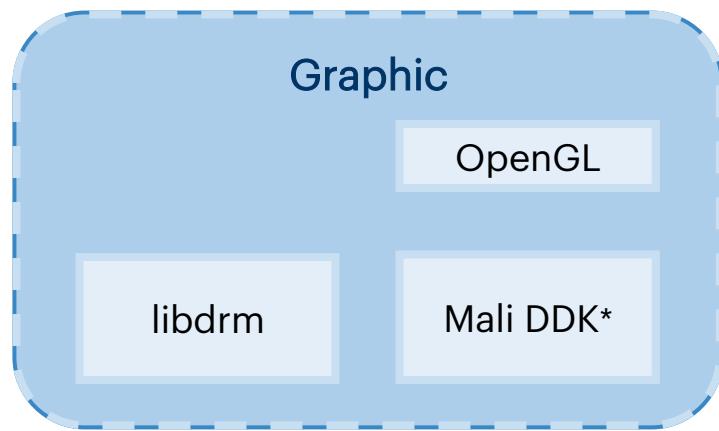
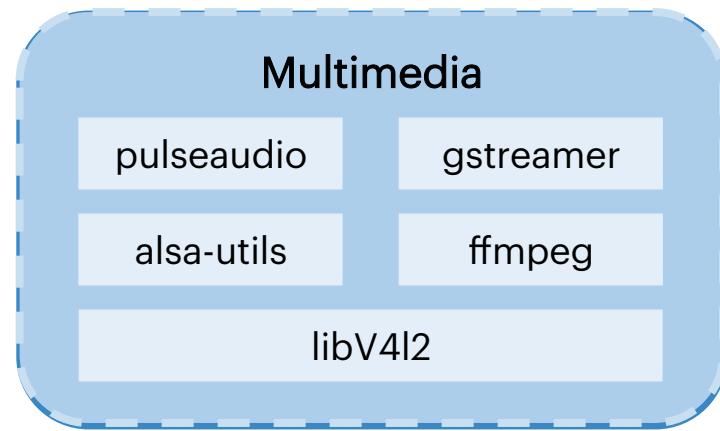
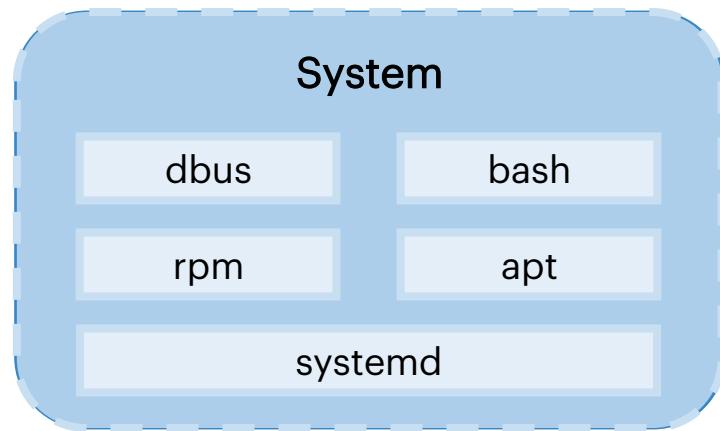
- Record a HD MP4 movie with sound and simultaneous preview on display



```
gst-launch-1.0 -e camerasrc camera-crop-width=1280 camera-crop-height=720 ! tee name=t \
t. ! queue ! nxvideoenc bitrate=12000000 ! queue ! mux. \
autoaudiosrc ! liveadder start-time-selection=2 start-time=600000000! lamemp3enc ! queue ! mux. \
t. ! nxvideosink \
mp4mux name=mux ! filesink location=result_a.mp4
```

Architecture of Rootfs

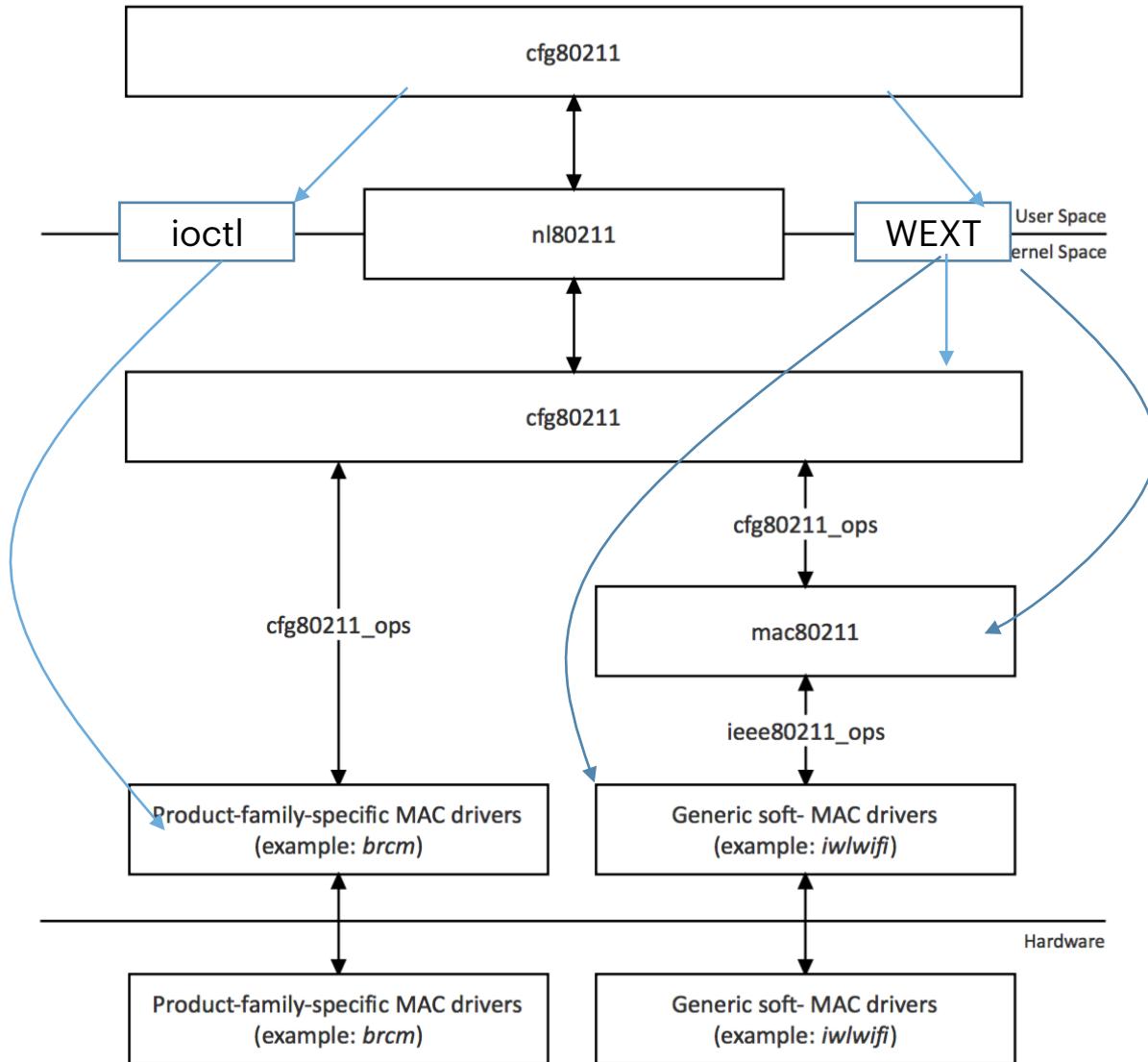
Rootfs



wpa_supplicant

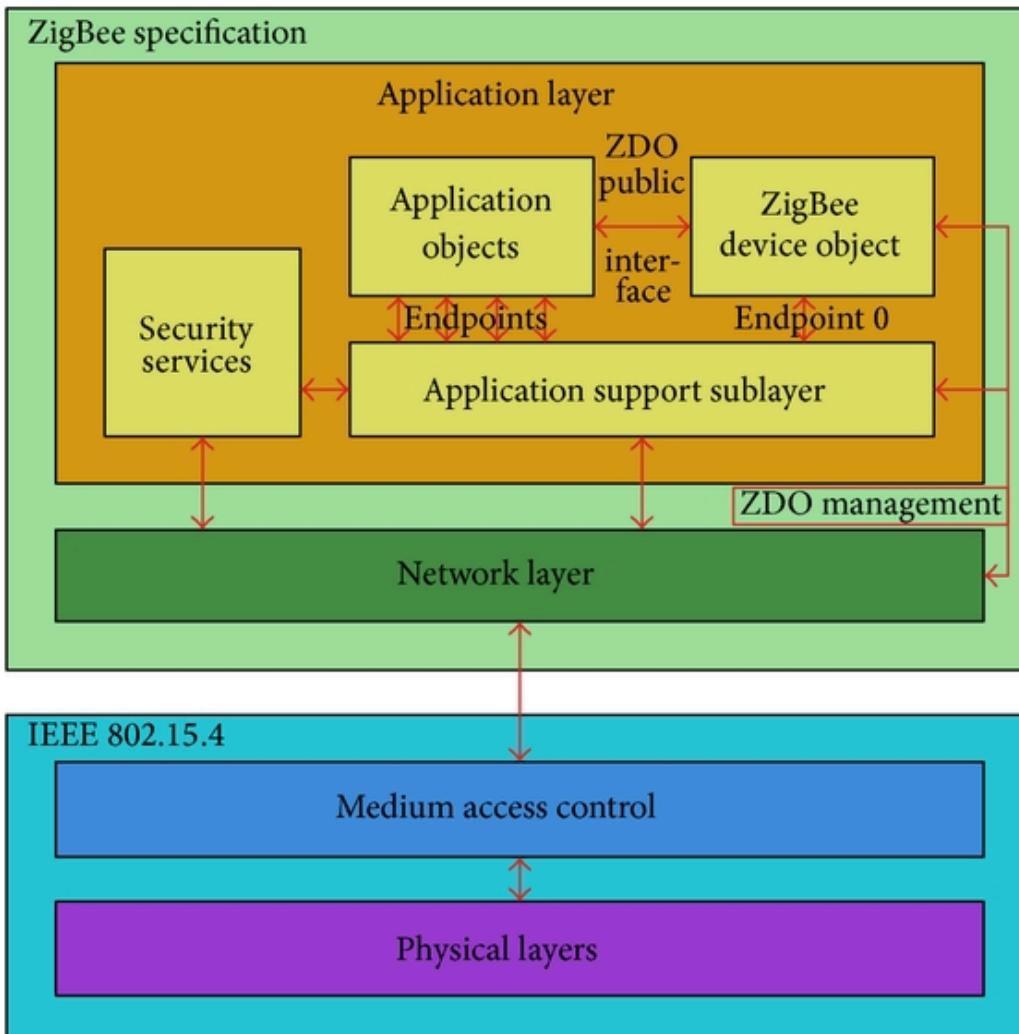
- Supplicant is used in the client stations for key negotiation with a WPA Authenticator.
- wpa_supplicant is designed for Linux, BSD and Windows with support for WEP, WPA and WPA2. It uses hardware, driver and OS independent, portable C code
- A daemon program running in the background and acting as the backend component controls the wireless connection.

WiFi Flow



- **nl80211:** Interface between user space and kernel. This works like a socket.
- **cfg80211:** configuration API for 802.11 devices.
- **cfg80211_ops:** a set of operations that **Full-MAC** drivers and **mac80211** module register to **cfg80211** module
- **ieee80211_ops:** a set of operations that **Soft-MAC** drivers register to **mac80211** module
- **mac80211:** Implements the MAC layer functions, also the **cfg80211** callbacks.

ZigBee



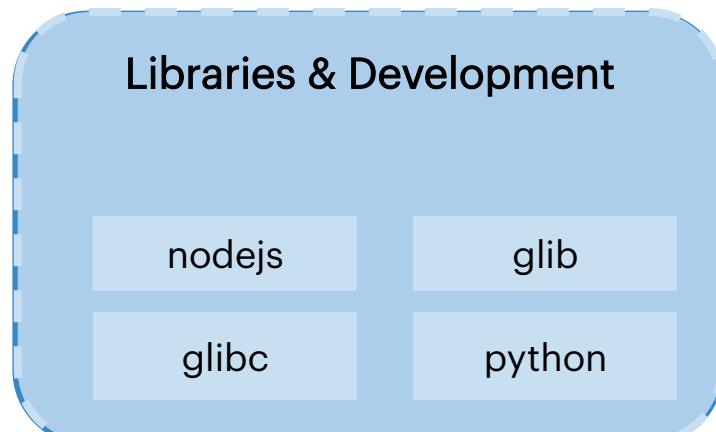
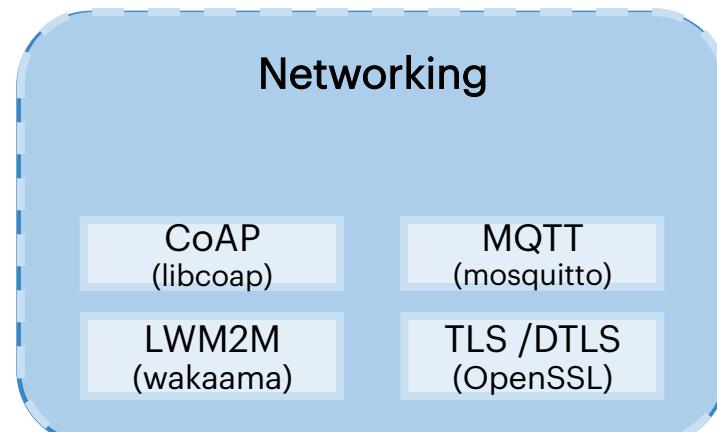
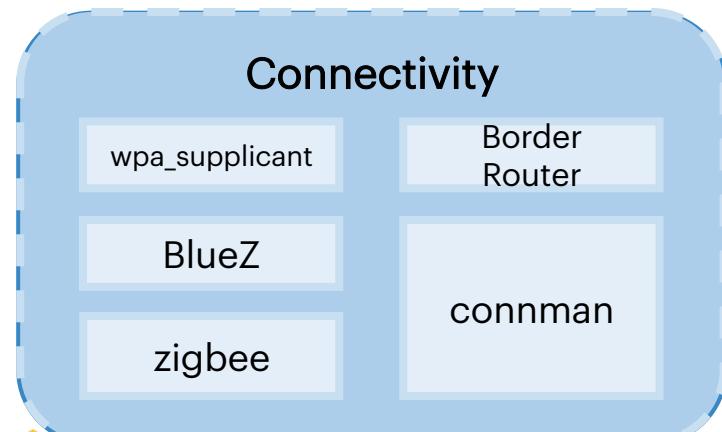
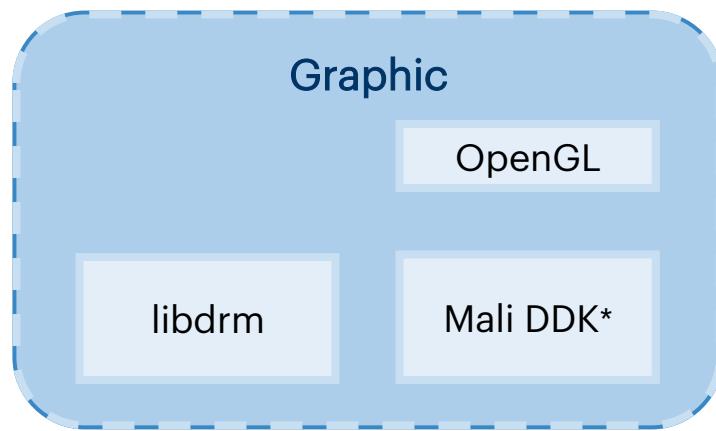
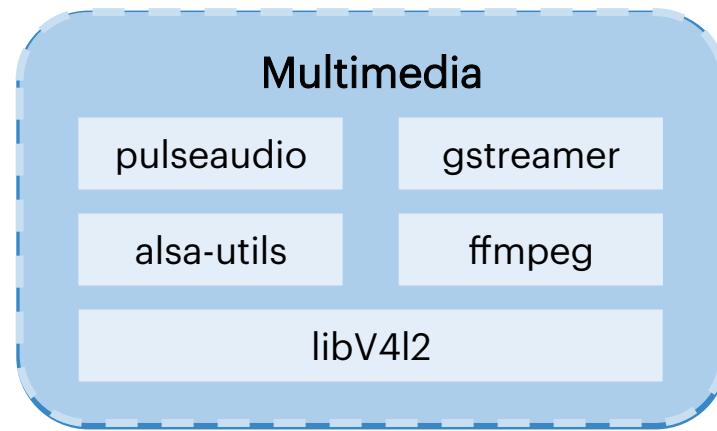
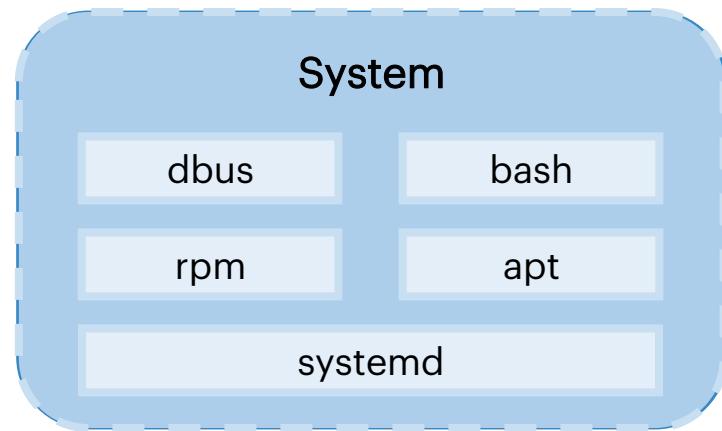
It defines various addressing objects including profiles, clusters and endpoints

How is the network formed?
How are addresses assigned?

How does transmission work?
What frequency and channel we should use?

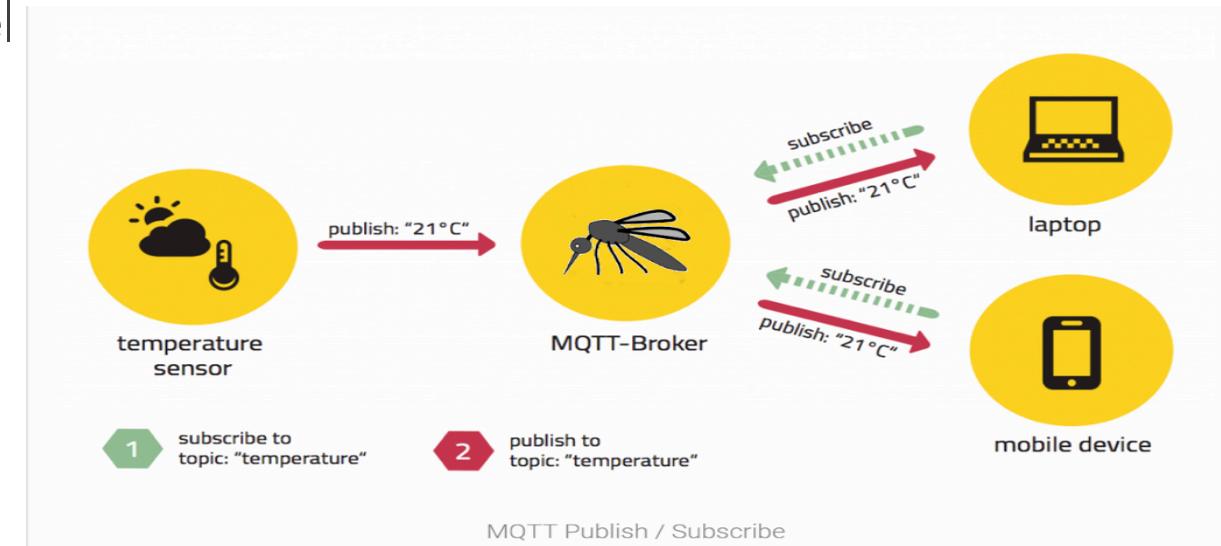
Architecture of Rootfs

Rootfs



Message Queue Telemetry Transport (MQTT)

- MQTT history
- Light-weight messaging protocol, rides on TCP
- Broker / Clients architecture
- Publication / Subscription messaging model
- No pre-defined format for payload



Message Queue Telemetry Transport (MQTT)

- The **publish/subscribe** message pattern to provide **one-to-many message distribution** and decoupling of applications
- Publish/subscribe is **event-driven** and enables messages to be pushed to clients
- The central communication point is the MQTT **broker**, it is in charge of dispatching all messages between the senders and the rightful receiver
- Each client that publishes a message to the broker, includes a **topic** into the message. The **topic is the routing information for the broker**
- Each client that wants to receive messages subscribes to a certain topic and the broker delivers all messages with the matching topic to the client
- This architecture enables highly scalable solutions without dependencies between the data producers and the data consumers

Message Queue Telemetry Transport (MQTT)

- MQTT client includes publisher or subscriber
- In general, a MQTT client can be both a publisher & subscriber at the same time
- A MQTT client can run on any device from a micro controller up to a server. MQTT C client code only takes 30KB, Java code is about 100KB.
- MQTT client libraries are available for a huge variety of programming languages, e.g, C/C++, Arduino, Java, JavaScript, Android, iOS, C#, .NET

<https://github.com/mqtt/mqtt.github.io/wiki/libraries>

- MQTT client: Eclipse Paho



MQTT.fx(available for Win/MacOS/Linux) etc.

Message Queue Telemetry Transport (MQTT)

- MQTT Broker is responsible for receiving all messages, filtering them, and sending the messages to all subscribed clients.
- It holds the session of all persistent clients including subscriptions and missed messages
- Authentication and authorization of clients.
- Self Hosted MQTT brokers:

Eclipse Mosquitto



HiveMQ(licensed)



- Cloud based MQTT brokers:

AWS



IBM Bluemix



HiveMQ (broker.hivemq.com)



Microsoft Azure

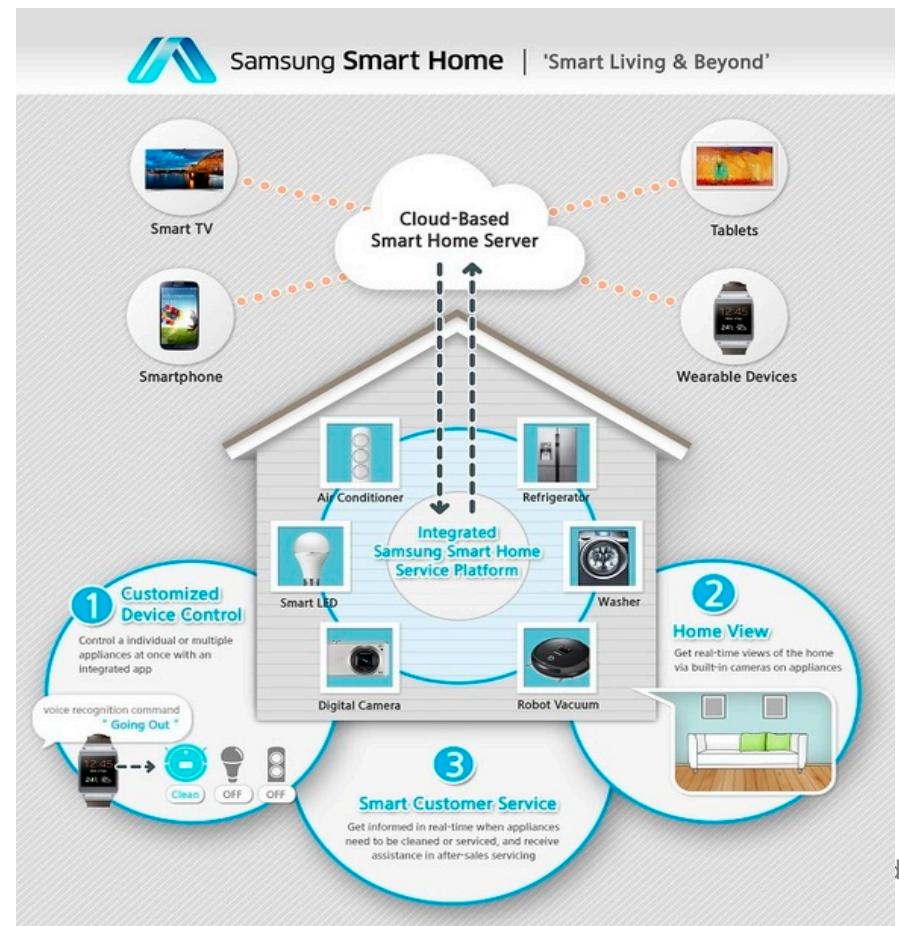


Eclipse Mosquitto (test.mosquitto.org)



CoAP

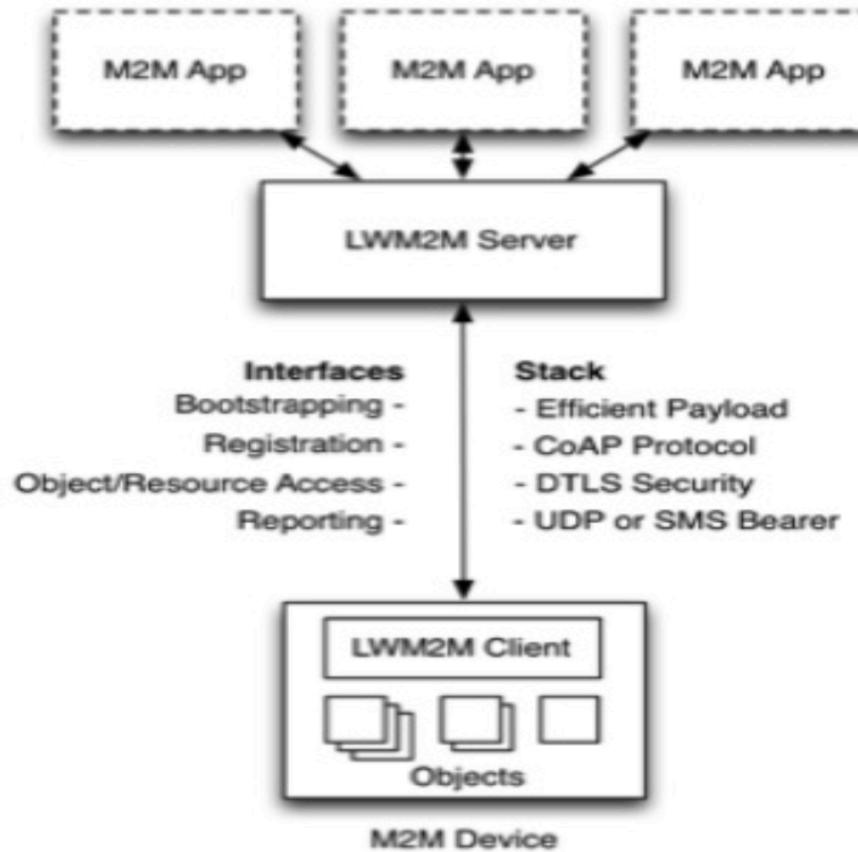
- Similar to HTTP, but designed for the needs of constrained devices
- Client/server model
- Runs over UDP
- Supported by ARTIK Cloud service



Device Management and LWM2M stack

- Lightweight M2M (LWM2M) is a device lifecycle management specification
- Provides a specification for functions like: firmware upgrade, provisioning of certificates, access control policies, connectivity monitoring etc.
- Based on CoAP protocol
- LWM2M allows the use of UDP for communication between client and server
- DTLS security for communication between an LWM2M client and ARTIK Cloud server(an LWM2M server).

LWM2M Architecture Overview



LWM2M server

- Persistent endpoint through which devices and apps interact
- Deployable on gateways and/or in the cloud

LWM2M client

- Hosts resources(objects) that represent a physical device

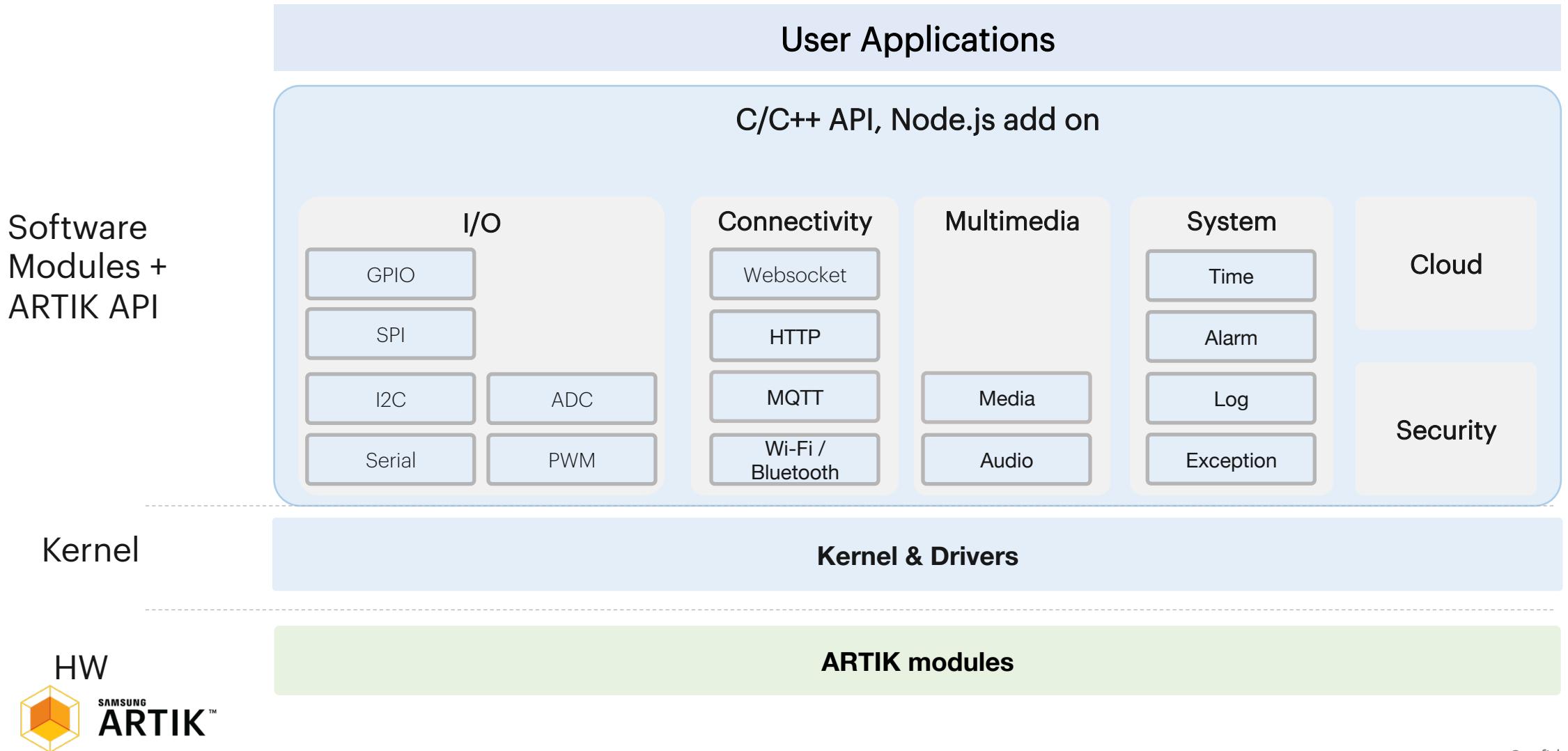
Eclipse Wakaama



- Eclipse Wakaama is an open source implementation of the OMA LWM2M protocol in C language.
- Includes 3 layers: LWM2M Protocol, CoAP and DTLS layer.
- Implements LWM2M Client, LWM2M Server and LWM2M Bootstrap Server.



ARTIK SDK (5, 7 series)

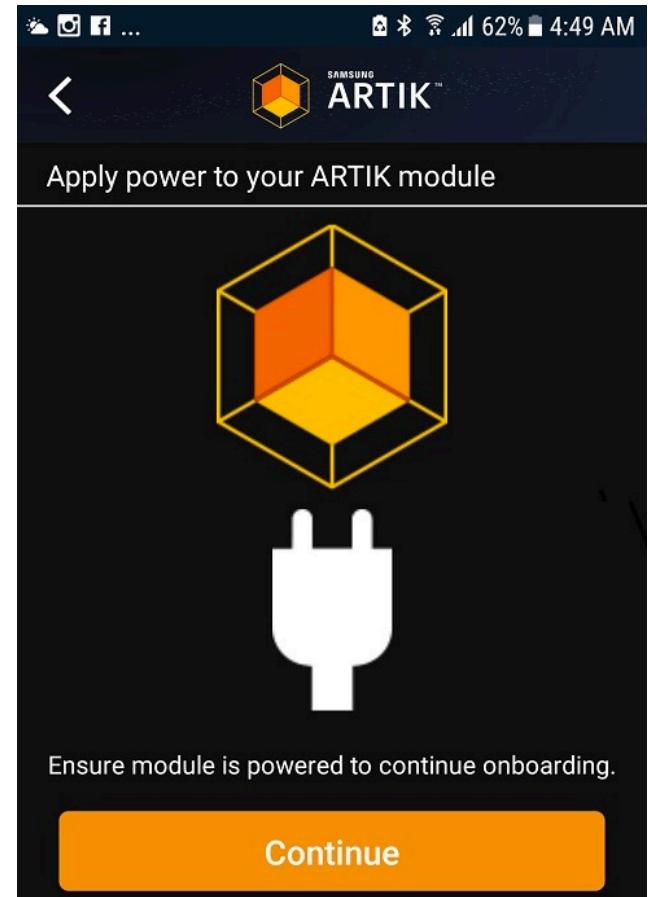
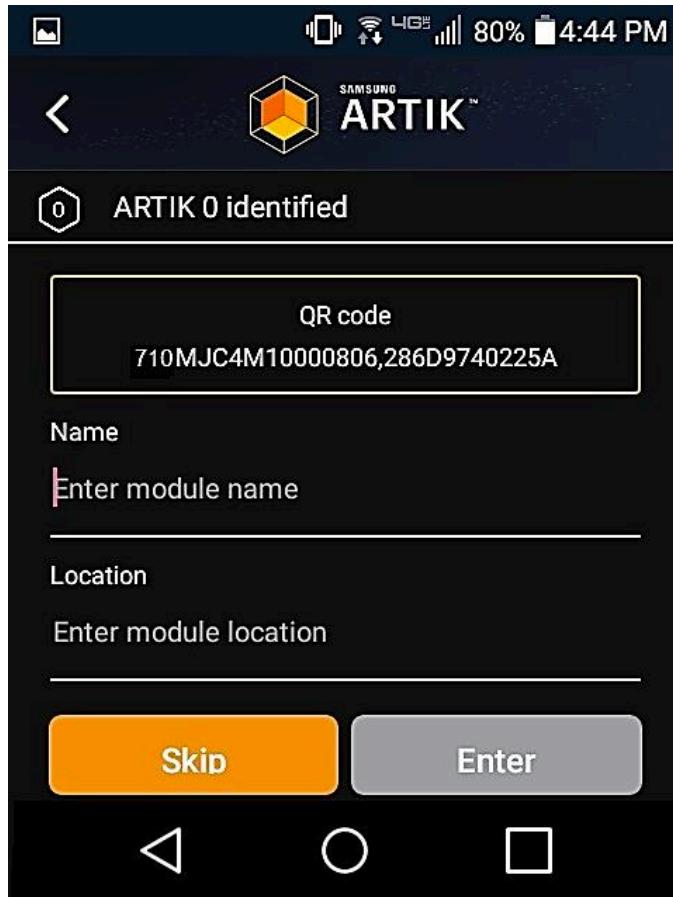
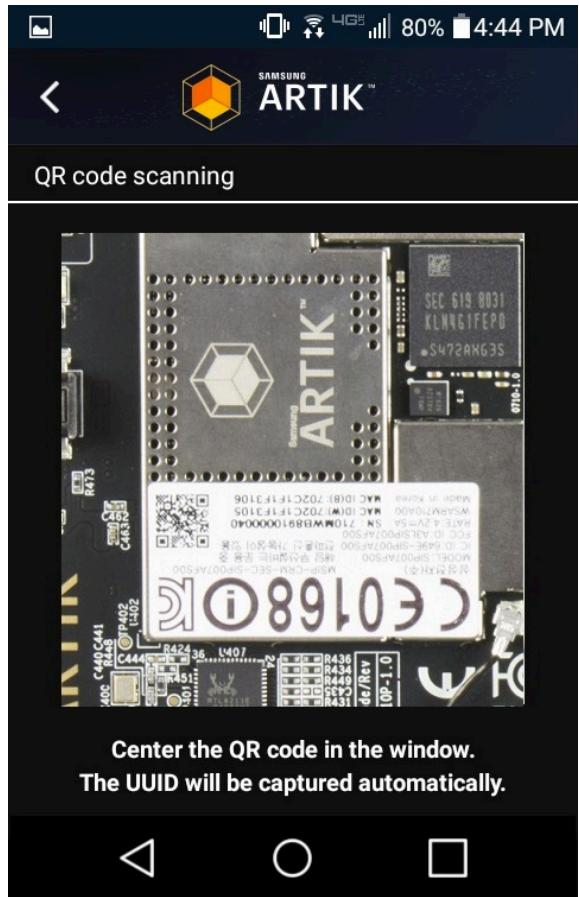


ARTIK End-to-end solution

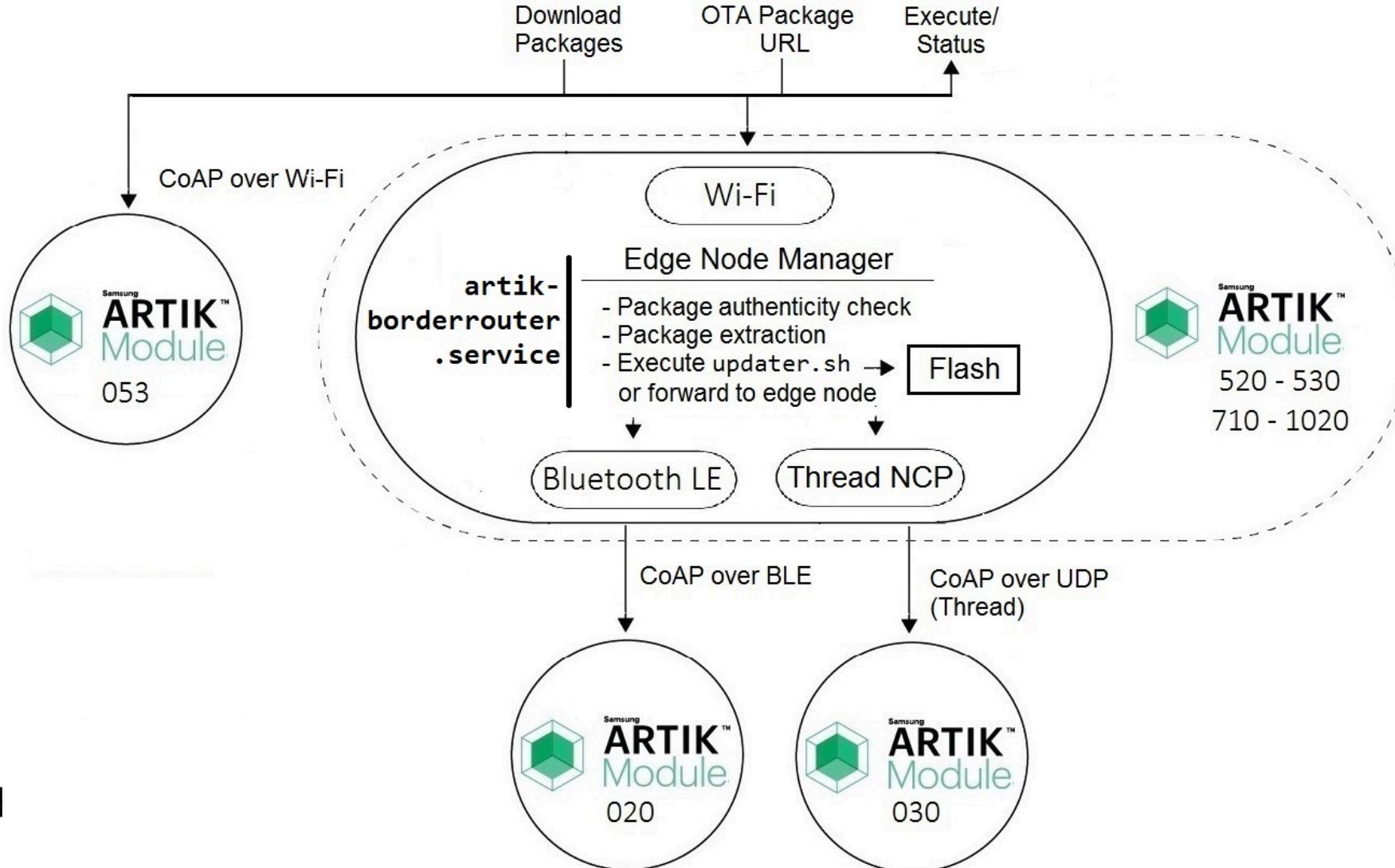
ARTIK Gateway Onboarding

- Support BLE onboarding on Gateway modules
 - QR code contains device information like MAC address, through which the mobile app learns the BLE service UUID of the ARTIK controller.
 - Mobile App scans for BLE devices and matches the service UUID with the one from the QR code.
 - Connection Manager connects ARTIK Gateway to WiFi.
 - Mobile App interacts with BLE on-boarding service through BLE GATT profile.

Onboarding app



Edge Node Manager



Edge Node Manager Dashboard

The screenshot shows the ENM DASHBOARD interface. At the top, it displays the version as Version 1.5.4, with the message "ENM up 17 minutes ago" and "Platform up 17 minutes ago". On the left sidebar, there are four main menu items: DEVICES (selected), ENM CONFIGURATION, DEBUG MODE, and ANALYTICS. At the bottom of the sidebar is the ARTIK.IO logo. The main content area contains a table listing detected devices. The table has columns for DEVICE, UUID, STATE, OS, FIRMWARE VERSION, HARDWARE MODEL, CLOUD, DETAILS, and DELETE. Two devices are listed:

DEVICE	UUID	STATE	OS	FIRMWARE VERSION	HARDWARE MODEL	CLOUD	DETAILS	DELETE
Edge Node Manager - 192.168.1.103	d2dd0fd8-6764-418f-9a29-702c1f378685	Online	UNRELEASED	1.5.4-1	ARTIK530S	X		
marka020	d2dd0fd8-6764-418f-9a29-000b5727c0db	Online	3.5.2	1.0.3	ARTIK-020			

Below the table is a "Refresh" button and an "AUTO-REFRESH EVERY 10 SECONDS" checkbox. A message at the bottom indicates "2 Devices detected". At the very bottom of the dashboard, there are links for "Home" and "Company", and a copyright notice: "© 2017 Samsung ARTIK, The ARTIK End-to-end IoT Platform".

Edge Node Manager Dashboard (Cont.)

The screenshot shows the ENM DASHBOARD configuration page. The left sidebar lists navigation options: ENM - 192.168.1.103, DEVICES, ENM CONFIGURATION (selected), DEBUG MODE, ANALYTICS, and ARTIK.IO. The main content area displays the Edge Node Manager Configuration Properties. It includes sections for REST API, DBUS API, DEBUG, LWM2M API, EVENTS API, and DISCOVERY ENABLE ON STARTUP API, each with an enable switch. Below these are fields for CLIENT ID (containing "client_id") and DATABASE PATH (containing "/var/local/enmd.db"). The top status bar shows Version 1.5.4, ENM up 9 minutes ago, and Platform up 10 minutes ago.

ENM DASHBOARD

Version 1.5.4 ENM up 9 minutes ago Platform up 10 minutes ago

Edge Node Manager Configuration Properties

REST API * ENABLE OR DISABLE THE REST API MODULE
 ON OFF

DBUS API * ENABLE OR DISABLE THE DBUS API MODULE
 ON OFF

DEBUG ENABLE OR DISABLE THE DEBUG TRACES
 ON OFF

LWM2M API * ENABLE OR DISABLE THE LWM2M API MODULE
 ON OFF

EVENTS API * ENABLE OR DISABLE THE EVENTS API MODULE
 ON OFF

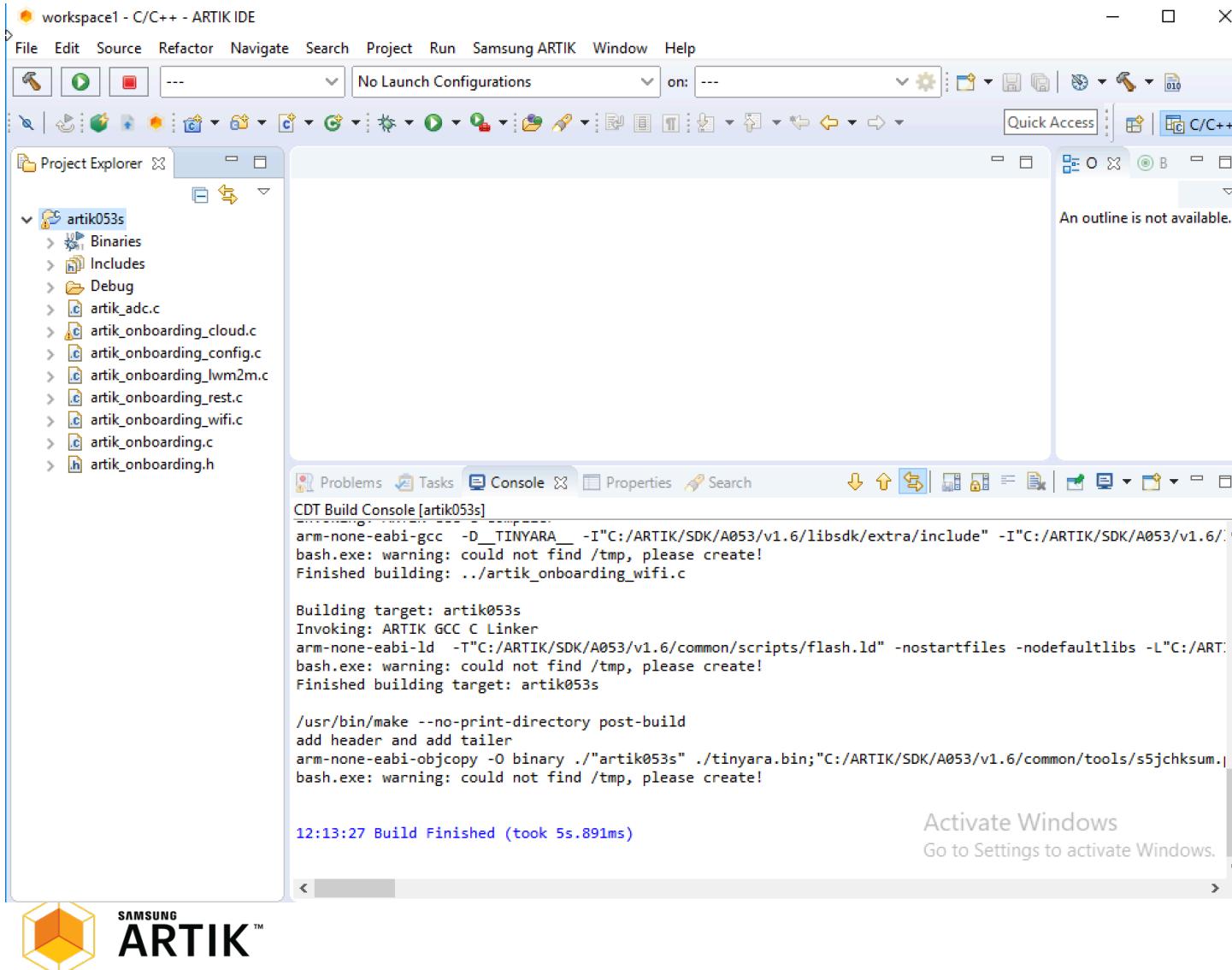
DISCOVERY ENABLE ON STARTUP API ENABLE OR DISABLE THE DISCOVERYENABLEONSTARTUP
 ON OFF

CLIENT ID
client_id

DATABASE PATH * SPECIFIES THE DATABASE STORAGE PATH
/var/local/enmd.db

ARTIK Gateway Module Development

ARTIK IDE



The screenshot shows the ARTIK IDE interface for a C/C++ workspace named "workspace1 - C/C++ - ARTIK IDE". The Project Explorer view displays a single project folder "artik053s" containing files like "Binaries", "Includes", "Debug", and several source files such as "artik_adc.c", "artik_onboarding_cloud.c", "artik_onboarding_config.c", "artik_onboarding_lwm2m.c", "artik_onboarding_rest.c", "artik_onboarding_wifi.c", and "artik_onboarding.h". The CDT Build Console window shows the build process for the target "artik053s". The log output includes:

```
arm-none-eabi-gcc -D_TINYARA -I"C:/ARTIK/SDK/A053/v1.6/libsdk/extra/include" -I"C:/ARTIK/SDK/A053/v1.6/^.^
bash.exe: warning: could not find /tmp, please create!
Finished building: ../artik_onboarding_wifi.c

Building target: artik053s
Invoking: ARTIK GCC C Linker
arm-none-eabi-ld -T"C:/ARTIK/SDK/A053/v1.6/common/scripts/flash.ld" -nostartfiles -nodefaultlibs -L"C:/ARTI^.^
bash.exe: warning: could not find /tmp, please create!
Finished building target: artik053s

/usr/bin/make --no-print-directory post-build
add header and add tailer
arm-none-eabi-objcopy -O binary ./"artik053s" ./tinyara.bin;"C:/ARTIK/SDK/A053/v1.6/common/tools/s5jchksu^.^
bash.exe: warning: could not find /tmp, please create!

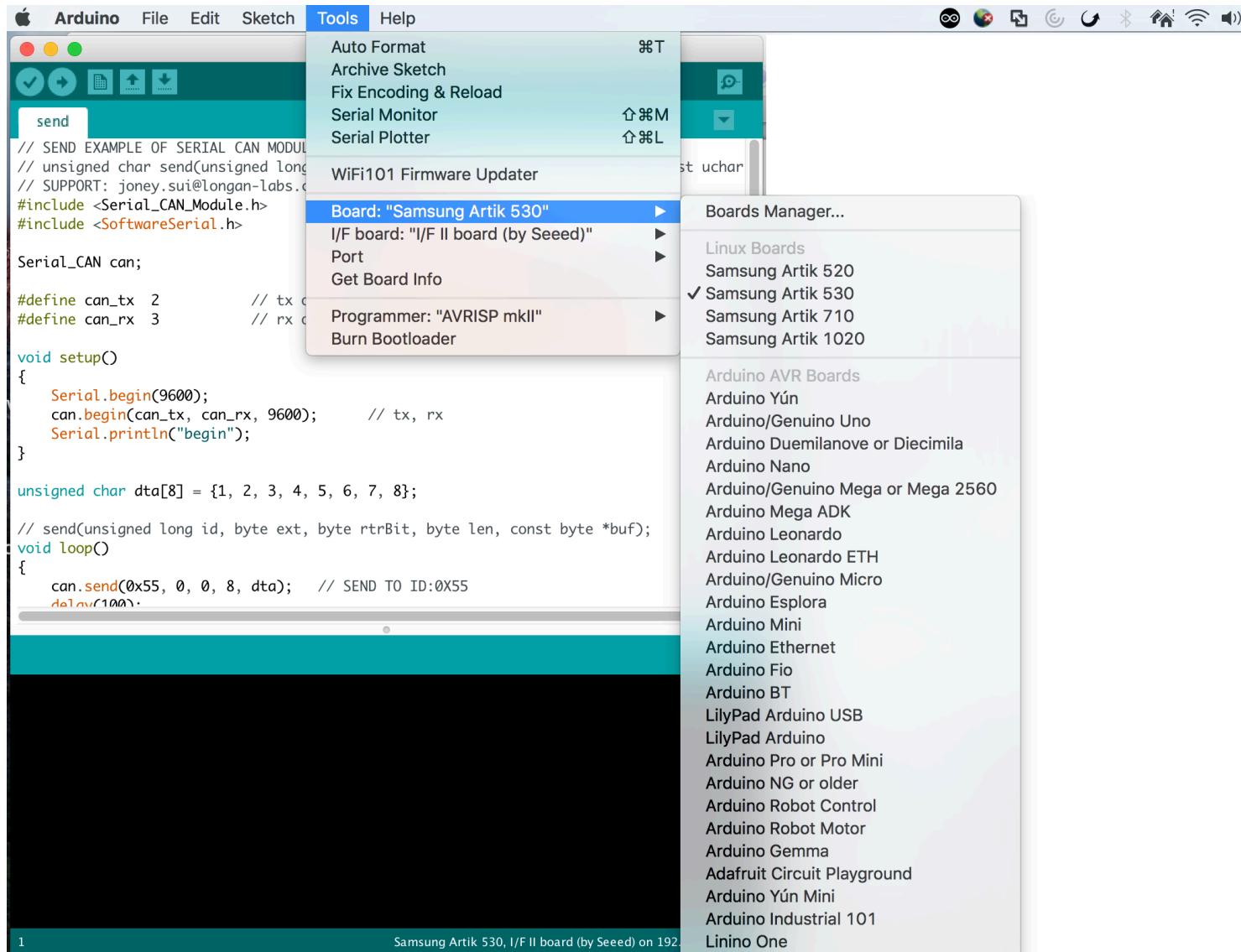
12:13:27 Build Finished (took 5s.891ms)
```

An "Activate Windows" watermark is visible at the bottom right of the IDE window.



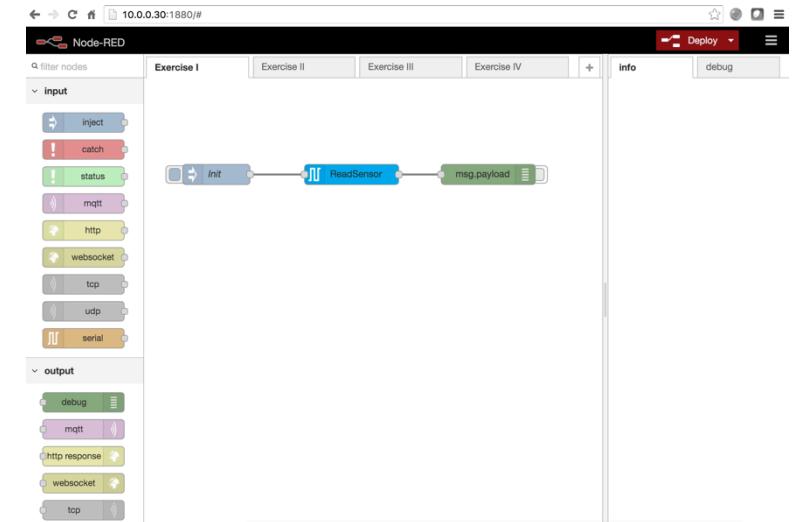
gcc-arm-linux-gnueabihf
and
aarch64-linux-gnu

Arduino



Node-RED

- A visual tool for wiring the internet of things, based on Node.js
- Utilizes flow programming technique
- Construct program flow by drag-and-drop
- You have the option not to write code
- Growing ecosystem
- Cloud-based solutions: IBM Bluemix, Front end Node-RED



Native Development

- C/C++: Most popular programming languages for embedded devices. e.g, ARTIK SDK
- Python: Rich libraries
- JS: Node.js is the most popular JavaScript runtime for high-end IoT devices.
- Java:

3rd party Libraries/APIs

- Multimedia: PyAudio, OpenCV, Speech Recognition etc.
- Communication Protocols/Frameworks:
 - MQTT(Eclipse Mosquitto/Paho)
 - OPC-UA(Eclipse Milo, open62541)
 - LWM2M(Eclipse Wakama, Eclipse Leshan)

Open Source Frameworks, Solutions

Gateway Solutions:



Communication Protocols/Frameworks:



ARTIK Gateway Module Use Case

Customer Use Cases



Legrand: Global residential and commercial digital building infrastructure

Challenge: Transform product line to meet new connected digital mkt requirements.
Fast time to mkt. Interoperability.

Products: ARTIK Ox, ARTIK 5/7 secure system-on-modules, ARTIK cloud services

Why ARTIK? Reduced product development time. Built-in software eliminated internal dev skills roadblock. Security allows them to meet new customer reqs. Interoperability expands switch capabilities, helped them get POC with Marriott "Room of the Future".



NDA Customer: Factory automation provider

Challenge: Retrofit customer OT to meet requirements for Industry 4.0, enable access to data and create digital twins for more efficient operations. Ensure secure operations.

Products: ARTIK 05x and 530s secure system-on-module, ARTIK Cloud service, PTC ThingWorx

Why ARTIK? Secure gateway solution for their industrial gateway with access to local sensors, ability to do local processing and edge node management, ARTIK Cloud service for onboarding, device management & OTA, data management via integration with PTC Thingworx front end application.

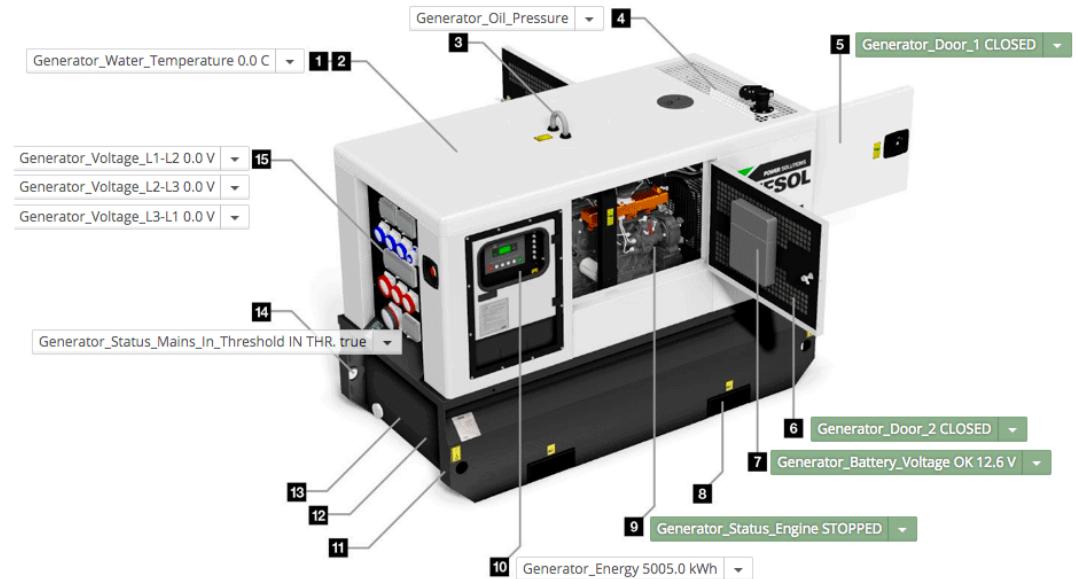
Kitra GTI ARTIK 710s

Use Kitra GTI as the Industrial IoT Gateway

Use case: Industrial IoT Gateway device, hubs

Hardware: ARTIK 710S

Software: Software based on your application



CAN Bus Solution for Access to Vehicle Data

ARTIK 5x, ARTIK 7x SoMs

Use ARTIK 5x/7x for CAN bus communication.

Use case: Vehicle/boat diagnostic system

Hardware: ARTIK 5x/7x & interface board, Grove Base Shield, Serial CAN bus module

Software: libArduino for ARTIK 5x/7x



Long-range Connectivity

ARTIK 530s with Multi-tech

Provide LTE support on ARTIK 530s with Multi-tech modem and Twilio SIM. Send a text message to Twilio phone number and receive real-time readings from sensors attached to ARTIK 530s.

Use case: Smart city, remote data transmission and monitoring systems, freight management

Hardware: ARTIK 530s, Multi-tech modem, Twilio SIM card, (optional) screen LCD

Software: Twilio APIs, Qt for UI



Facial Recognition Security Camera

ARTIK 530s

Uses ARTIK 530s and camera accessories for facial recognition. Non-enrolled faces will trigger alerts. Motion detection and video capture can be enabled.

Use case: Home surveillance, access control system

Hardware: ARTIK 530s, OV5640 5M Auto Focus USB camera, 10.1" PCAP Touch Screen LCD, sensors

Software: OpenCV, Kairos face recognition APIs, Qt



Voice Enablement

ARTIK 530s SoM and Google Assistant

Run Google Assistant or Amazon AVS on ARTIK530s. Use voice commands to control peripherals or sensors attached to ARTIK.

Use case: Voice-controlled gateway, home and building products

Hardware: ARTIK 530s, speaker, (optional) LCD

Software: Google Assistant SDK or Alexa Voice Service Device SDK. Can develop additional Google Actions or Alexa skills to extend basic capabilities.



Machine Learning Inference

ARTIK 710

Run Machine Learning Inference on ARTIK 710

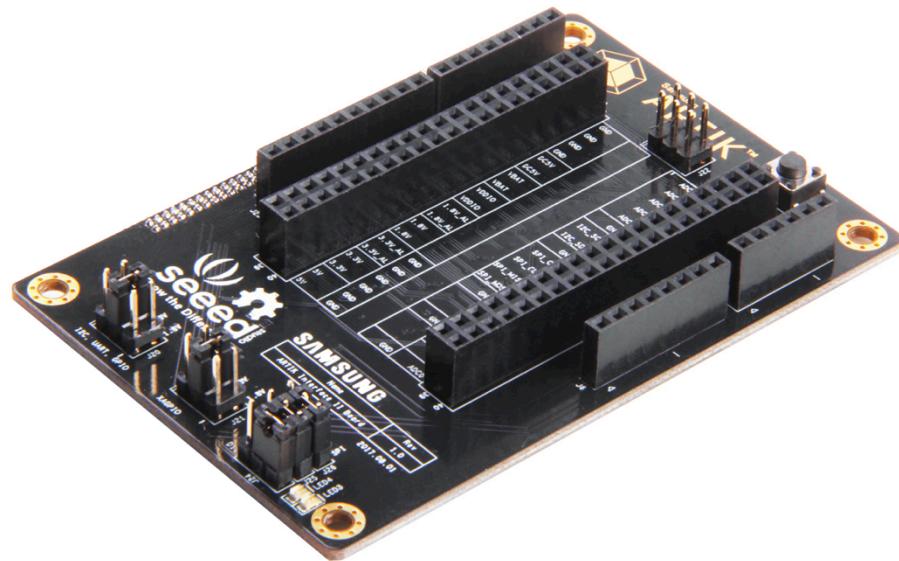
Use case: Smart Factory, Smart Building, Facial Recognition etc.

Hardware: ARTIK 710(s)

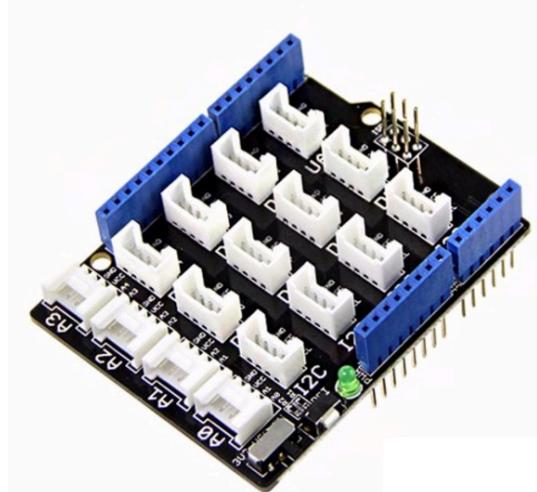
Software: Tensor Flow trained model; AWS Greengrass ML
Inference



Arduino Shields



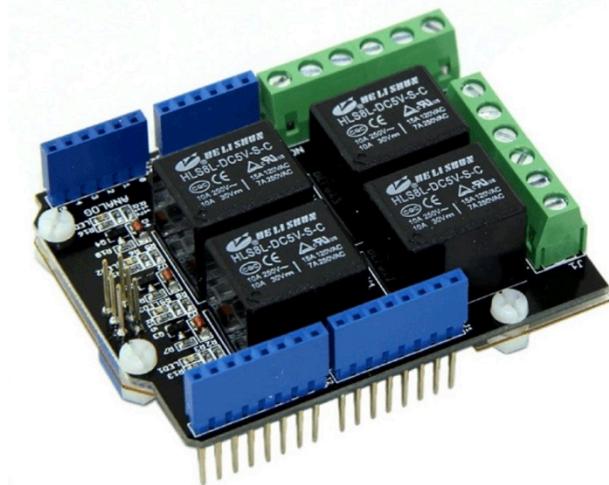
Arduino IF II board



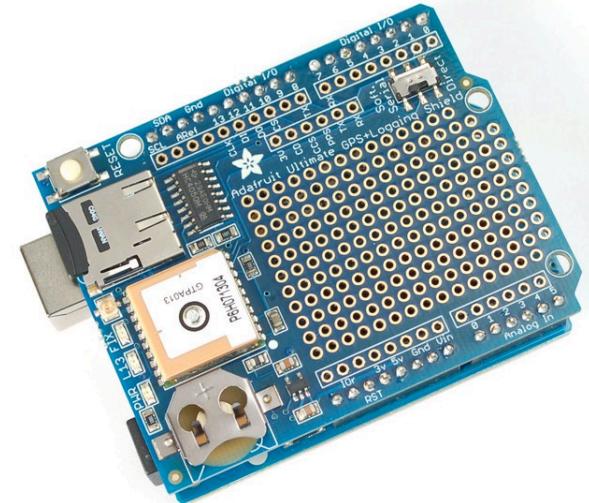
Base Shield



Motor Shield



Relay Shield



GPS Logger Shield
64
Confidential

Hands-On Labs

Configure GPIO Pins



- Configure GPIO from device trees (U-boot or kernel)
 - Configure GPIO in User Mode via Sysfs

Table 2. GPIO Software and Hardware Pin Mapping

Software Sysfs Numbering Scheme ¹	Software Device Tree Numbering Scheme ²	Hardware Numbering Scheme ³	Software Sysfs Numbering Scheme ¹	Software Device Tree Numbering Scheme ²	Hardware Numbering Scheme ³
gpio0	gpioa-0	AP_GPA0	gpio96	gpiod-0	AP_GPD0
gpio1	gpioa-1	AP_GPA1	gpio97	gpiod-1	AP_GPD1
gpio2	gpioa-2	AP_GPA2	gpio98	gpiod-2	AP_GPD2
.....
gpio31	gpioa-31	AP_GPA31	gpio127	gpiod-31	AP_GPD31
gpio32	gpiob-0	AP_GPB0	gpio128	gpioe-0	AP_GPE0
gpio33	gpiob-1	AP_GPB1	gpio129	gpioe-1	AP_GPE1
gpio34	gpiob-2	AP_GPB2	gpio130	gpioe-2	AP_GPE2
.....
gpio63	gpiob-31	AP_GPB31	gpio159	gpioe-31	AP_GPE31
gpio64	gpioc-0	AP_GPC0			
gpio65	gpioc-1	AP_GPC1			
gpio66	gpioc-2	AP_GPC2			
.....			
gpio95	gpioc-31	AP_GPC31			