



Zephyr™ Project

Developer Summit

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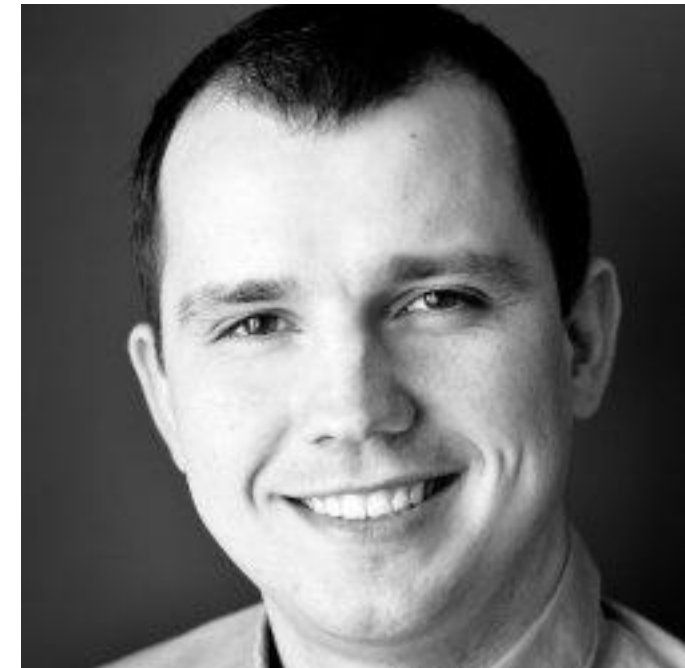


Zephyr™ Project
Developer Summit

How to perform Zephyr OTA update over LoRaWAN

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PLANT

- Managing Embedded Firmware projects since 2015
- Zephyr enthusiast, developer and PM since January 2017
- Conference speaker and organizer
- Open Source Firmware evangelist
- 13 years in business
- C-level in:



*Piotr Król,
CEO and Co-Founder of LPN Plant*



@lpnplant
@pietrushnic

Who we are?

- Wireless connectivity integrator for Industrial IoT
- Smart Metering and Smart Lighting based on OSS components
- Embedded Software Developers leveraging Zephyr on nodes
- Yocto-based gateways using Xen and TrenchBoot
- Open Source Firmware enthusiasts and evangelists



Agenda

- LoRaWAN introduction
- Device Firmware Upgrade in Zephyr
- DFU strategies using MCUboot
- Problem statement
- Proposed solution
 - Gateway
 - Node
 - LoRaWAN multicast
 - Update logic
- “Demo”

LoRaWAN introduction

- **Long Range** Wide Area Networking standard which leverages unlicensed radio spectrum in the Industrial, Scientific and Medical (ISM) band
- Works well in urban, industrial and in door environment
- AES128 end-to-end encryption
- Good alternative for NB-IoT and LTE-M low bandwidth applications like smart metering or smart lighting
- Low power
- Ability to leverage public or built private infrastructure for your application

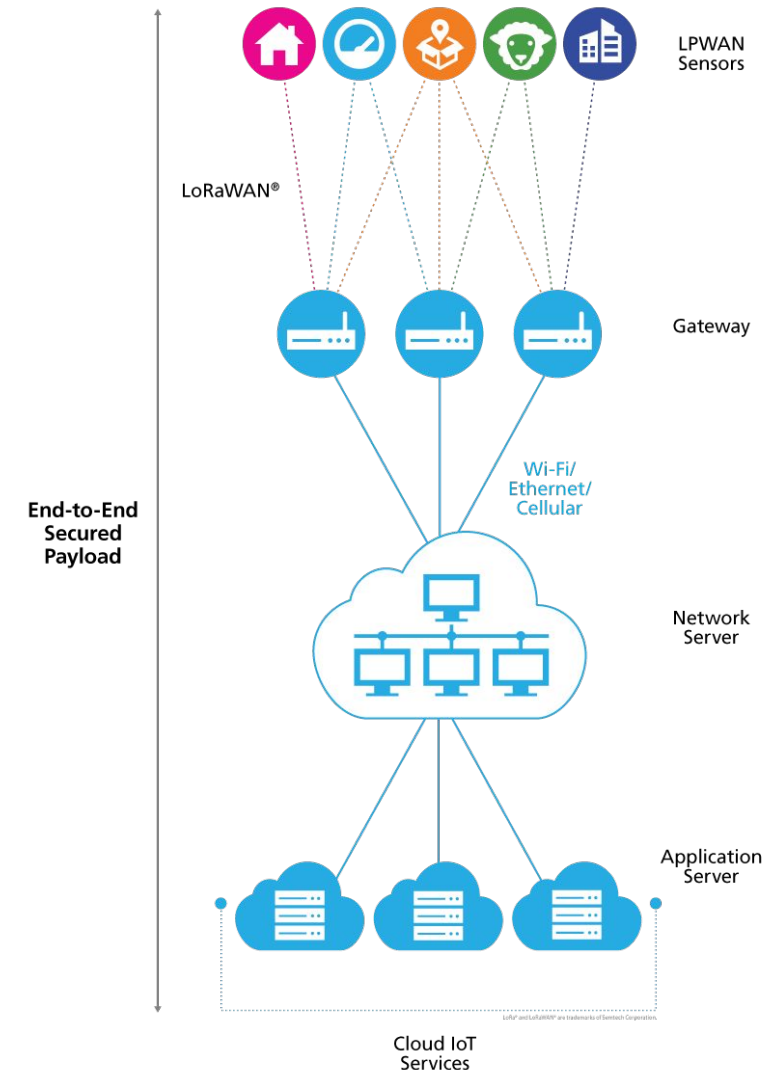


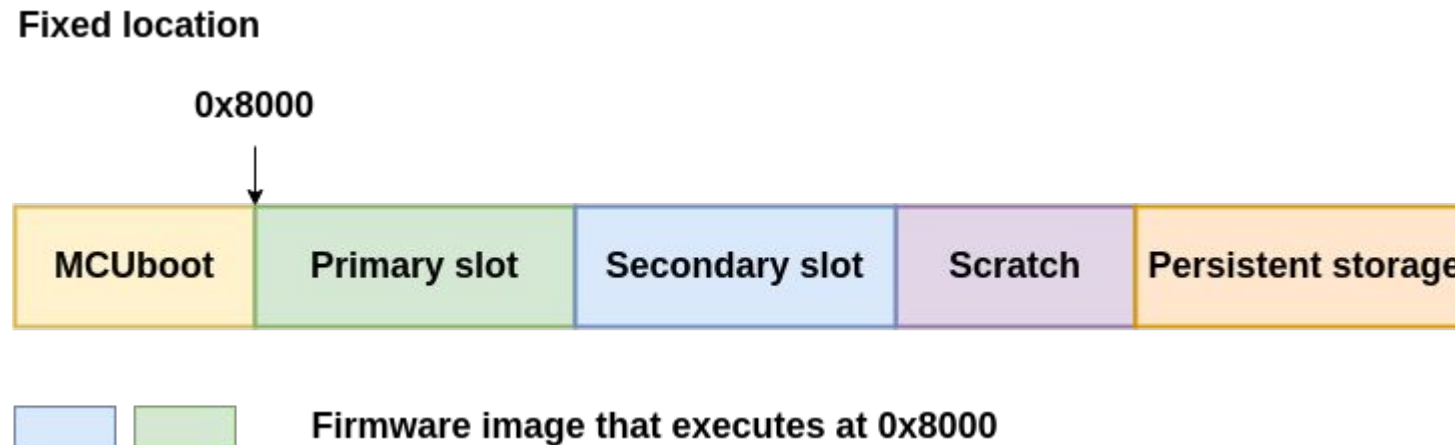
Image: <https://www.semtech.com/lora/what-is-lora>

Device Firmware Upgrade in Zephyr

- Zephyr-based applications can be updated using code from Device Firmware Upgrade subsystem
 - subsys/dfu/boot - interface code for bootloaders
 - subsys/dfu/img_util - firmware image management code
- The goal is to deal with firmware images not transport and management protocols required to tx/rx image
- As example Zephyr supports BLE and serial as DFU transport
- Zephyr is directly compatible with MCUboot - Apache 2.0 licensed cross-RTOS bootloader
- Enabling MCUboot for your Zephyr-based application is straight forward and described well in documentation:

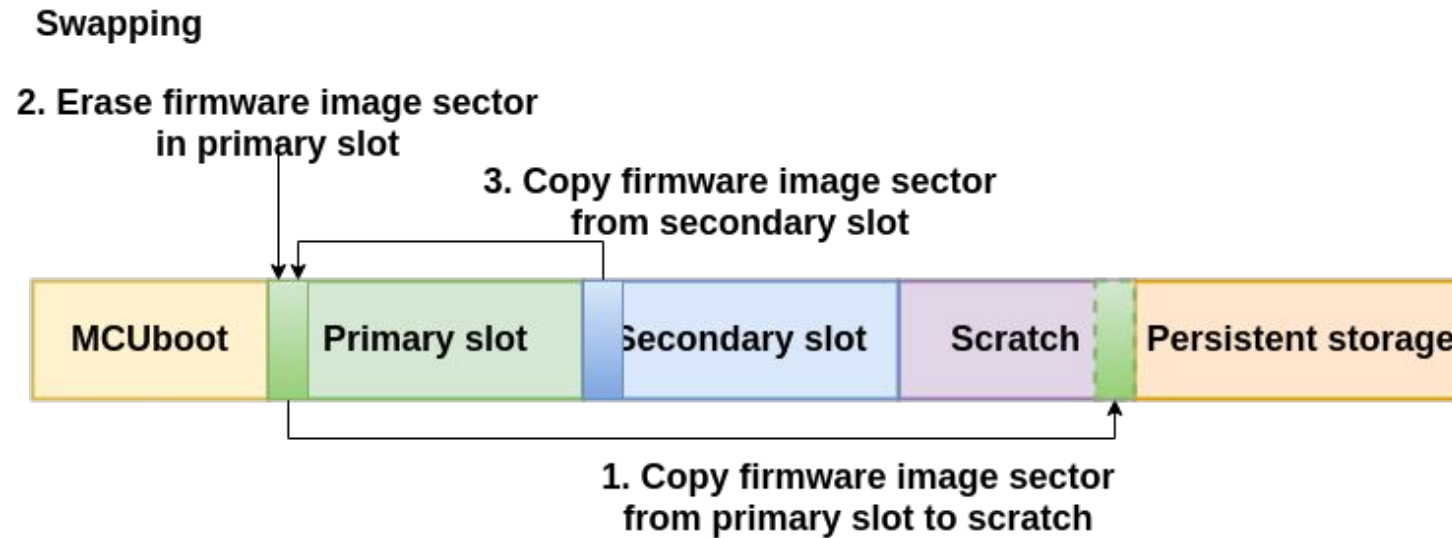
https://docs.zephyrproject.org/latest/guides/device_mgmt/dfu.html

DFU strategies using MCUboot



- Fixed location - firmware images are built to run only from fixed location in flash, strategy how to handle transition to new firmware has to be configured at build time
 - Swapping
 - Overwriting

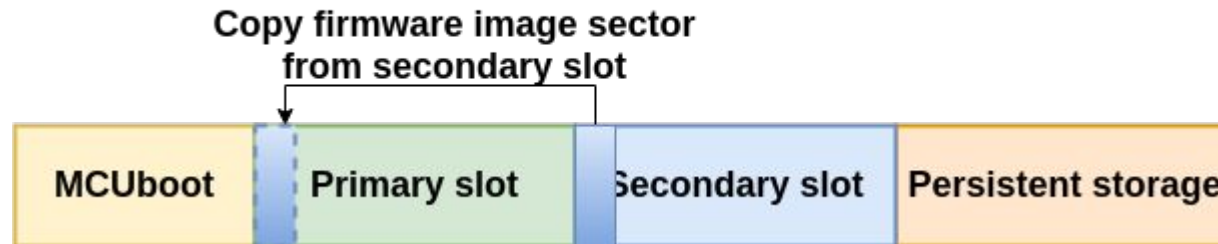
DFU strategies using MCUboot



- Swapping - strategy use scratch area to swap content of primary and secondary image

DFU strategies using MCUboot

Overwriting



- Overwriting - bootloader overwrite primary slot with the content of secondary slot

- Other strategies:
 - Direct XIP - use active image flag to mark active image, requires awareness of execution location both by build system and update client
 - RAM load - execution happen in memory
- More details can be found in MCUboot documentation:
<https://mcuboot.com/design.html>
- *Terminology clarification:* Device Firmware Upgrade which happen using wireless technology we often call Over-The-Air (OTA) upgrade/update

- Nodes downtime should be minimized
- LoRaWAN payload size is small in comparison to firmware size
- We operate in crowded noisy environment some packets may be lost or broken - progress of upgrade on each node can be different
- Transmission time depends on regulation
 - For example in Europe **duty cycle** is 0.1% and 1% depending on channel
 - There are some features of LoRaWAN that help optimizing data rates, airtime and energy consumption like Adaptive Data Rate but it has its own limitation depending on transmission
- **Duty cycle** or power cycle is the fraction of one period in which a signal or system is active

LoRaWAN constraints

LoRaWAN data rates and payload sizes

Data Rate	Configuration	Indicative Bit Rate (b/s)	N
0	LoRa: SF12 / 125 kHz	250	51
1	LoRa:SF11 / 125 kHz	440	51
2	LoRa:SF10 / 125 kHz	980	51
3	LoRa:SF9 / 125 kHz	1760	115
4	LoRa:SF8 / 125 kHz	3125	222
5	LoRa:SF7 / 125 kHz	5470	222
6	LoRa:SF7 / 250 kHz	11000	222
7	FSK: 50 kbps	50000	222

EU863-870 Data Rates – Source: <https://loro-alliance.org/resource-hub/rp2-101-lorawanr-regional-parameters>

N: maximum application payload length, in the absence of the optional FOpt control field

In Europe the data rate that is the most resilient to noise is *LoRa: SF12 / 125 kHz* (Data Rate 0)

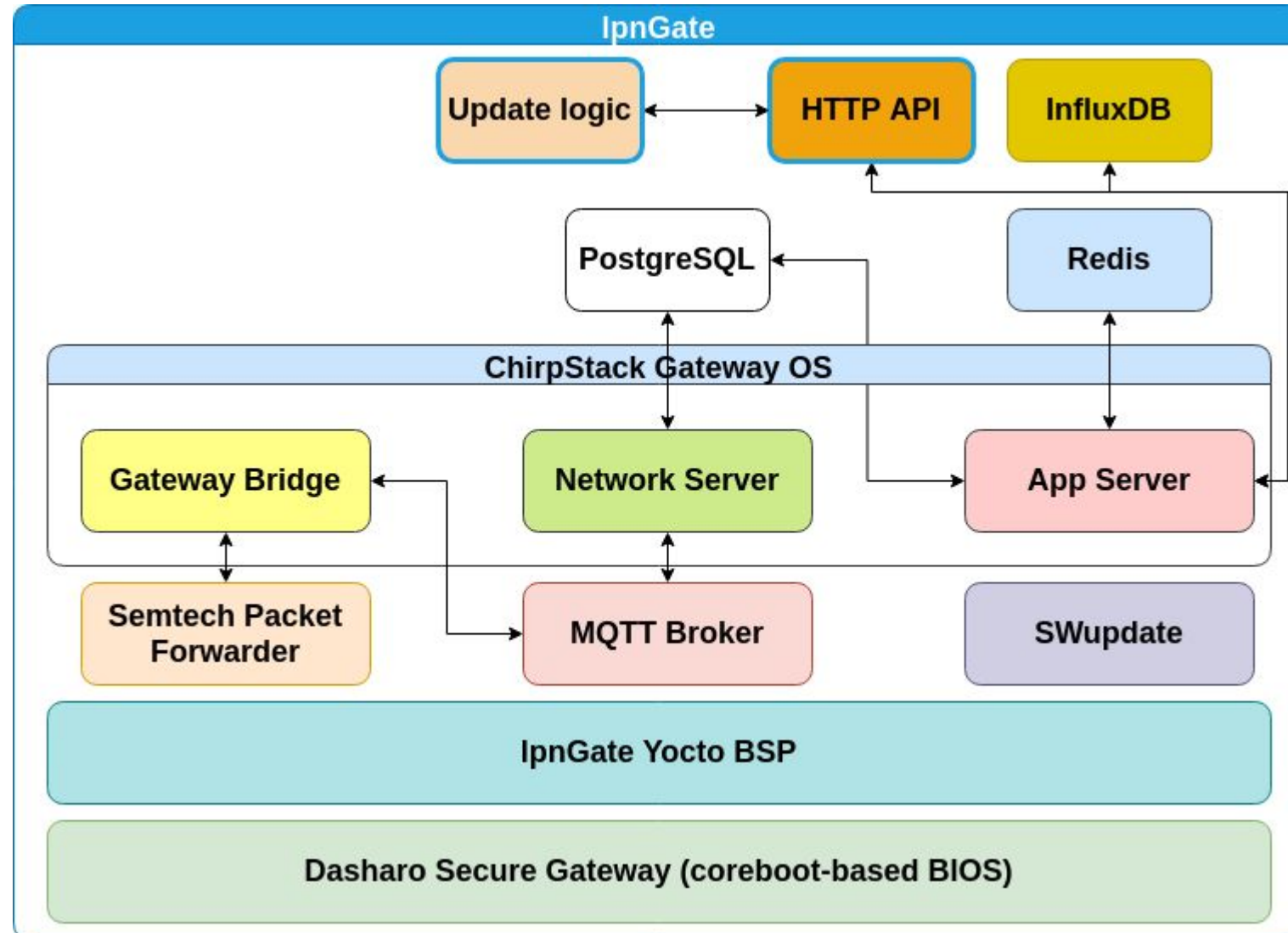
In this case the payload limitation is 51 bytes.

Proposed solution: LoRaWAN gateway

- AMD Quad Core 1GHz, 4GB DDR3-1333 DRAM
- RS-232, 2x USB 3.0
- 3x Intel i210AT NICs
- mSATA and 2x mPCIe slots
- Open Source Firmware (Dasharo Secure Gateway coreboot-based)
- TPM support
- LTE and WiFi ready
- In-door and Outdoor (IP67) option



Proposed solution: LoRaWAN gateway

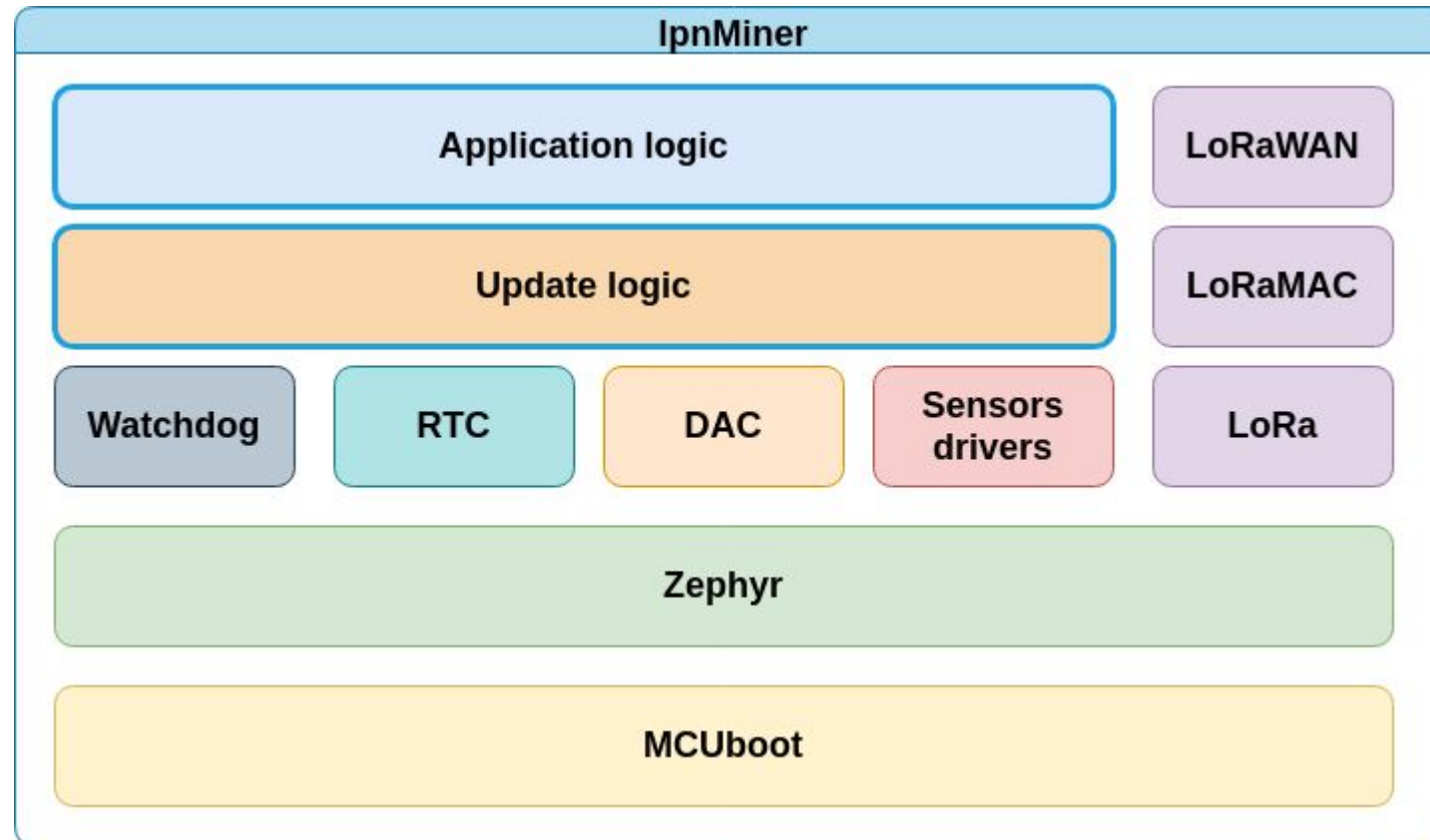


Proposed solution: LoRaWAN node

- STM32L4 + LoRaWAN module
- MCUboot and Zephyr RTOS
- on-board temperature measurement
- energy consumption monitoring
- 2 isolated digital inputs and outputs
- power: 12-24 V DC input or internal battery
- RS-485, 4-20mA, 1-wire
- sensor can be powered by the node



Proposed solution: LoRaWAN node



Proposed solution: LoRaWAN multicast

- LoRaWAN nodes can receive only unicast messages unless **DevID** is assigned
- **DevID** is integer number which uniquely identifies the device in whole network
- The **DevID** is used later in the multicast messages to determine part of message which is related to given node.
- **Multicast mask** describes which nodes are active in multicast operation like FOTA
- Nodes apart from their device specific LoRaWAN keys can be assigned with multicast keys common to the nodes within the same multicast group.
- Using **multicast mask** and **DevID** we can solve 2 problems
 - Delivering messages to multiple nodes
 - Retransmitting missing packets to specific nodes

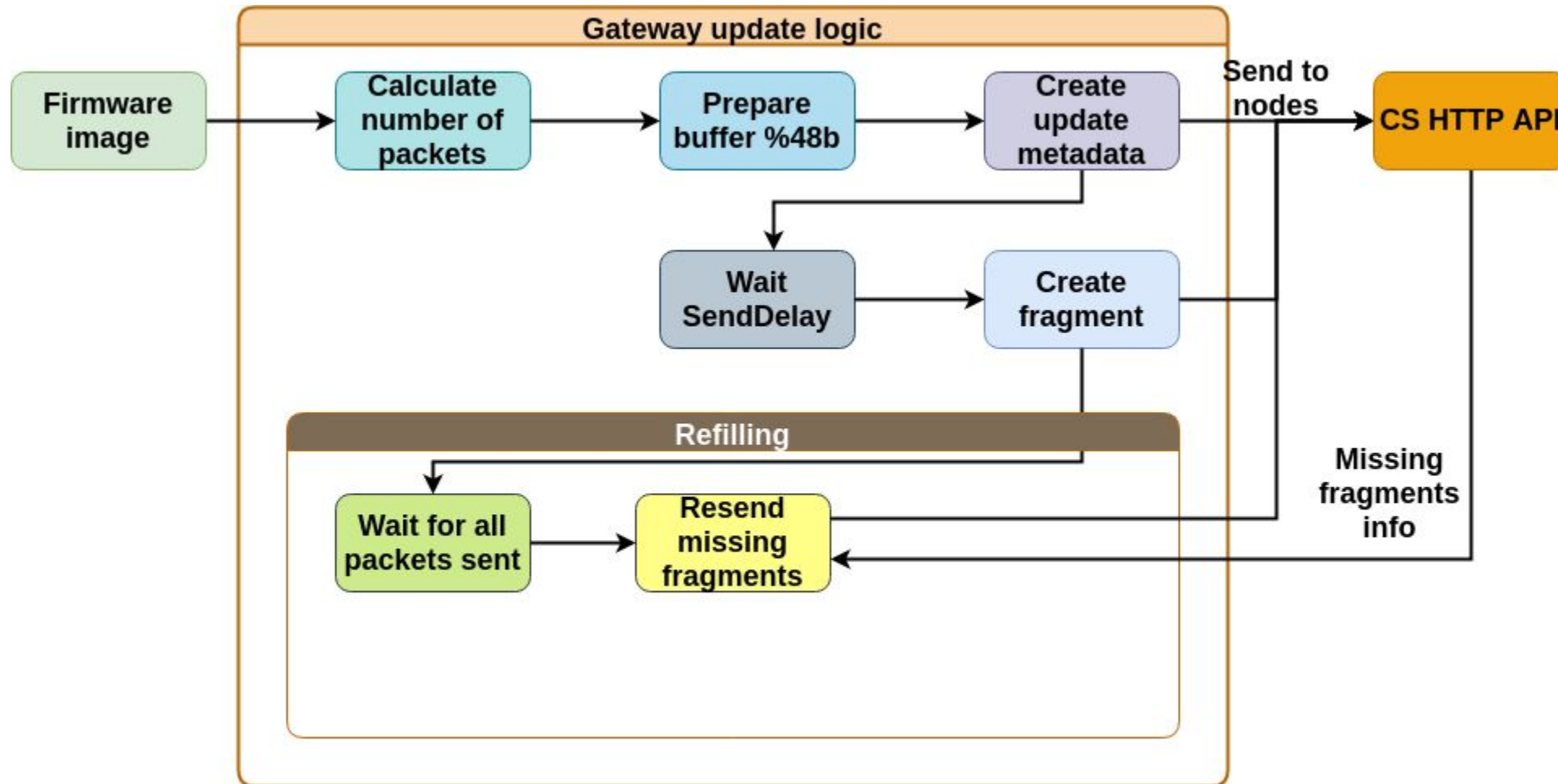
Proposed solution: gateway update logic

- Gateway update logic start update with following information
 - msk - Device mask used in multicast downlinks
 - c - CRC32 of the whole binary
 - tp - Total number of packets
- Each binary fragment contains also a packet id and CRC8 of the packet itself:

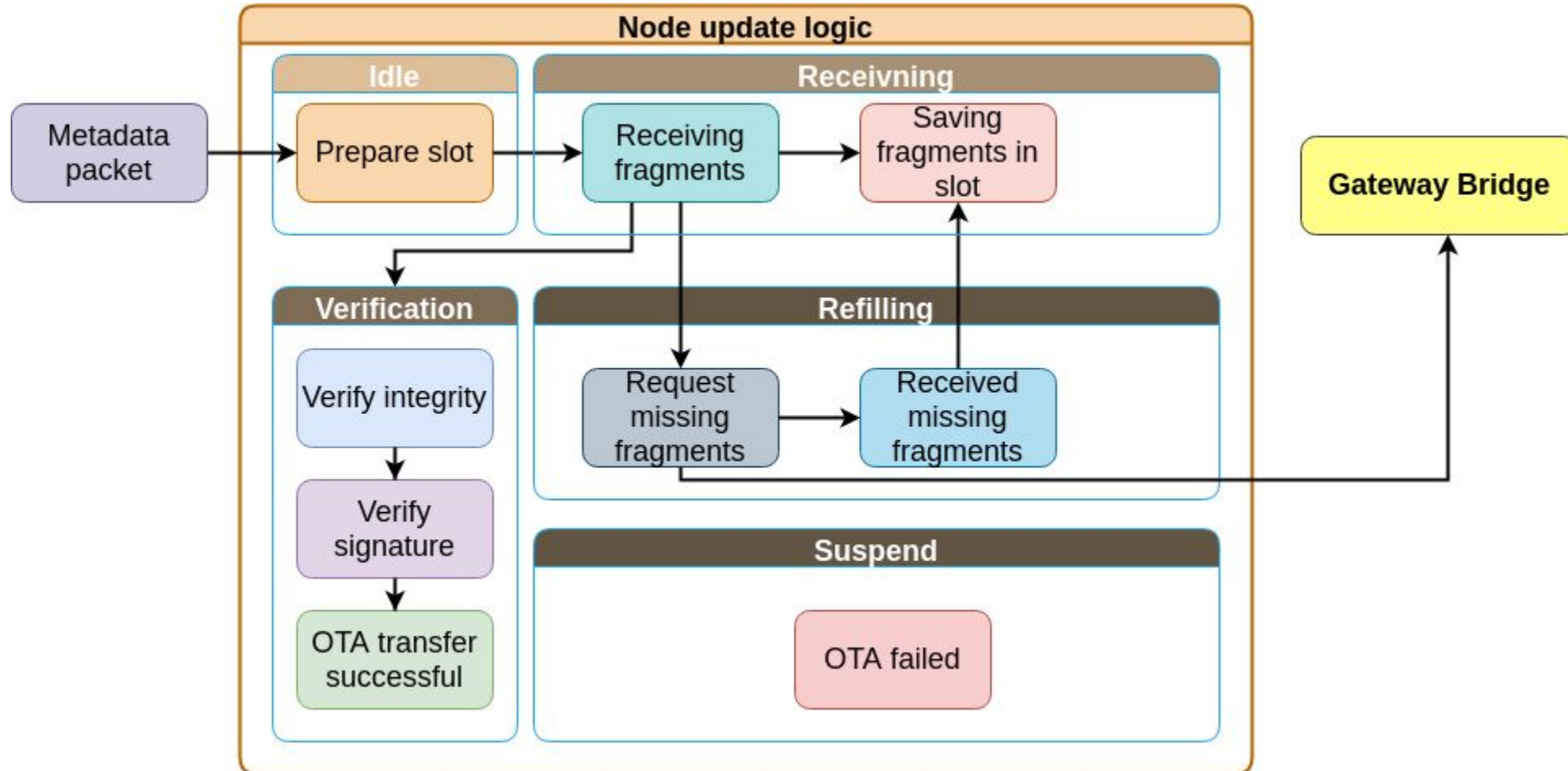
```
{"tp":1877,"c":1406356305,"msk":512}
```

2 bytes		48bytes	1byte
FW_packet_no		FW_packet	CRC8

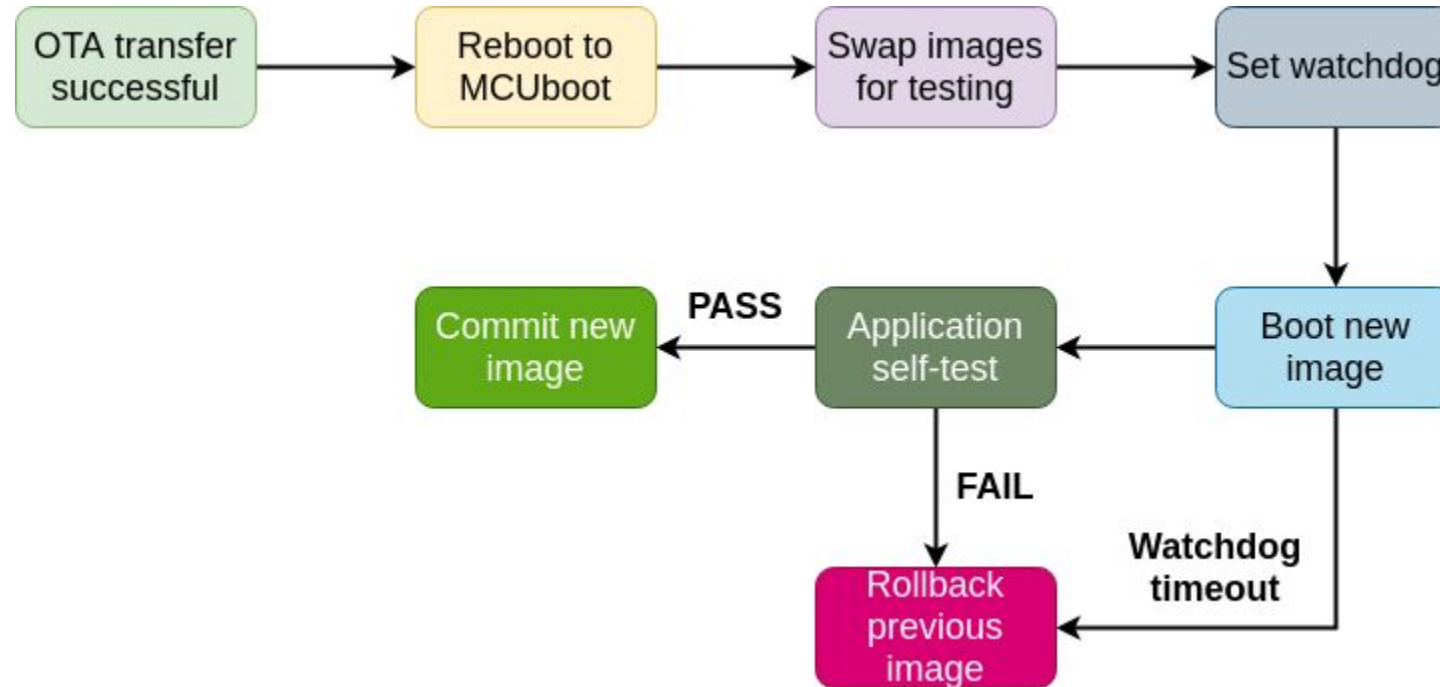
Proposed solution: gateway update logic



Proposed solution: node update logic



Proposed solution: node update logic



Demo - Node

- Running application on the MCU

```
[00:00:00.222,000] <inf> sx1276: SX1276 Version:12 found
[00:00:00.277,000] <inf> lplnlight: VERSION 1.1.3
[00:00:00.277,000] <inf> config: Detected HW Version: 0
[00:00:00.277,000] <inf> config: Device Configuration: NO_BRIGHTNESS
[00:00:00.277,000] <inf> format: EUI: 73c5601be8f0d305
[00:00:00.278,000] <inf> relay: Relay switched off
[00:00:00.278,000] <inf> lplnlight: Device ID: 1
[00:00:00.278,000] <inf> lora: Configuring LoRaWAN stack
[00:00:00.281,000] <inf> lora: Joining network
[00:00:05.457,000] <inf> lorawan: Joined network! DevAddr: 01eb0b0d
[00:00:05.457,000] <inf> lorawan: Device Class C Switch
[00:00:05.459,000] <inf> lora: Configuring multicast channel: 0
[00:00:05.459,000] <inf> lorawan: Multicast channel 0 config success
```

- Starting OTA update

```
[00:43:30.277,000] <inf> rtc: Day: 1, Month: 1, Year: 0
[00:43:30.277,000] <inf> rtc: Hour: 0, Minute: 43, Sync: 0
[00:43:30.277,000] <inf> rtc: Total timetable saved events: 1
[00:43:37.149,000] <inf> data_sender: RxDataRate: 0
[00:43:37.149,000] <inf> data_sender: RSSI: -29
[00:43:37.149,000] <inf> data_sender: Size: 36
[00:43:38.328,000] <inf> ota: OTA started, waiting for packages
[00:43:39.452,000] <inf> data_sender: Frame sent
[00:43:40.277,000] <inf> rtc: Day: 1, Month: 1, Year: 0
[00:43:40.277,000] <inf> rtc: Hour: 0, Minute: 43, Sync: 0
[00:43:40.277,000] <inf> rtc: Total timetable saved events: 1
[00:43:50.277,000] <inf> rtc: Day: 1, Month: 1, Year: 0
[00:43:50.277,000] <inf> rtc: Hour: 0, Minute: 43, Sync: 0
[00:43:50.277,000] <inf> rtc: Total timetable saved events: 1
[00:43:55.664,000] <inf> data_sender: RxDataRate: 0
[00:43:55.664,000] <inf> data_sender: RSSI: -29
[00:43:55.664,000] <inf> data_sender: Size: 51
[00:43:55.664,000] <inf> ota: Recived binary package with id: 0
[00:44:00.277,000] <inf> rtc: Day: 1, Month: 1, Year: 0
[00:44:00.277,000] <inf> rtc: Hour: 0, Minute: 44, Sync: 0
[00:44:00.277,000] <inf> rtc: Total timetable saved events: 1
[00:44:04.677,000] <inf> data_sender: RxDataRate: 0
[00:44:04.677,000] <inf> data_sender: RSSI: -29
[00:44:04.677,000] <inf> data_sender: Size: 51
[00:44:04.677,000] <inf> ota: Recived binary package with id: 1
```


Demo - Gateway

```
root@pcengines-apu2:~# ./cs-app-manager fota -b demo-update.bin --mcg="a10158ac-629b-4fc6-b108-5d14c8775061" --msk=255
INFO[0000] binary file size: 101744
INFO[0000] no of packets: 2120
DEBU[0000] Metadata: eyJ0cCI6ImJyYm9uMTU3MzUwNSwibXNrijoyNTV9 CRC32=3901573505 Mask=255 TotalPackets=2120
DEBU[0018] AAA9uPOWAAAAAAAAAAAgigEAAAAAAAAEBBQAAAAAAAAAAAAAAAAAAAAAAAAAAAC8 CRC8=188 PktId=0
DEBU[0027] AQAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA CRC8=0 PktId=1
DEBU[0036] AgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA CRC8=0 PktId=2
DEBU[0045] AwAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA CRC8=0 PktId=3
DEBU[0054] BAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA CRC8=0 PktId=4
DEBU[0063] BQAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA CRC8=0 PktId=5
DEBU[0072] BgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA CRC8=0 PktId=6
DEBU[0081] BwAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA CRC8=0 PktId=7
DEBU[0090] CAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA CRC8=0 PktId=8
DEBU[0100] CQAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA CRC8=0 PktId=9
DEBU[0109] CgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAPgmACA97AID7QBCEXrAAip CRC8=169 PktId=10
DEBU[0118] CwBF6wAIResACEXrAagAAAAAAAAAAAAAAAAAAQeoACEXrAagAAAAA+ekACPHnAAhx CRC8=113 PktId=11
DEBU[0127] DAAV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAAjR CRC8=209 PktId=12
DEBU[0136] DQAV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAAjR CRC8=209 PktId=13
DEBU[0145] DgAV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAAjR CRC8=209 PktId=14
DEBU[0154] DwAV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAAjR CRC8=209 PktId=15
DEBU[0163] EAAV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAAjR CRC8=209 PktId=16
DEBU[0172] EQAV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAAjR CRC8=209 PktId=17
DEBU[0182] EgAV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAagV7AAIFewACBxsAAjR CRC8=42 PktId=18
DEBU[0191] EwAB8P8BECor2xDbwB8I0BD4ATsB0oTCLdAQ8ACpQrP20fC0QeoBIUHQAUEl8ACef/Ae CRC8=30 PktId=19
DEBU[0200] FAAAABwAj80gCVgg8heoBBYbqAQaF+kf1o/qH9Yb6R/aL+of2jrnU0fC8AFD/AQLwBwKt CRC8=173 PktId=20
DEBU[0209] FQAYSrD4ATsB0oPqAQMTsfjRACBwRwE4cEcALQa/NUYD0Ac4FfABDwFRATAV9IB/Ar/a CRC8=218 PktId=21
DEBU[0218] FgABMBX0wD8BMPc8AThWwC/gfAAQQLgAL+D8ABDMLVP6kEET+pDBZTqBQ8Iv5DqAg+8 CRC8=188 PktId=22
DEBU[0227] FwAFv1TqAAxV6gIMf+pkXH/qZVwA80KAT+pUVNtrVVW4v21CDN0sRIDqAgK6gMDgur3 CRC8=247 PktId=23
DEBU[0236] GAAAAlPqAQGA6gICgeODAZtL8wvRHwAE9P6gEXT/SAHEZqETECE0EBCYetBARPwAE8V CRC8=21 PktId=24
DEBU[0245] GQBP6gMzT0oTmWLUKJj60MDL0oFDwDwp4Ck8QEEIfEgDg3bAvo0/CL6BfKAGEHxAAF5 CRC8=108 PktId=25
DEBU[0254] GgAD+g7ygBhD+gXzWUE04KXxIAU08SAQASoD+g78KL9M8AIMQ/oF88AYUevjcQHwAEXx CRC8=241 PktId=26
DEBU[0263] GwAH1U/wAA7c8QAMfusAAG7rAQGX9YafG90x9QAFDNNJCF/qMABP6jwMBPEBBE/qRFKc CRC8=156 PktId=27
DEBU[0273] HAAS9YAPgPCagLzxAE8Iv1/qUAXQ8QAAQesEUUHQ0EQEwvV/qTAXAQUHRAQEBPCl/sFwi CRC8=162 PktId=28
DEBU[0282] HQCAH+nSkfAADwS/AUYAILH6gFMivYAzO/ELA7PxIAIM2gwyCN0C8RQMwvEMAgh6DPBK CRC8=74 PktId=29
DEBU[0291] HgAh+gLxD0AC8RQC2L/C8SAMAfoC8SD6DPzc0vHqDAGQQOQaoR8B6wRRKUMwvW/qBAS0 CRC8=180 PktId=30
DEBU[0300] HwAFPBZaDQ03ATxFATE8SACIPoE8AH6AVNA6gMAIf0E80XqAwEwctXDATE8SACIPrc CRC8=220 PktId=31
DEBU[0309] IAAC8AH6BPNA6gMAKUyYwvSH6BPAPrjC9LPAAD4P0gBMGv4H0gBEBNAE9Tud/6mRcGL8z CRC8=51 PktId=32
DEBU[0318] IQB/6mVcKdCU6gUPCL+Q6gIPBdBu6gAMBL8ZRHGML2R6gMPHR8AIAQgML1f6LrcBdHg CRC8=224 PktId=33
DEBU[0327] IgBAAE1BKL9B8ABBMLOU9YAEPL8B9YARML0B8ABFRfD+QUH0cAFP8AAAML1/6mRcGr/V CRC8=213 PktId=34
DEBU[0336] IwAZRhBgF+pLXBy/C0YCRlDqATQGV1LqAZwR6gMPQfQAITC9AL+Q8AAPBL8AIXBMLUA CRC8=0 PktId=35
DEBU[0345] JABP9IBkBPEyBE/wAAVP8AABU0cAv5DwAA8EwvAhcEcwtU/0gQGE8TIEEPAAUuI/QEJ9 CRC8=125 PktId=36
DEBU[0354] JQBP8AABPucAv0IAT+rIAU/qMQFP6gJwH78SBH9dK/B/T4HwYFFwRzLwF0Iiv3BHK/Ae CRC8=30 PktId=37
DEBU[0364] JgB/TwS/QfQAIXBMLVP9GB0AfaARSHwAEec5wC/U0oBAGl/cEcwtU/wAAUK4FDqAQJG CRC8=70 PktId=38
DEBU[0373] JwAiv3BHMUR8ABFatVAQmHrQQFP9IBkBPEyBF/qkVw/9NiuT/ADAL/q3AwYvWMyX+o0 CRC8=52 PktId=39
DEBU[0382] KADcDBi/AzIC69wCwvEgAwD6A/wg+gLwAFoD/kDqDgAh+gLxFES95gC/cLVP8PMTPT7 CRC8=251 PktId=40
DEBU[0391] KQDgbBzqEVQdvxzqE1WU6gwPLeoMDwDw3vgsRIHQAwYh6kxRI+pMU1DqATUYv1LqAZwG CRC8=134 PktId=41
DEBU[0400] KqBB9IARO/SAEZj0oPsCzk/wAAAXh+wLLBvAAQUD7A+VP8AAG4f5DVpZwAA8Yv07wAQ4I CRC8=8 PktId=42
```

- Starting CLI helper tool sending packetized new demo-update.bin binary with fw version 1.1.5
- Firstly the tool sends the METADATA about the update to devices in the specified MULTICAST GROUP. Individual devices from the multicast group can be selected with device mask (part of our custom protocol).



**SIX HOURS
LATER...**

Demo - Node

```
[00:00:00.222,000] <inf> sx1276: SX1276 Version:12 found
[00:00:00.277,000] <inf> lpinlight VERSION 1.1.5
[00:00:00.277,000] <inf> config: Detected HW Version: 0
[00:00:00.277,000] <inf> config: Device Configuration: NO_BRIGHTNESS
[00:00:00.277,000] <inf> format: EUI: 73c5601be8f0d305
[00:00:00.278,000] <inf> relay: Relay switched off
[00:00:00.278,000] <inf> lpinlight: Device ID: 1
[00:00:00.278,000] <inf> lora: Configuring LoRaWAN stack
[00:00:00.281,000] <inf> lora: Joining network
[00:00:05.457,000] <inf> lorawan: Joined network! DevAddr: 01eb0b0d
[00:00:05.457,000] <inf> lorawan: Device Class C Switch
```

<https://asciinema.org/a/cjKoWkNVxzM3LEcvsVGdEcHle>



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Q&A



ZephyrTM Project

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