NuttX 2019
International workshop

NuttX in Long Range RFID Readers

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Agenda

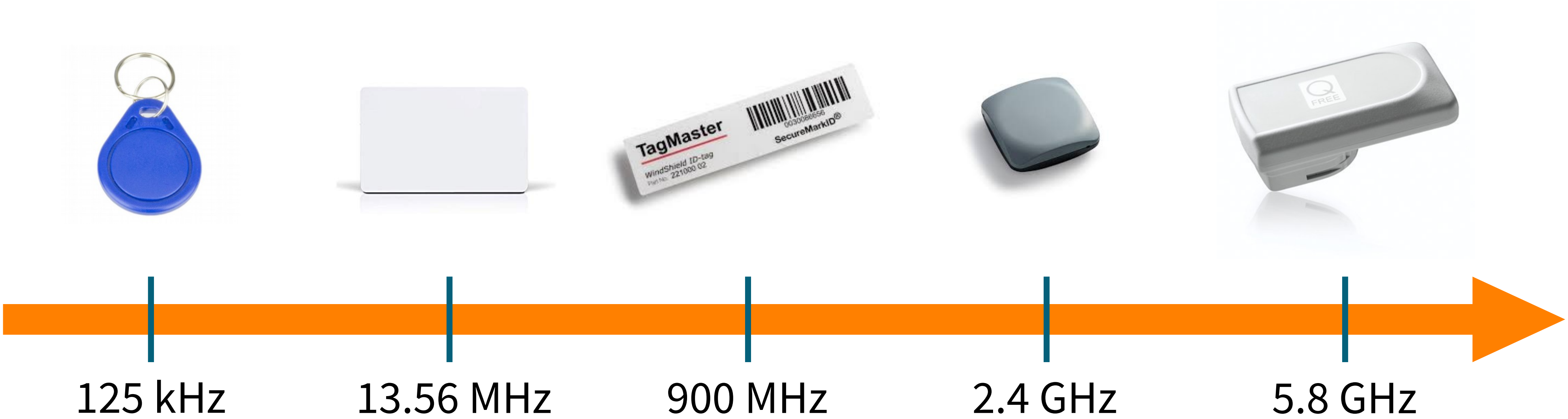
- RFID
- TagMaster
- Why NuttX?
- Our Implementation
- A Minimal Boot Loader
- My NuttX Wish List

RFID

RFID

- **R**adio **F**requency **ID**entification
- Uses radio waves to identify and/or track tagged objects
- A system consists of readers and tags
- Tags contain electronically stored information
- Active tags have a local power source and an active transmitter
- Passive tags collect energy from the radio waves
  and do not have an active transmitter

RFID Frequencies



125 kHz

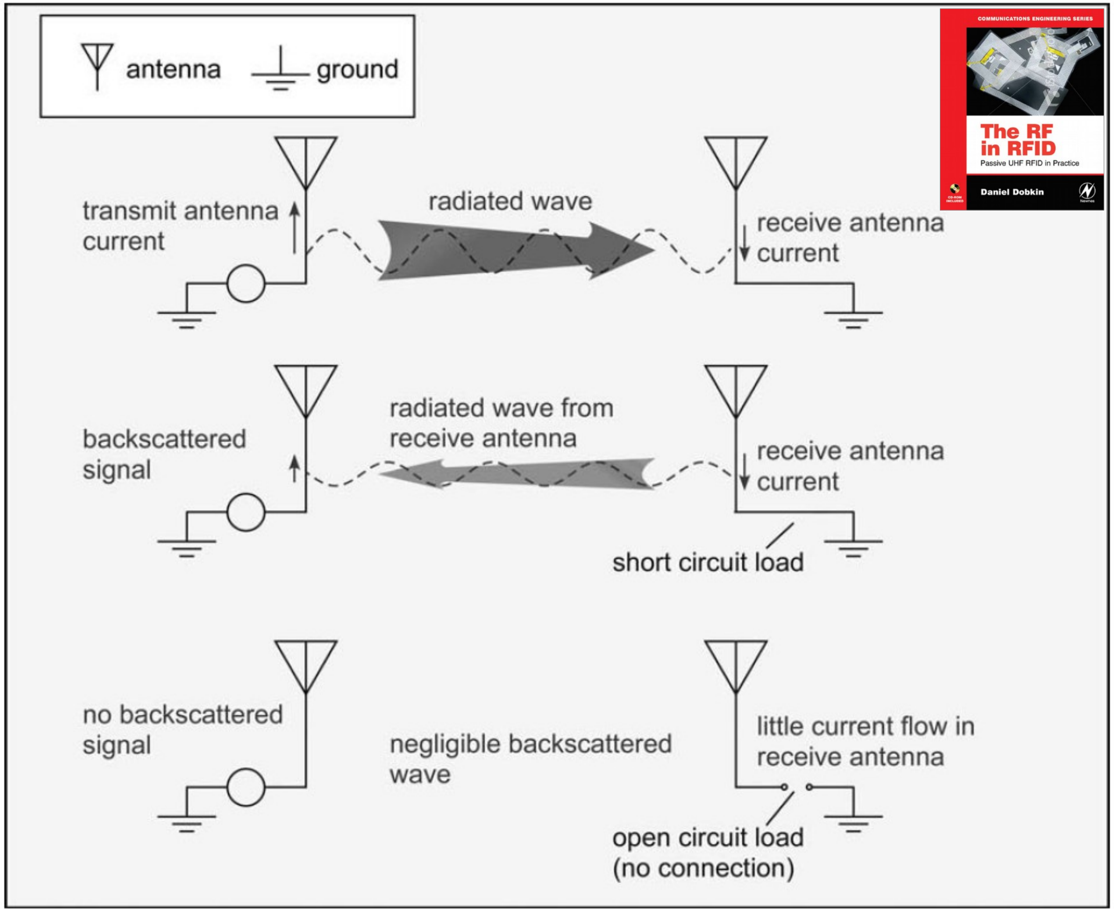
13.56 MHz

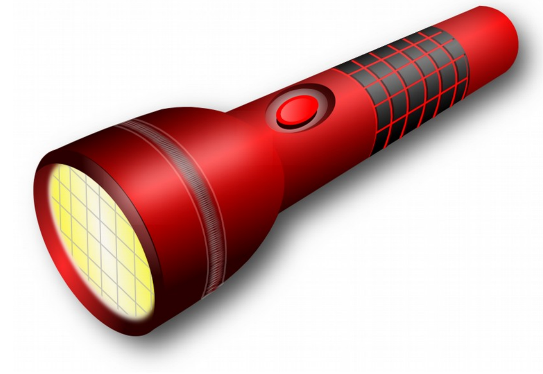
900 MHz

2.4 GHz

5.8 GHz

Backscattering

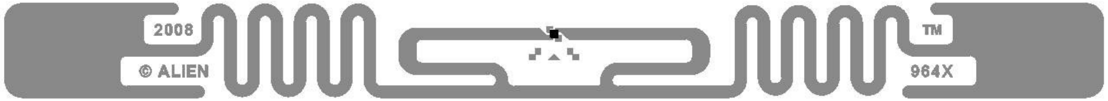

antenna
ground
transmit antenna current
radiated wave
receive antenna current
backscattered signal
radiated wave from receive antenna
receive antenna current
short circuit load
no backscattered signal
negligible backscattered wave
little current flow in receive antenna
open circuit load (no connection)
COMMUNICATIONS ENGINEERING SERIES
The RF in RFID
Passive UHF RFID in Practice
Daniel Dobkin



- A reader has a radio transmitter and receiver
- A tag does not have a radio transmitter
- Compare with a flashlight and a mirror

RAIN RFID

- Global standard for backscattering RFID @ 860-960 MHz
- Used to identify, locate and authenticate things
- Typical read range up to 10 meters



TagMaster

TagMaster

TagMaster
LEARN FROM REALITY

CitySync

- Founded 1994 with HQ in Kista, Sweden
- Originally a 2.45 GHz RFID company
- Now a global group of companies, focusing on traffic and rail solutions for Smart Cities

BALOGH

CA Traffic
Click for CA Traffic website

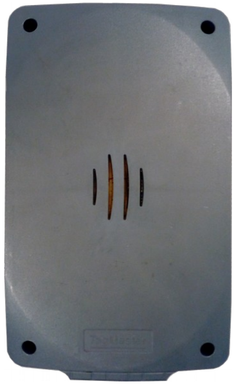
MAGSYS
Click for Magsys website

HIKOB
Click for Hikob website

SENSYS networks

TagMaster - RAIN RFID Readers

XT Mini

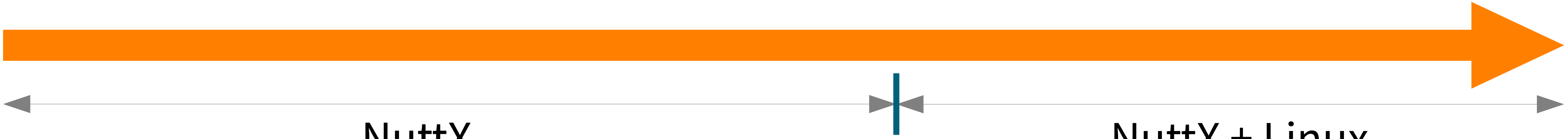


XT-1

XT-1 ETC

XT-5

XT-5 ETC



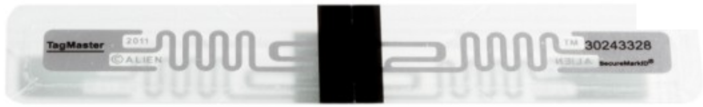
NuttX

NuttX + Linux

TagMaster - RAIN RFID Tags

WindShield Tag

ISO Card

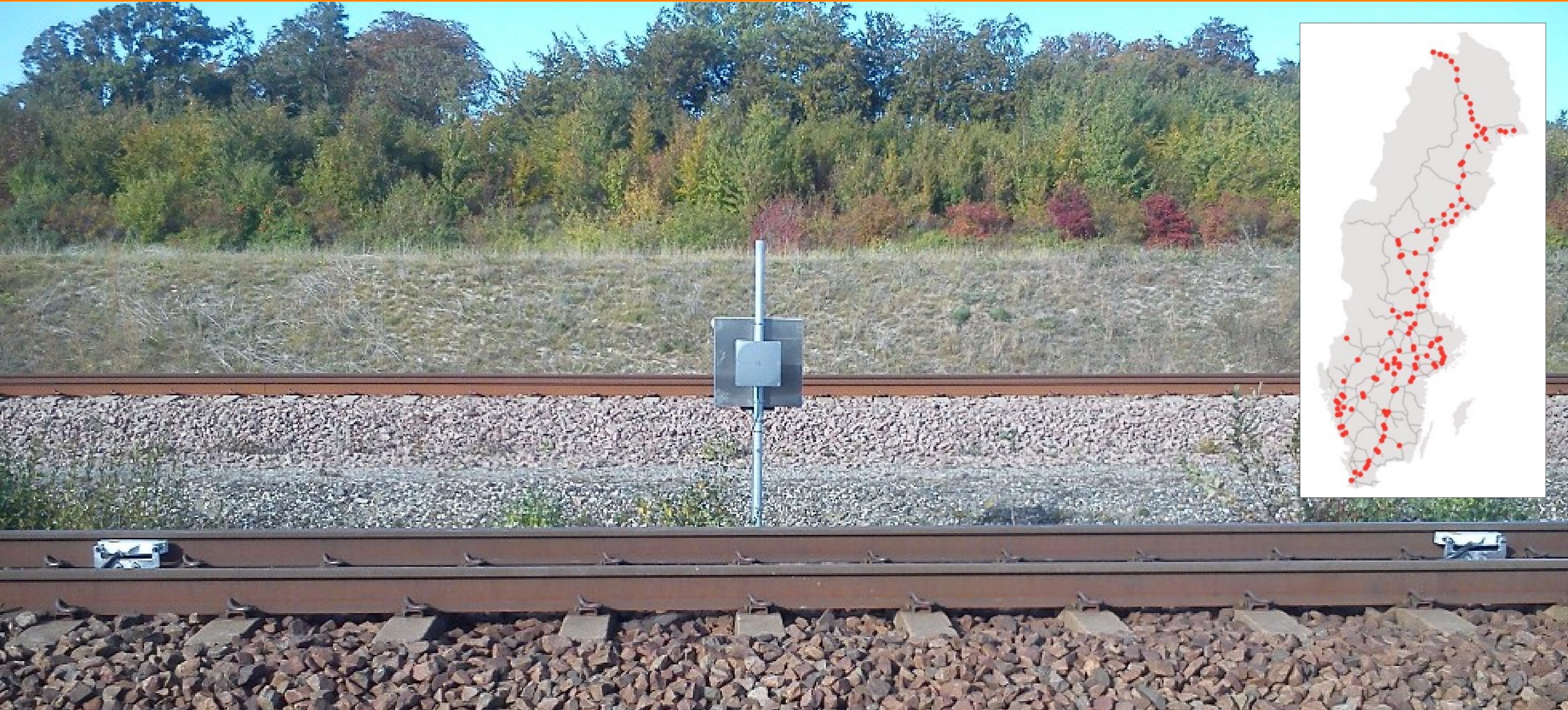


HeadLight Tag

Other tags...

TagMaster - RFID for Parking

TagMaster - RFID for Rail

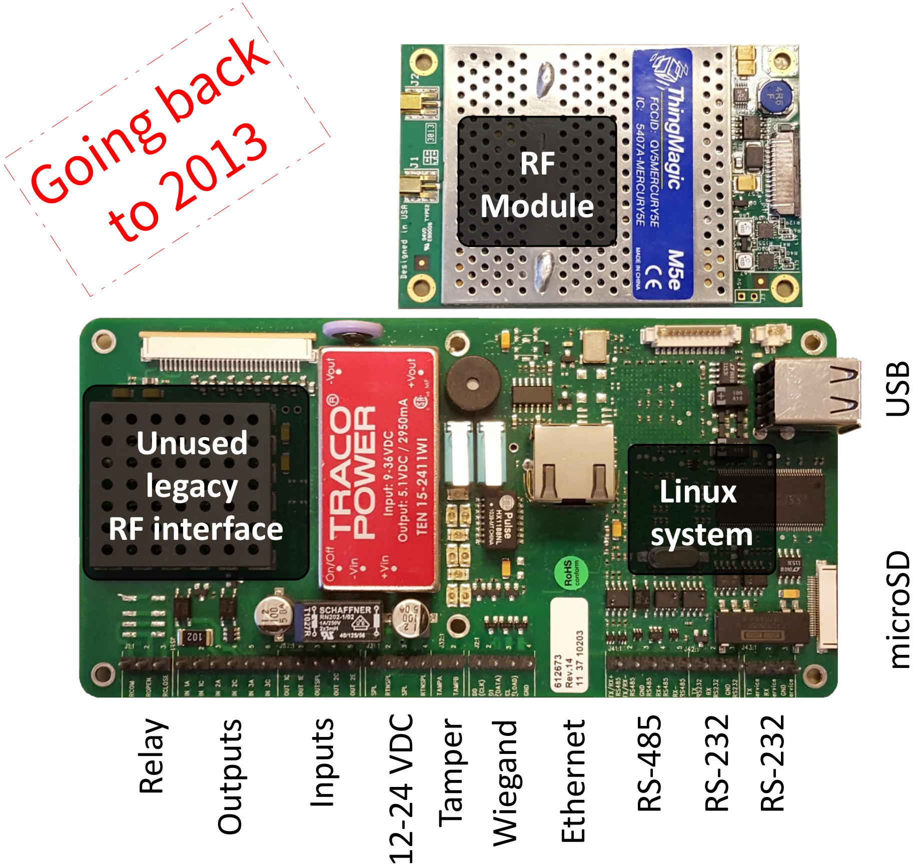


TagMaster - RFID for Road Tolls

24/7

Why NuttX?

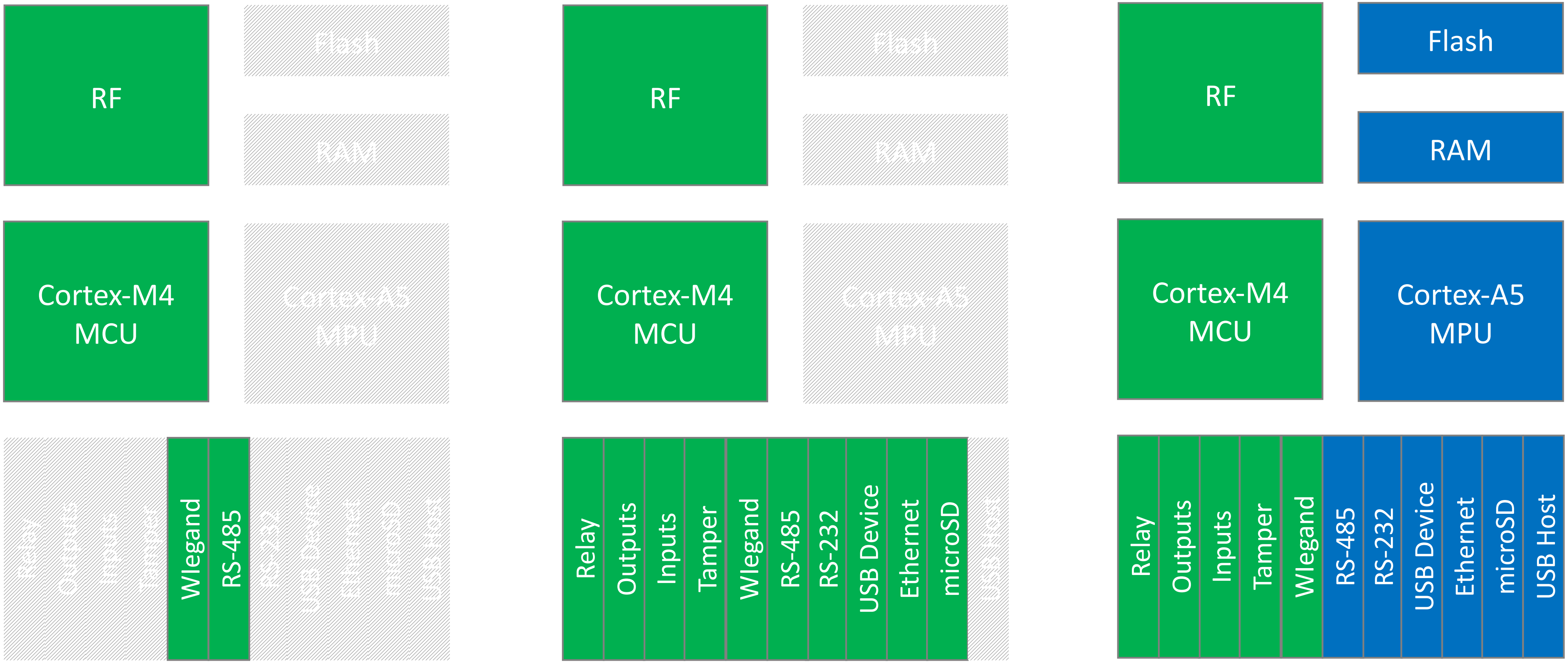
2005 Reader Platform Getting Old



Going back to 2013

- RF module approaching end of life
- Unused legacy RF interface
- Aging Linux system
- Diverging user requirements
  - Most users want a cheap reader and don’t care about the Linux system.
  - Many users only need a few of the interfaces
  - Power users need the programmable Linux system but wants higher performance and more memory.

A New Scalable Architecture



RF

Flash

RAM

Cortex-M4 MCU

Cortex-A5 MPU

Relay

Outputs

Inputs

Tamper

Wiegand

RS-485

RS-232

USB Device

Ethernet

microSD

USB Host

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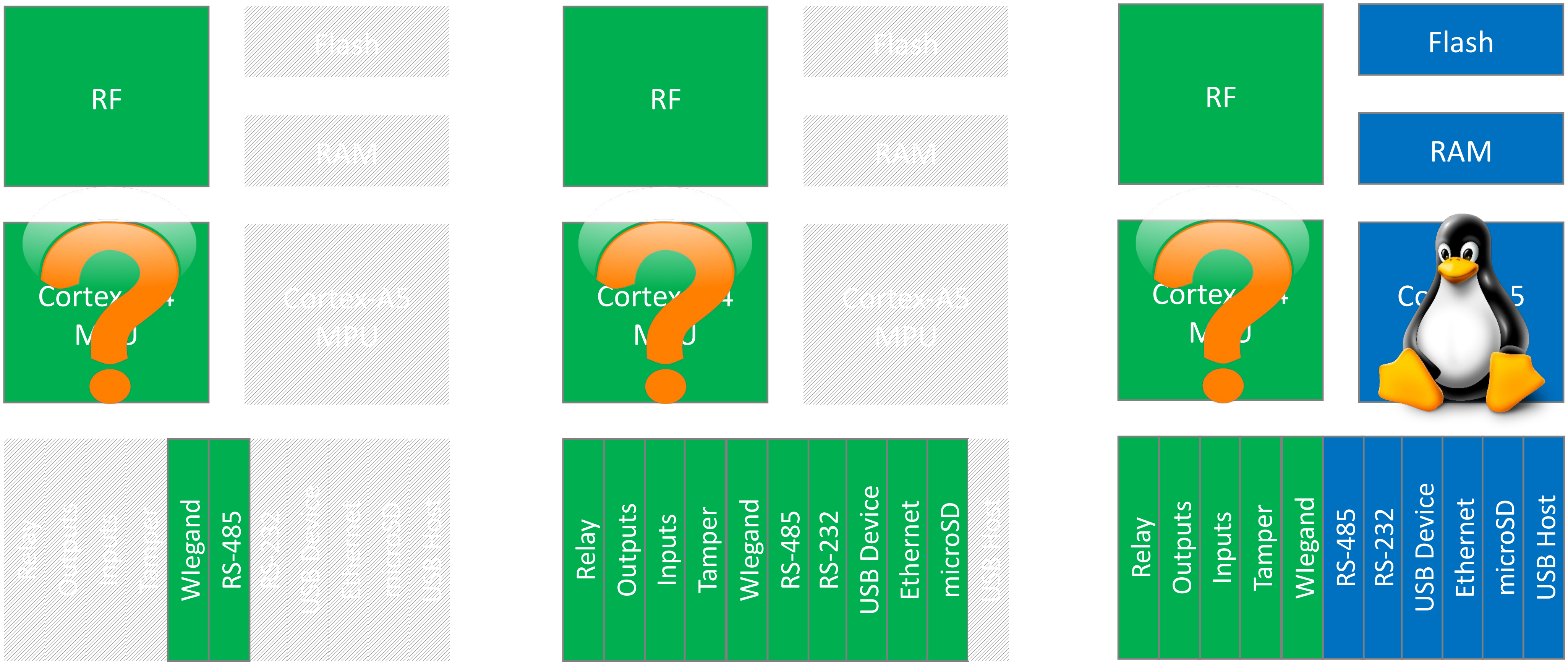
Needing a New Operating System



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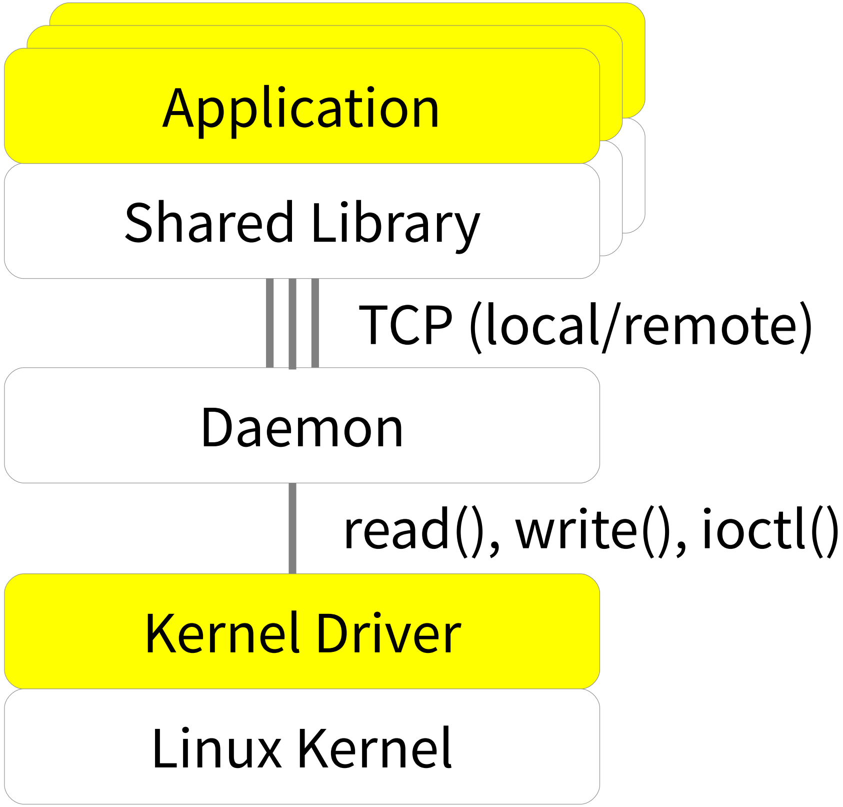
Existing Software Architecture



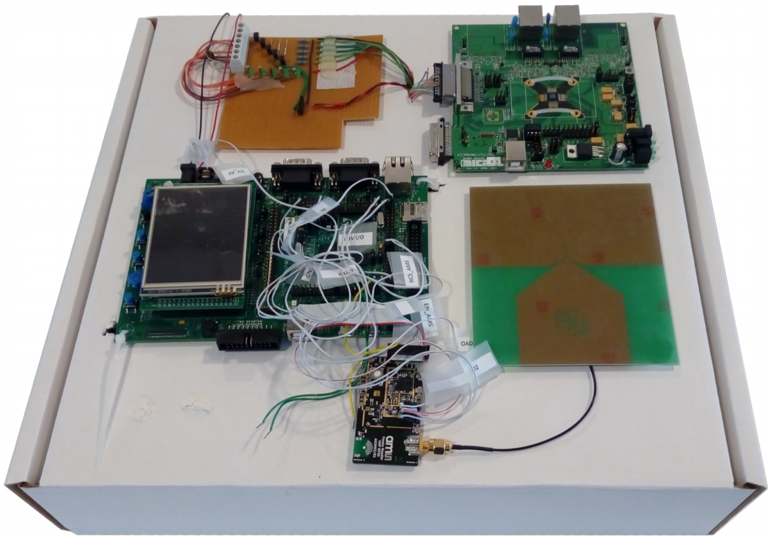
- Existing applications depending on shared library and Linux APIs for networking, serial ports, file system, etc.
- Kernel driver for time critical radio control and application specific interfaces.

Operating System Wish List

- Open source
- Available for STM32
- As close to Linux as possible
- Drivers for RS-232, RS-485, microSD, GPIOs, USB, and Ethernet
- Networking support (TCP/UDP)
- Web server

Selecting NuttX (this was 2013)

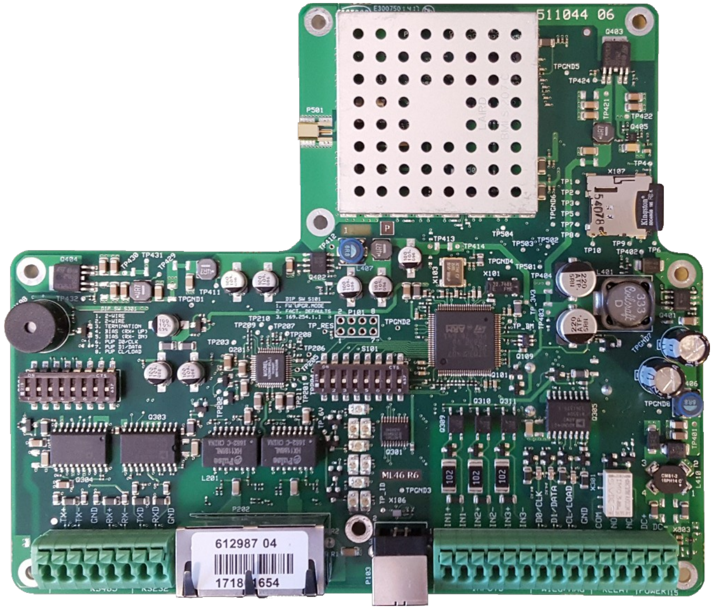
- NuttX seemed to be the perfect fit, but...
  - There was no big organization behind it
  - There was no big user group
  - The future was unclear
- Due to our previous good experience with open source software we decided to build a prototype.



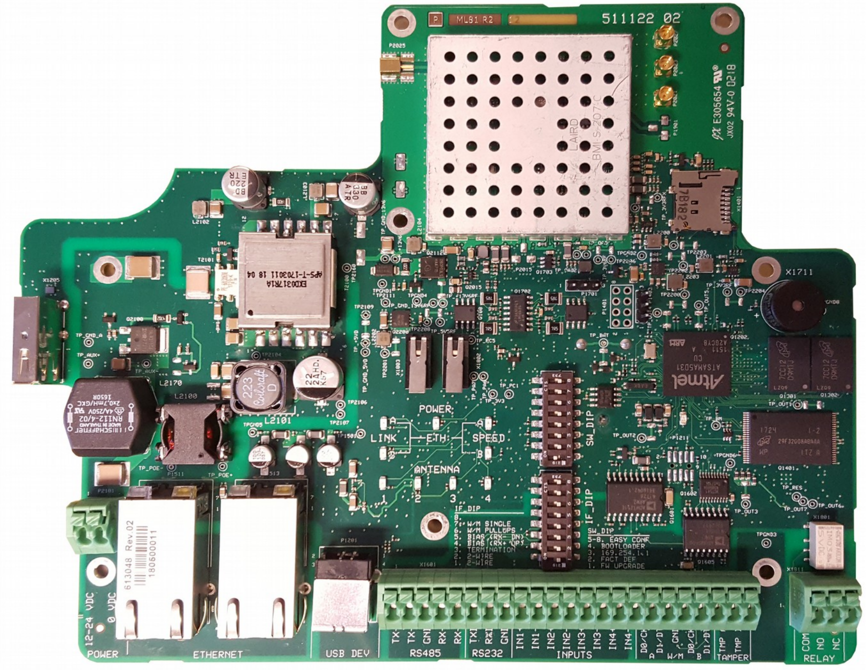
- After a few days we had a basic but working RFID reader!

Our Implementation

Hardware Examples

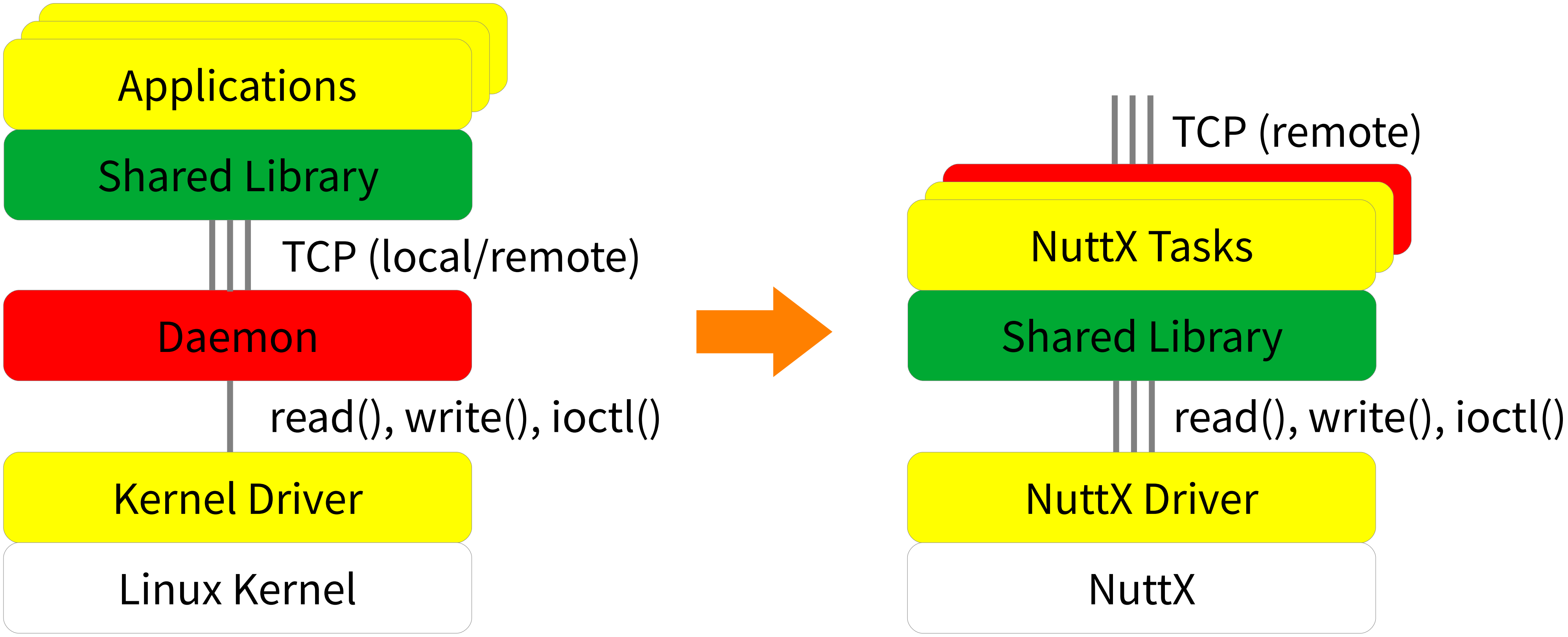


RFID Reader with NuttX (2013)

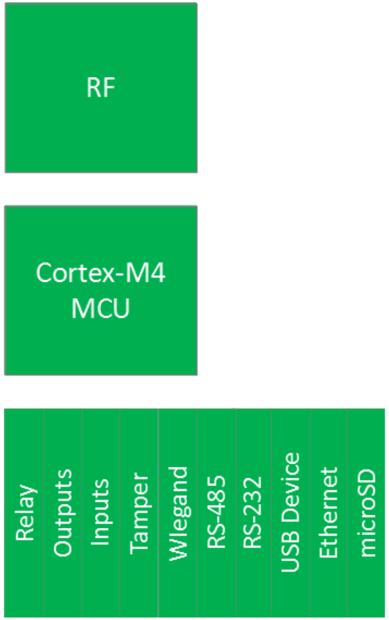


RFID Reader with NuttX + Linux (2018)

Modified Software Architecture



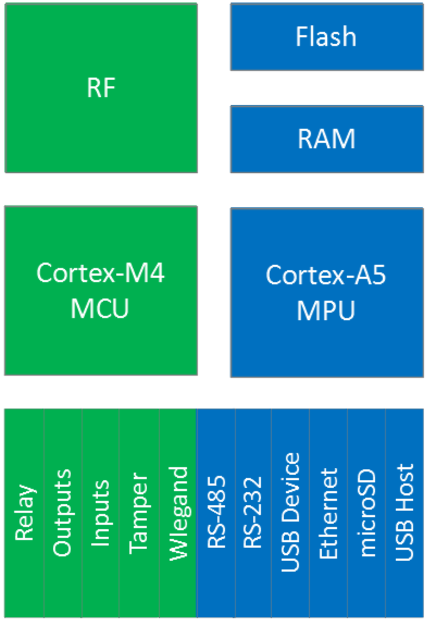
NuttX + Linux



RF

Cortex-M4 MCU

Relay, Outputs, Inputs, Tamper, Wiegand, RS-485, RS-232, USB Device, Ethernet, microSD



RF

Flash

RAM

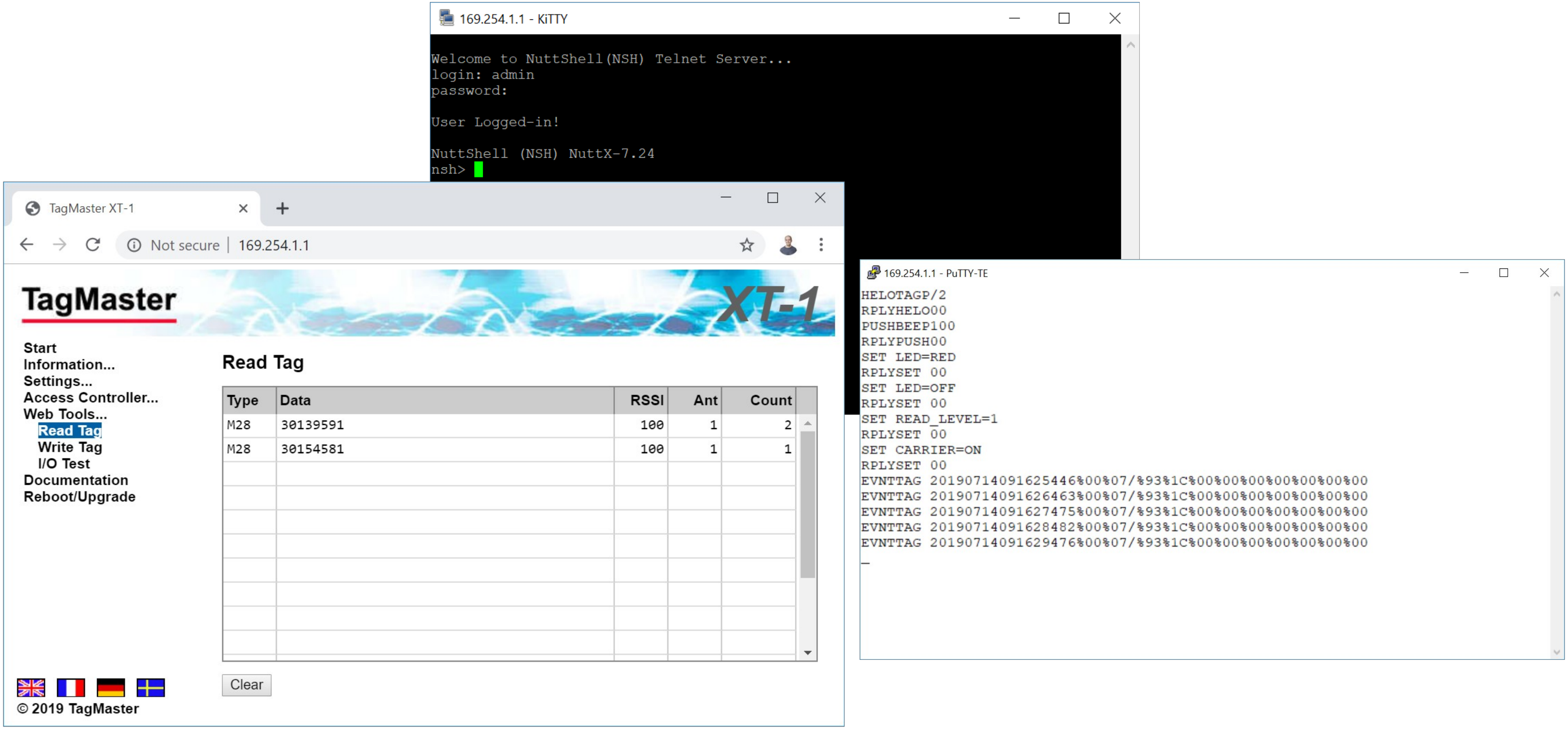
Cortex-M4 MCU

Cortex-A5 MPU

Relay, Outputs, Inputs, Tamper, Wiegand, RS-485, RS-232, USB Device, Ethernet, microSD, USB Host

- Linux system communicates with NuttX system over on-board USB
- Applications and web interface compiles from the same code for both NuttX and Linux
- The microcontroller binary is exactly the same in both systems

Demo



```
Welcome to NuttShell(NSH) Telnet Server...
login: admin
password:

User Logged-in!

NuttShell (NSH) NuttX-7.24
nsh>
```

Read Tag

Type	Data	RSSI	Ant	Count
M28	30139591	100	1	2
M28	30154581	100	1	1

```
HELOTAGP/2
RPLYHELO00
PUSHBEEP100
RPLYPUSH00
SET LED=RED
RPLYSET 00
SET LED=OFF
RPLYSET 00
SET READ_LEVEL=1
RPLYSET 00
SET CARRIER=ON
RPLYSET 00
EVNTTAG 20190714091625446%00%07/%93%1C%00%00%00%00%00%00%00
EVNTTAG 20190714091626463%00%07/%93%1C%00%00%00%00%00%00%00
EVNTTAG 20190714091627475%00%07/%93%1C%00%00%00%00%00%00%00
EVNTTAG 20190714091628482%00%07/%93%1C%00%00%00%00%00%00%00
EVNTTAG 20190714091629476%00%07/%93%1C%00%00%00%00%00%00%00
_
```

A Minimal Boot Loader

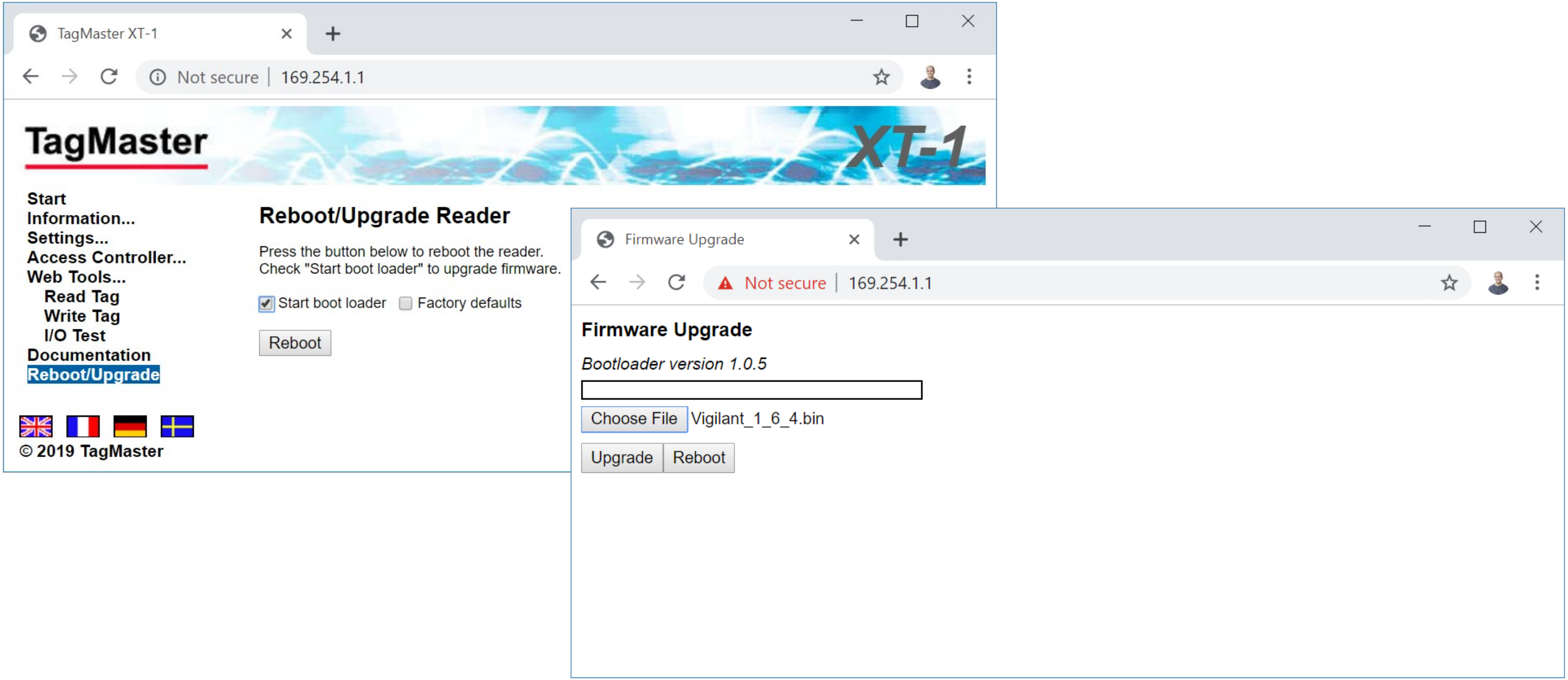
A Minimal Boot Loader

- Invisible during normal start
- Public key verification of stored firmware
- Web interface for firmware upgrade
- Fail safe environment for user settings
- Minimal footprint (< 16 KB + environment)

Boot Loader Startup

- The boot loader is started if:
  - The “Force boot loader” DIP switch is active
  - The user has requested start of the boot loader from software (through magic number in RAM)
  - The RSA signature of the firmware is not ok
- In all other cases, the MCU is reset and the firmware is started.

Web Interface for Firmware Upgrade



Start
Information...
Settings...
Access Controller...
Web Tools...
Read Tag
Write Tag
I/O Test
Documentation
Reboot/Upgrade

© 2019 TagMaster

Reboot/Upgrade Reader

Press the button below to reboot the reader.
Check "Start boot loader" to upgrade firmware.

☑ Start boot loader □ Factory defaults

Reboot

Firmware Upgrade

Bootloader version 1.0.5

Choose File Vigilant_1_6_4.bin

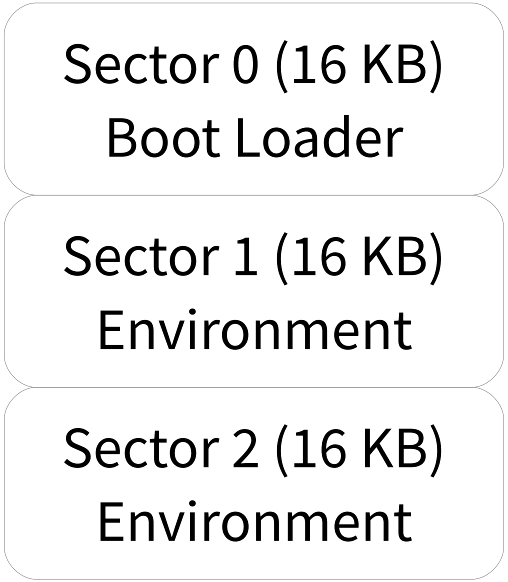
Upgrade Reboot

Fail Safe Environment

- Stores user settings as typical environment variables: NAME=VALUE
- Shared between boot loader and firmware (IP settings, etc.)
- Keeps settings when firmware is upgraded
- Guarantees that a value is either completely written or not written at all even if power is lost during a write
- Requires two erasable flash sectors with single byte write capability

Minimal Footprint

- Boot loader and environment fits in the first three 16 KB sectors on STM32F407
- These sectors are not overwritten when firmware is upgraded (all user settings are saved)



Sector 0 (16 KB)
Boot Loader

Sector 1 (16 KB)
Environment

Sector 2 (16 KB)
Environment

My NuttX Wish List

My NuttX Wish List

- Let NuttX (continue) to be “Linux on a microcontroller”
  - Many developers are familiar with Linux
  - Use similar APIs whenever possible
- *The Linux features that were missing in NuttX became a way for us to differentiate our products. If available we would have used:*
  - *Discovery protocols: UPnP, mDNS/DNS-SD (Bonjour/Avahi)*
  - *Secure network protocols: TLS, HTTPS*
  - *Network Time Protocol: NTP*

Thank you for listening!