REALIZATION OF AN 802.15.4-LIKE MAC LAYER WITH MOTE RUNNER

DISIM - Università degli Studi dell'Aquila

Students:
Andrea Salini - 231413
Lorenzo Di Giuseppe - 227515
Matteo Gentile - 230997

Professors:
Fortunato Santucci
Luigi Pomante

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INTRODUCTION

- Object of this project is the exploration of Mote Runner, an IBM's infrastructure platform for WSN
- For a deep understanding of MR the focus of this works was the design and develop of a 802.15.4-like MAC layer
- Oscilloscope is an applications developed to test the MAC layer
- The application was tested on IRIS mote

INDEX

- Introduction to Mote Runner
- Testing Mote Runner
- A MAC Layer in Mote Runner
- Conclusion

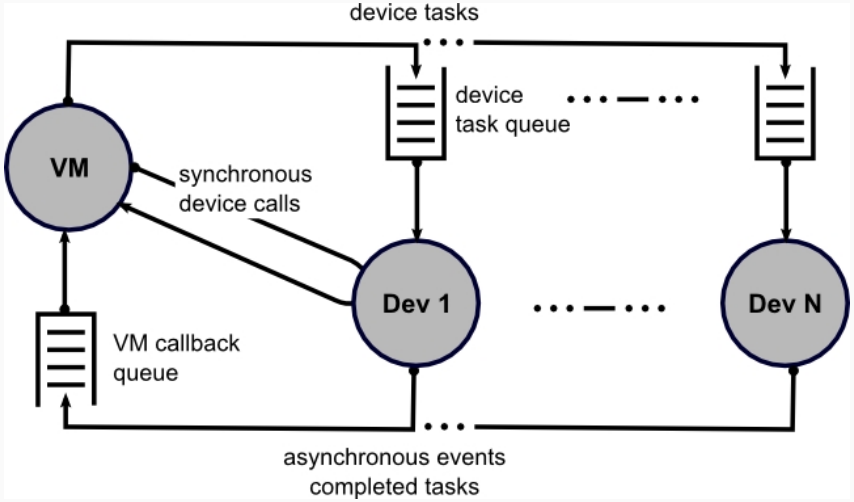
INTRODUCTION TO MOTE RUNNER

MOTE RUNNER

- An OS and a runtime and development environment for WSN
- Key features:
  - Support for RT constraints & energy awareness
  - Portability thanks to a VM that abstracts the HW
  - Event oriented programming paradigm
  - High level coding (Java - C#)
  - Debugging & simulation environments
- It’s still in beta and is evolving towards IoT

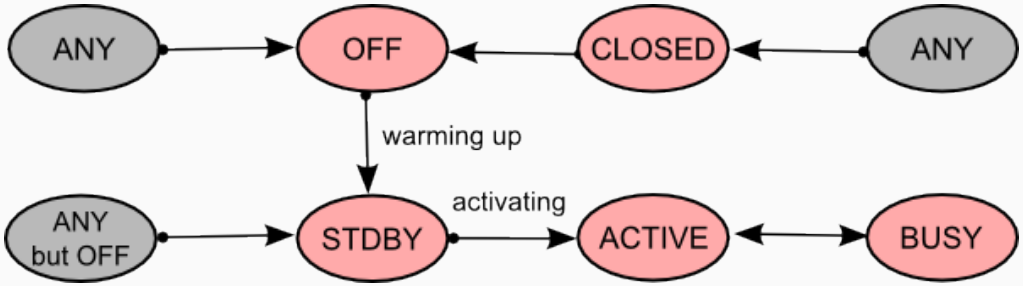
MOTE RUNNER OPERATING SYSTEM

- Mote Runner system provides:
  - A Virtual Machine for executing byte codes
  - An Operating System for:
    - organizing access to different devices
    - scheduling the various activities



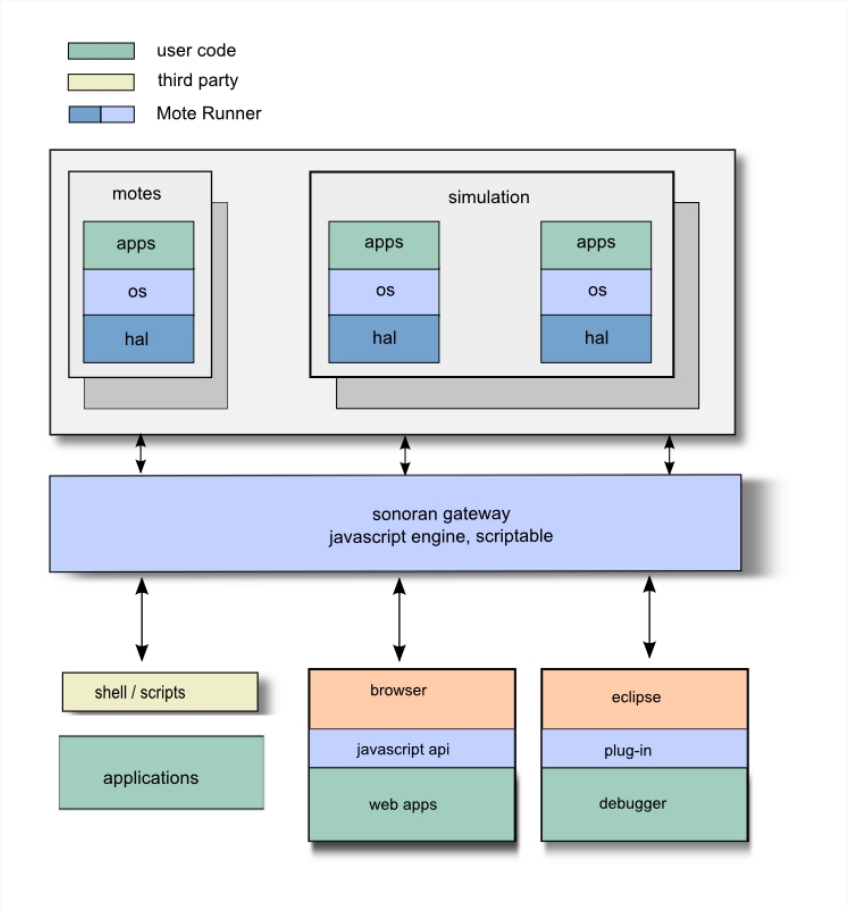
DEVICE MODEL

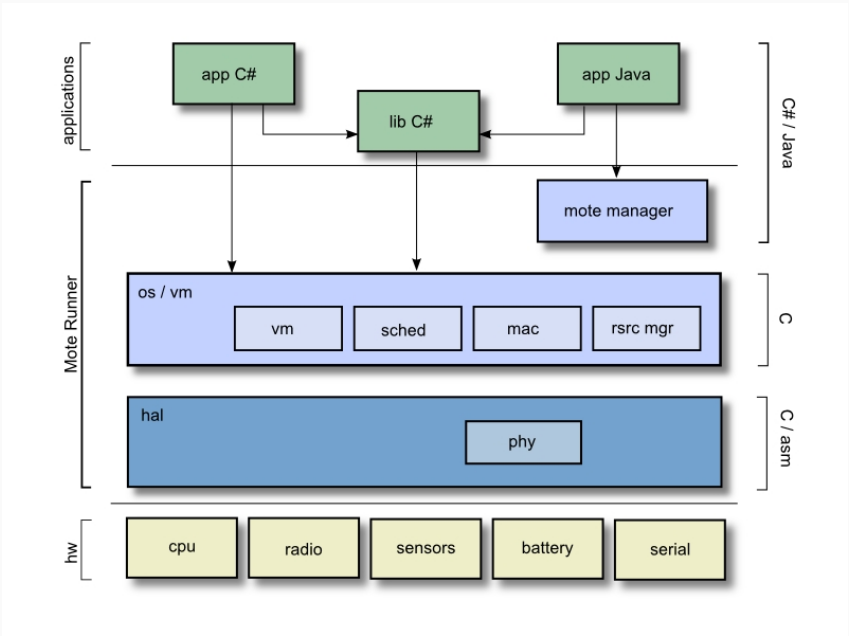
- The OS assumes that all devices have the following states



- The OS manage implicitely most of the state changes:
  - Makes sure that the device ramp up happens before the requested time
  - Keeps device in states with the lowest energy consumption
  - Application, however, can put devices into the states CLOSED, OFF and STDBY

MOTE RUNNER


user code
third party
Mote Runner
motes
apps
os
hal
simulation
apps
os
hal
apps
os
hal
sonoran gateway
javascript engine, scriptable
shell / scripts
applications
browser
javascript api
web apps
eclipse
plug-in
debugger


applications
app C#
lib C#
app Java
C# / Java
mote manager
Mote Runner
os / vm
vm
sched
mac
rsrc mgr
C
hal
phy
C / asm
hw
cpu
radio
sensors
battery
serial

Mote runner - v.11, v.13 beta

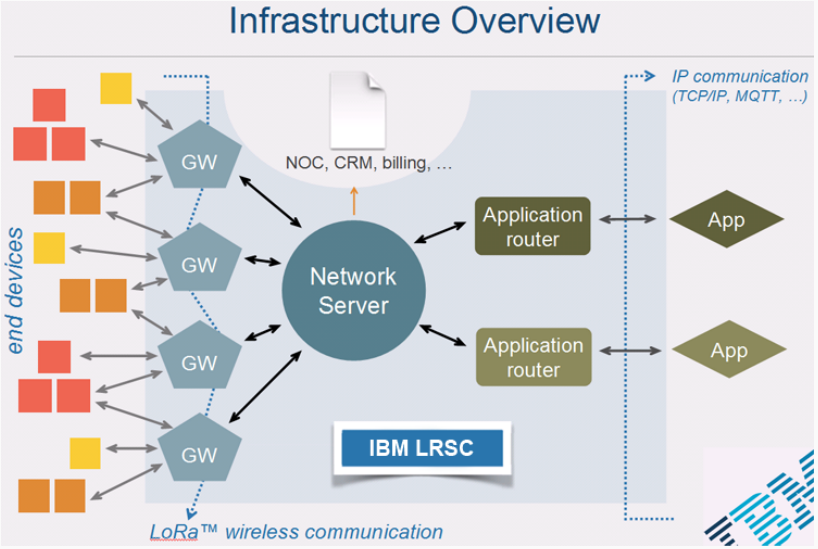
- They support IEEE 802.15.4
  - exposing a low radio level API that can be used to implement custom MAC layer
  - dropping messages with header structure not 802.15.4 compliant in the radio stack
- Offer Hopi
  - A multi-hop data gathering protocol
  - Used to collect data from motes setting automatically a tree network

Mote runner - v.17.1.8c (latest)

- Supports only two platforms: IMST & Blipper
- It's based on a different radio layer: LoRa™
- It offers a build-in MAC layer: LRSC - Low Range Signaling & Control
  - It supports only a network topology: the LRSC one
  - The offered API is poor since the radio is hidden in the firmware (not compatible with previous versions)

LRSC - ARCHITECTURE

- Gateways (GW) are connected to server on IP
- Motes comunicate with server in tunneling TCP/UDP over IP
- Motes comunicate with GW with LoRa single-hop



IBM LRSC

- The Long Range Signaling and Control (LRSC) system is a network infrastructure which relies on LoRa™, modulation technology developed by Semtech for wireless bidirectional communication over distances of up to 15 km in semi-rural environments and up to five km in dense urban environments.
- All communication is generally bi-directional, although uplink communication from end devices to the network server is strongly favored, and is based on LoRa.

LRSC NETWORK SIMULATION

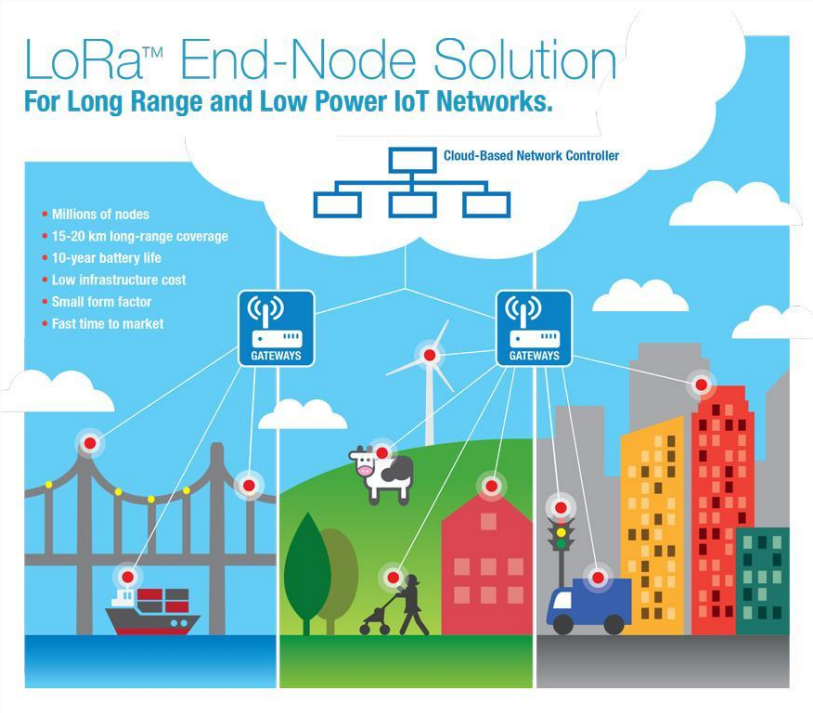
The Mote Runner SDK ships with:

- LoRa Mac library providing an API for accessing a LRSC network.
- LIP shell interface to control the Mac from the Mote Runner shell MRSH.

The main constraint for our intial purpose depends on the fact that the end devices cannot communicate directly. Any message should be sent over the LRSC network.

LORA™

- LoRa™Alliance
  - Target: IoT, machine-to-machine (M2M), smart city, and industrial applications
  - Intiated to standardize Low Power Wide Area Networks (LPWAN)



LORA™

- LoRa™Technology
  - LoRaWAN pledeges to extend the radio range by 10x while using only one third of the power used by competing solutions
  - Star (of stars) topology
  - Gateways relay messages between end-devices and a central network server
  - Communication between end-devices and gateways is spread out on different frequency channels and data rates.
  - Data rates: 0.3 - 50 kbps

LORA™

- ...and more
  - adaptive data rate (ADR)
  - secure communication (on network and application layers and end-point device key)
  - three classes of end-point devices.
  - More info on http://lora-alliance.org/

MOTE RUNNER - CONCLUSION

- For the purpose of this work:
  - MR allows dynamic reprogramming of motes with a control server using WLIP
  - v.17.1.8c is not suitable
    - LoRa is available only for a limited number of platforms (until now!)
    - LRSC doesn't permit to customize the MAC behaviour
    - The radio is not exposed
  - v.11, v.13 are better choices:
    - radio interface could be used to implement an 802.15.4 MAC
    - this MAC could be possibly used to build upper layer with WIDS
- This does not exclude a future integration with LoRa-LRSC

TESTING MOTE RUNNER

POINTS TO EXPLORE

- MR v.13 offers:
  - Radio interface IEEE 802.15.4 compliant
  - Hopi
  - An IRIS-friendly simulation environment
  - Many nice features (Debugger, Logger and so on)

PROGRAMMING THE RADIO

- com.ibm.saguaro.system.Radio
  - This is a generic class in the IBM saguaro system to use the device radio
  - It offers a low level API with the following functionality:
    - open: opens the radio, once opened no other assembly can use it
    - close: releases the radio so that others can use it
    - setter and getters for channel and network parameters (addresses, panid...)
    - startReceive: listens the channel (in one of the many receiption mode)
    - transmit: begin to transmit a pdu

TRANSMISSION & RECEPTION

- These operations require much attention:
  - The radio permits to transmit every type of pdu, but it's possible to receive only packets with 802.15.4 well formed headers
  - It's also possible to receive in promiscuous mode to sniff for every packet, but this exposes to interferences
- Each mote holds 3 addresses:
  - a 16-bit PAN identifier
  - a 64-bit extended address that uniquely identifies a mote
  - a 16-bit short address that's application and protocol specific

TRANSMISSION & RECEPTION

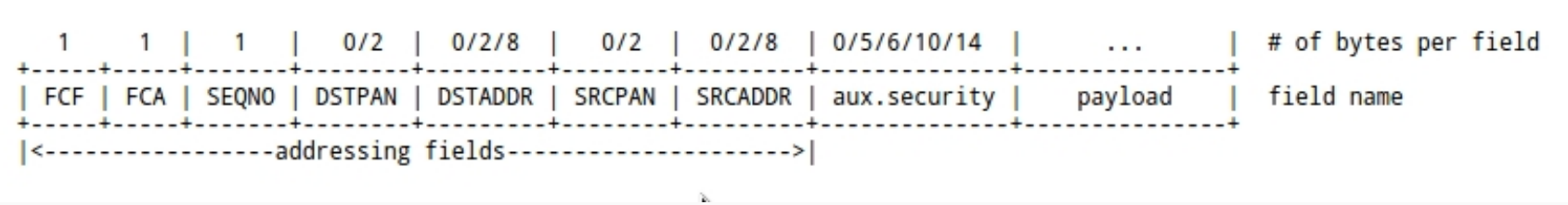


Figure 1: PDU header format

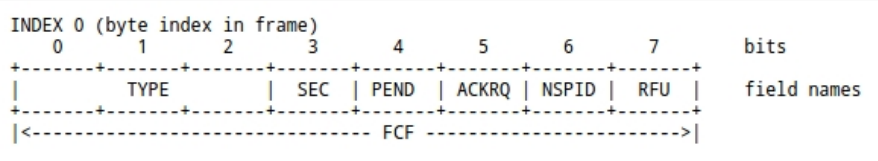


Figure 2: Frame Control Flags

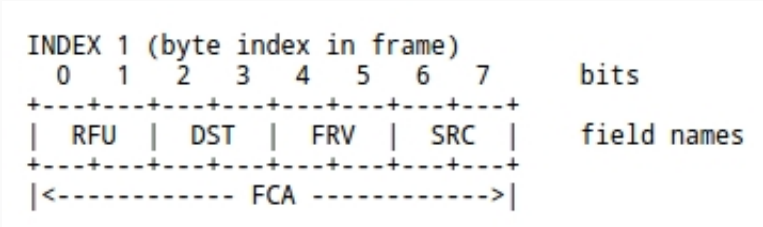


Figure 3: Frame Control Address Flags

TX/RX REAL AND REAL TIME CONSTRAINTS

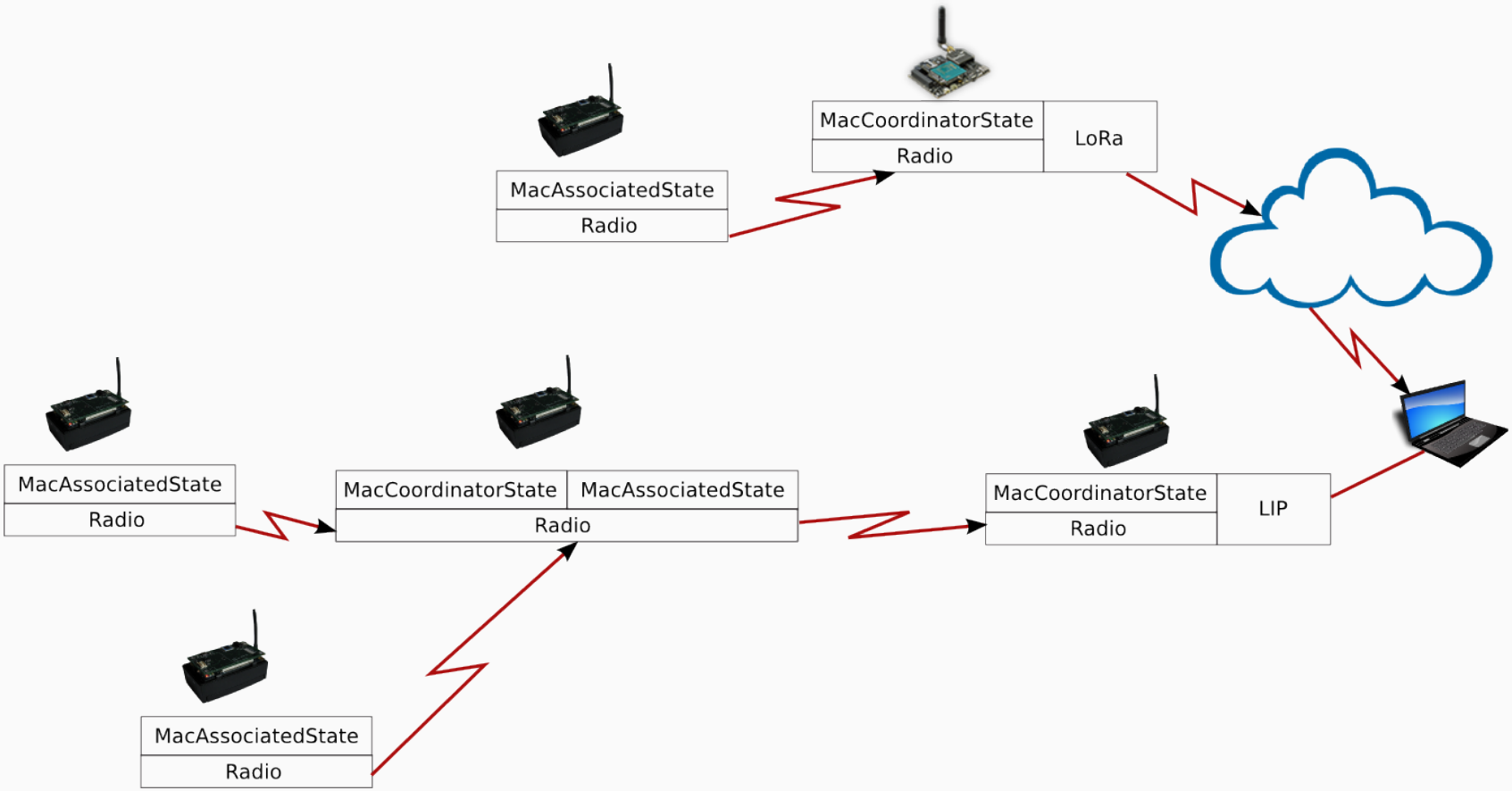
- It’s possible to operate in many different ways with regards to real time constraints:
  - It’s possible to receive/transmit ASAP (As Soon As Possible) or EXACTLY at the specified time or ...
  - Rx/Tx require a start operation time and an end one
  - MR manages autonomously all warm up and ramp up to make the device ready at the specified time
  - The device turn off at the end and an event is raised to be managed with delegation
  - If the device cannot be ready at the specified time or an error occurs which reports this status

A MAC LAYER IN MOTE RUNNER

DESIGN STRATEGY

- Mac class behaviours:
  - Coordinator -> Beacon enabled, Slotted CSMA/CA
  - Unassociated -> Handles association with a Coordinator
  - Associated -> Sends data from upper layer and receives data from Coordinator
- Flexibility:
  - State changes are ruled by Mac class through events
  - Mac can handle more than one state -> Mac - entities
    - e.g.: Coordinator - Associated

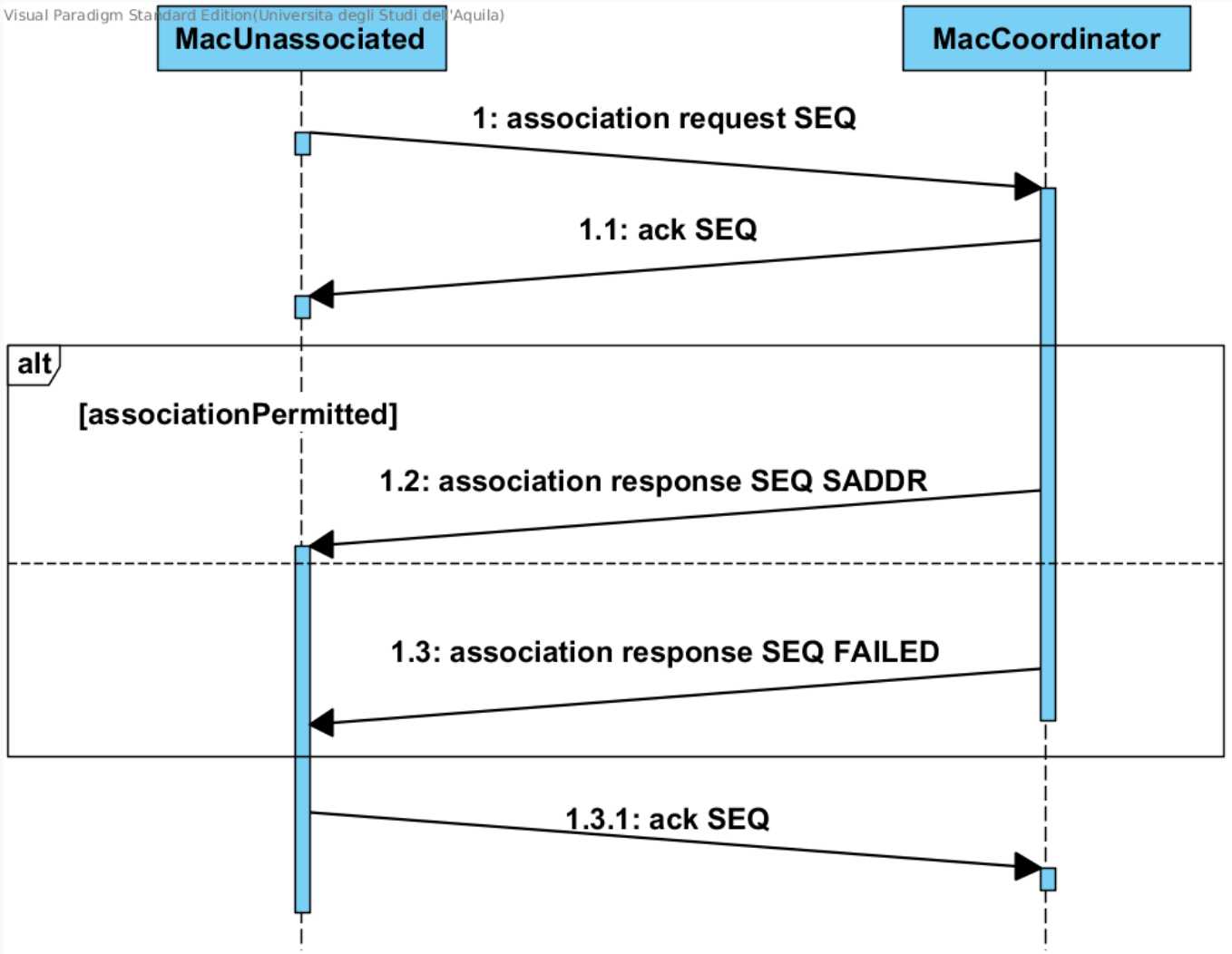
THE CONCEPT


MacAssociatedState
Radio
MacCoordinatorState
LoRa
Radio
MacAssociatedState
Radio
MacCoordinatorState
MacAssociatedState
Radio
MacAssociatedState
Radio
MacCoordinatorState
LIP
Radio

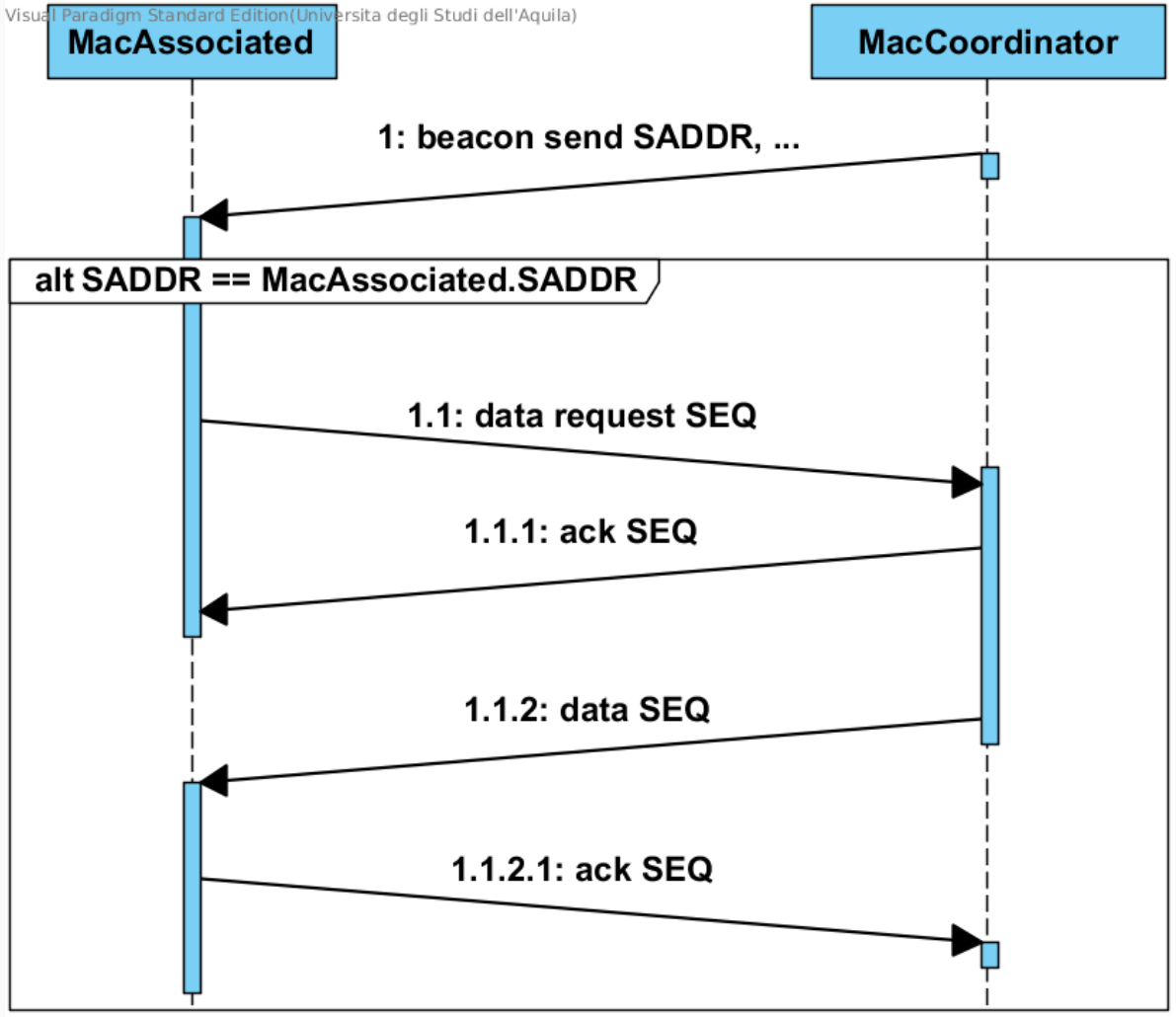
ABOUT THE CONCEPT

- Motes have to be subdivided into PANs
  - Every PAN has a PAN Id
  - Every mote has a unique short address (SADDR) inside the PAN
- To obtain the SADDR the mote must associate with the PAN coordinator
- To grant communication between motes synchronization is crucial
  - Beacon + Superframe
- The adopted procedures follow 802.15.4 standard

ASSOCIATION

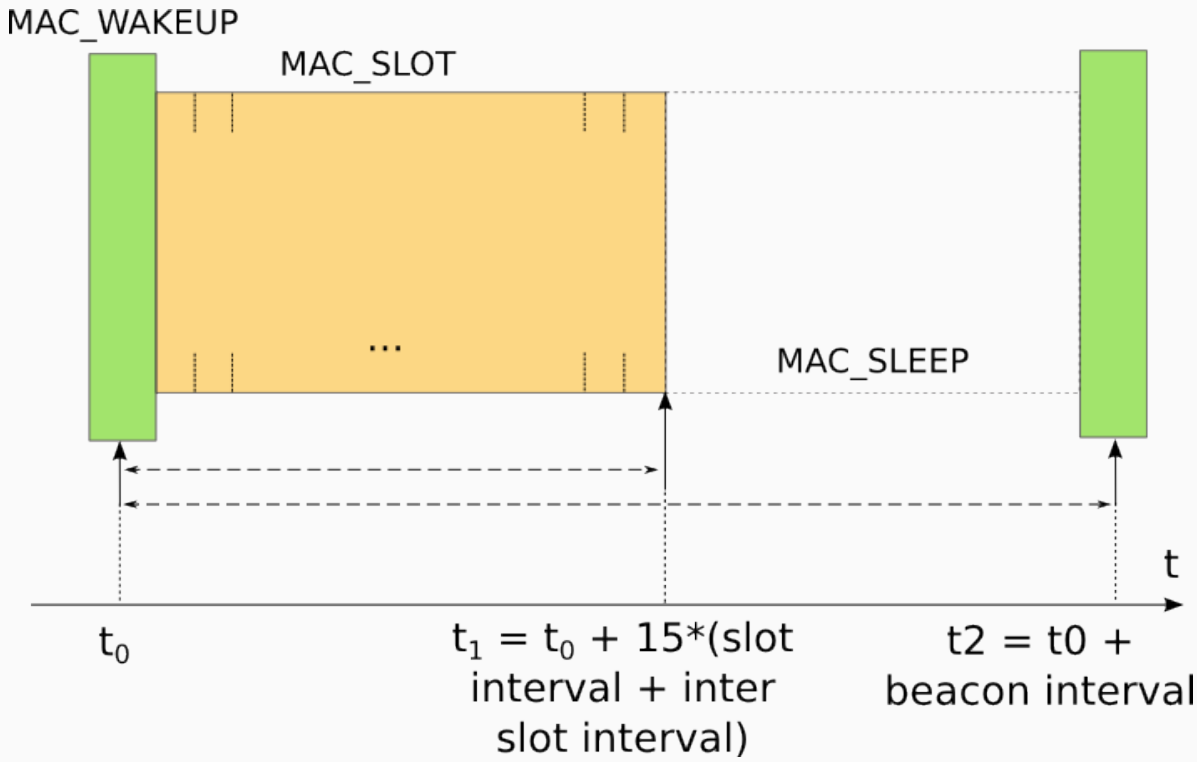


DATA INDIRECT



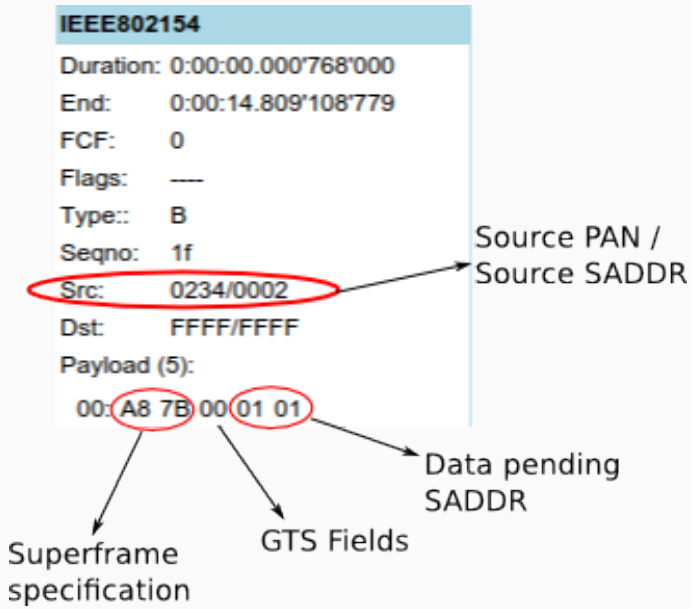
TIMING WITH BEACON

- Grants synchronization between mote and coordinator
- Realized with a timer and scheduled events



BEACON

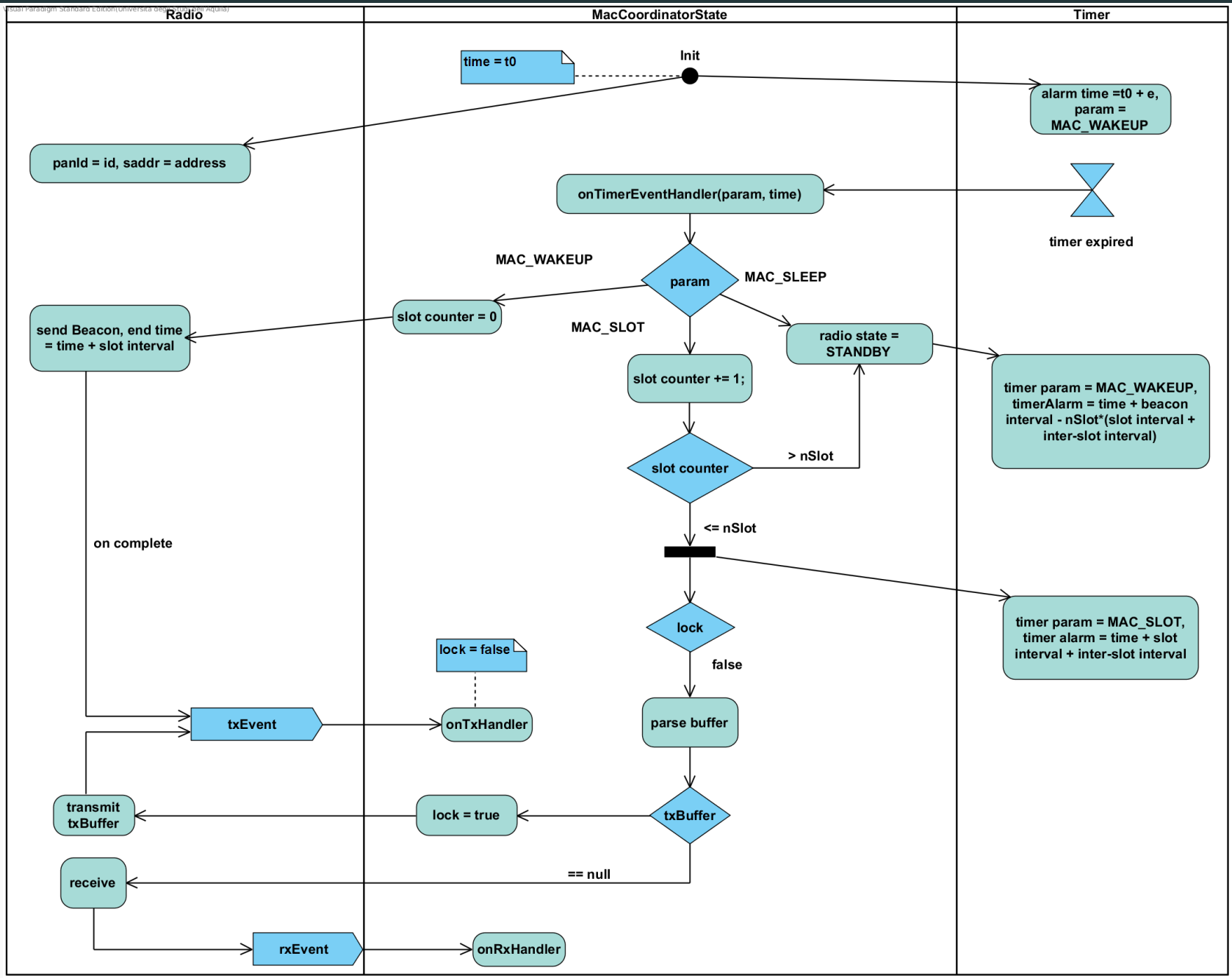
- Superframe Specification:
  - Beacon Order -> BO
  - Superframe Order -> SO
  - Association permitted



$$\text{Beacon Interval} = \frac{60sym \cdot n.Slot \cdot 2^{BO}}{20\text{kbps}}$$

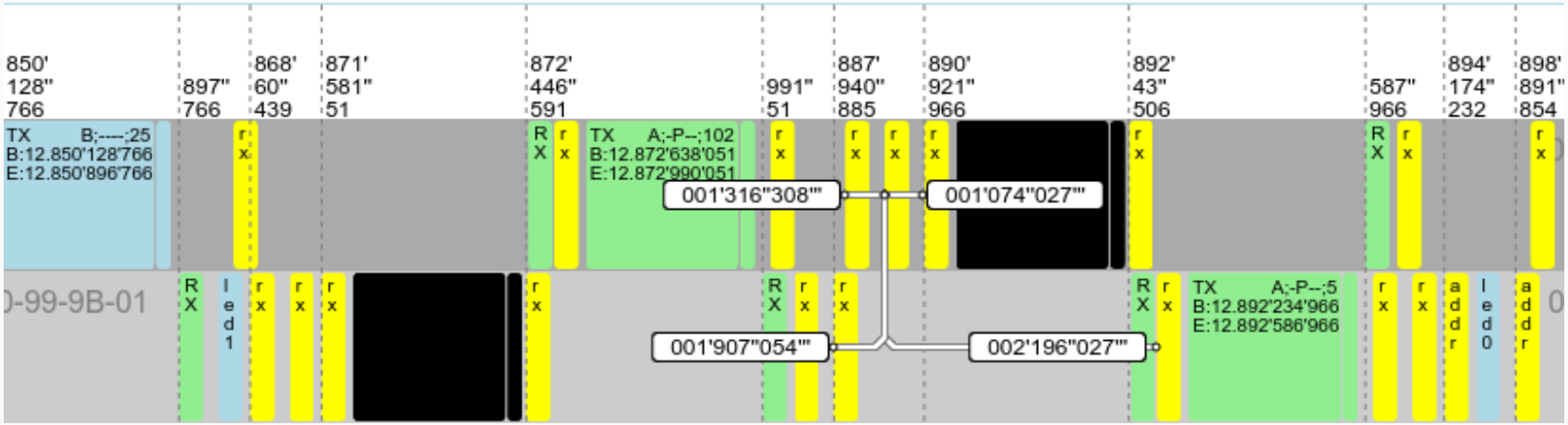
$$\text{Superframe Duration} = \frac{60sym \cdot n.Slot \cdot 2^{SO}}{20\text{kbps}}$$

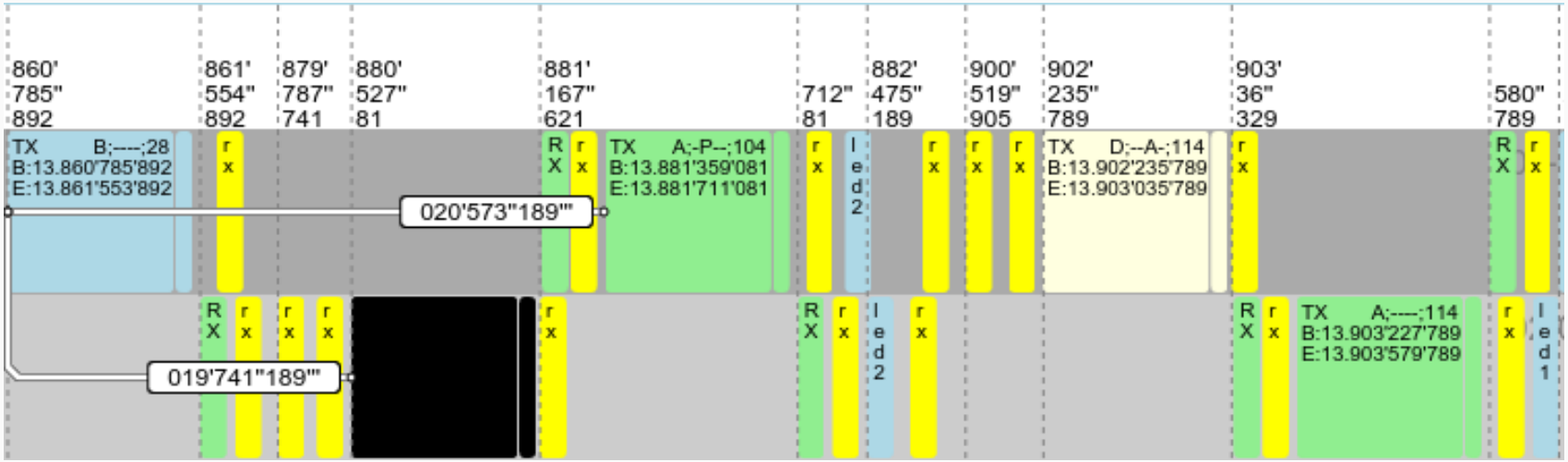
MAC COORDINATOR BEHAVIOUR



EXAMPLE

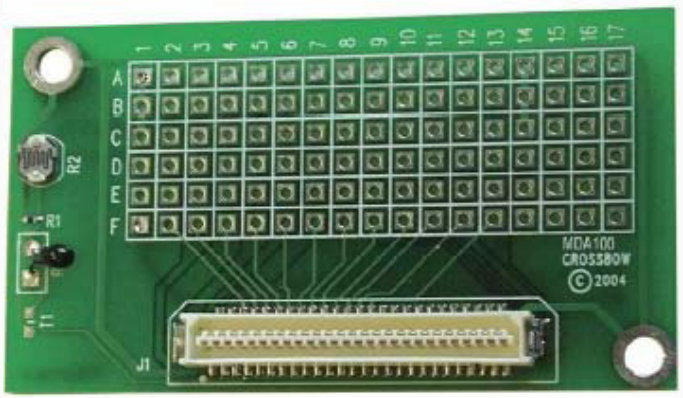
The node associates with coordinator, then responds to beacon pending list and gets data.





OSCILLOSCOPE

- Periodically reads values of TEMPERATURE and LIGHT
- Read interval and type can be setted by master
- Readings are sent through MAC once associated to master
- Readings done by MDA100 board



MASTER OSCILLOSCOPE

- It creates a PAN with the MAC layer
- It listens LIP for commands that sends to associated motes
- MAC layer sends readings to Master Oscilloscope that are redirected through LIP
- A JavaScript Socket running on Sonoran process displays the readings

CONCLUSION

CONCLUSION

FINAL CONSIDERATIONS ABOUT MOTE RUNNER

- Pro:
  - Good simulation environment
  - It allows to develop mote applications in high-level object-oriented languages
  - Good assumptions and expectations with respect to LoRa
- Con:
  - It's still in beta
  - Low support (docs, API, ...)