Increased flexibility in long-range IoT deployments with transparent and light-weight 2-hop LoRa approach

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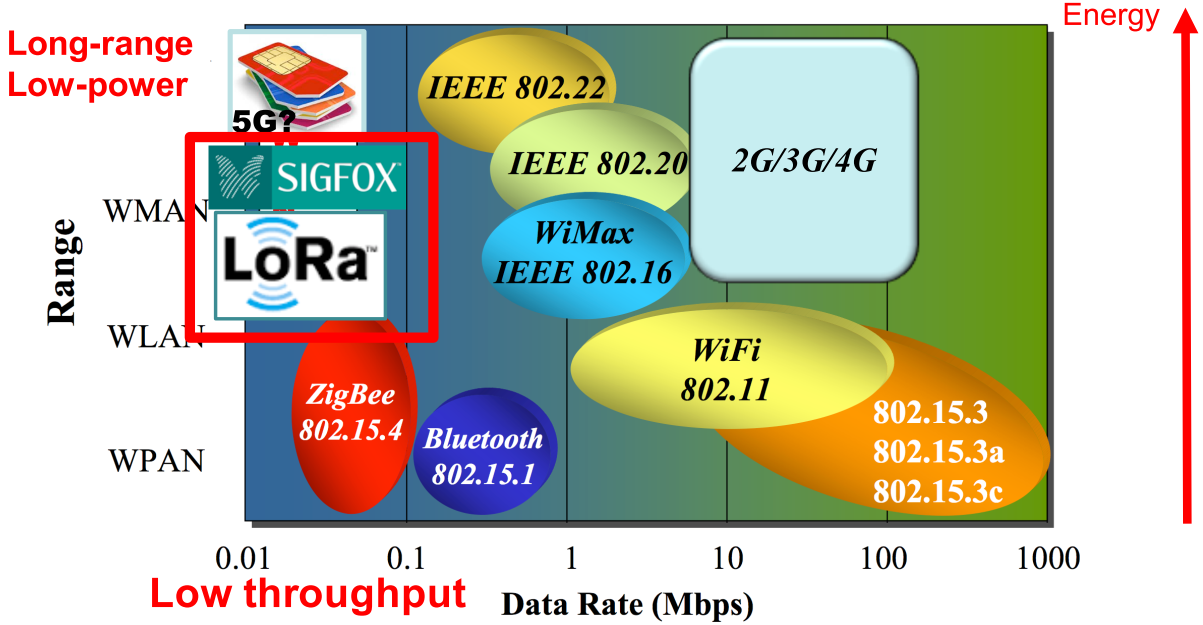
IoT – from idea to reality

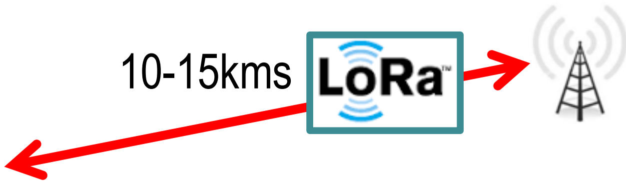
LoRa LPWAN wireless technology

Energy-Range dilemma



Semtech's LoRa provides low-power long-range transmission enabling several years of operation on batteries

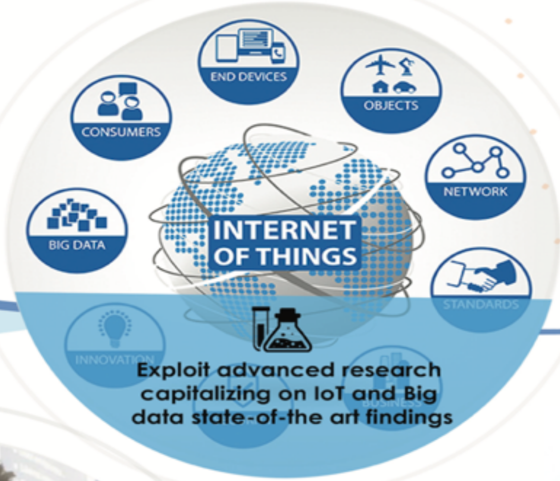
Soil moisture monitoring



LoRa networks are 1-hop, gateway-centric with possible roaming

WAZIUP Open IoT and Big data platform for Africans, by Africans

HORIZON 2020



DO MORE with LESS

www.waziup.eu

Waziup IoT

Waziup IoT

Waziup

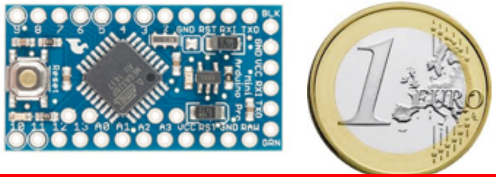
Waziup

CREATE-NET CTIC Farmerline iSpace coders africa INNOTEC

waziup.community@create-net.org

(very) low cost hardware

Arduino Pro Mini

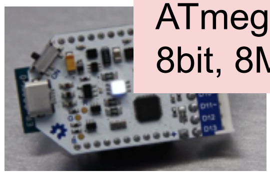


ATmega328P 3.3v
8bit, 8MHz, 32K flash, 2K RAM

LoPy

http://blog.atmel.com/2015/12/16/rewind-50-of-the-best-boards-from-2015/

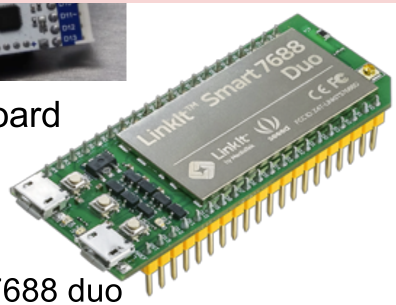
http://blog.atmel.com/2015/04/09/25-dev-boards-to-help-you-get-started-on-your-next-iot-project/



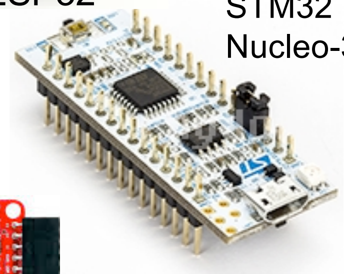
Theairboard

Expressif ESP32

Teensy 3.2



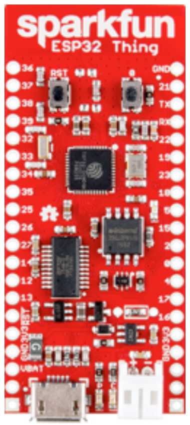
LinkIt
Smart7688 duo



STM32
Nucleo-32

Heltec ESP32 + OLED

Adafruit Feather



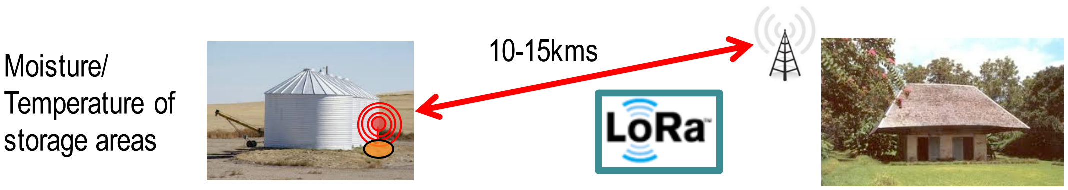
Sparkfun ESP32
Thing

Tessel

SodaqOnev2

Tinyduino

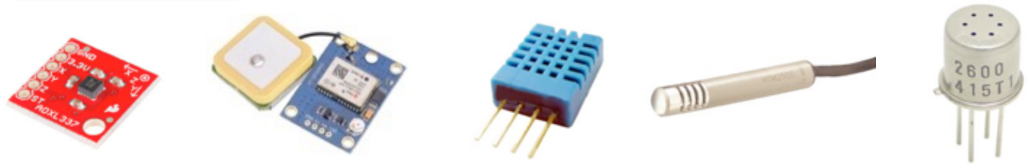
Generic templates



Physical sensor

Physical sensor

Physical sensor



Physical sensor mgmt

Arduino Pro Mini @3.3V

VERY IMPORTANT

Activity duty-cycle, low power

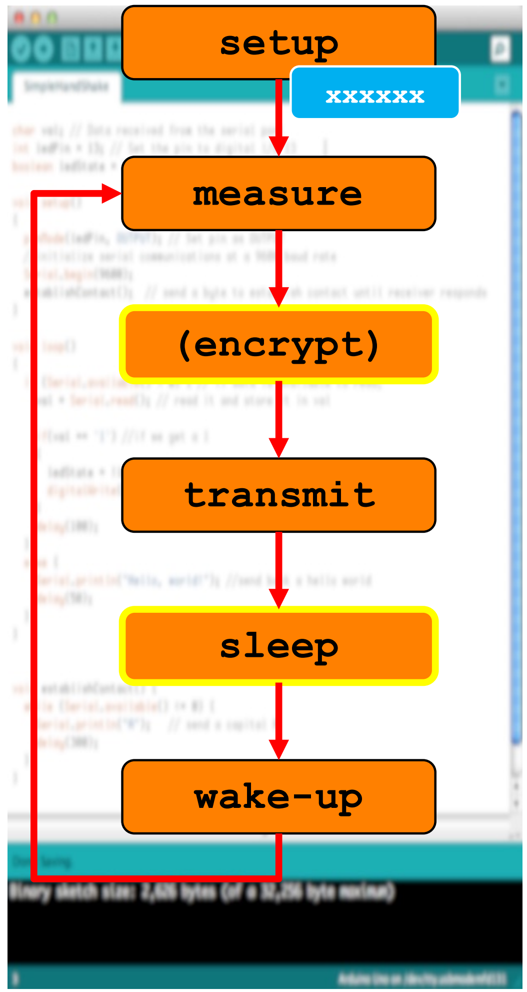
VERY IMPORTANT

data encryption

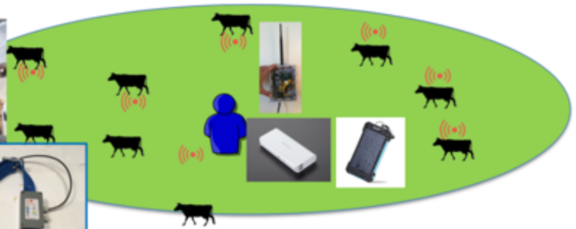
Long-range transmission

LoRa

Logical sensor mgmt



Low-cost collar for cattle rutling: CIMEL farm, Senegal



A web interface displays the position of the gateway those of the remote GPS devices

In Africa, the practice of animal husbandry has always been and still remain farmers' livelihood and incomes

Their main problem in this activity remain the cattle rustling and some families are put in dramatic situation after a theft (reported 2 billions CFA losses)

Low-cost buoy for fish farming

In Sub-Saharian Africa, the volume of natural captured fish doesn't meet half of the population demand

Increasing production of aquaculture will help reduce the quantity of imported fishes in Africa

The aim is to monitor in real-time different parameters to control water quality and prevent some diseases that could affect fish in order to improve the quality and quantity of the production

Kumah farm, Ghana

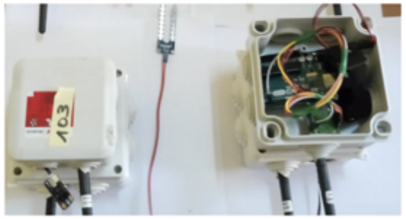
- The Kwame Nkrumah University of Science and Technology (KNUST)
- Located on the campus of the Kwame Nkrumah University of Science and Technology in Kumasi, Ghana.
- The farm comprises 30 constructed fish ponds, a farm house, a recirculating aquaculture system (RAS) laboratory and store houses.

Sanar farm, Senegal

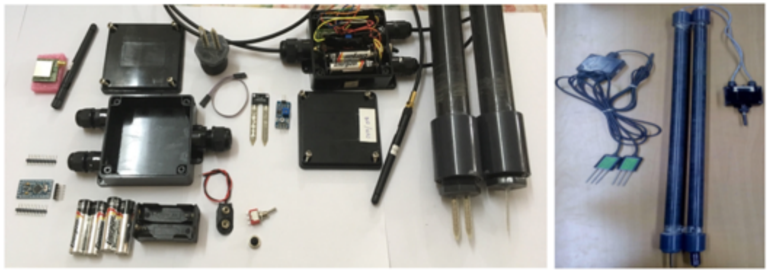
- Farm located at less than 2 km from UGB.
- One pond is dedicated for the Waziup application : 50x25m, average depth of 0.5 meters, populated by 4000 individuals of saltwater tilapia.
- The basin is irrigated via a water supply system fed by a river in proximity.
- The water in the pond is changed every 10 days

UBG farm, Senegal

Soil humidity sensor for agriculture

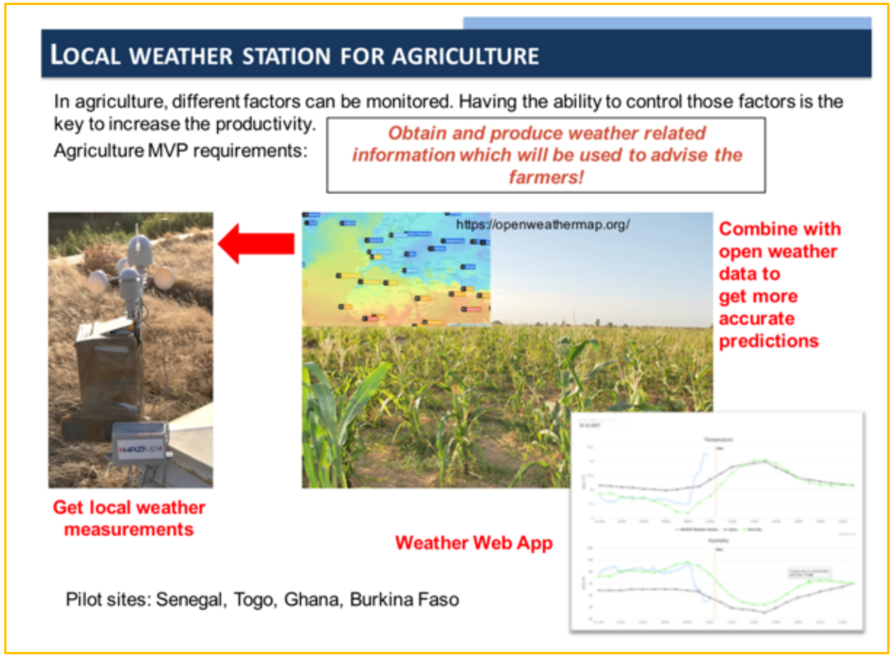


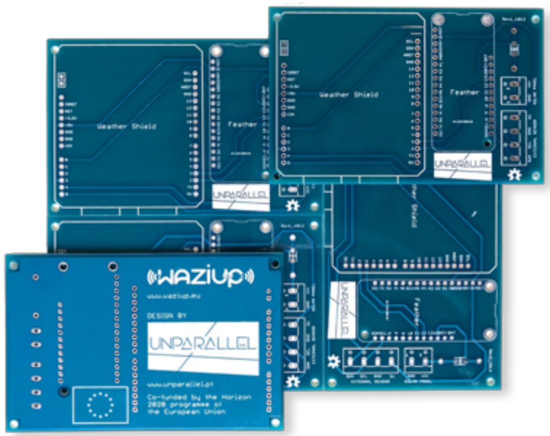
Monitoring soil moisture and other parameters to provide insightful recommendations and notifications to farmers, and advisors



Nasso site, Burkina Faso

Urbannatic gardens, Togo

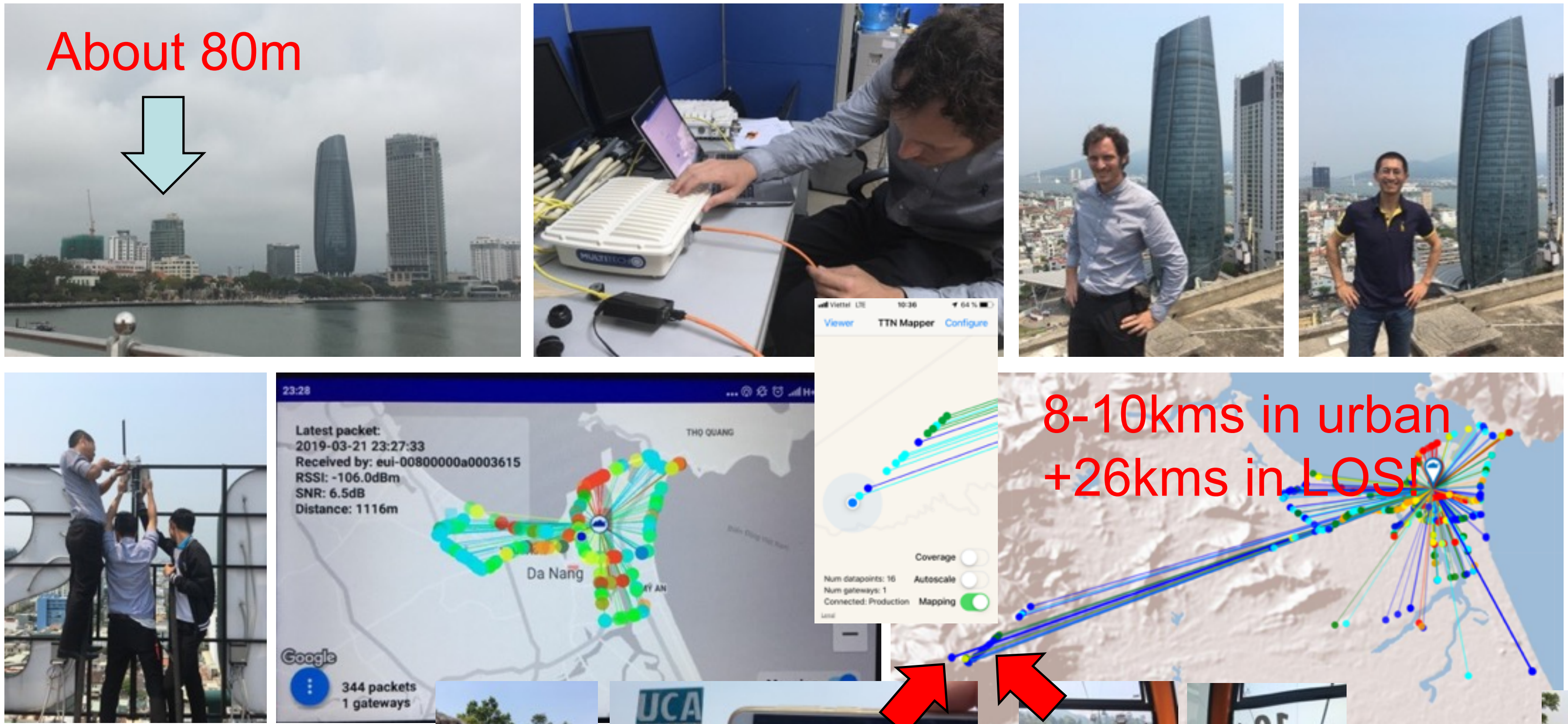


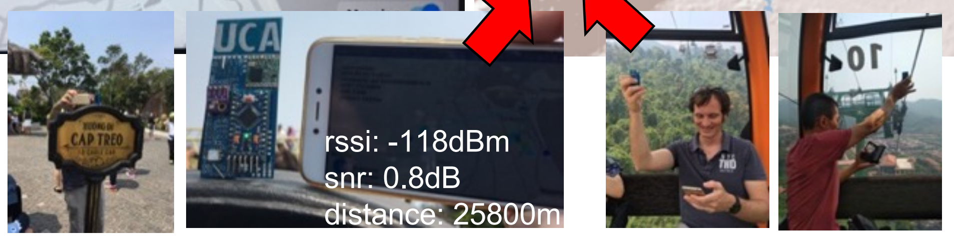


From Unparallel for WAZIUP

High building=large coverage

- LoRaWAN gateway on top of DSP building by F. Ferrero (U. Nice), U. Danang and DSP team. Congrats Fabien!

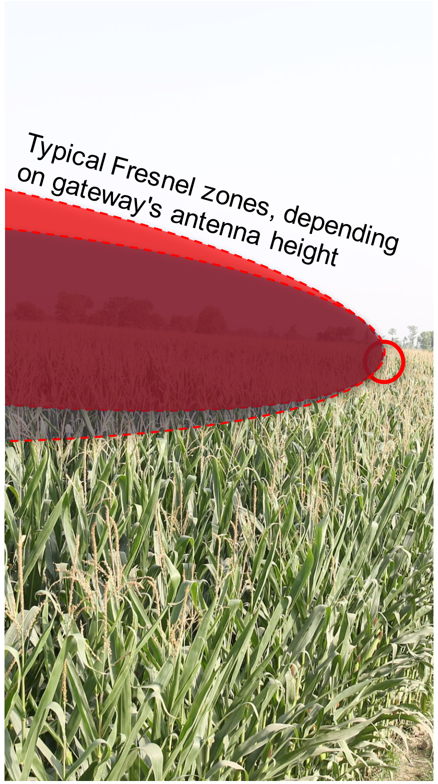




See TTN Mapper
https://ttnmapper.org/

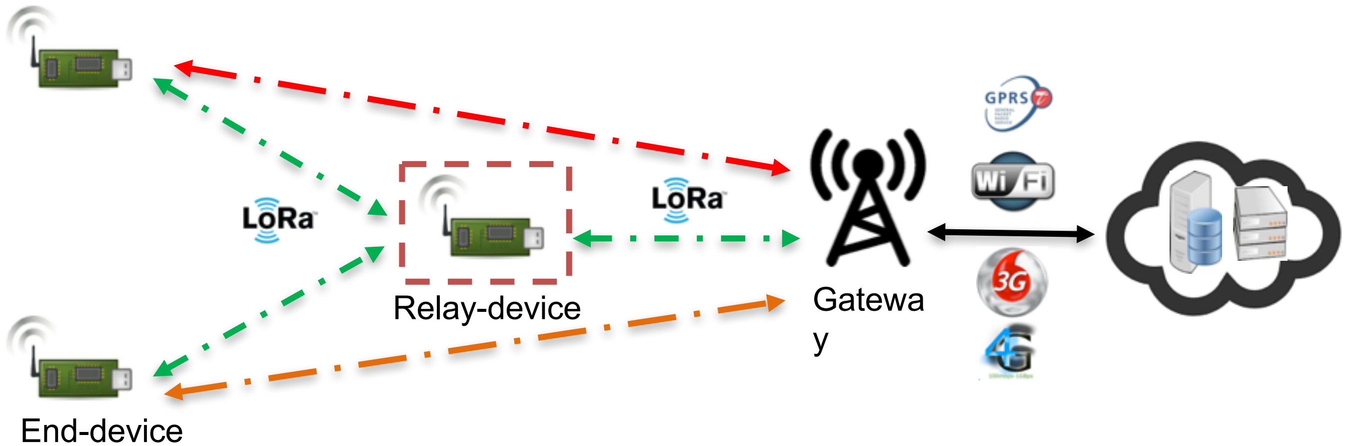
Deployment in rural areas
no high building ☹

- Expected range: about 2-4kms
- 1-hop connectivity to gateway is difficult to achieve in real-world, remote, rural scenarios



2-hop long-range approach

- **smart, transparent** relay node should be able to be inserted at anytime between end-devices and gateway to increase range

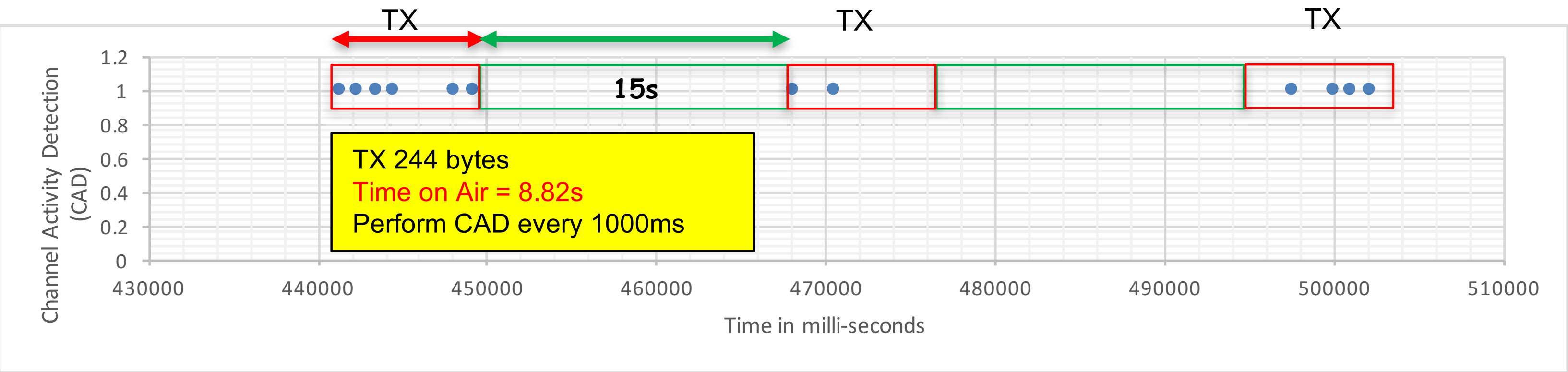


- **2 possible approaches**
  - Use short Channel Activity Detection (CAD) to dynamically detect uplink messages (recent draft from Semtech)
  - Use an observation phase to determine device's schedule

LoRa's Channel Activity Detection

- CAD reliability decreases as distance increases
  - A CAD returning false does not mean that there is no activity!
- During a long transmission (i.e. several seconds) there is usually at least one CAD returning true

However, a relay node using short CAD will miss uplink packets!



Our relay's design choices

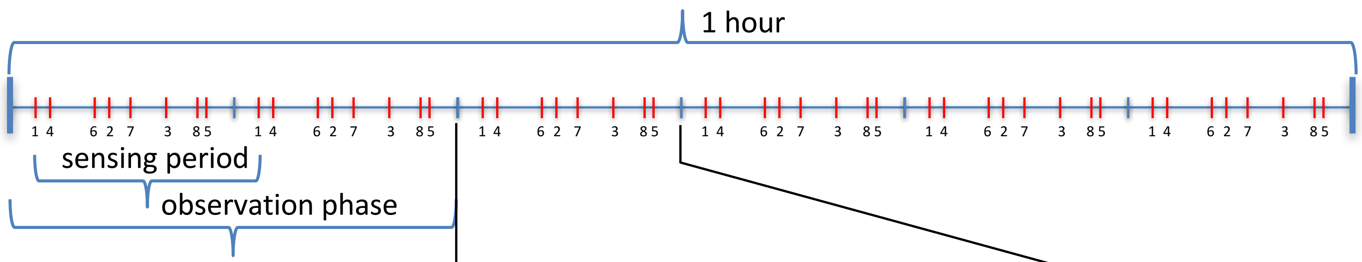
- Observation phase + data forwarding phase
- On-the-fly learning of incoming traffic from end-devices: **observation phase**
- Just-in-time wake up in **data forwarding phase**
- Minimum guard time to limit energy consumption
- Deep sleep between 2 wake up
- No additional hardware ➔ low-cost sensor nodes can be recycled as relay node
- Can handle downlink messages from gateway

Observation phase

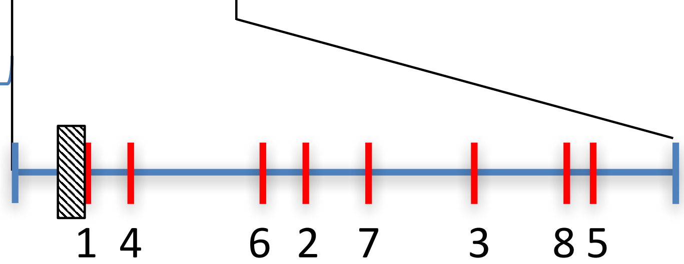
- Device i wakes up and transmit every I_target_i
  - Target TX time for device i: T0_i+n*I_target_i
  - Real TX time for device i: T0_i+n*I_real_i
- I_real_i from device i is determined during observation phase

Device i	I_real_i	ToA_i
Device j	I_real_j	ToA_j
Device k	I_real_k	ToA_k

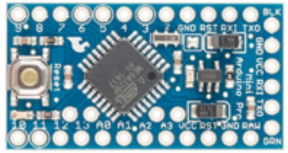
Note that I_real_i can also take into account pkt collisions that are resolved with some kind of back-off procedure



- Relay wake up
  - Minimized guard time



Synchronizing devices<->relay



- ATMega328P (8bit, 8MHz, 32K flash, 2K RAM)
- Available deep sleep durations with internal watchdog timer
  - [8, 4, 2, 1] seconds, [500, 250, 120, 60, 30, 15] milliseconds
  - Use multiple deep sleep cycles of [8, 4, 2, 1]s
  - Last 1000ms do not use deep sleep mode
- Each deep sleep cycle adds time overhead
  - Take into account the cycle time overhead
- Without RTC, external timers are disabled during deep sleep
  - No "absolute" time available
  - Need to re-adjust all stored timestamps at each wake up
    - Before deep sleep -> T1wake_up
    - After deep sleep -> T2wake_up
    - Re-adjust by T2wake_up – T1wake_up

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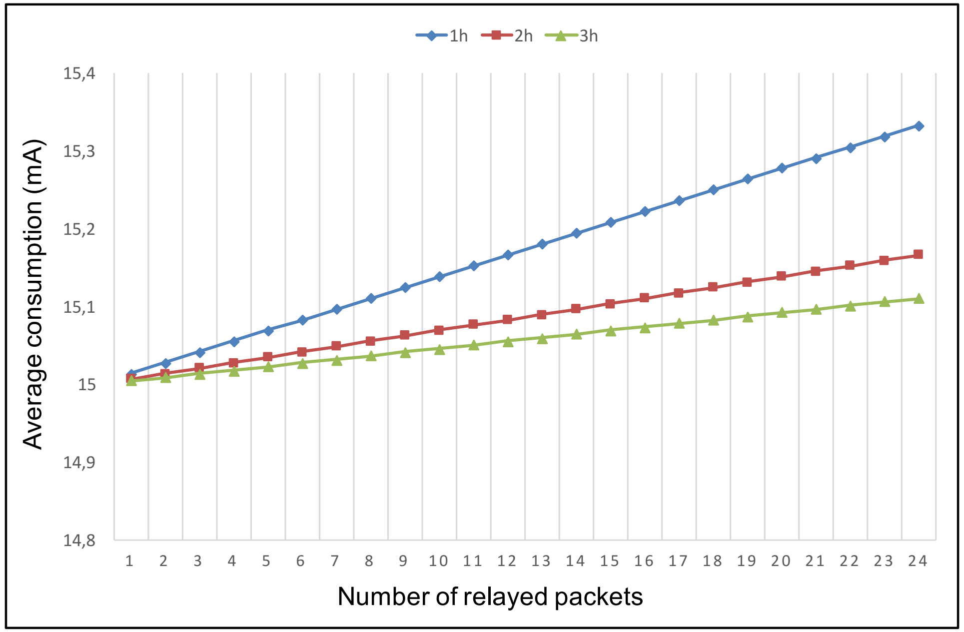
Energy consumption (1)

- Continuous receive: 15mA, Deep sleep: 5uA, Transmit: 40mA
- For an observation phase of 1 hour
  - Continuous receive (2s) and relay/transmit uplink messages (2s)
  - Ex: 8 msg in 1h (4 devices, assuming 2msg/device/hour)
  - ((8*2s)*40mA+(3600s–8*2s)*15mA)/3600s = 15.11mA



2500mAh

1h of observation consumes 1/165th of the battery capacity

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Energy consumption (2)

- In forwarding phase
  - Each wake up introduces about 2s of continuous receive followed by 2s of transmission (like previously)
  - (2s*15mA+2s*40mA)/4s = 27.5mA for each wake up
  - for 8 uplink msg (8*4s*27.5mA+ (3600s−8*4s)*0.005mA)/3600s=0.250mA
  - 414 days of operation
- We considered 2s to receive and 2s to transmit
- When considering only 1s for receiving and 1s for transmission, the lifetime is greatly increased
- Depending on terrain configuration, LoS conditions,... smaller spreading factor values can be used instead

Time on Air & spreading factor

- Using smaller spreading factor greatly decreases the time on air, but decrease receiver 's sensibility!

Sensibility/Range

Throughput

			time on air in second for payload size of							
LoRa mode	BW	SF	5 bytes	25 bytes	55 bytes	105 bytes	155 Bytes	205 Bytes	255 Bytes	max thoughput (255B
1	125	12	0.9585	1.6138	2.5969	4.2353	5.8737	7.5121	9.1505	223
2	250	12	0.4792	0.8069	1.2165	1.8719	2.5272	3.2645	3.9199	520
3	125	10	0.2806	0.4854	0.6902	1.0998	1.5094	1.919	2.3286	876
4	500	12	0.2396	0.4035	0.6083	0.9359	1.2636	1.6323	1.9599	1041
5	250	10	0.1403	0.2427	0.3451	0.5499	0.7547	0.9595	1.1643	1752
6	500	11	0.1198	0.2222	0.3041	0.5089	0.6932	0.8776	1.0619	1921
7	250	9	0.0701	0.1316	0.1828	0.2954	0.4081	0.5207	0.6333	3221
8	500	9	0.0351	0.0658	0.0914	0.1477	0.204	0.2604	0.3167	6442
9	500	8	0.0175	0.0355	0.0508	0.0815	0.1148	0.1455	0.1788	11408
10	500	7	0.0088	0.0203	0.028	0.0459	0.0638	0.083	0.1009	20212

Transmitting: `TC/22.5/HUM/67.7` ; about 20 bytes with packet header
Time on air is 1.44s

Radio duty-cycle

- In Europe, duty-cycle imposes a maximum of 36s/hour of transmission for a device. The relay is considered a device
- Assuming 1msg/device/hour and 1s for receiving and 1s for transmission then the relay can support 36 devices
- How to increase the number of devices?
  - Decrease spreading factor – OK, but not always possible
  - Decrease #msg per device/hour – depend on the application
  - Do not forward every message – how to select which packet to forward?
- We are investigating similarity detection in relay node to detect "similar" devices
  - "similar" devices means their measures are considered "similar"
  - Relay node can decide to forward only 1 pkt from a set of similar devices
  - Can still use encryption but relay needs to be able to decrypt

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Conclusions

- 1-hop to gateway can be challenging in real-world, rural LoRa deployment
- 2-hop LoRa will provide much higher flexibility in deployment
- Using CAD approach can be very unreliable
- We demonstrate the feasibility of a 2-hop relay node based on very low-cost hardware
  - No additional hardware (hard design choice)
  - Observation phase to schedule future wake up
  - Can handle packet collision if observation phase >> sensing period
  - Just-in-time wake up in data forwarding phase
  - Relay can keep synchronization with devices
  - Low-energy consumption
- Embedded similarity detection mechanism under study