Robust CSMA for long-range LoRa transmissions with Image Sensing Devices

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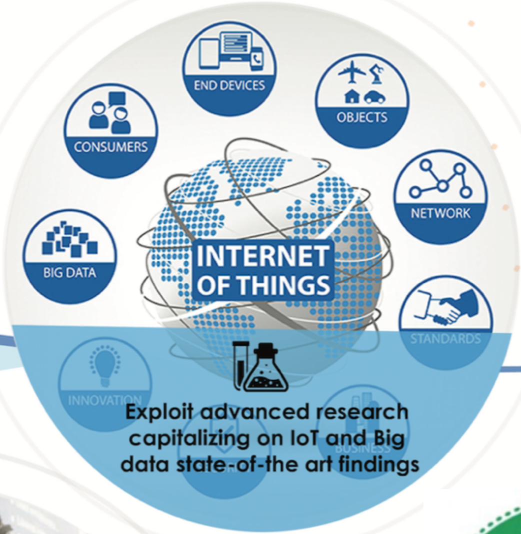
Université de Pau, France

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

HORIZON 2020



DO MORE with LESS

www.waziup.eu
Waziup IoT
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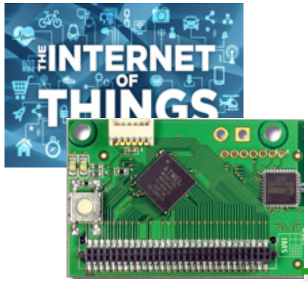
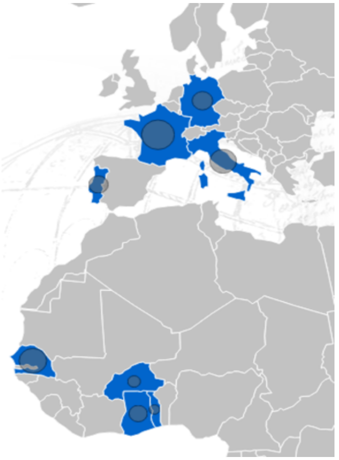


Scaling up!

Feb 2016 - 2019

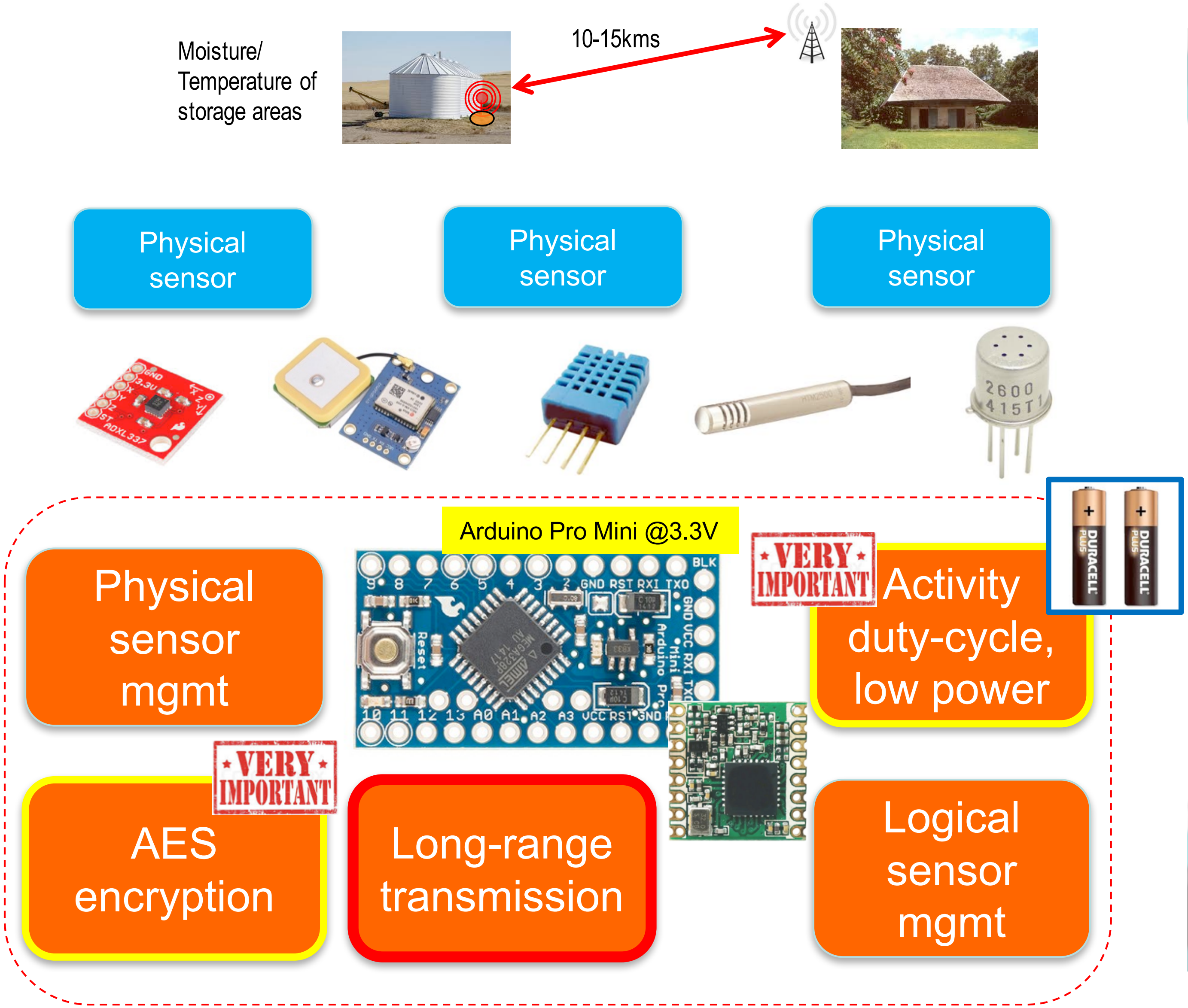
WAZIUP

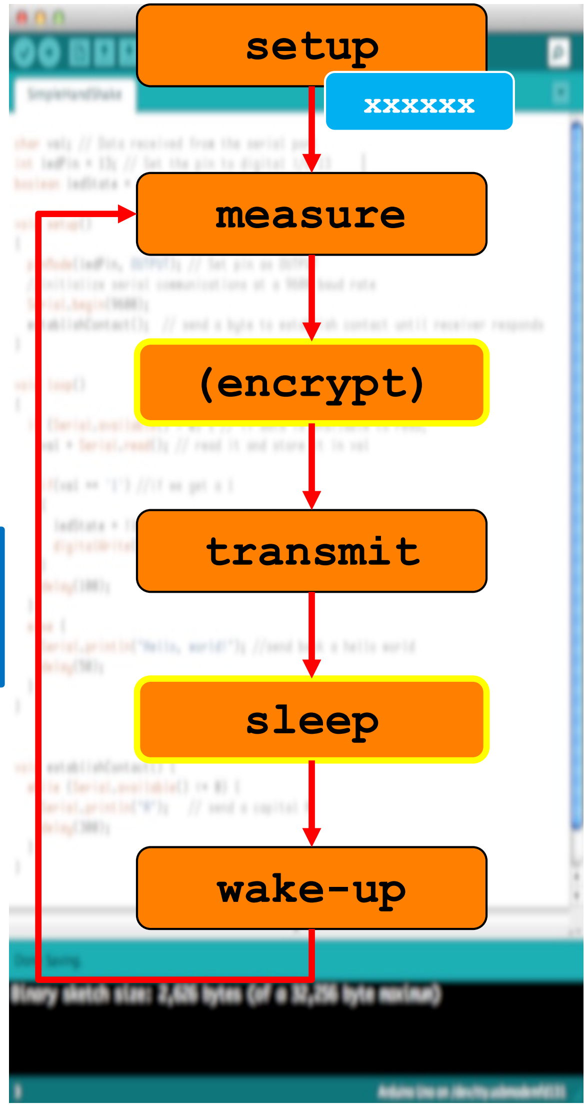


May 2018 - 2021

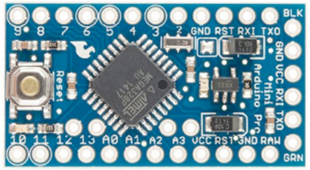
WAZIHUB

Generic low-cost IoT device

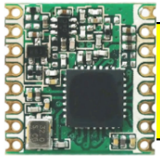




Low-cost integration

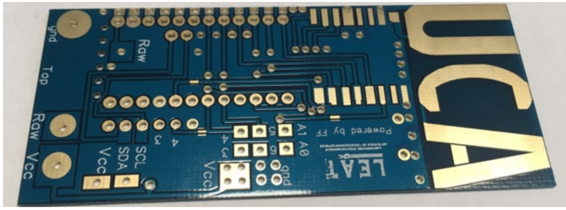


1.5€

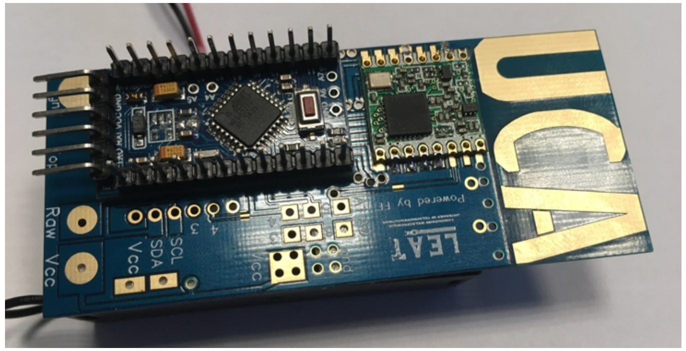


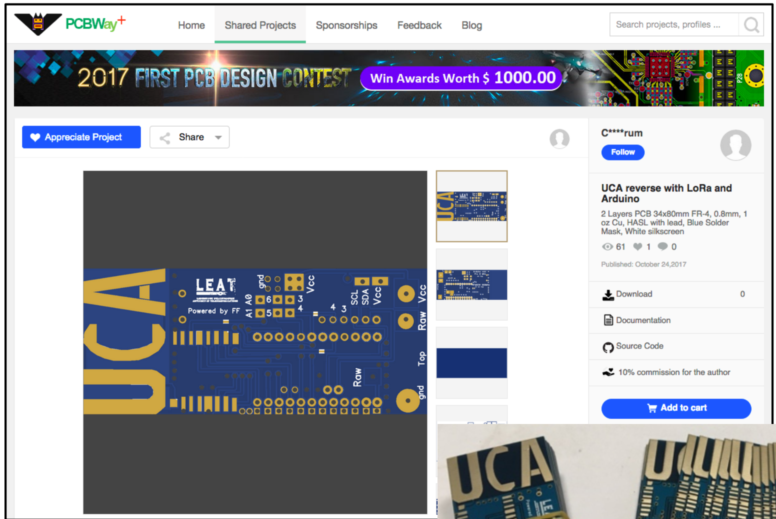
5€

https://github.com/FabienFerrero/UCA_Board

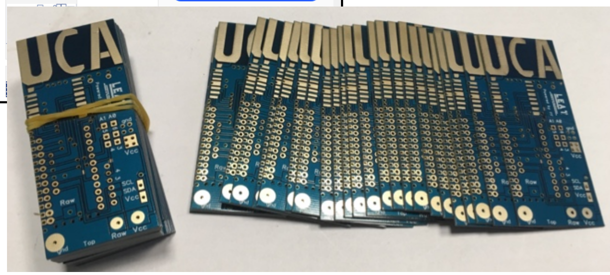


1€

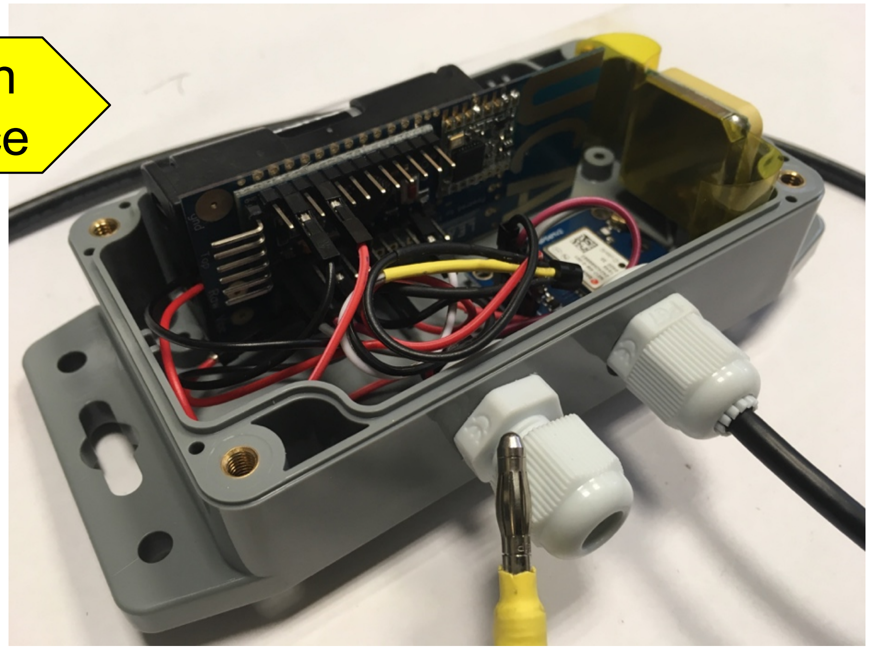




1-click order



Less than 10€/device



From generic to specific applications

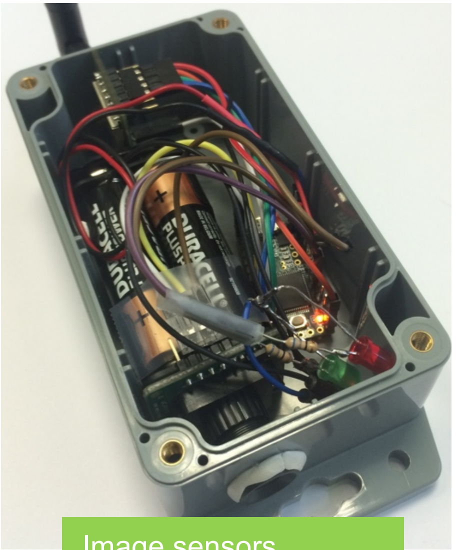
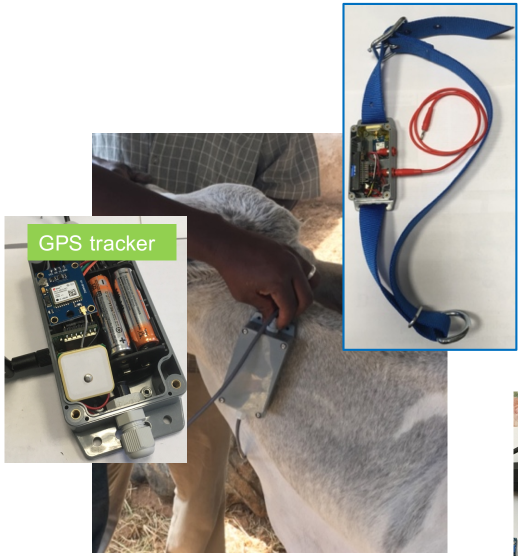
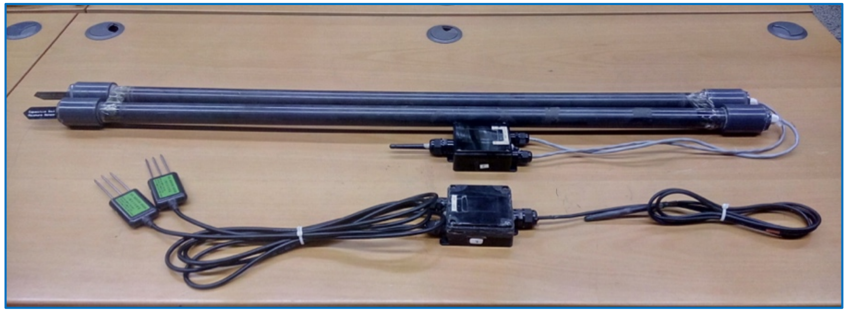


Image sensors


GPS tracker




Soil moisture


Bin presented at Woelab

Waste Mngt


Photo from EGM

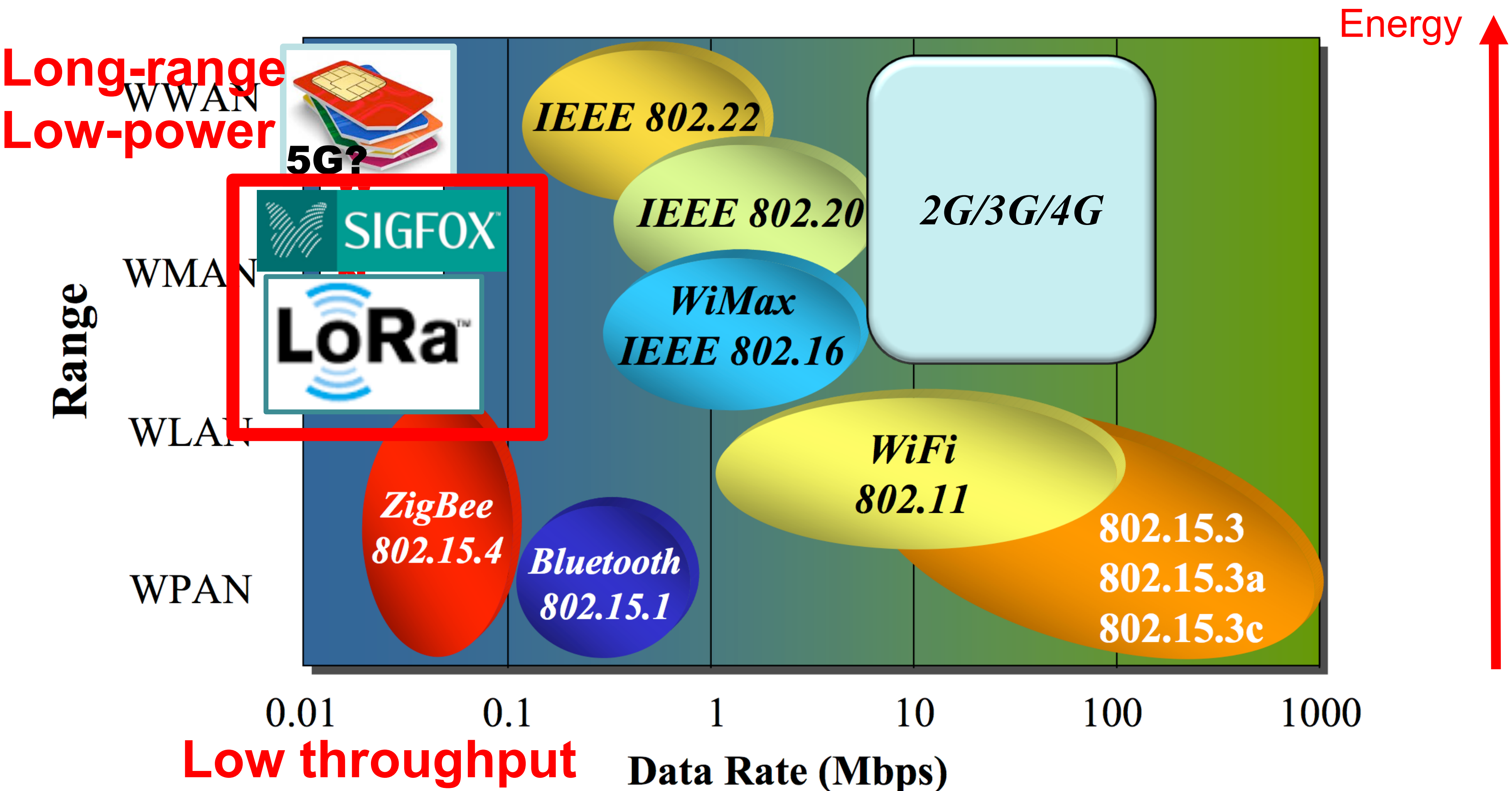
Buoy for water quality


Weather Station

Photo from Unparallel

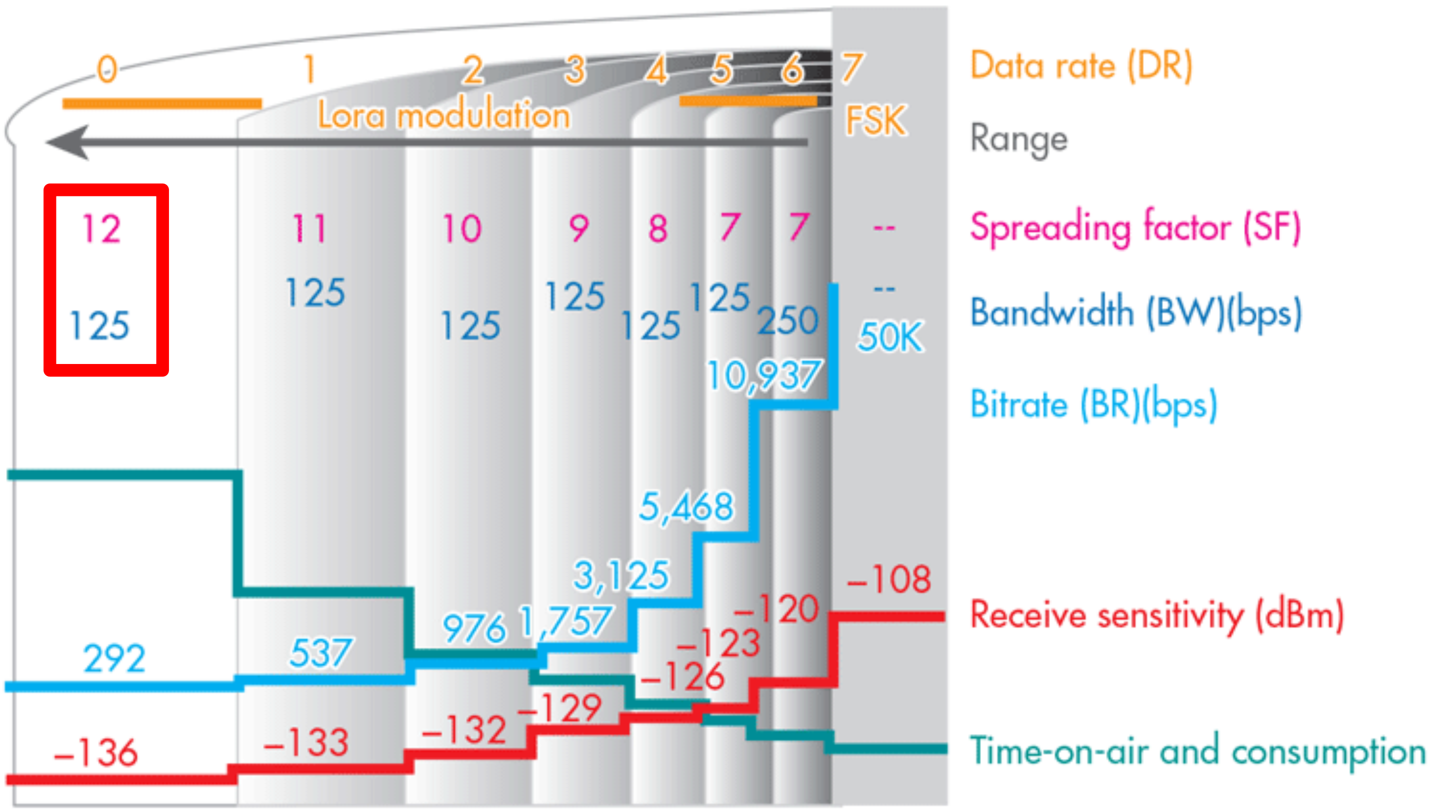
LOW-POWER & LONG-RANGE RADIO TECHNOLOGIES

Energy-Range dilemma

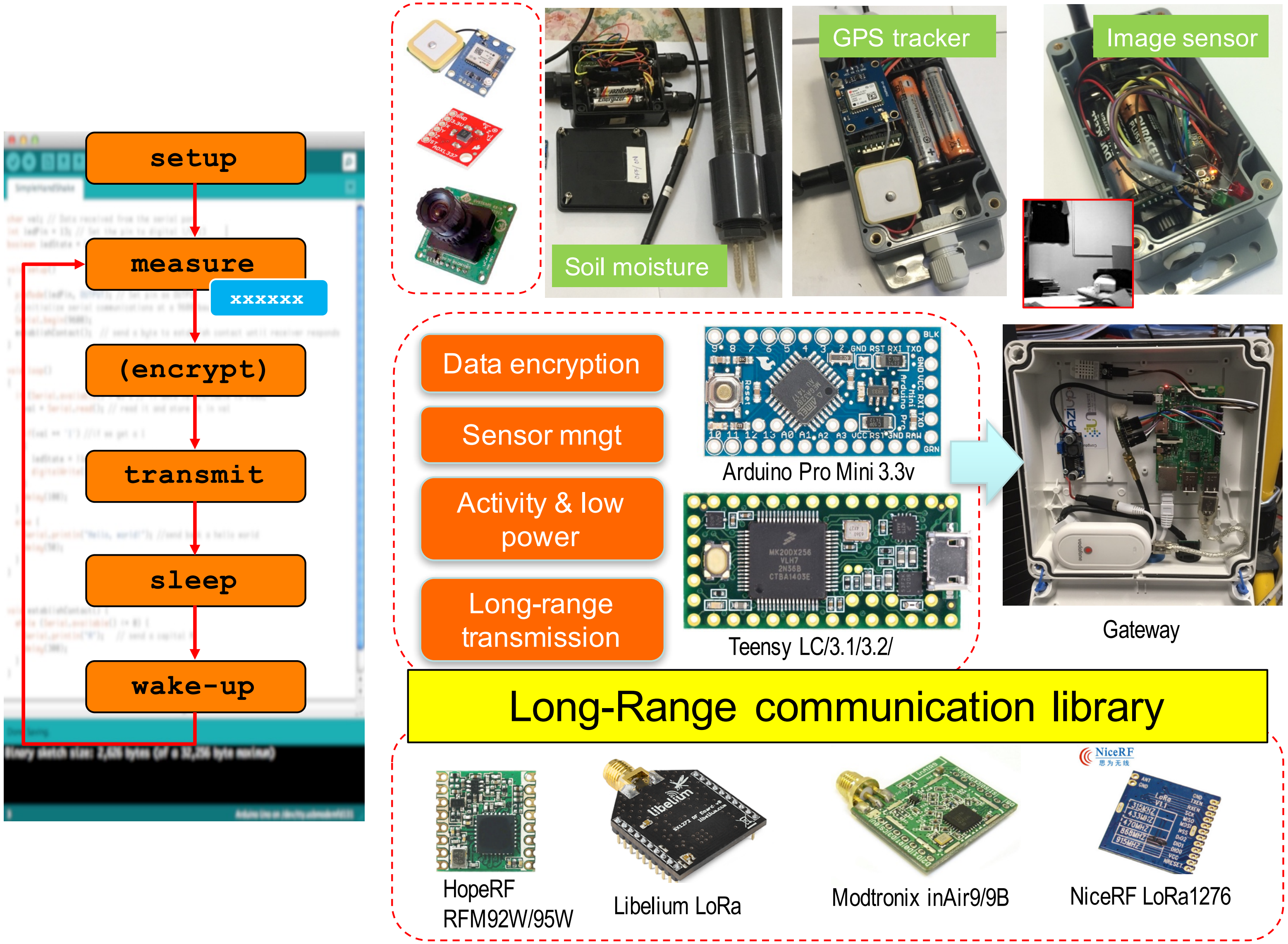


Main LoRa parameters

- Main parameters
  - Bandwidth: 62.5kHz, 125kHz, 250kHz, 500kHz
  - Spreading factor: 6 to 12



Deploying low-cost-long-range IoT



Innovative image sensor Teensy32+uCamIII

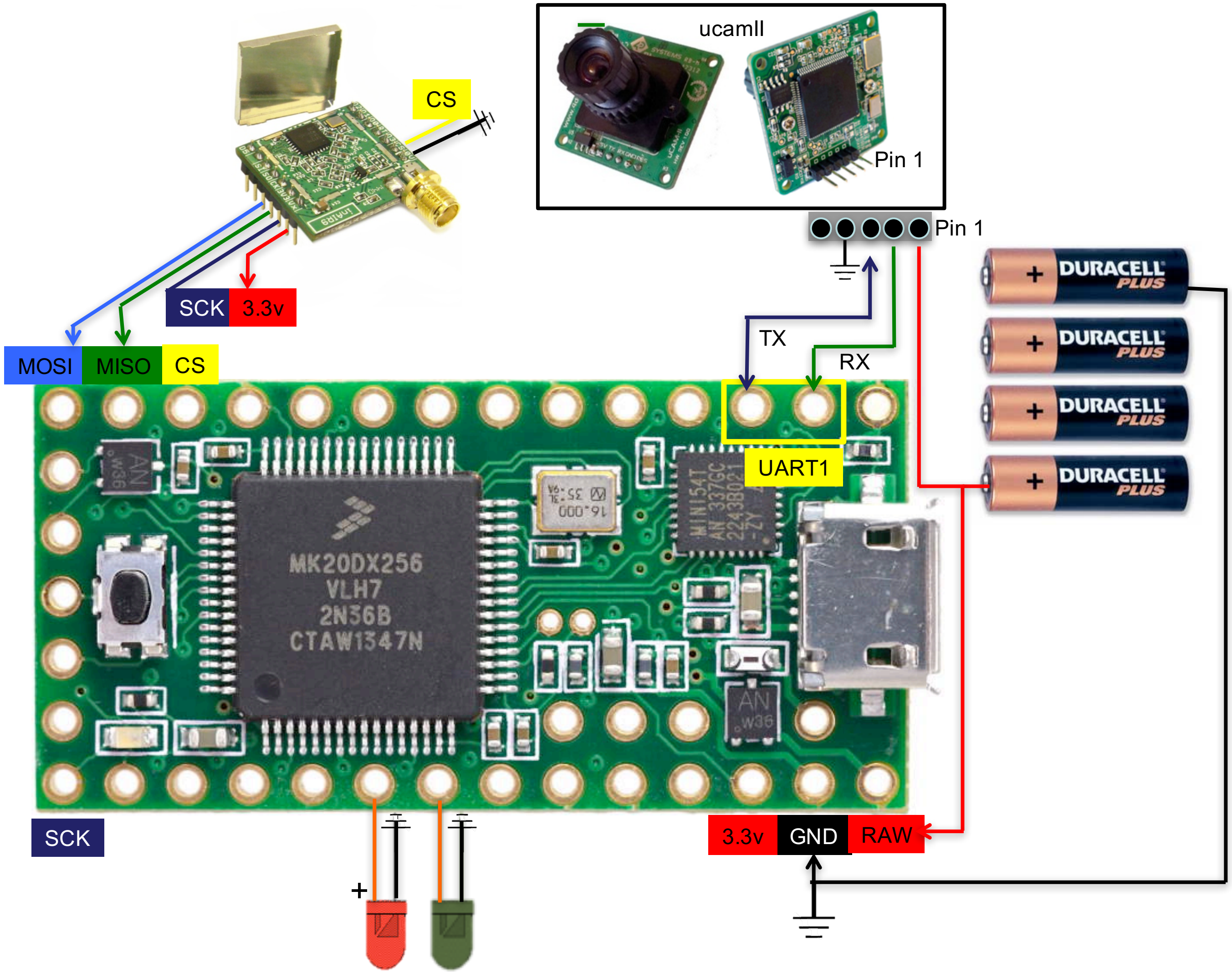
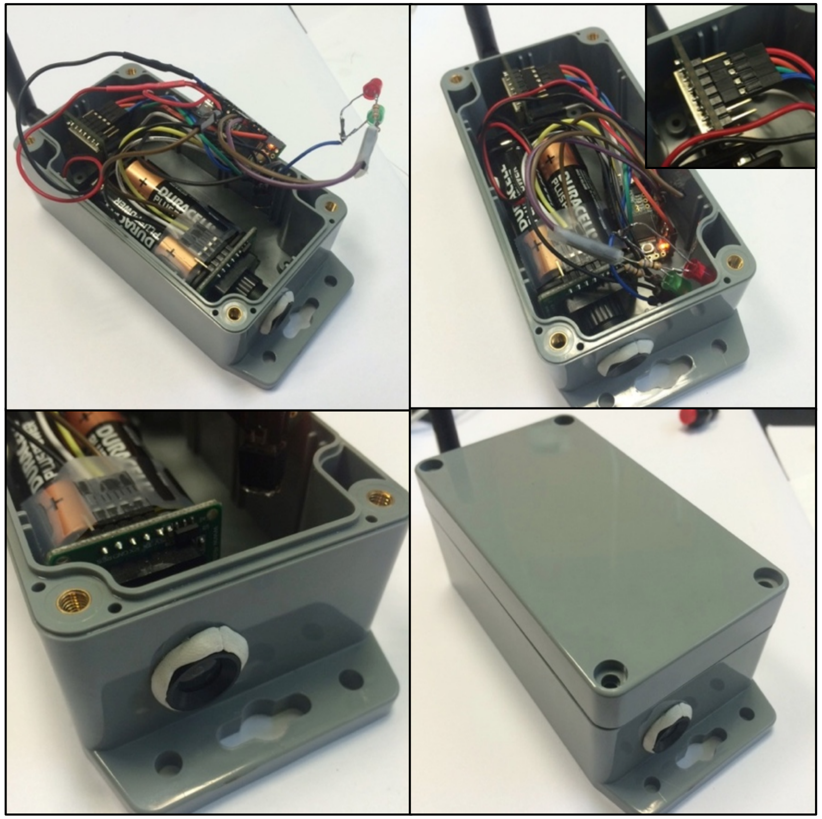
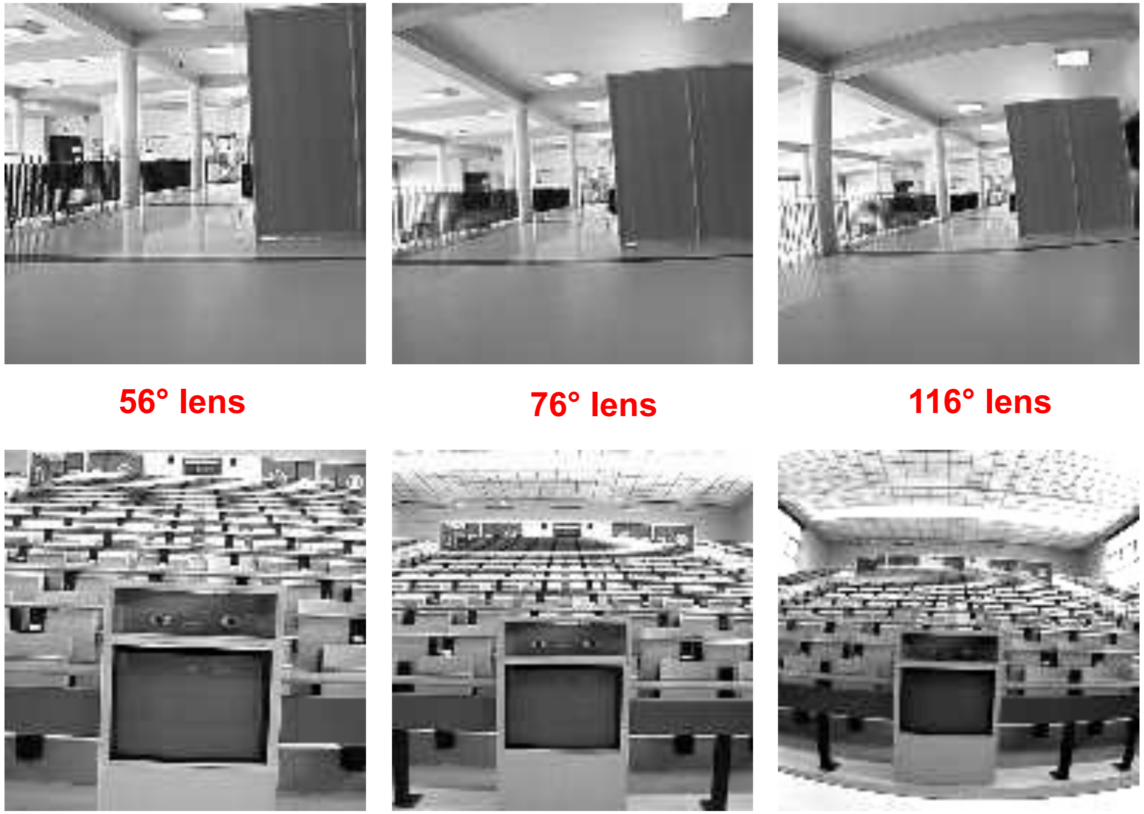


Image sensor device

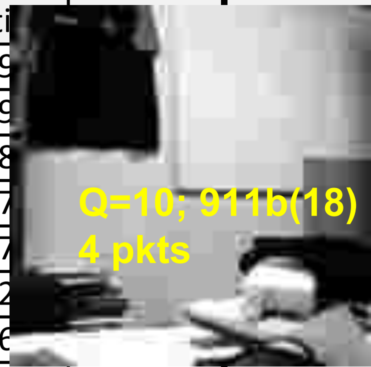




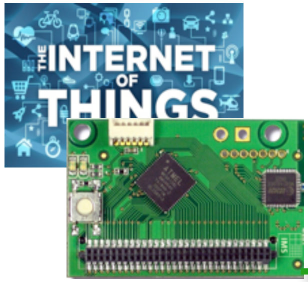
The uCamII is shipped with a 56° angle of view lens but 76° and 116° lenses are also available for various application needs.

Image encoding performances, Q=10 & 20

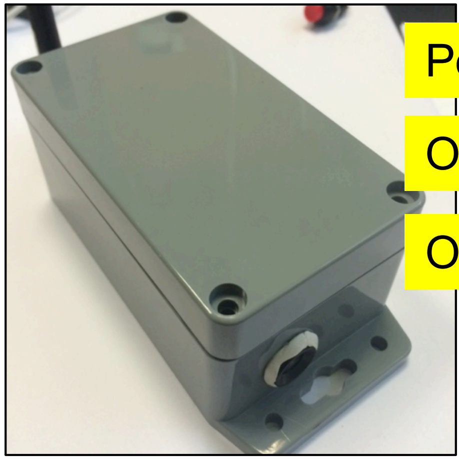
									MSS=240	
	96MHz		72MHz		48MHz		24MHz		N	S
Quality Factor Q	encode	packetiza	encode	packetiza	encode	packetiza	encode	packetiza tion time	number of packets	size in bytes (compression ratio)
100								813	47	9982 (1.64)
90								322	23	5090 (3.21)
80								218	16	3595 (4.55)
70								178	13	2842 (5.76)
60								162	11	2461 (6.65)
50								150	10	2129 (7.69)
40								139	9	1898 (8.63)
30	224	33	260	44	345	64	637	127	7	1608 (10.19)
20	223	31	260	39	345	58	636	115	6	1279 (12.81)
10	223	26	260	31	345	50	636	99	4	824 (19.88)
5	223	23	259	31	344	45	635	89	3	503 (32.57)



- Capturing an image and encoding it roughly take 2.3s
  - Time to sync & config ucam is about 400ms
  - Time to read raw image data from ucam is 1512ms
  - Time of compare with reference image is neglectible
  - Time for encoding and packetization is about 300ms



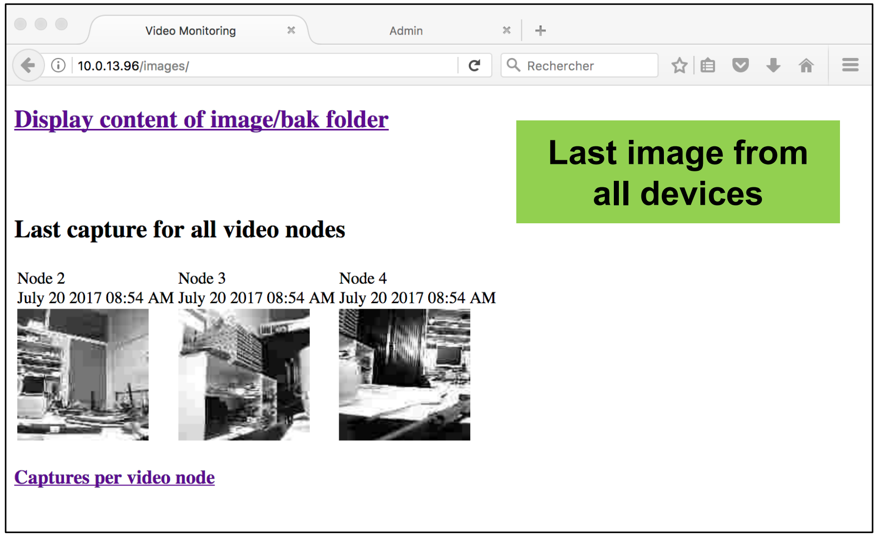
OUT-OF-THE-BOX !



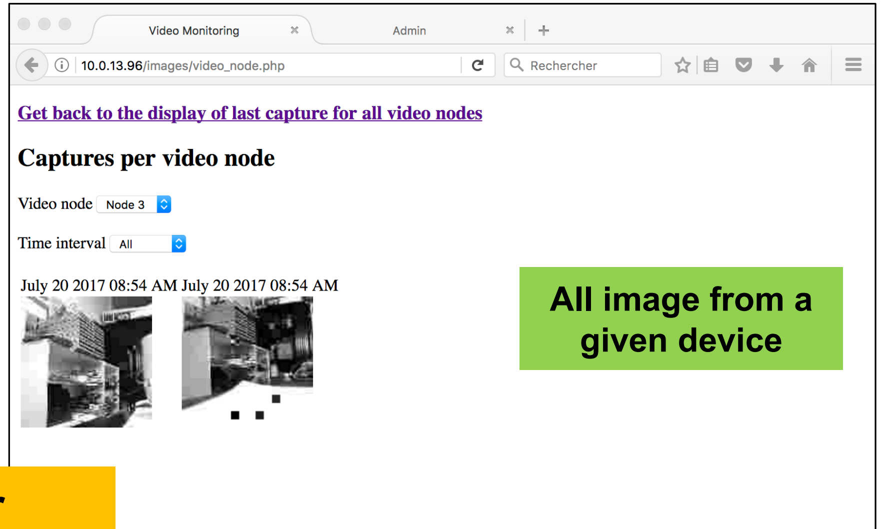
Periodic

On-demand

On event



Last image from all devices

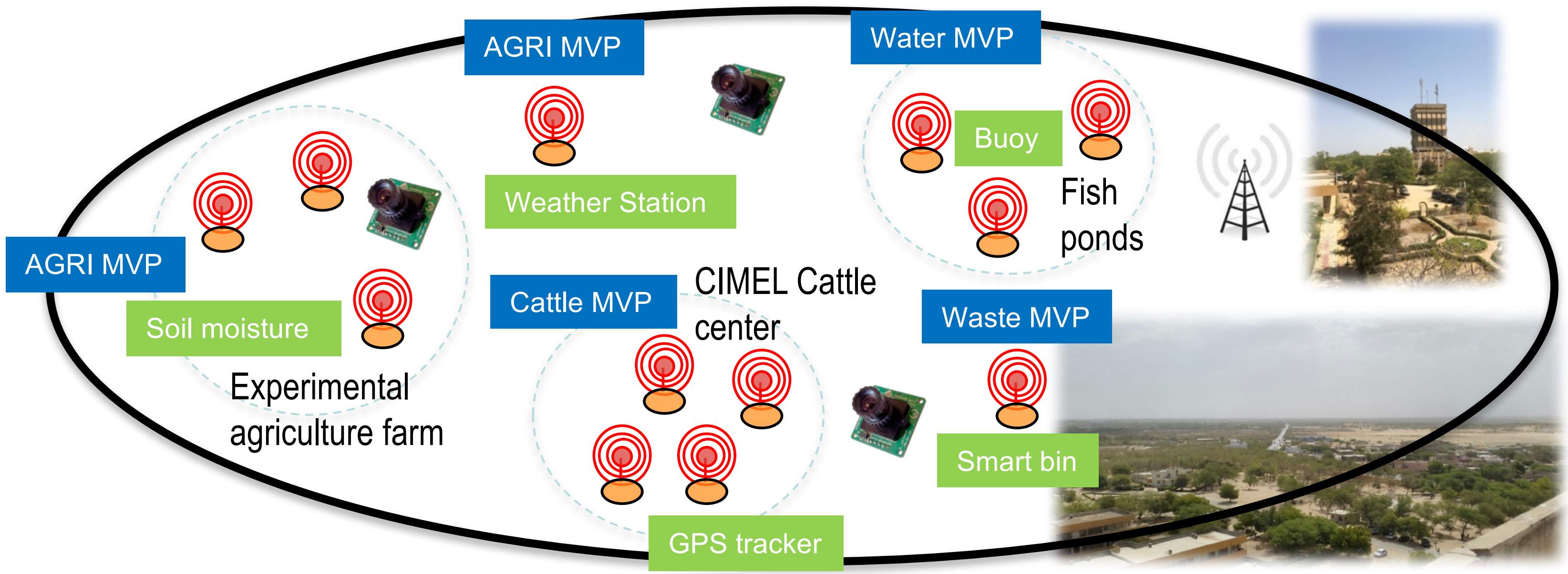


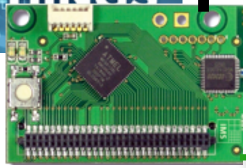
All image from a given device

Embedded web server
http://192.168.200.1/images

Deploying in WAZIUP pilot test-bed

- Pilot test-bed in Gaston Berger University, Saint-Louis, Senegal, to test all WAZIUP use-cases
- Gateway placed on top of a 30m building



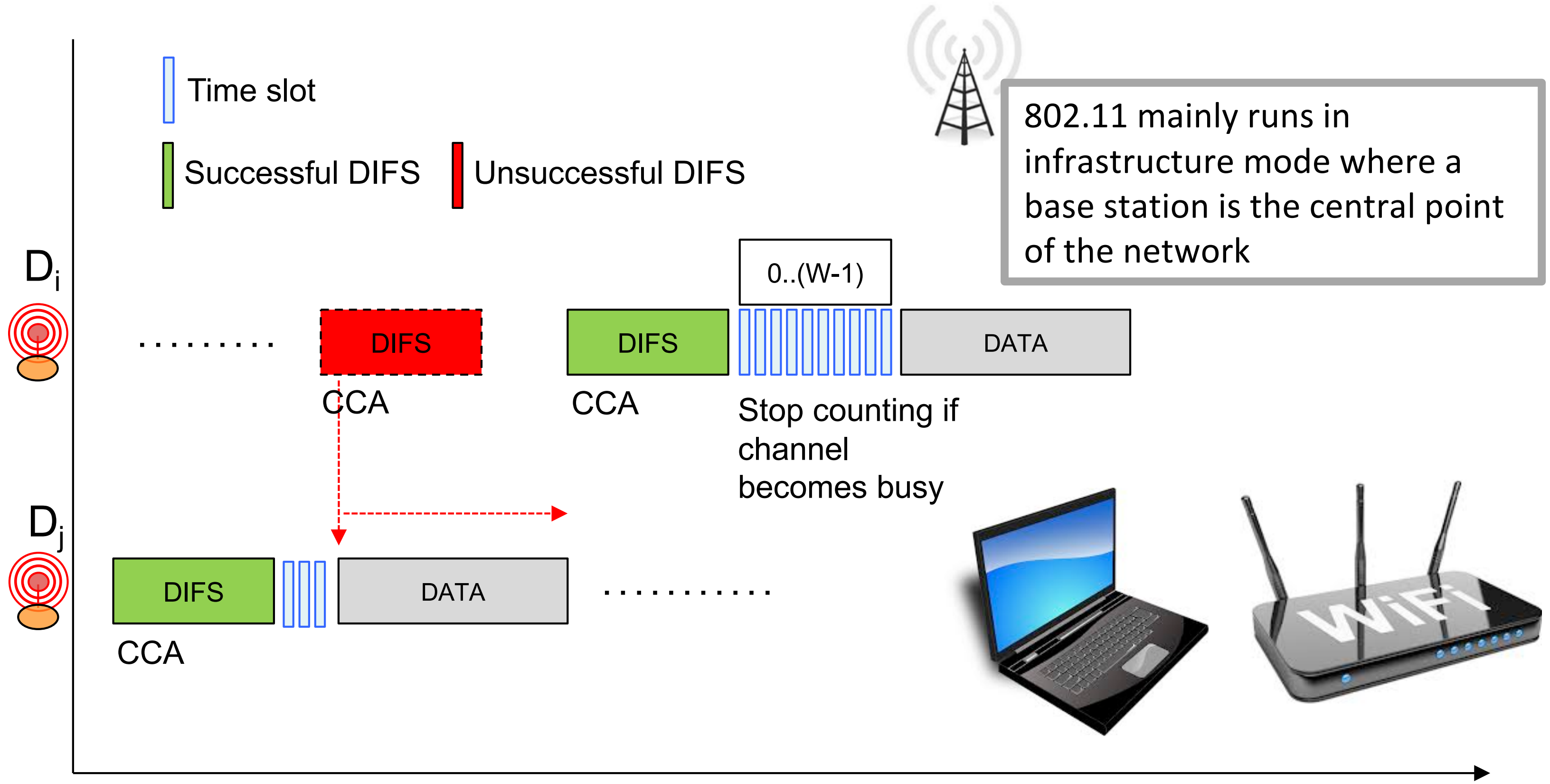


Robust channel access mechanisms

- LoRa networks will get densier with a large variety of devices and data traffic profiles
- With image devices, packets are longer and transmission can take about 8s-9s, thus dramatically increasing the vulnerability time
- Objectives are to reduce packet collisions, thus reducing delivery latency, and reduce power consumption due to unsuccessfull transmissions
- Current LoRa neworks under LoRaWAN use simple mechanism
- Current raw LoRa networks are mainly pure ALOHA systems

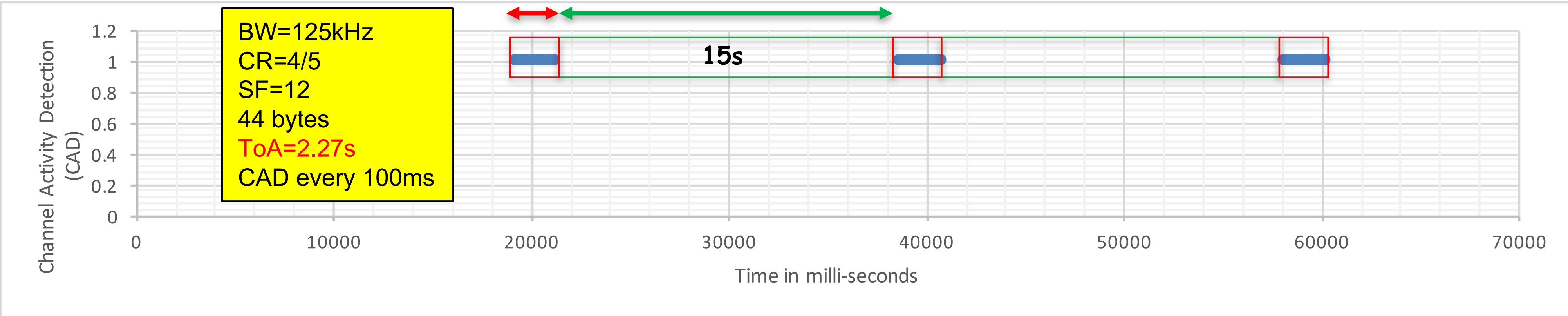
Review of IEEE 802.11

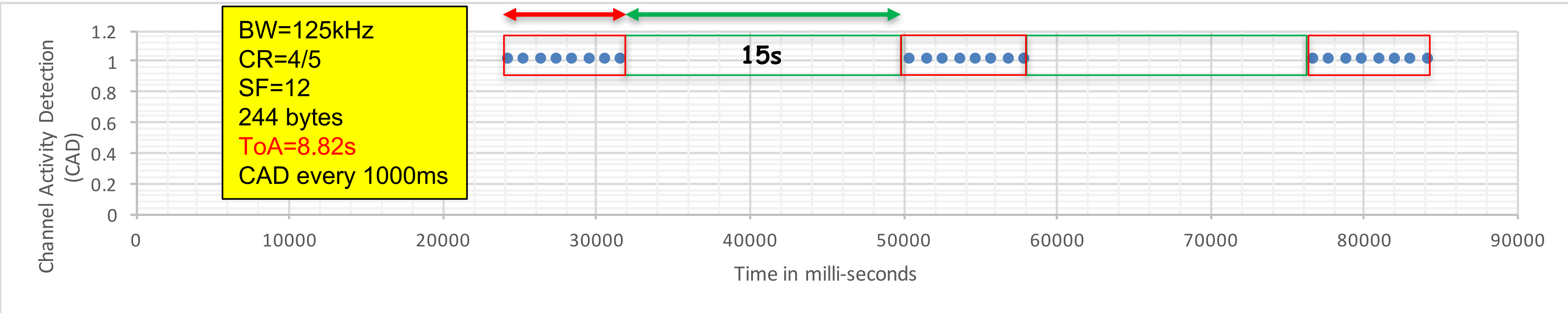
- DIFS, SIFS
- Random backoff [0..W[



Clear Channel Assessment with LoRa

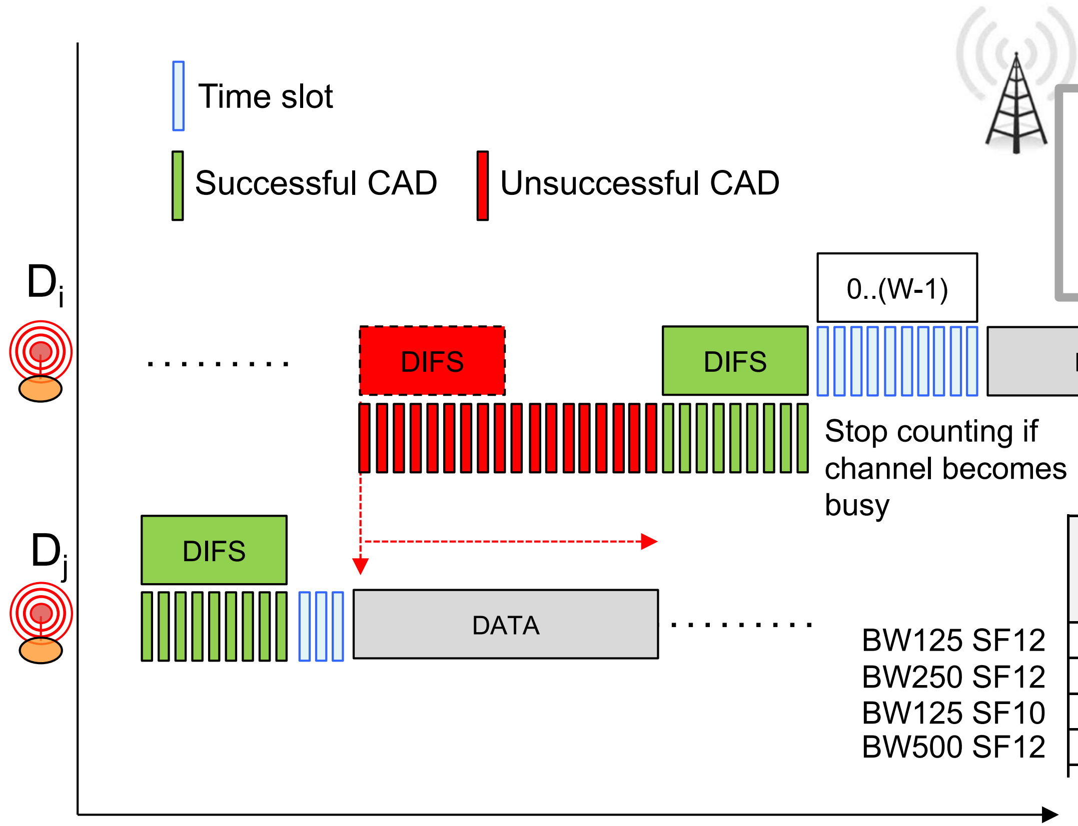
- CCA uses dedicated LoRa's Channel Activity Detection (CAD) as data reception can be done below the noise floor





LoRa CSMA derived from 802.11

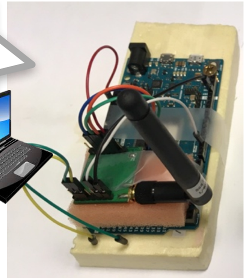
- CAD duration is between $1.75T_{sym}$ and $2.25T_{sym}$
- T_{sym} depends on bandwidth & spreading factor
- SIFS & DIFS are mapped to a number of CAD



LoRa mainly runs in gateway-centric mode where a gateway is the central point of the network

	LoRa mode	Tsym (ms)	CAD duration (Tsym)	CAD duration (ms)	Experimental measures min value	max value
BW125 SF12	1	32.768	1.86	60.948	60	62
BW250 SF12	2	16.384	1.86	30.474	29	31
BW125 SF10	3	8.192	1.77	14.500	14	16
BW500 SF12	4	8.192	1.86	15.237	15	16

Experiments on the test-bed



A node will constantly perform Channel Activity Detection to monitor radio activity

Teensy32 with a uCamII camera will be the sources of large image packets to the gw

Simple sensors will send short messages to the gw

An interactive end-device is also use to send both short and medium size message to the gw

Photo from EGM

Buoy for water quality

Multi-sensors nodes will send medium size messages to the gw

Weather Station

Photo from Unparallel

Bin presented at Woelab

Waste Mngt

Device	QT	Message type	Traffic profile
GPS Tracker	5	small	1 message every 10mins
Soil Moisture	10	small	1 message every 60mins
Smart bin	2	small	1 message every 60mins
Weather Station	1	medium	1 message every 15mins
Buoy	2	medium	1 message every 30mins
Image sensor	3	long	1 image (4-5 packets) every 15 mins

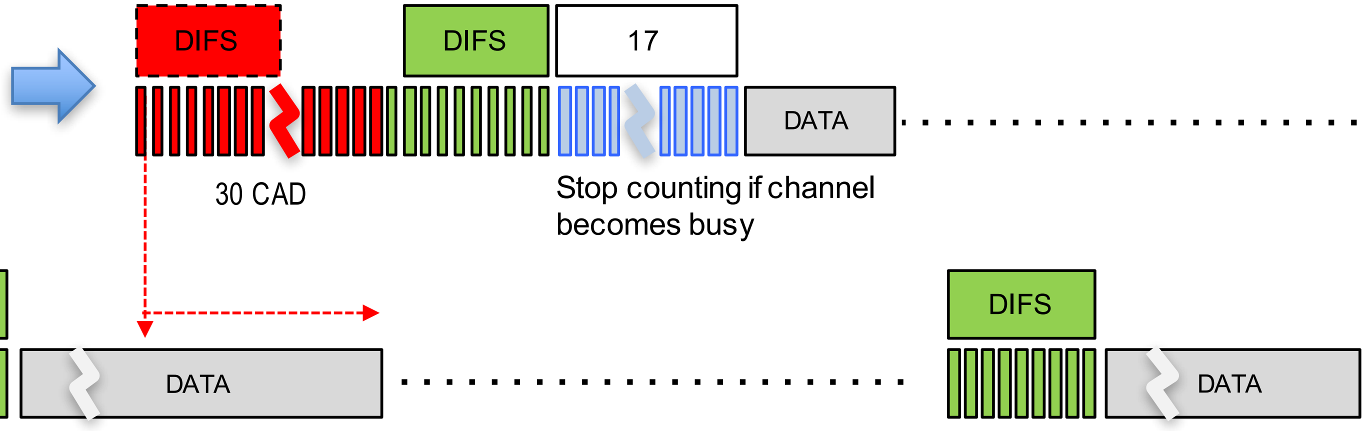
Experiment 1

```
Sending buoy water data
########################################
Packet number 1
Payload size is 40
ToA is w/4B header 2270
--> CarrierSense2: do CAD for DIFS=9CAD
--> DIFS duration 61
###1
--> Channel busy. Retry CAD until free channel
RRRRRRRRRRRRRRRRRRRRRRRRRRRRRR
--> found busy during 30 CAD
--> wait duration 1891ms
--> retry
--> DIFS duration 547ms
--> counting for 17 CAD
-----------------
--> found busy during 0
LoRa Sent in 2390ms
LoRa Sent w/CAD in 6231
Packet sent, state 0
```

No pkt loss

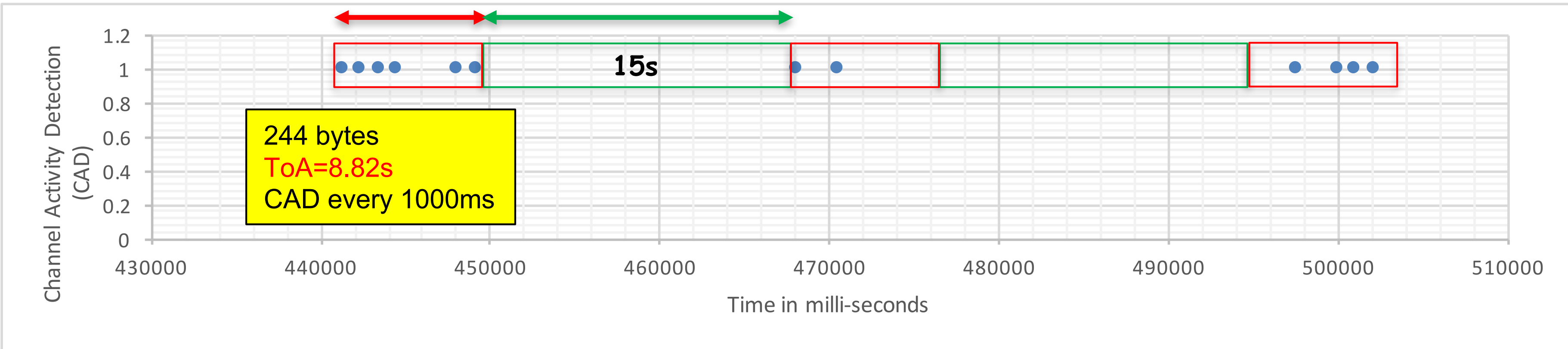
1 pkt lost

2 pkt lost

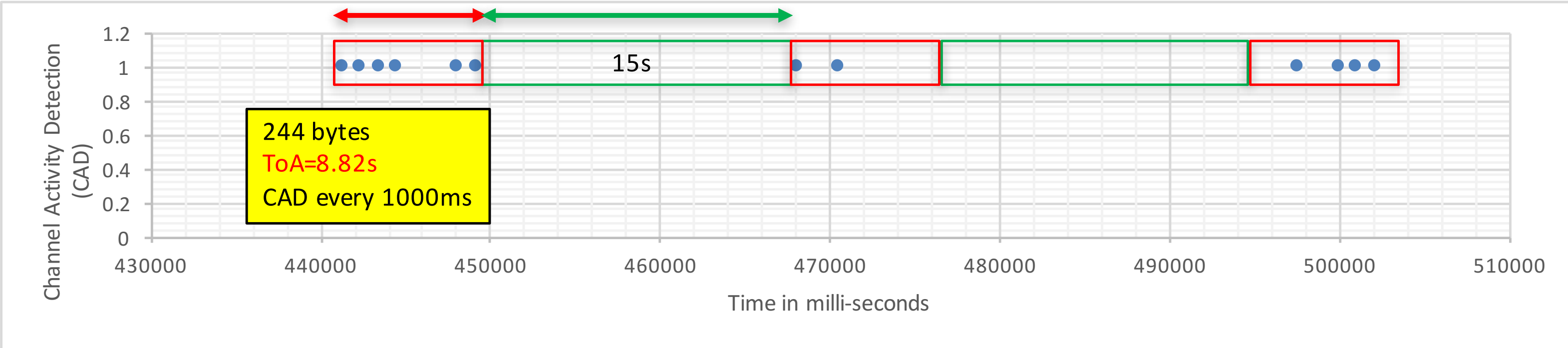


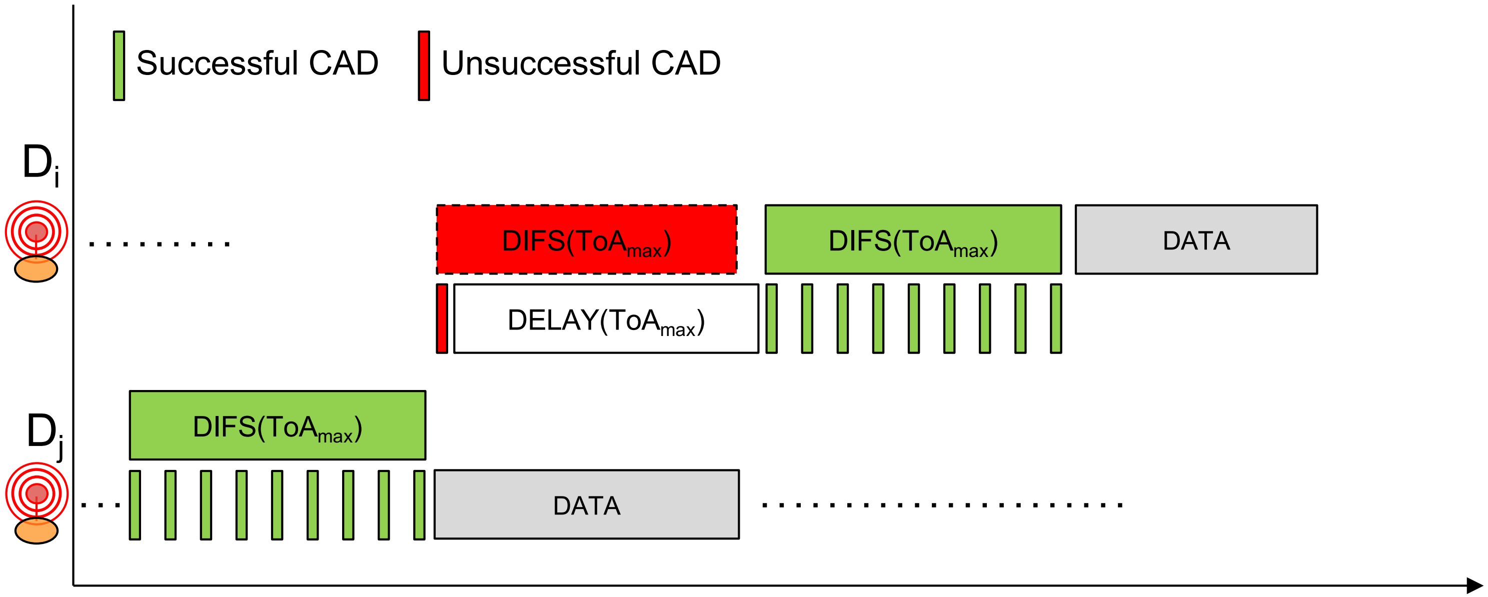
CAD RELIABILITY?

- 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

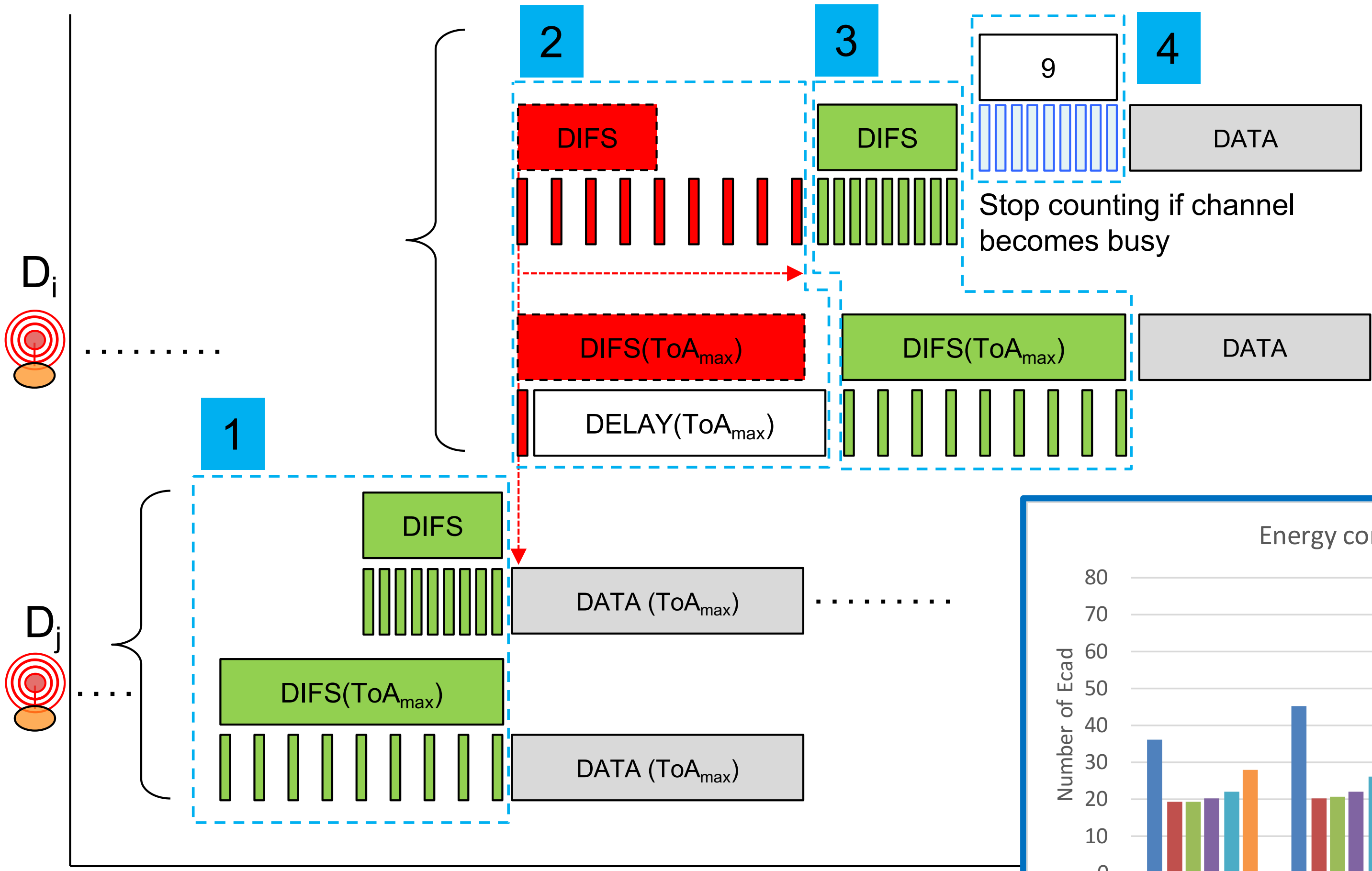


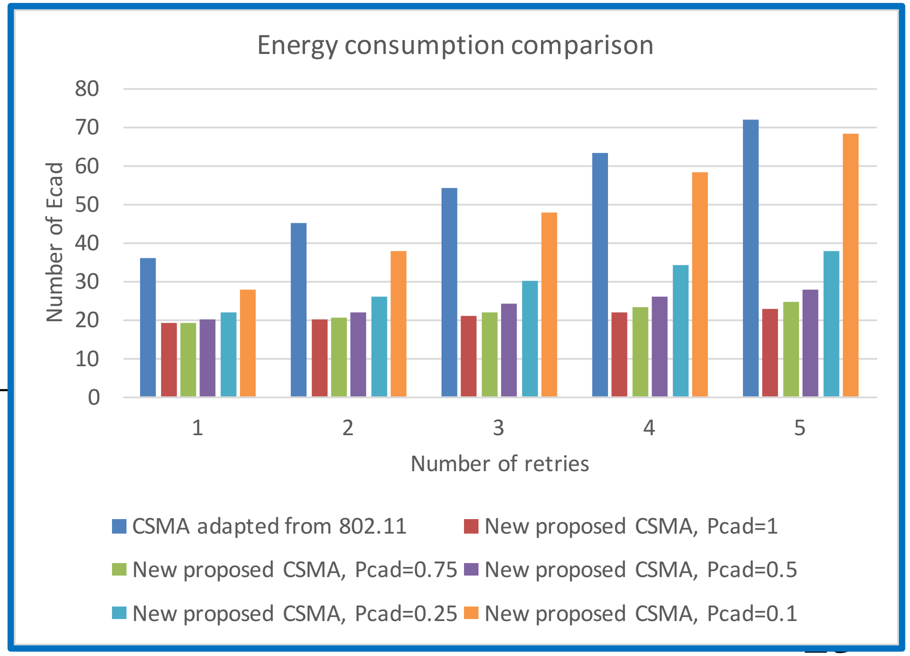
LoRa CSMA adapted to longer msg

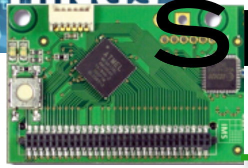




CSMA VARIANTS & COMPARISON



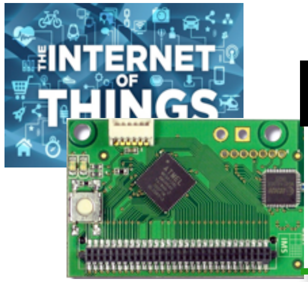




SELECT THE CSMA VARIANT

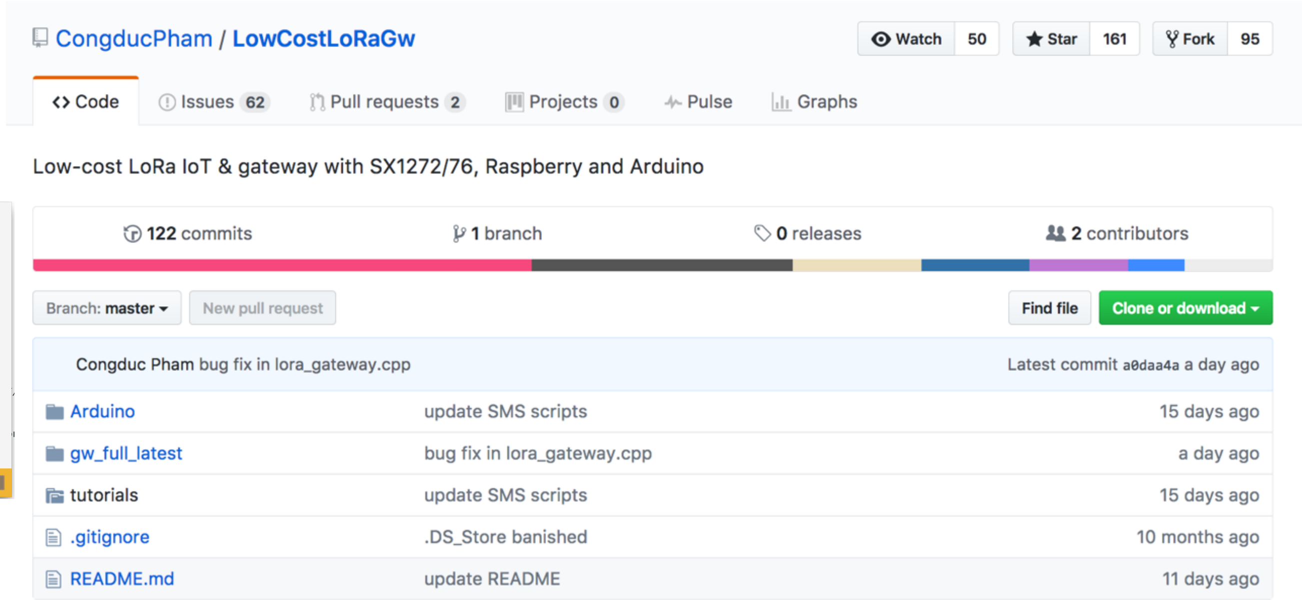
- Latency depends on maxToA, i.e. max packet length
- When maxToA is small (only traditional devices)
  - CSMA derived from 802.11 has lowest latency and is efficiently handling packet collisions
  - as maxToA is small, vulnerability time is small and…
  - …CAD reliability issue has little impact
- When maxToA is larger (e.g. image sensors)
  - CAD reliability is a concern
  - To improve robusteness, latency is directly linked to maxToA
  - However, it is possible to decrease maxToA by not using the maximum packet size for image packet
  - Overhead is 4 bytes per additional packet

				time on air in second for payload size of						
LoRa mode	BW	CR	SF	5 bytes	55 bytes	105 bytes	155 Bytes	205 Bytes	255 Bytes	max thr. for 255B in bps
1	125	4/5	12	0.95846	2.59686	4.23526	5.87366	7.51206	9.15046	223
2	250	4/5	12	0.47923	1.21651	1.87187	2.52723	3.26451	3.91987	520



Implemented in our IoT communication lib

- Run on most of Arduino-compatible boards



LowCostLoRaGw github has latest general distribution: https://github.com/CongducPham/LowCostLoRaGw

Low-cost DIY LoRa gateway