# Investigating and Experimenting CSMA Channel Access Mechanisms for LoRa IoT Networks

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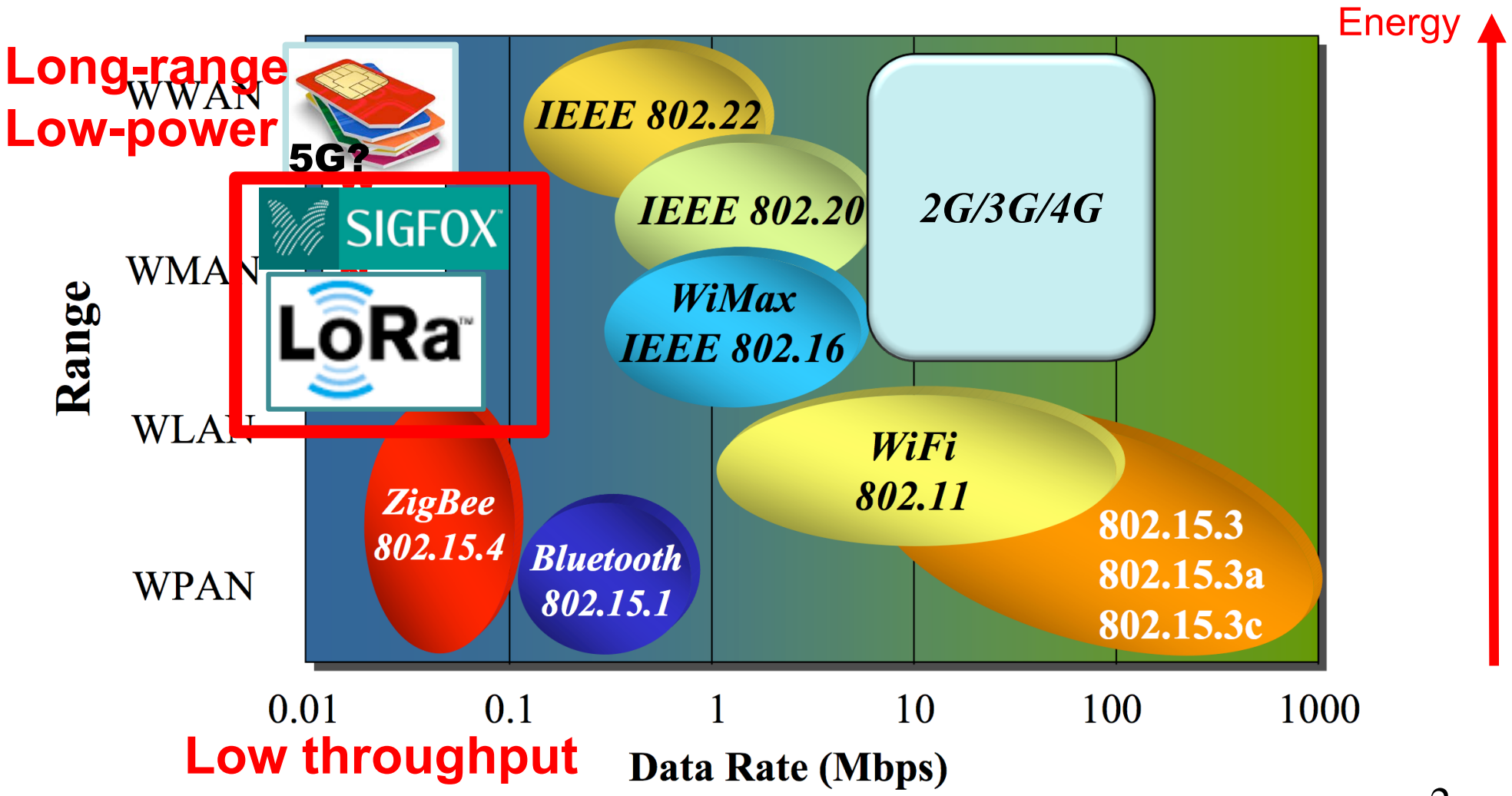
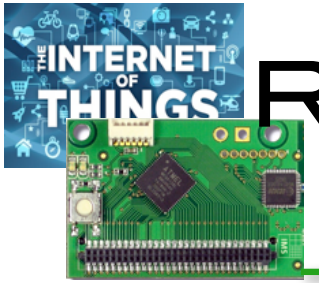
# LOW-POWER & LONG-RANGE RADIO TECHNOLOGIES

## Energy-Range dilemma






# Robust channel access mechanisms

- LoRa networks will get densier with a large variety of devices and data traffic profiles
  - Traditional simple sensor ➔small messages
  - Traditional multi-sensor ➔ medium messages
  - Innovative image sensors ➔ large messages ➔ Time on Air can be of several seconds!

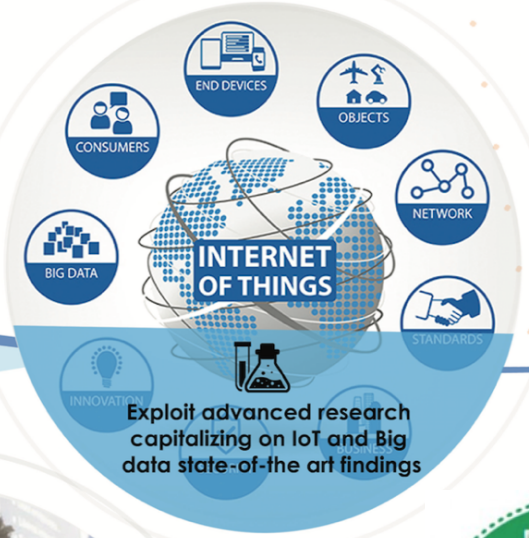
| | | | time on air in second for payload size of | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| LoRa mode | BW (kHz) | SF | 5 bytes | 55 bytes | 105 bytes | 155 Bytes | 205 Bytes | 255 Bytes | max thoughput in bps |
| 1 | 125 | 12 | 0.9585 | 2.5969 | 4.2353 | 5.8737 | 7.5121 | 9.1505 | 223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

- Objectives are to reduce packet collisions, thus reducing delivery latency, and reduce power consumption due to unsuccessfull transmissions
- Current raw LoRa networks are mainly pure ALOHA systems
- Some LoRaWAN implementations proposes simple Listen-Before-Talk mechanism

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

HORIZON 2020

Affordable technologies to empower rural economics




Exploit advanced research capitalizing on IoT and Big data state-of-the art findings

Develop IoT solutions and applications meeting African needs

DO MORE with LESS

www.waziup.eu

Waziup IoT

Waziup IoT

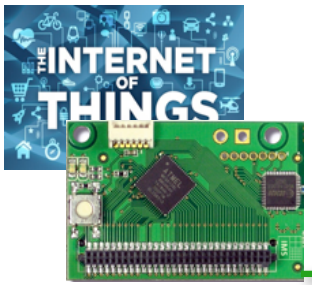
Waziup

Waziup

CREATE-NET · CTIC · Farmerline · iSpace · coders africa · INNOTEC

waziup.community@create-net.org

# Generic low-cost IoT device





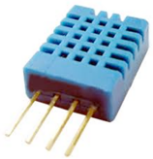
Moisture/
Temperature of
storage areas

10-15kms

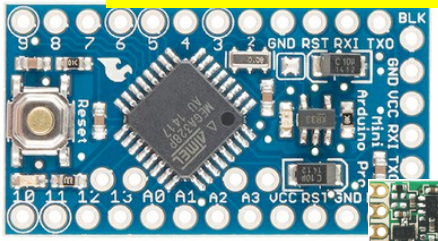
Physical sensor

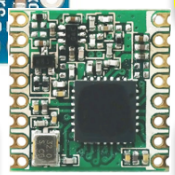
Physical sensor

Physical sensor



Arduino Pro Mini @3.3V





Physical sensor mgmt

VERY IMPORTANT

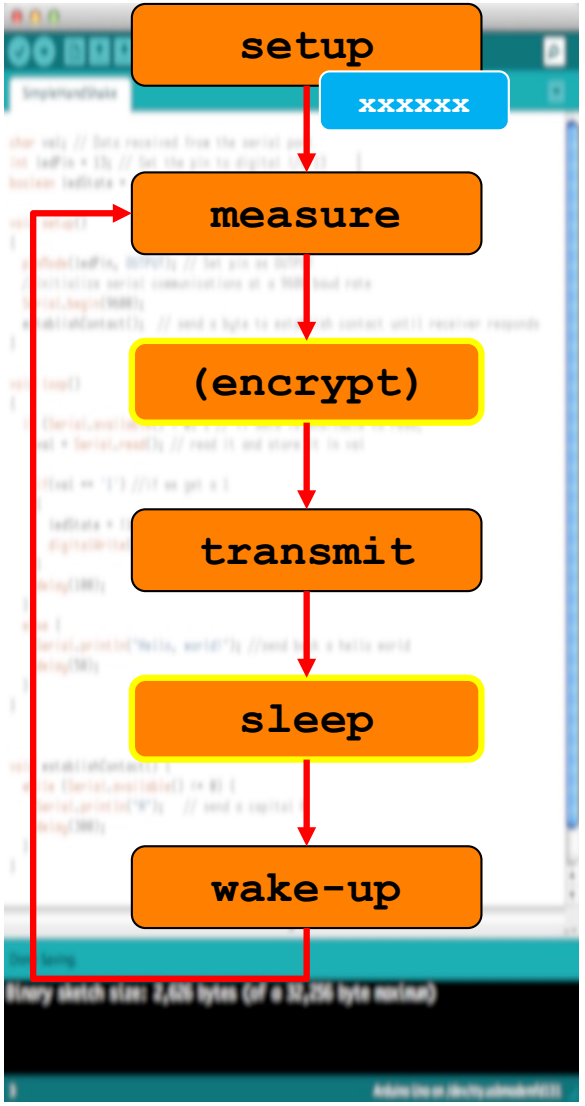
Activity duty-cycle, low power

VERY IMPORTANT

AES encryption

Long-range transmission

Logical sensor mgmt



# From generic to specific applications

LARGE MESSAGES

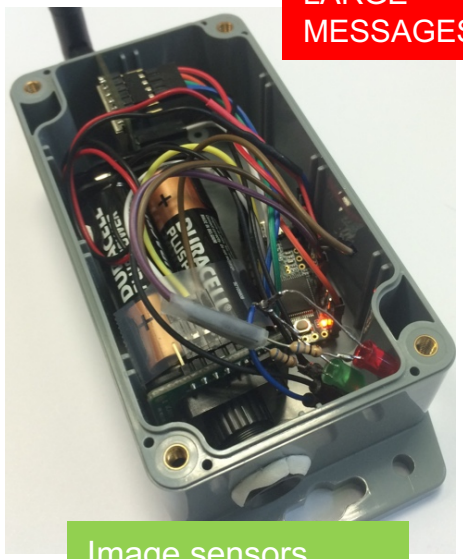
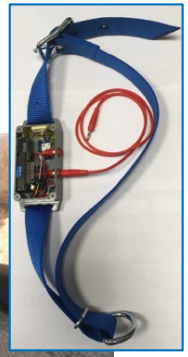


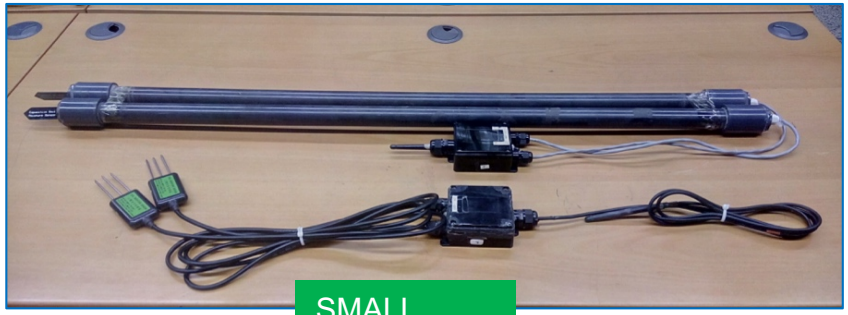
Image sensors



GPS tracker



MEDIUM MESSAGES



SMALL MESSAGES

Soil moisture

Bin presented at Woelab

SMALL MESSAGES

Waste Mngt

MEDIUM MESSAGES



Photo from EGM

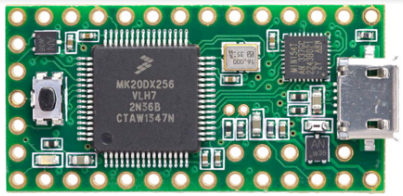
Buoy for water quality

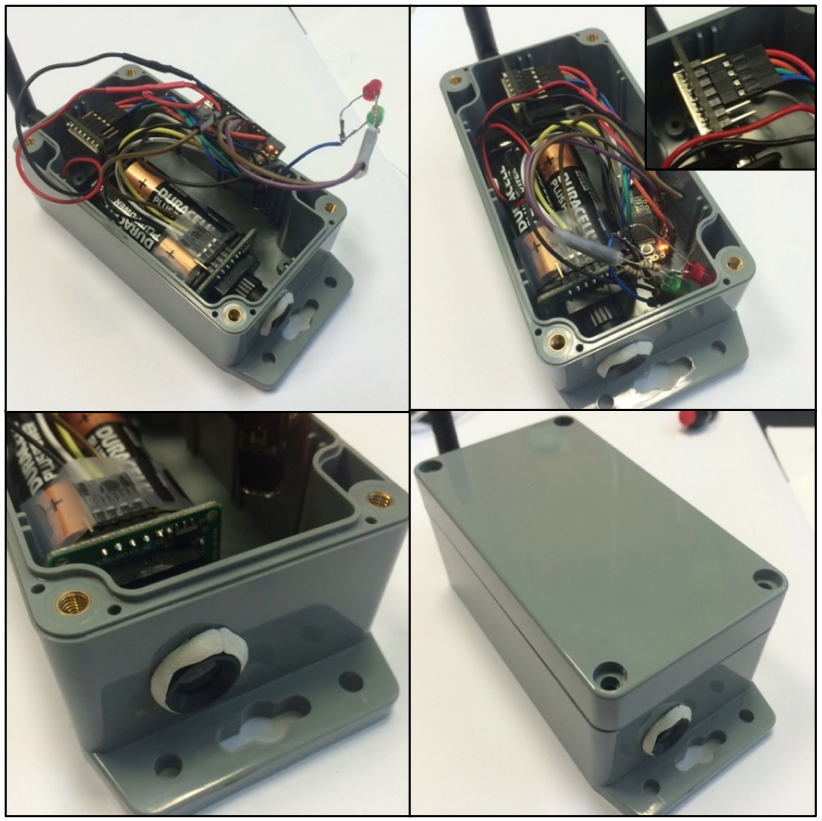
MEDIUM MESSAGES

Photo from Unparallel

Weather Station

# IMAGE SENSOR DEVICE

- Teensy32  + uCamII/III 



56° lens

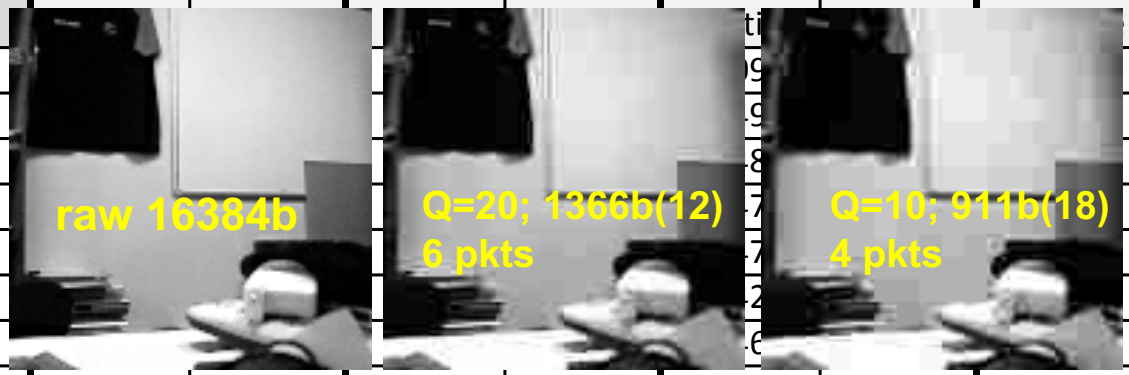
76° lens

116° lens

The uCam 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

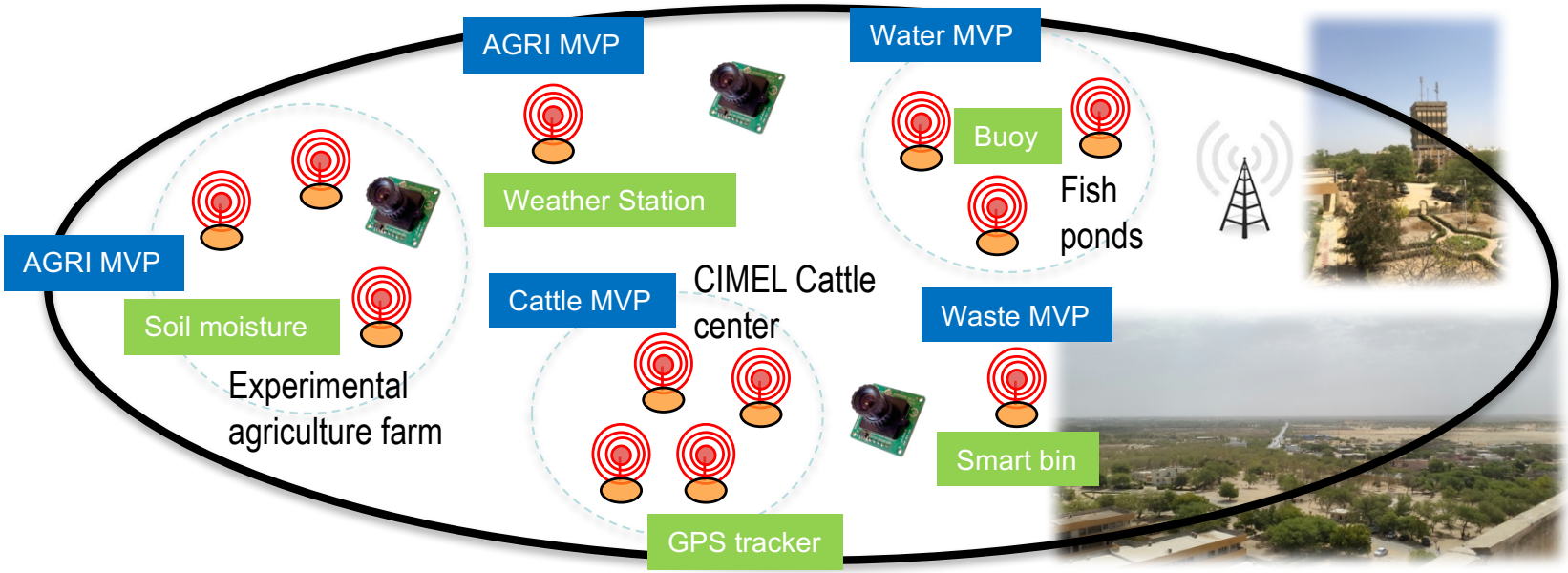
| | 96MHz | | 72MHz | | 48MHz | | 24MHz | | MSS=240 N | MSS=240 S |
|---|---|---|---|---|---|---|---|---|---|---|
| Quality Factor Q | encode | packetiza | encode | packetiza | encode | packetiza | encode | packetization time | number of packets | size in bytes (compression ratio) |
| 100 | | | | | | | | 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

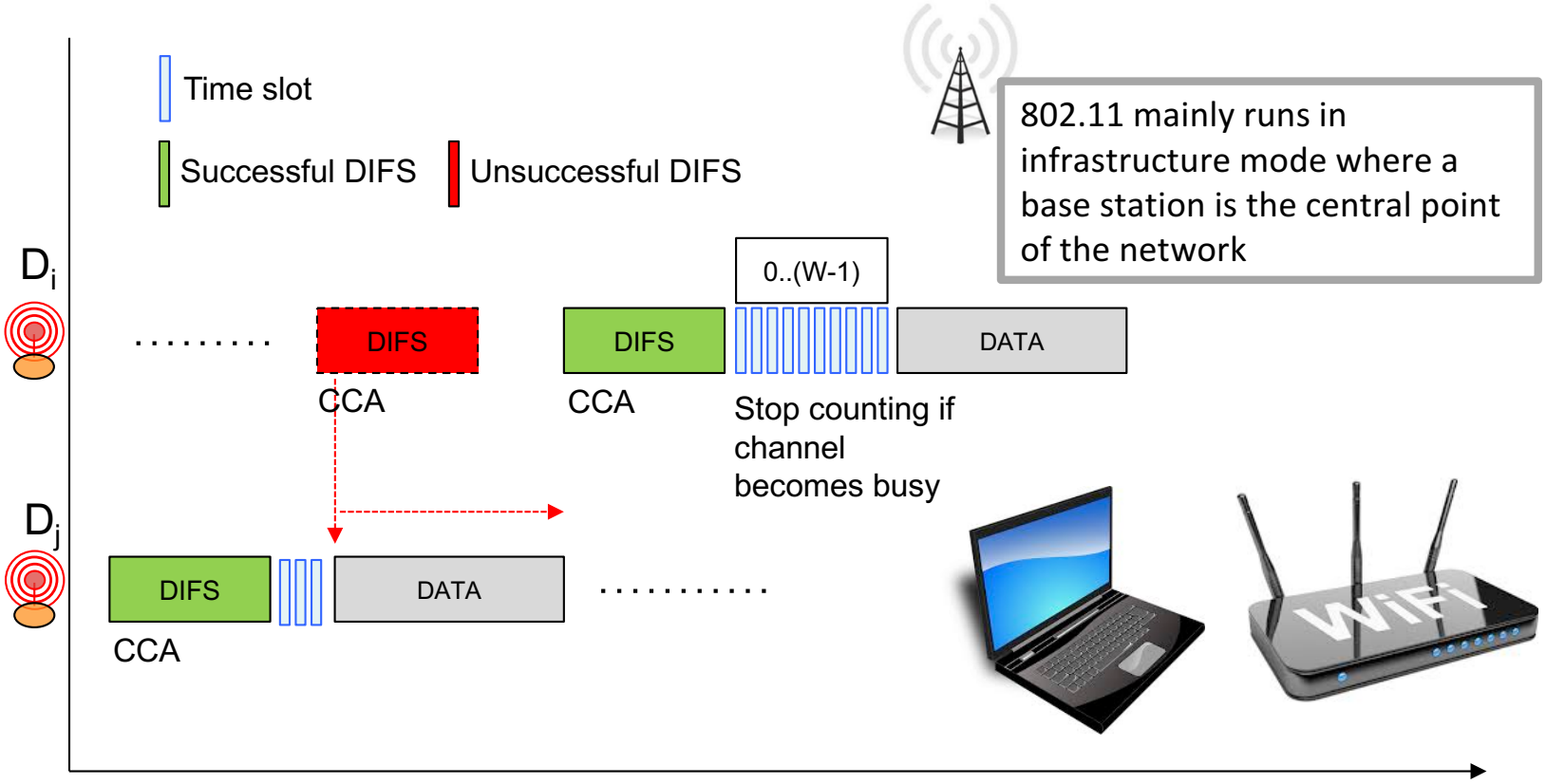
# DEPLOYING IN WAZIUP PILOT TEST-BED

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



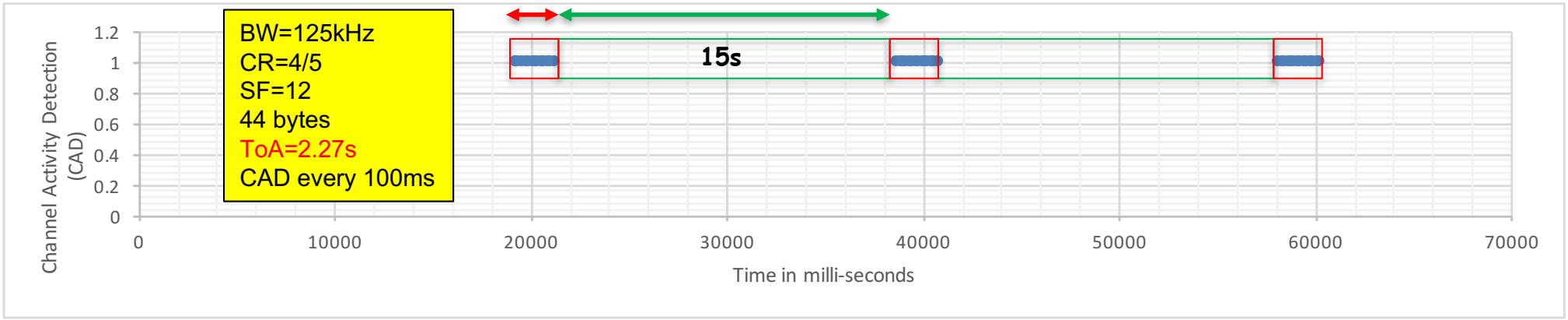
# Review of IEEE 802.11 CSMA/CA

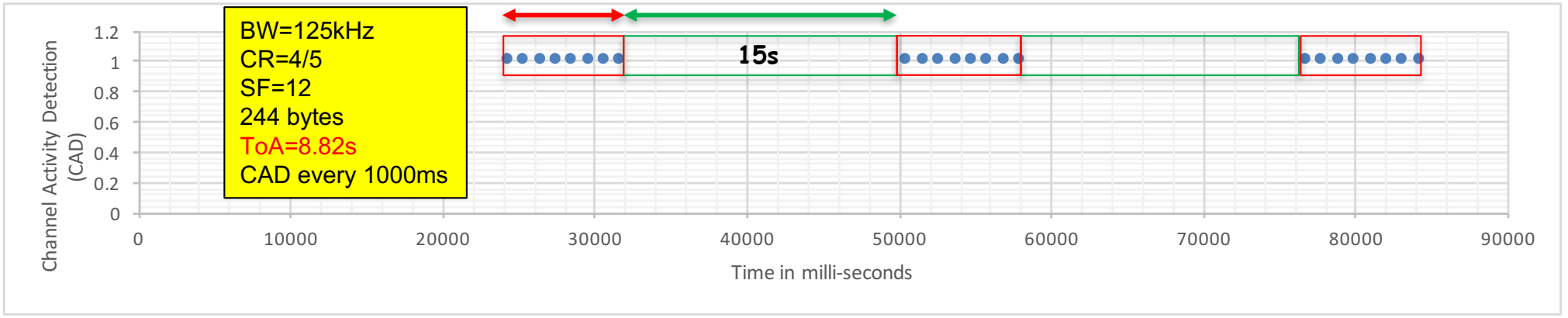
- DIFS, SIFS
- Random backoff [0..W[



# Clear Channel Assessment with LoRa

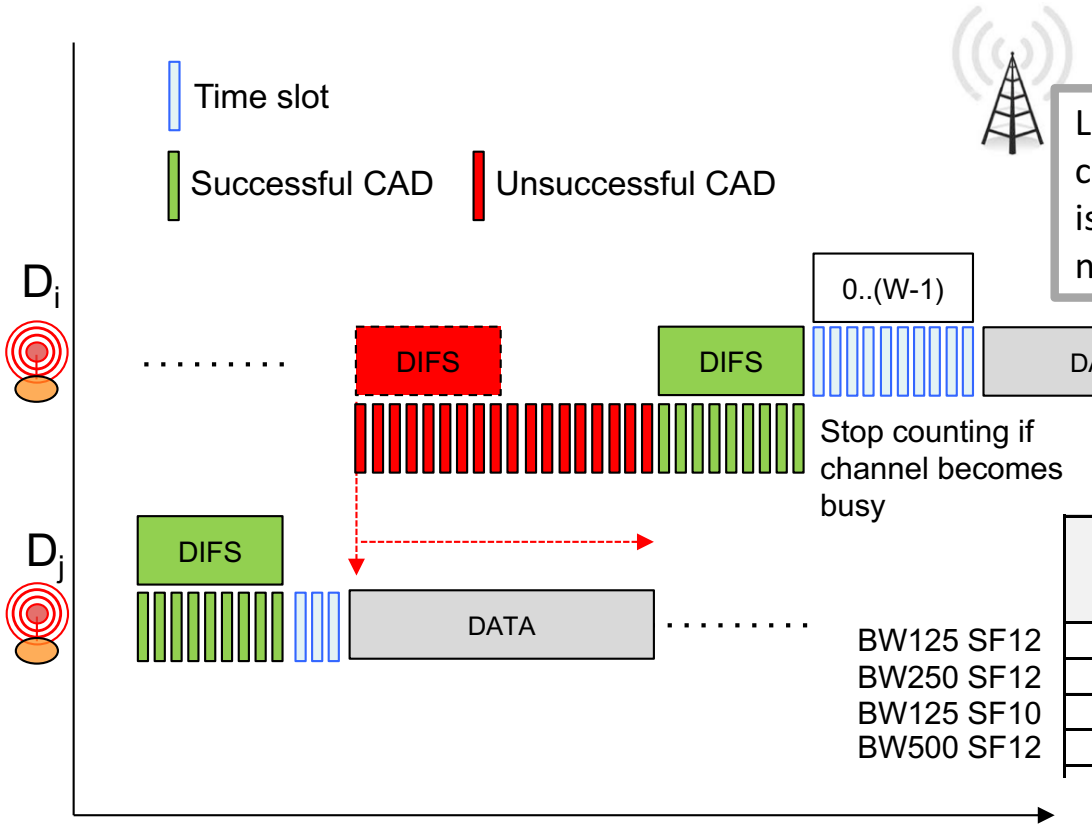
- CCA uses dedicated LoRa's Channel Activity Detection (CAD) as data reception can be done below the noise floor



# LoRa CSMA derived from 802.11

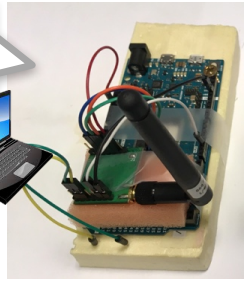
- CAD duration is between $1.75T_{sym}$ and $2.25T_{sym}$
- $T_{sym}$ depends on bandwidth & spreading factor
- SIFS & DIFS are mapped to a number of CAD




| | LoRa mode | Tsym (ms) | CAD duration (Tsym) | CAD duration (ms) | Experimental measures min value | Experimental measures 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

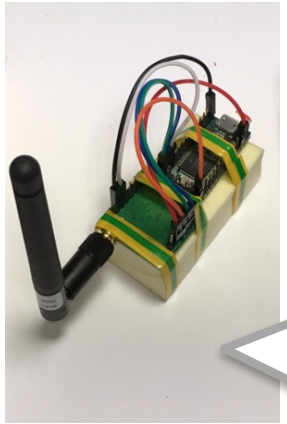


Teensy32 with a uCamII camera will be the sources of large image packets to the gw





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

Photo from Unparallel

Weather Station

Bin presented at Woelab

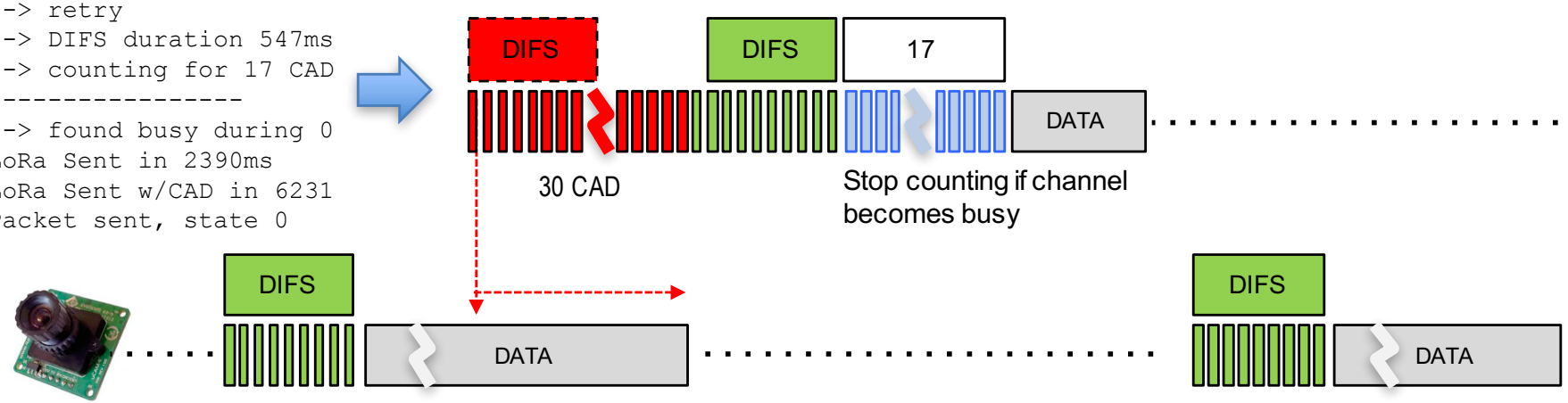
Waste Mngt

| 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

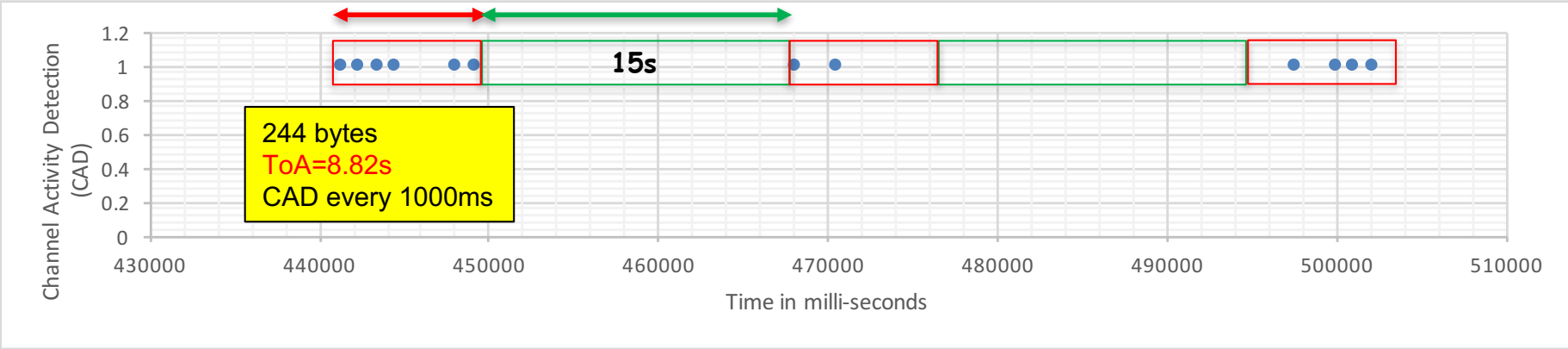
```
Sending buoy water data
########################################
Packet number 1
Payload size is 40
ToA is w/4B header 2270
--> CarrierSense2: do CAD for DIFS=9CAD
--> DIFS duration 61
###1
--> Channel busy. Retry CAD until free channel
RRRRRRRRRRRRRRRRRRRRRRRRRRRRRR
--> found busy during 30 CAD
--> 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

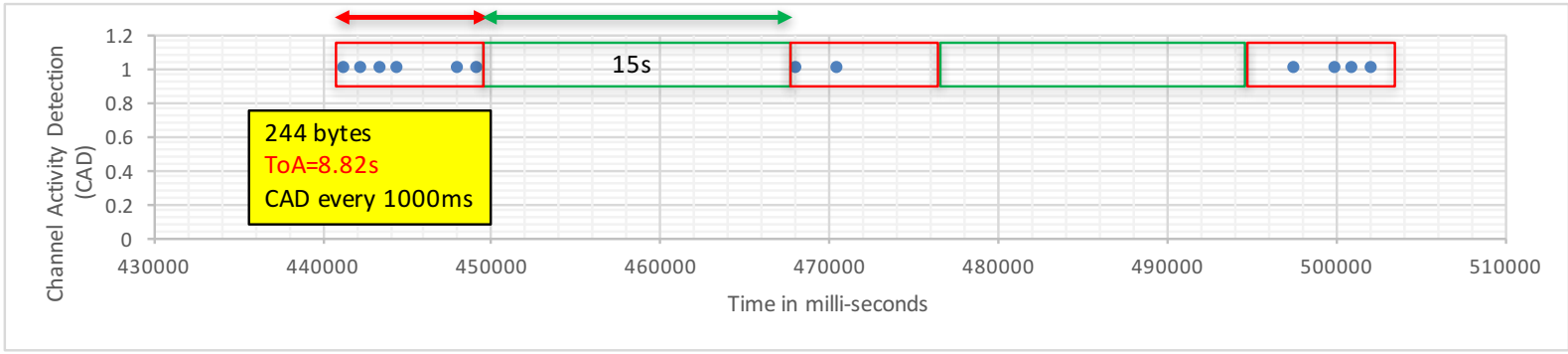


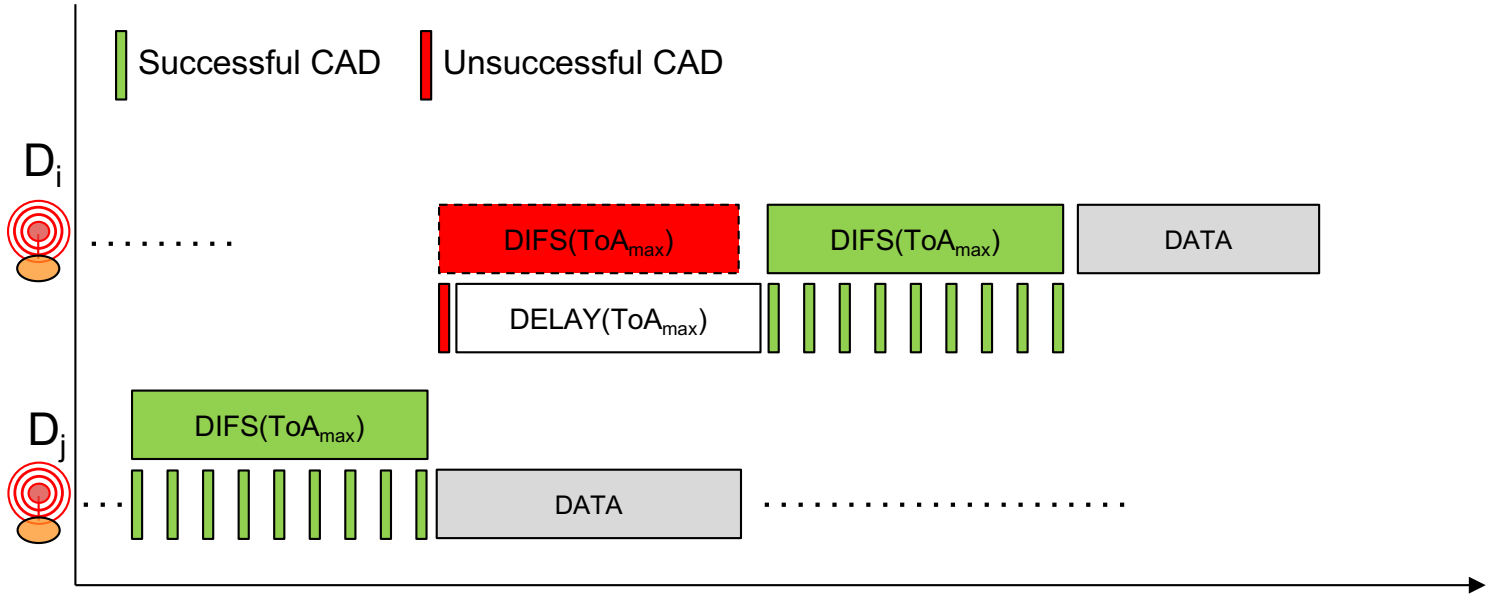
# CAD RELIABILITY?

- 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

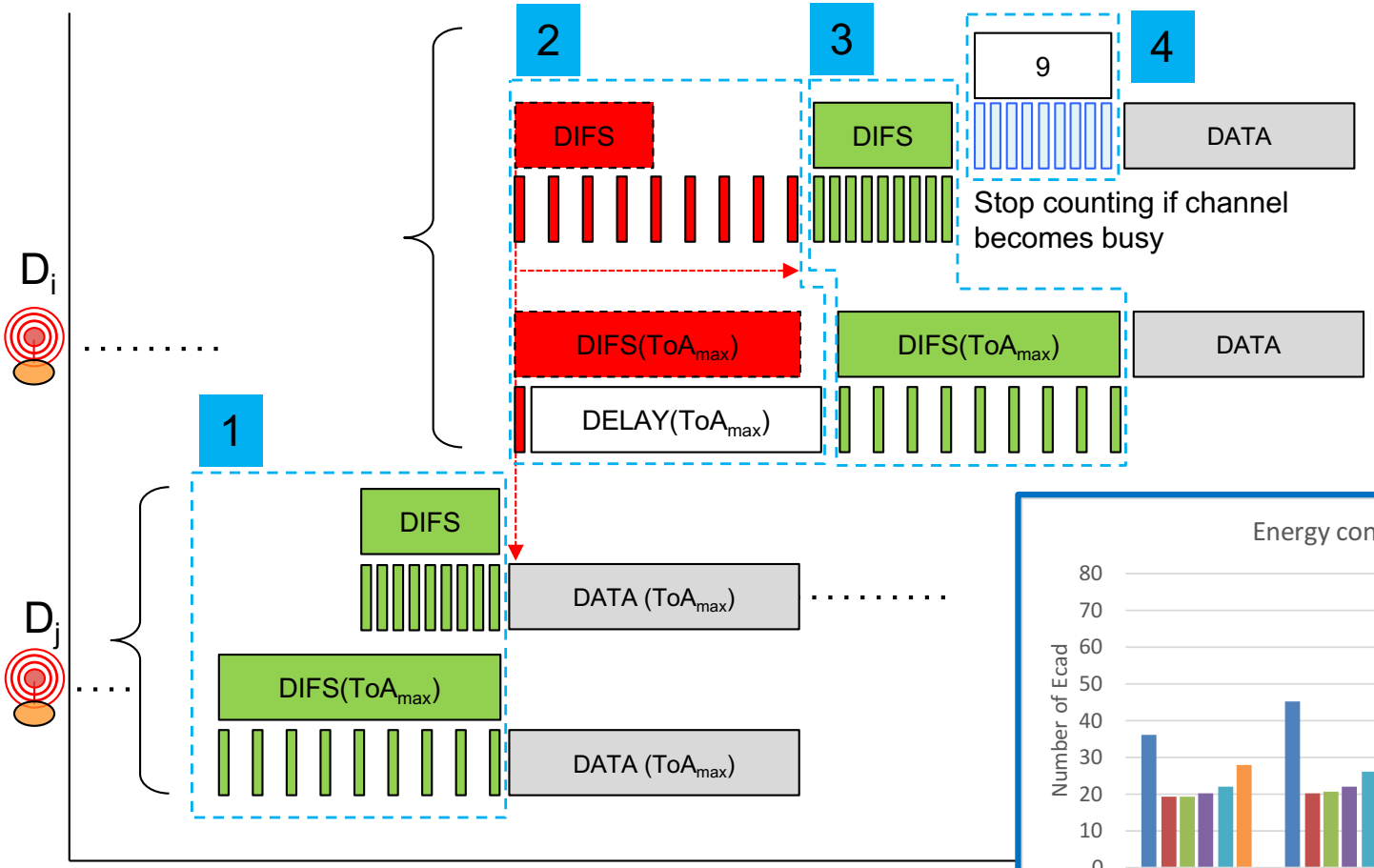


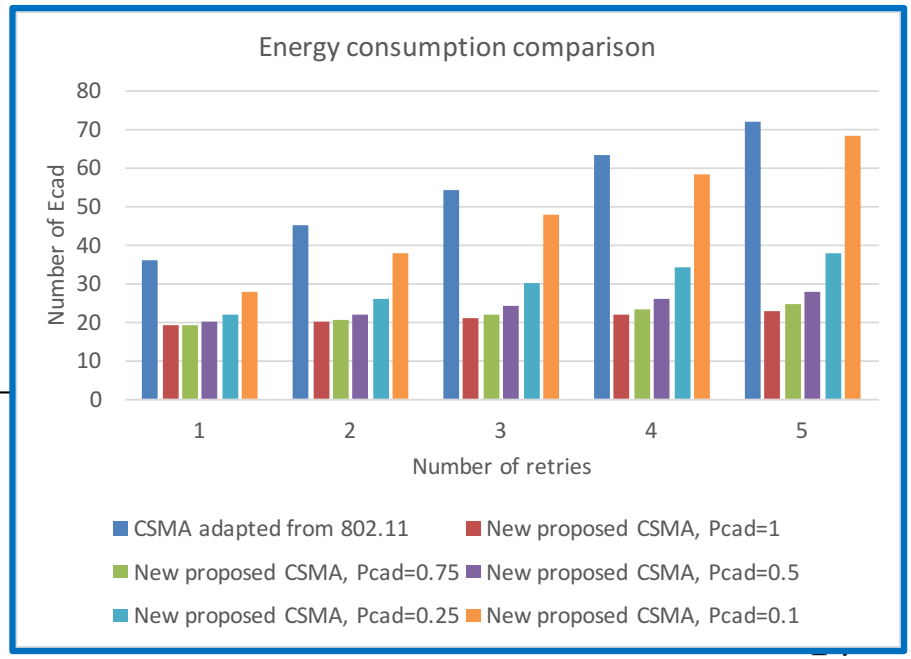
# LoRa CSMA adapted to longer msg

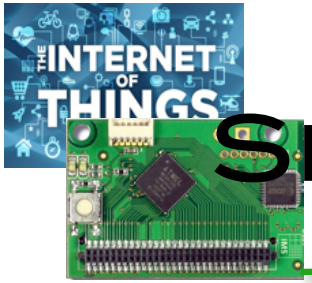


# CSMA VARIANTS & COMPARISON





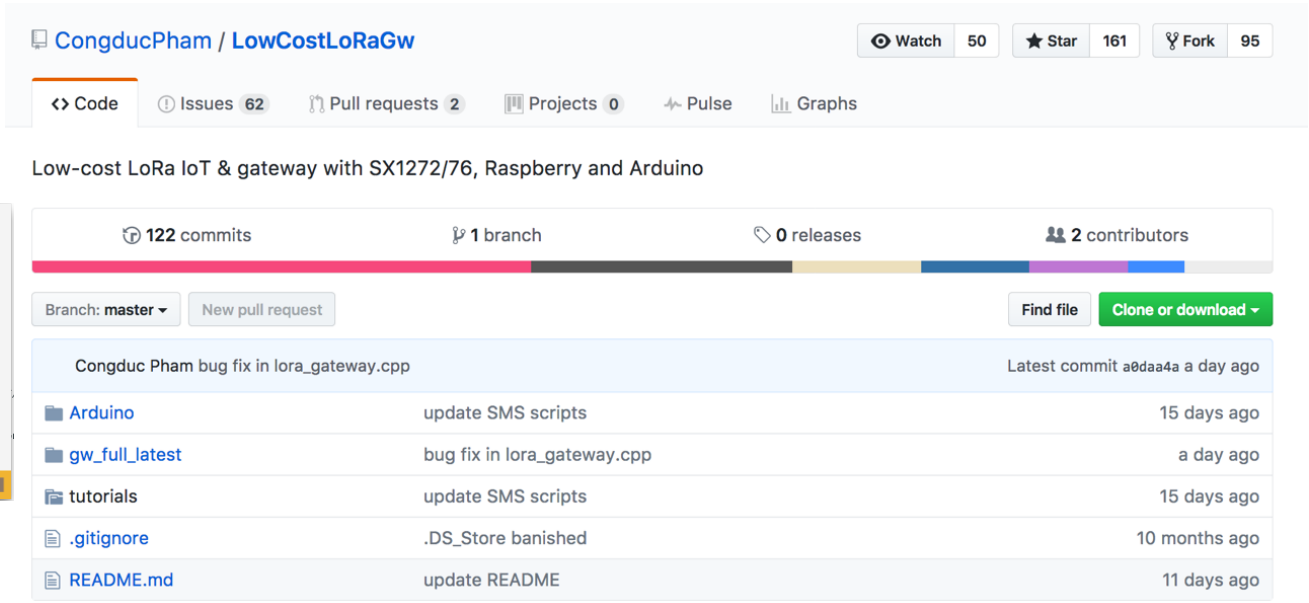

# SELECT THE CSMA VARIANT


- 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
- Support most of SPI-based LoRa radio modules


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