Deploying a Pool of Long-Range Wireless Image Sensor with Shared Activity Time

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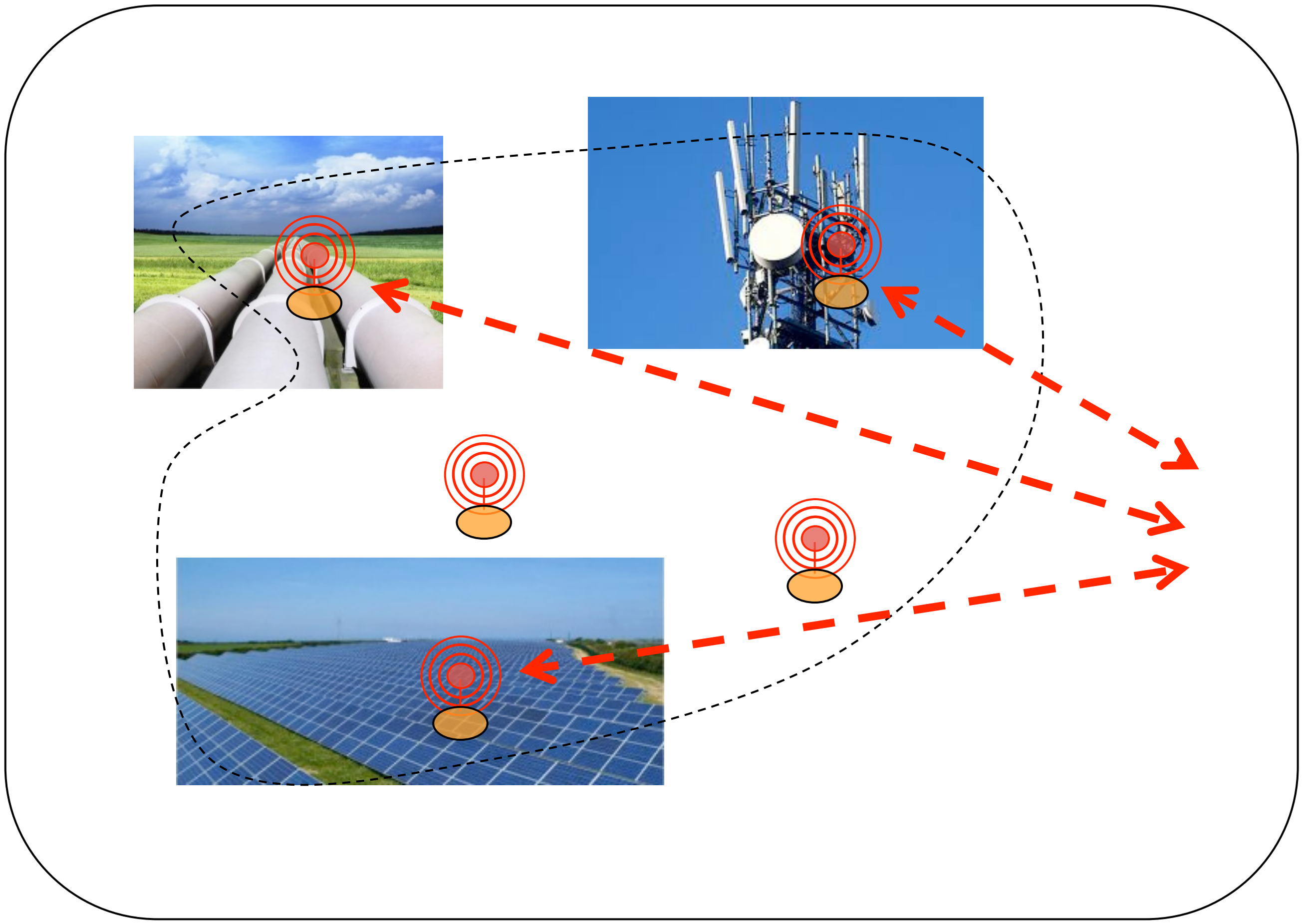
Sensors/IoT for surveillance



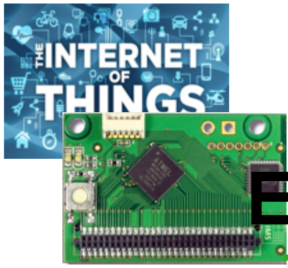
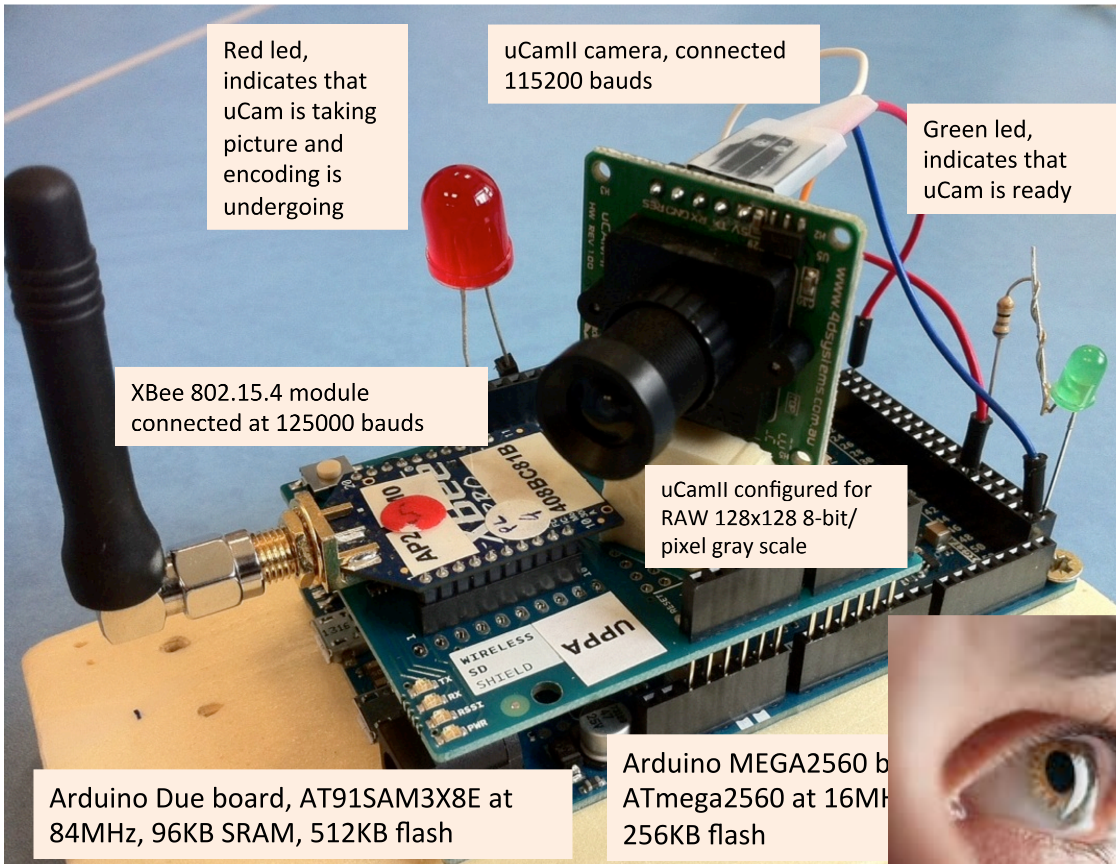
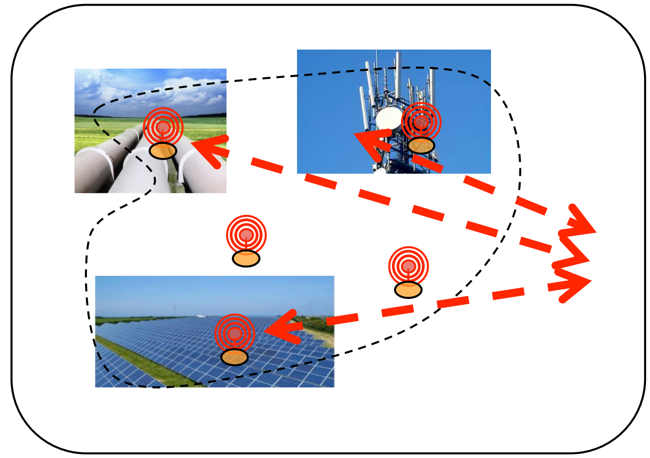
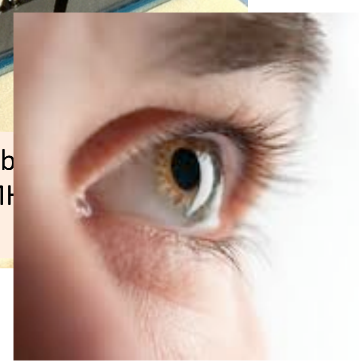


IMAGE SENSORS FOR ENHANCED SURVEILLANCE







Connectivity is a challenge

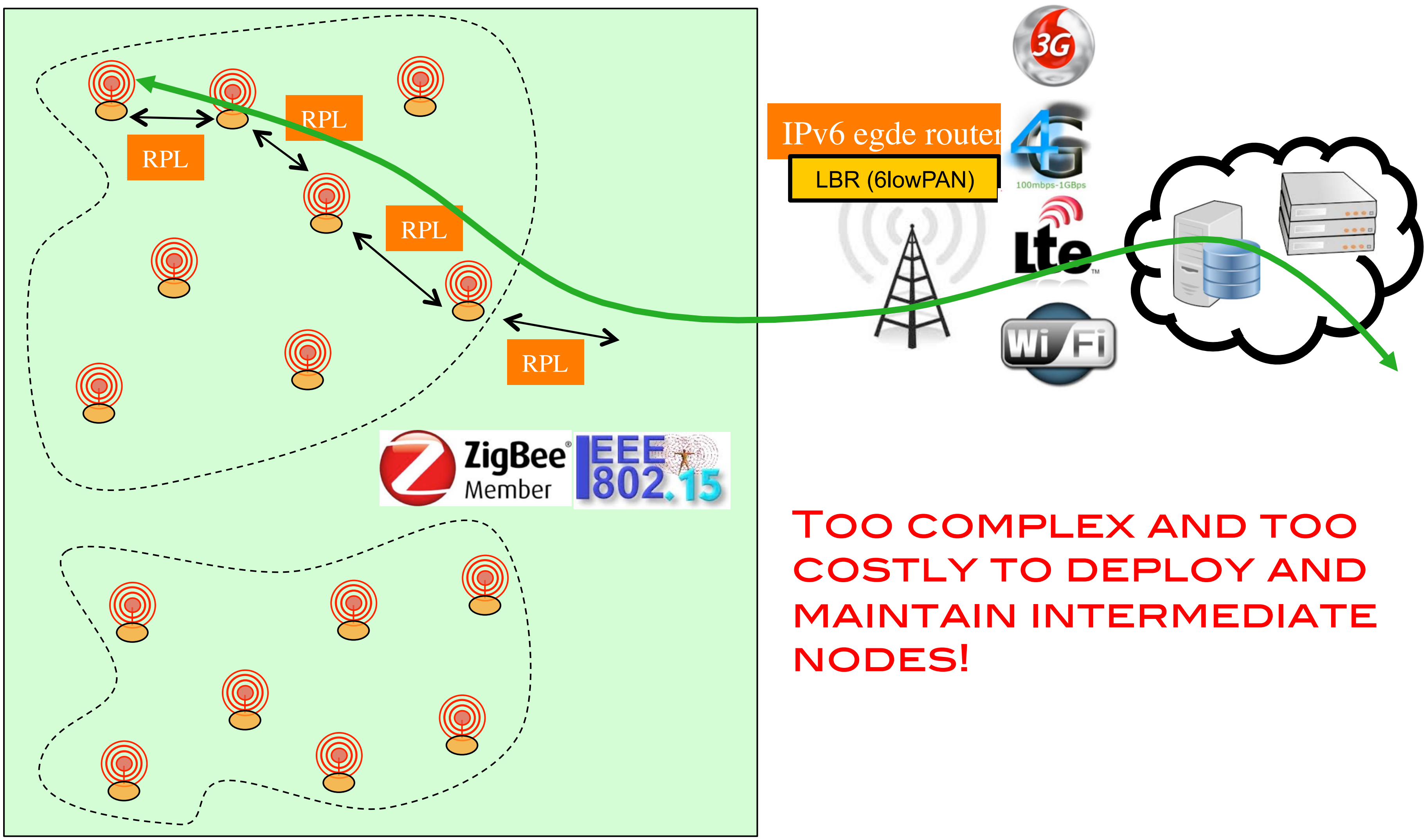
Internet of Objects
80% of volume

Requirements:

- How to connect Low Cost Assets or having no Energy source, non rechargeable?
- Low Cost communication
- Low Cost Infrastructure
- Low Power Technology
- Robust Communication
- Allowing Mobility
- Scalability

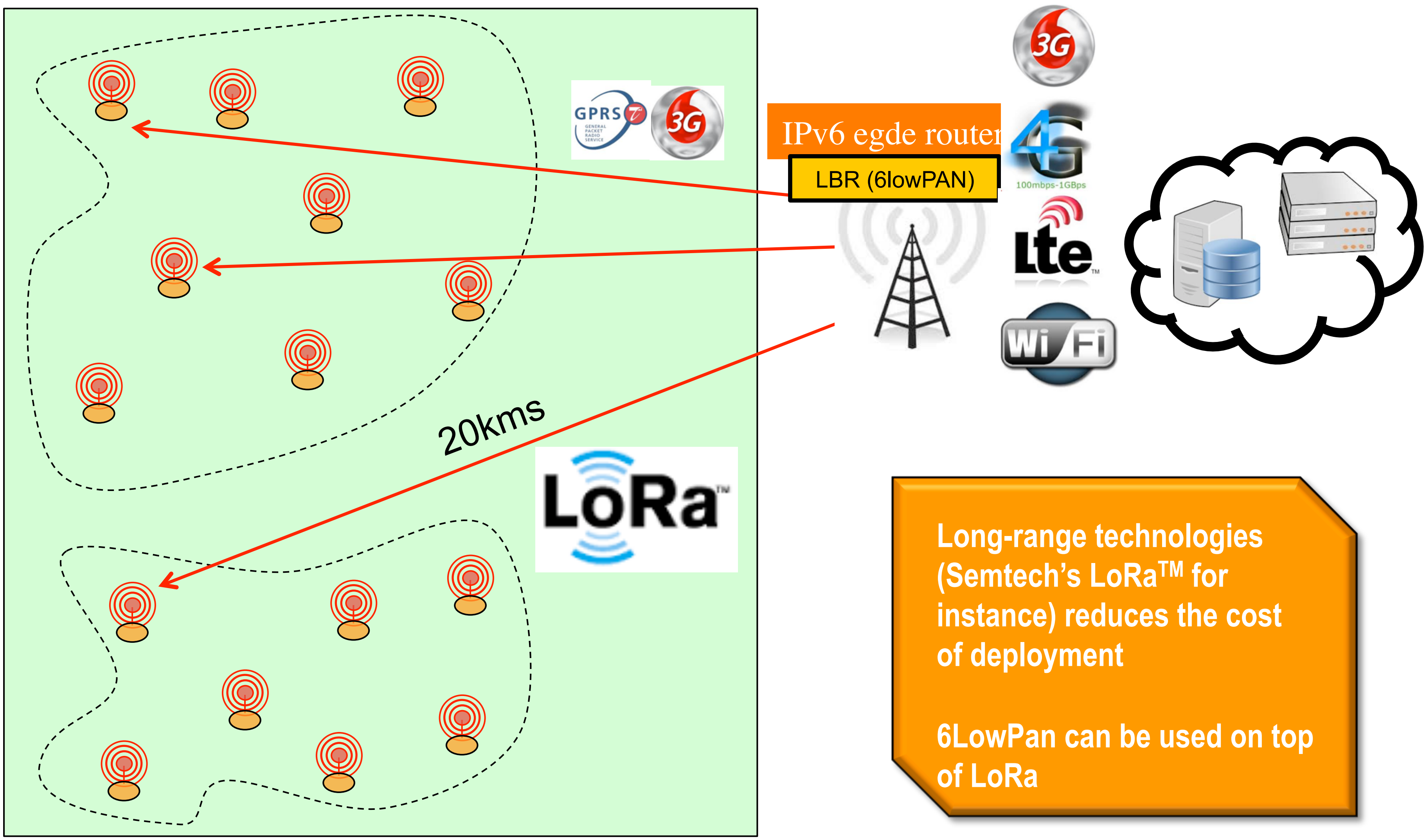
Slide from Semtech

Traditional multi-hop to Sink



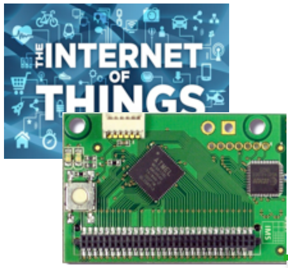
Too complex and too costly to deploy and maintain intermediate nodes!

1-HOP TO SINK WITH LONG-RANGE TECHNOLOGY

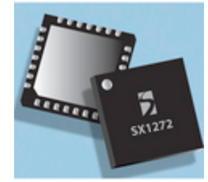


Long-range technologies (Semtech's LoRa™ for instance) reduces the cost of deployment

6LowPan can be used on top of LoRa



SEMTECH'S LORA TECHNOLOGY



dBm – **power referred to 1 mW,**

P_{dBm}=10log(P/1mW)

- Parameters
  - Bandwidth: 125kHz, 250kHz, 500kHz
  - Coding rate: 4/5, 4/6, 4/7, 4/8
  - Spreading factor: 6 to 12

Sensitivity: lowest input power with acceptable link quality, typically 1% PER

SpreadingFactor (RegModemConfig2)	Spreading Factor (Chips / symbol)	LoRa Demodulator SNR
6	64	-5 dB
7	128	-7.5 dB
8	256	-10 dB
9	512	-12.5 dB
10	1024	-15 dB
11	2048	-17.5 dB
12	4096	-20 dB

Bandwidth (kHz)	Spreading Factor	Nominal Rb (bps)	Sensitivity (dBm)
125	6	9380	-122
125	12	293	-137
250	6	18750	-119
250	12	586	-134
500	6	3750	-116
500	12	1172	-131

Rule of thumb

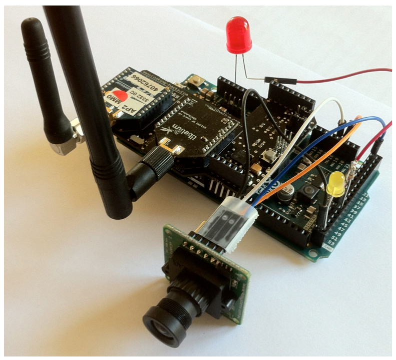
6dB increase = twice the range in LOS

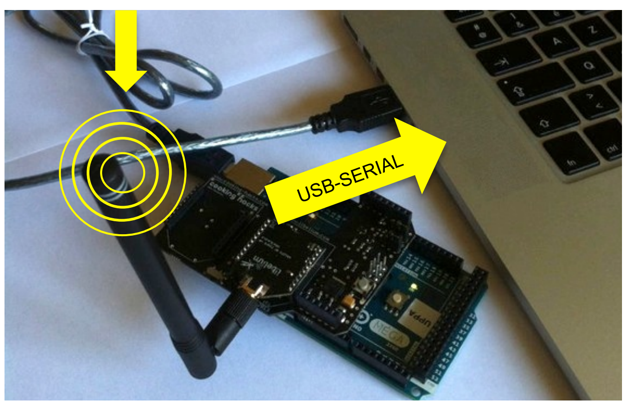
12dB needed for urban areas

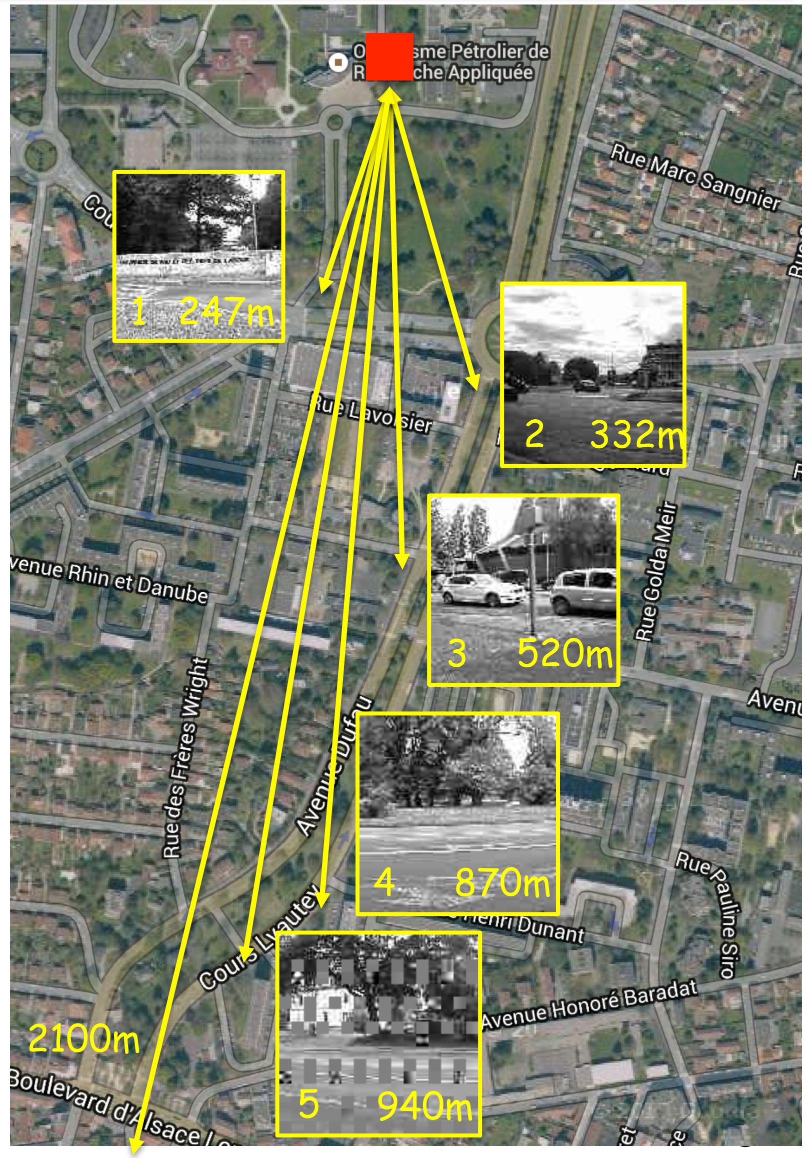
Bandwidth (kHz)	Spreading Factor	Coding rate	Nominal Rb (bps)	Sensitivity (dBm)
125	12	4/5	293	-136
250	12	4/5	586	-133
500	12	4/5	1172	-130

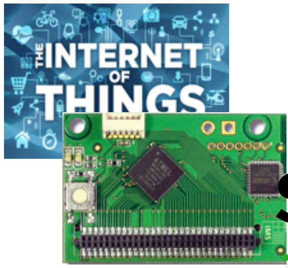
Tables from Semtech

Long-range version of our image sensor





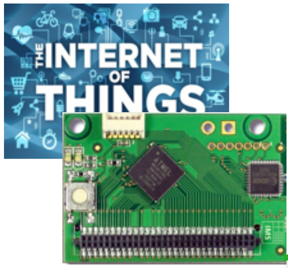




Unlicense sub-GHz spectrum constraints

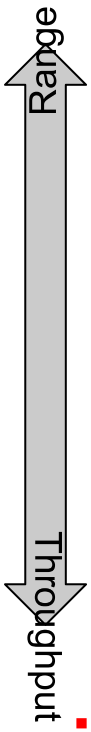
- It is shared medium so long-range transmission in dense environments can create lots of interference!
- Activity time is constrained from 0.1% to 1% duty-cycle depending on frequency: 3.6s to 36s/hour

Band	Edge Frequencies		Field / Power	Spectrum Access	Band Width
	Fc-	Fc+			
g(Note 7)	865 MHz	868 MHz	+6.2 dBm /100 kHz	1 % or LBT AFA	3 MHz
g(Note 7)	865 MHz	870 MHz	-0.8 dBm / 100 kHz	0.1% or LBT AFA	5 MHz
g1	868 MHz	868.6	14 dBm	1 % or LBT AFA	600 kHz
g2	868.7 MHz	869.2 MHz	14 dBm	0.1% or LBT AFA	500 kHz
g3	869.4 MHz	869.65 MHz	27 dBm	10 % or LBT AFA	250 kHz
g4	869.7 MHz	870 MHz	7 dBm	No requirement	300 kHz
g4	869.7 MHz	870 MHz	14 dBm	1 % or LBT AFA	300 kHz



Time on Air of LoRa Transmissions

With 1% radio activity time…



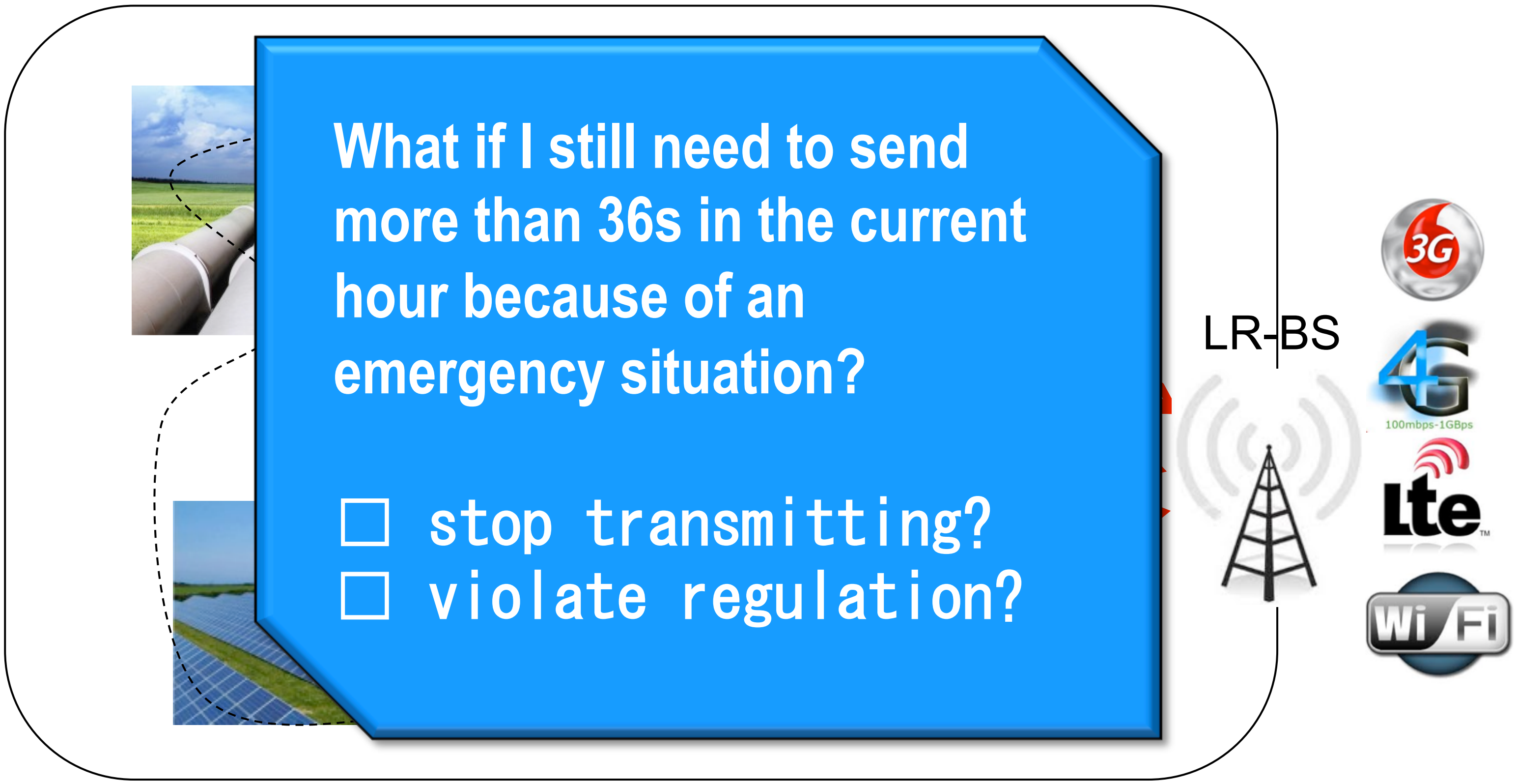
				time on air in second for payload size of					
LoRa mode	BW	CR	SF	5 bytes	55 bytes	105 bytes	155 Bytes	205 Bytes	255 Bytes
1	125	4/5	12	0.95846	2.59686	4.23526	5.87366	7.51206	9.15046
2	250	4/5	12	0.47923	1.21651	1.87187	2.52723	3.26451	3.91987
3	125	4/5	10	0.28058	0.69018	1.09978	1.50938	1.91898	2.32858
4	500	4/5	12	0.23962	0.60826	0.93594	1.26362	1.63226	1.95994
5	250	4/5	10	0.14029	0.34509	0.54989	0.75469	0.95949	1.16429
6	500	4/5	11	0.11981	0.30413	0.50893	0.69325	0.87757	1.06189
7	250	4/5	9	0.07014	0.18278	0.29542	0.40806	0.5207	0.63334
8	500	4/5	9	0.03507	0.09139	0.14771	0.20403	0.26035	0.31667
9	500	4/5	8	0.01754	0.05082	0.08154	0.11482	0.14554	0.17882
10	500	4/5	7	0.00877	0.02797	0.04589	0.06381	0.08301	0.10093

…can send 13 50-byte msg/h or 59 50-byte msg/h

LoRa Devices & gateways

Regulations stipulate that radio activity duty-cycle should be enforced at devices and that end-users should not be able to modify it « easily ».

LoRaWAN specification from LoRa Alliance is a first attempt to standardize LoRa networks but no issues on quality of service.



What if I want to transmit images?

				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
1	125	4/5	12	0.95846	2.59686	4.23526	5.87366	7.51206	9.15046
2	250	4/5	12	0.47923	1.21651	1.87187	2.52723	3.26451	3.91987
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10	500	4/5	7	0.00877	0.02797	0.04589	0.06381	0.08301	0.10093

Optimized image encoding at medium quality: 16384b down to 1366b (ratio 12).

Will generate 7 pkts using 250 max payload

7*9.15= 64.05s

7*1.96 = 13.72s

Deploying your LoRa network

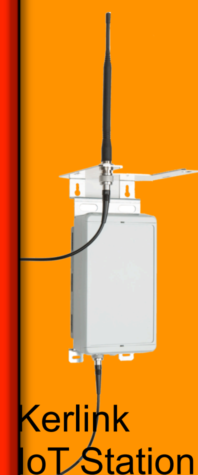
Operator-based
approach (
subscripti

Whatever the deployment approach, the gateway knows how many devices are deployed by a given organization

Our proposition is to view all device' activity time in a global manner, with the gateway taking care of radio time usage consistency

Privately-based
roach

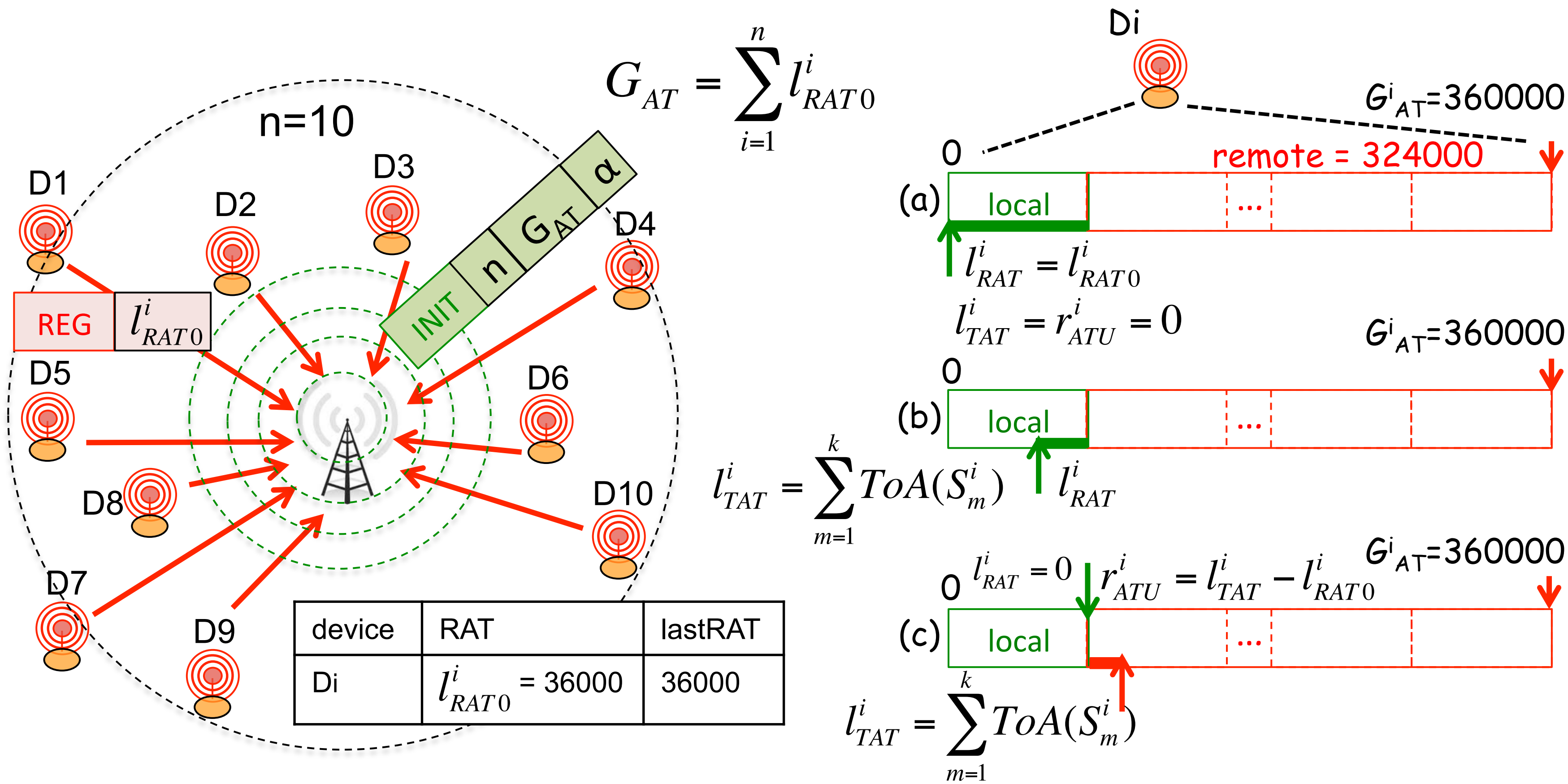
-Tech Conduit



Kerlink
oT Station

And much more...

Long-range Activity Sharing (LAS)



$$G_{AT} = \sum_{i=1}^{n} l^i_{RAT0}$$

device	RAT	lastRAT
Di	l^i_{RAT0} = 36000	36000

(a) $l^i_{RAT} = l^i_{RAT0}$

$l^i_{TAT} = r^i_{ATU} = 0$

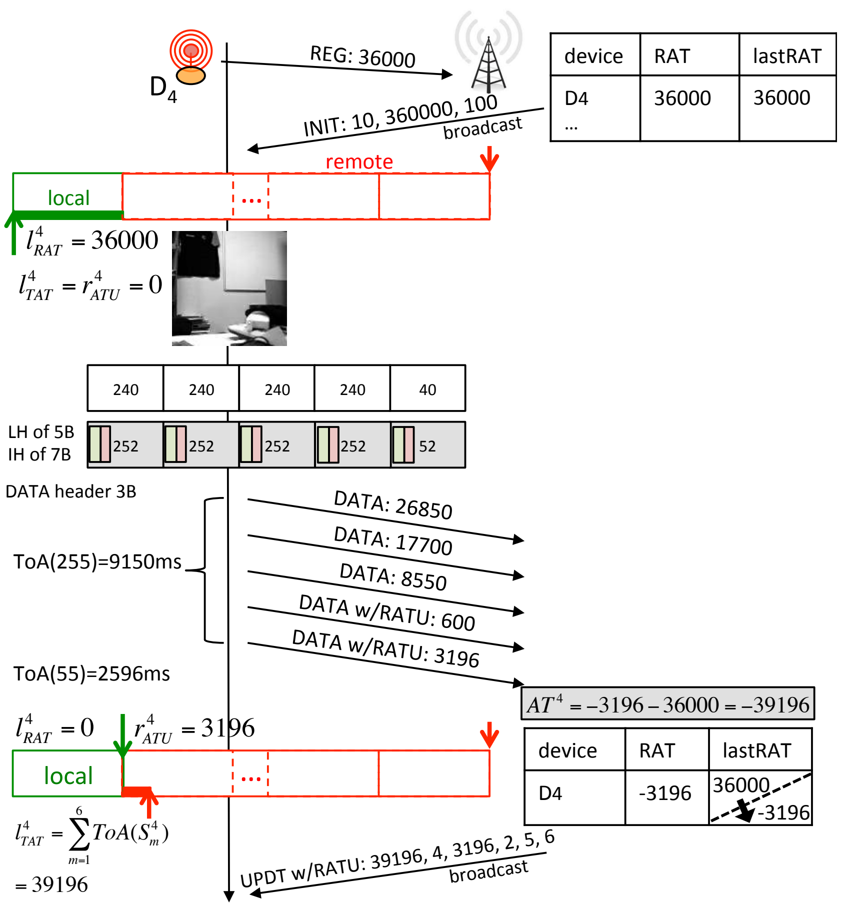
(b) $l^i_{TAT} = \sum_{m=1}^{k} ToA(S^i_m)$ $\quad l^i_{RAT}$

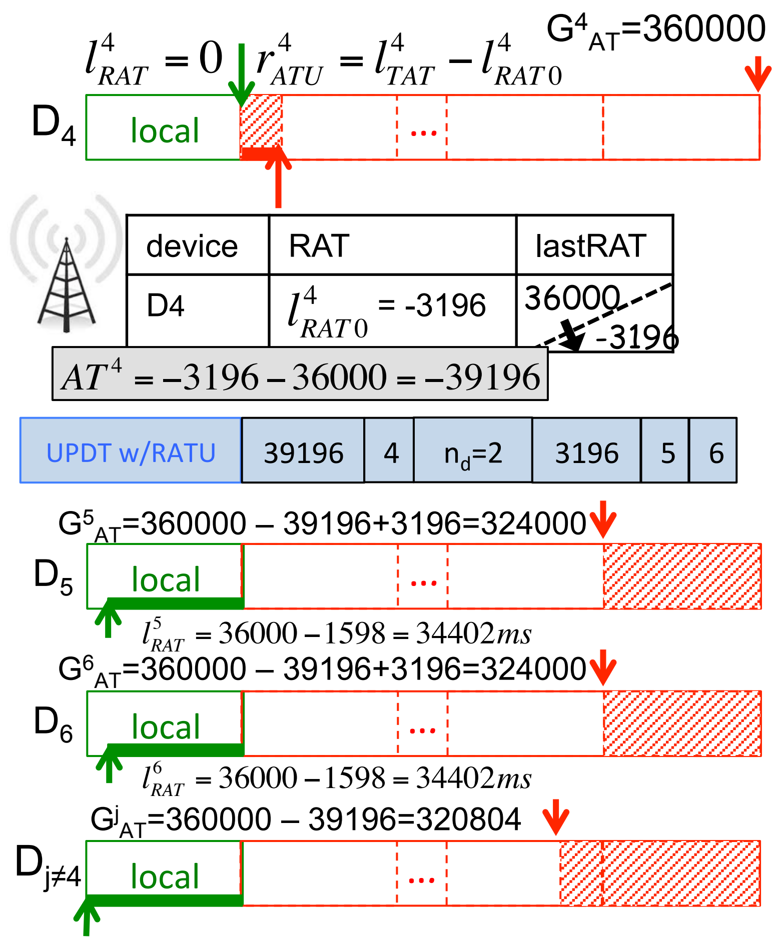
(c) $l^i_{RAT} = 0$ $\quad r^i_{ATU} = l^i_{TAT} - l^i_{RAT0}$

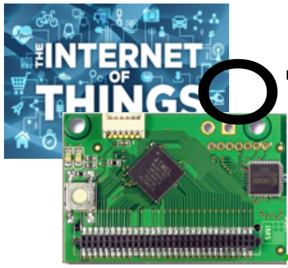
$$l^i_{TAT} = \sum_{m=1}^{k} ToA(S^i_m)$$

A device can transmit more if needed, provided that other devices will decrease their radio activity time accordingly.

Distributing Remote Activity Time Usage



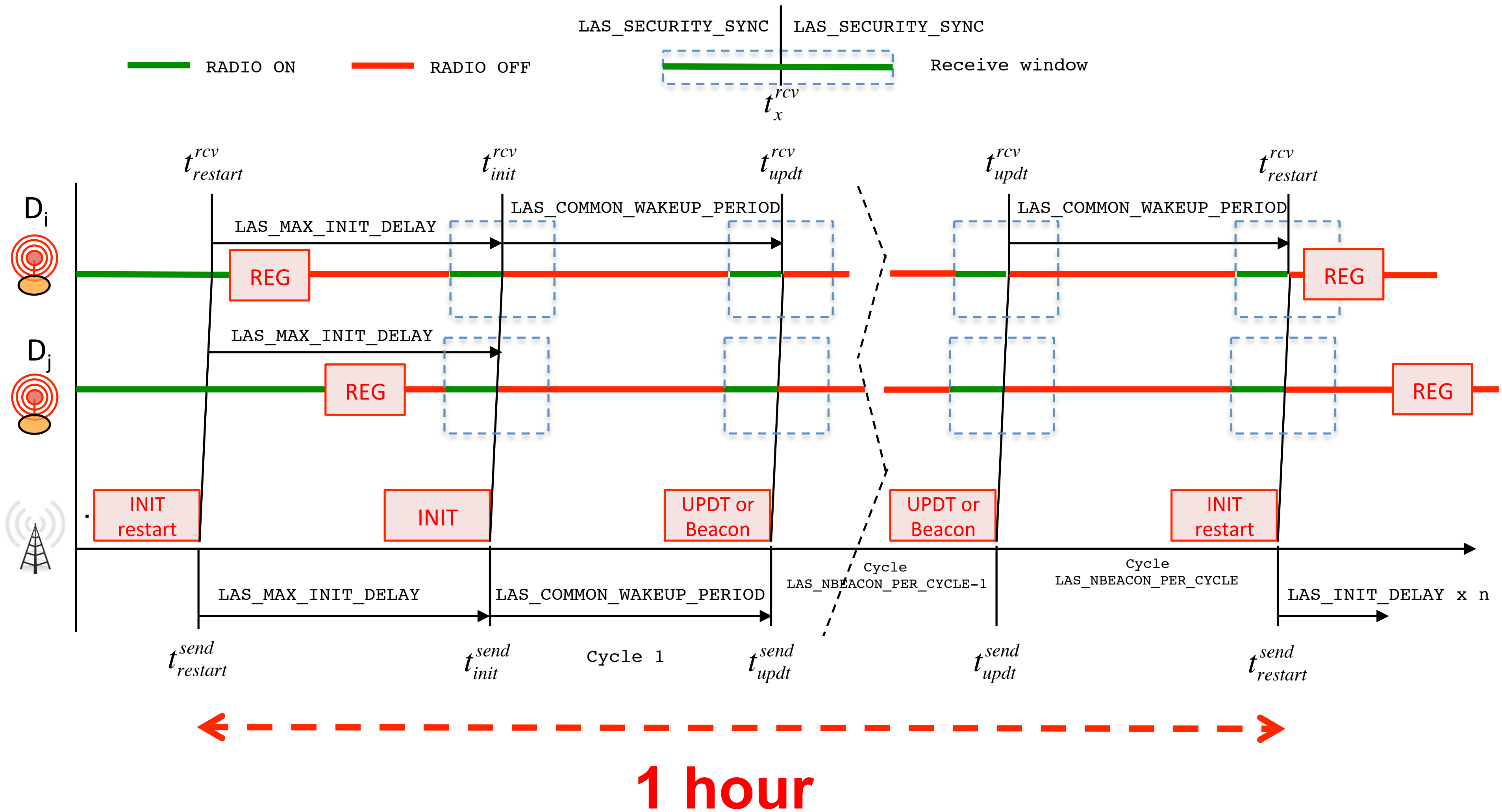




Other issues to take into account

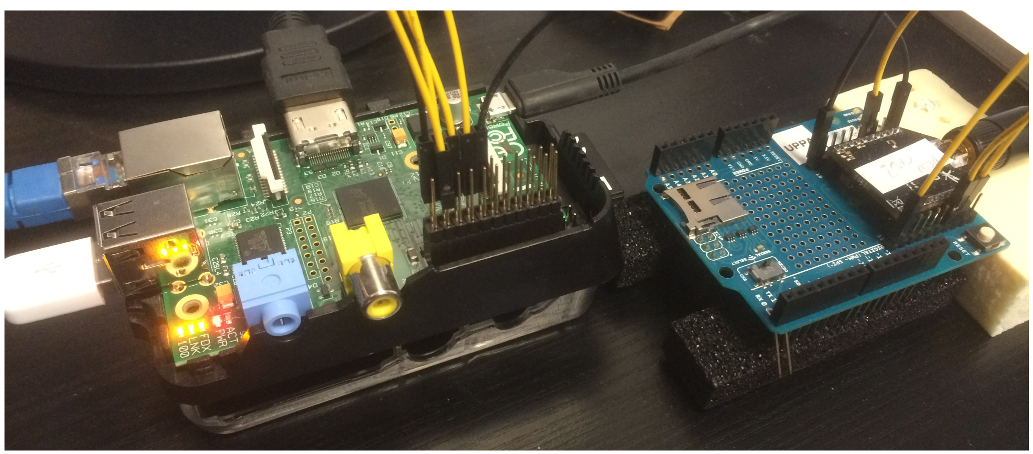
- Minimise the number of UPDT messages sent by the gateway because the gateway's radio time is also limited
  - UPDT can have cumulative behavior if no remote activity time has been used
- Support sleep periods of end-devices
  - The network is synchronized for control messages (REG, INIT, UPDT). UPDT msg that can not use cumulative behavior are queued for transmission at next transmission slot. At rcv, UPDT have to be applied sequentially.
- Maintain (loose) synchronization
  - If no UDPT are scheduled, the gateway periodically sends a BEACON. Clock drift is limited to a BEACON period
- Dynamic insertion of new end-devices
  - New devices can either stay out of the managed pool (then only 36s of activity time/h is allowed), or join by waiting for the next UPDT/BEACON msg
  - Every hour, end-devices decide if they want to join the pool or not
- Give priority to control msg
  - SIFS/DIFS mechanism are implemented using LoRa Channel Activity Detection
- Avoid interleaving of several image transmissions
  - Use DIFS for first image packet, then SIFS
- Improve LoRa network efficiency
  - Move from pure ALOHA to CSMA mechanism with CAD+RSSI tests prior to any transmission

Sumary of gateway-device scheduling

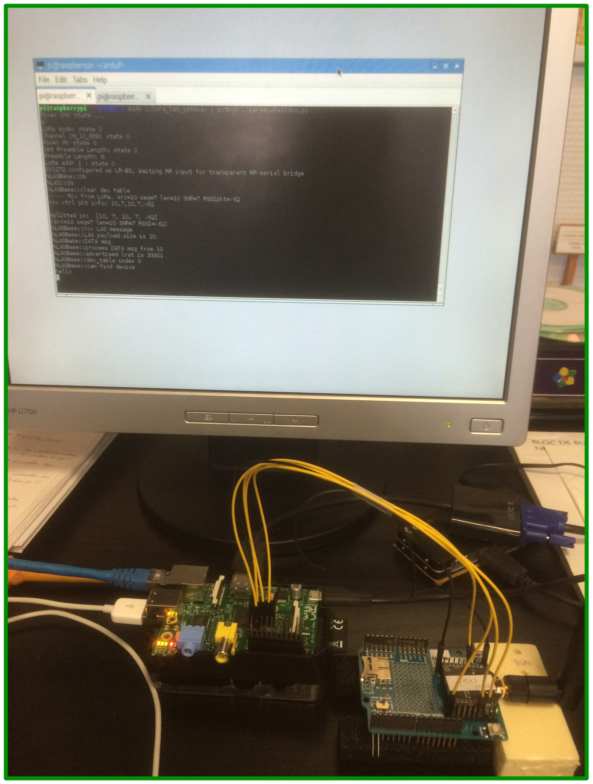


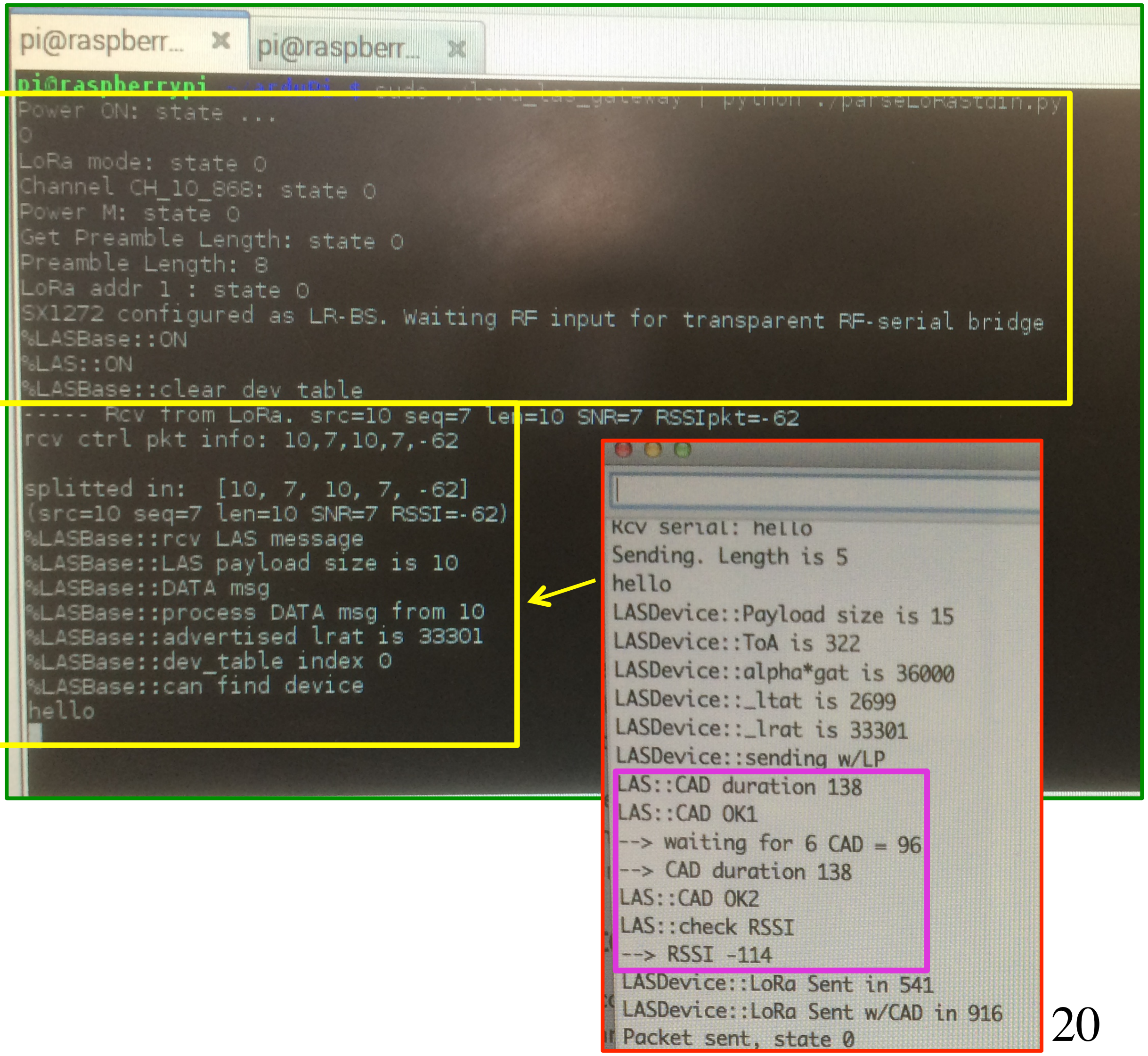
Implementations & libraries

- Own gateway based either Raspberry PI or Arduino MEGA/Due with gateway LAS services
- C/C++ Library for end-devices to send data packets under LAS services. Radio duty-cycling and interactions with LAS gateway are performed automatically

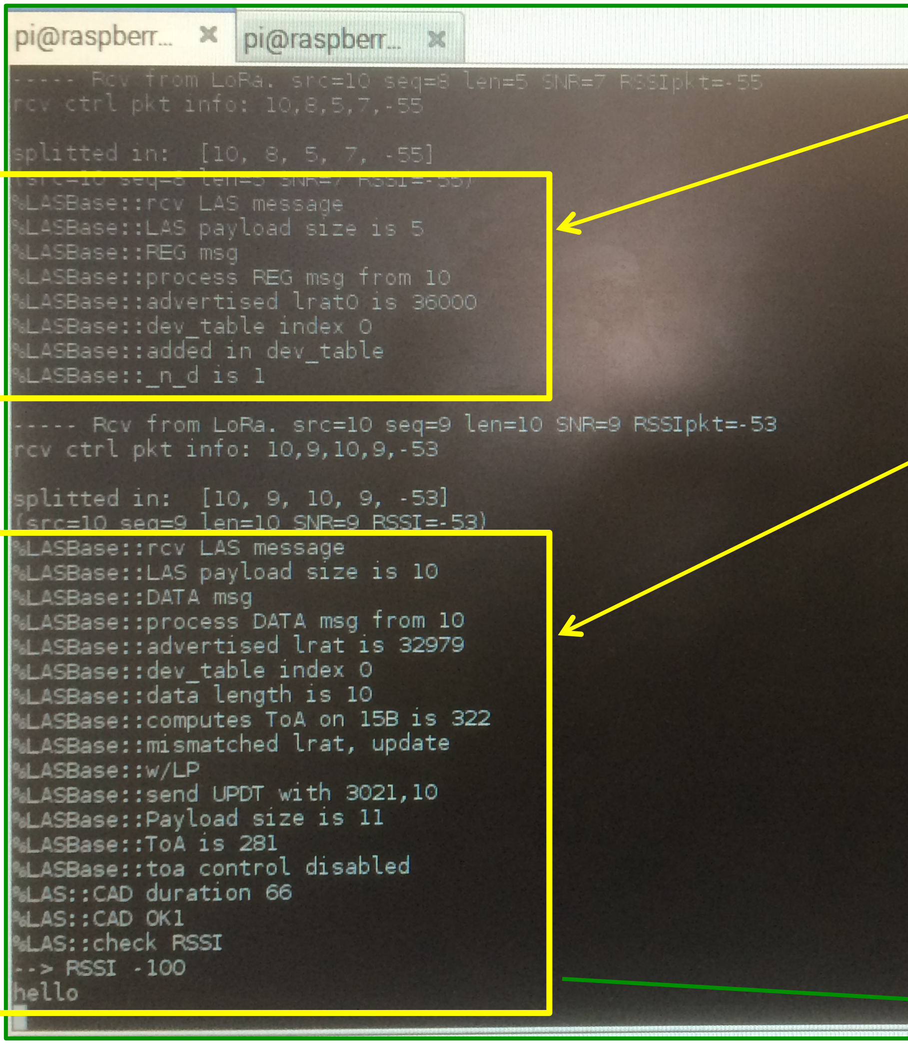


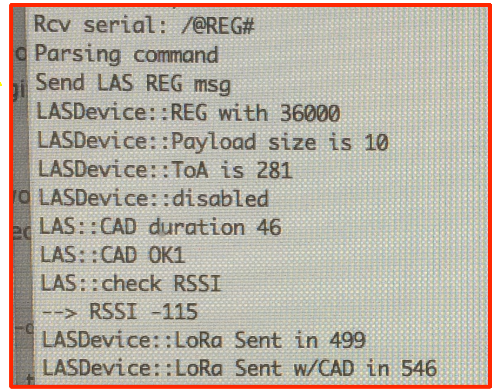
Gateway startup

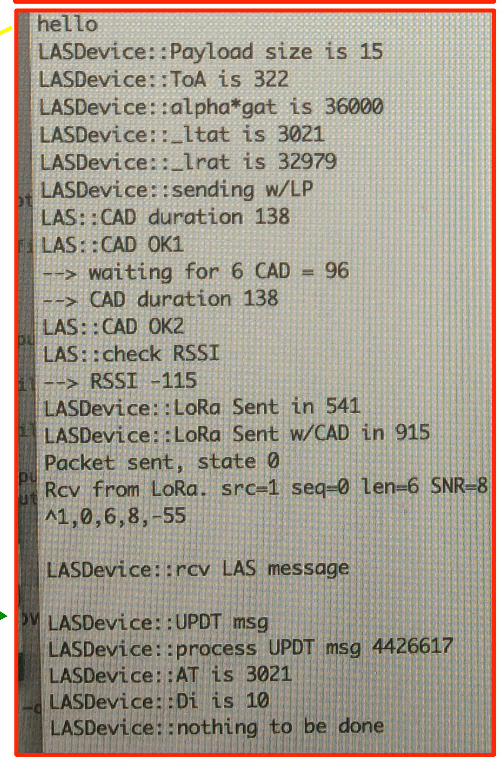


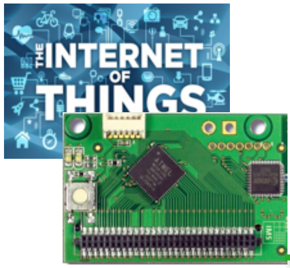


Sending message under LAS services









Conclusions

- Long-range radios appear as a very promising technology to deploy sensors and so-called IoT devices without the complexity and cost of multi-hop networking
- However, as the radio activity time is limited by regulations, it is difficult to guarantee a level of service of the deployed infrastructure, especially for some data-intensive applications
- We propose a Long-range Activity Sharing mechanism to manage a pool of deployed devices in a flexible manner
- Quality of Service can be ensured as devices can transmit critical information when needed