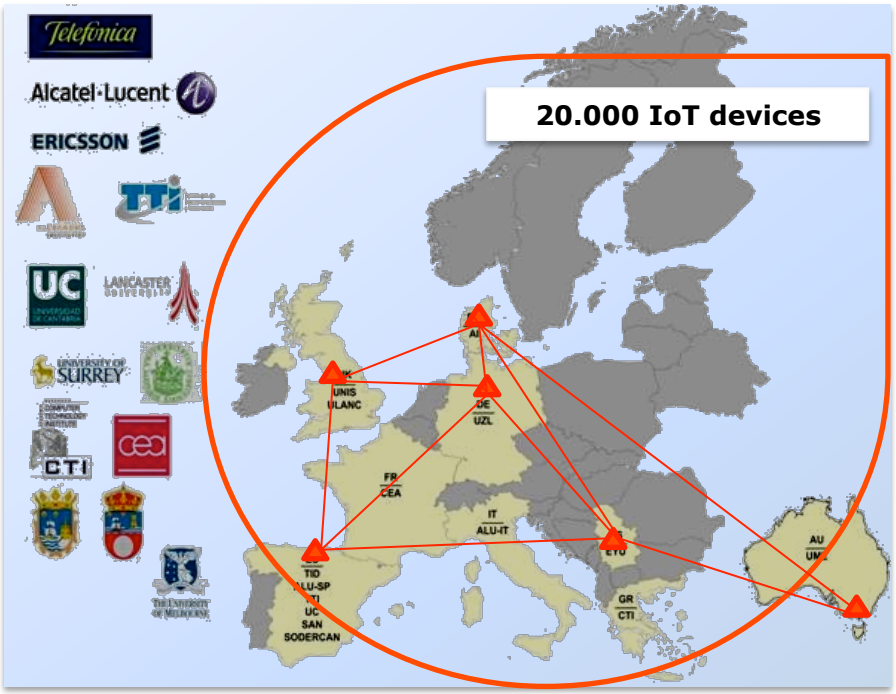
Capitalizing on Sound for a Smarter Future Internet

P.Cousin – C.Pham

FP7 EAR-IT project www.ear-it.eu

SmartSantander at a glance

SmartSantander aims at providing a European **experimental test facility** for the **research** and **experimentation** of architectures, key enabling technologies, **services** and applications for the Internet of Things (IoT) in the context of the **smart city**.



Smart Santander Highlights

- **Targeting:**
  - Researchers
  - End users
  - Service providers
- **Duration**
  - 36 months
- **Consortium**
  - 15 Organisations
  - 8 EU countries + AU
- **Budget / Funding**
  - 8.6 M€ / 6 M€
- **Resources**
  - 746.2 PM

SmartSantander

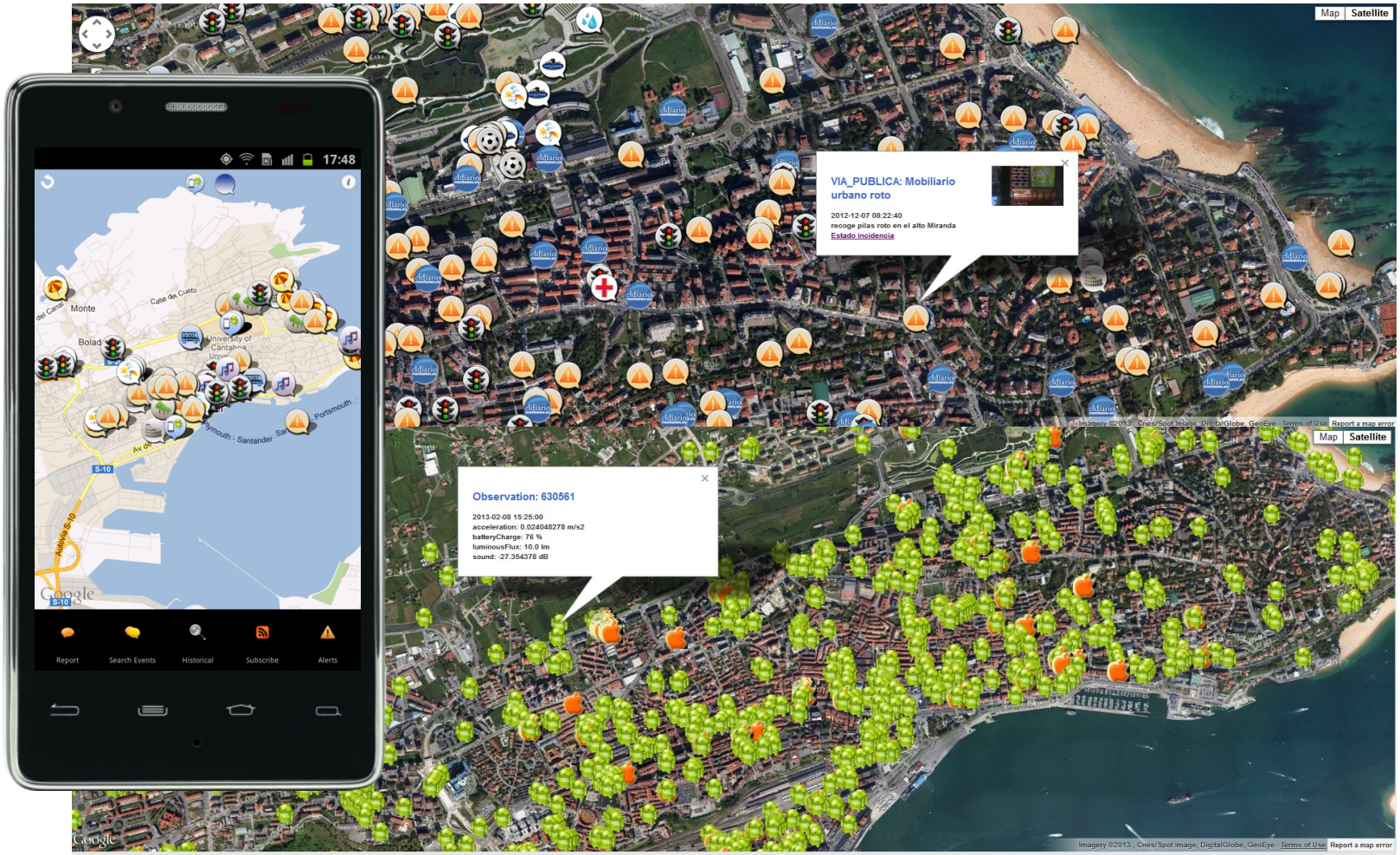
Sensor Network Deployment

SmartSantander

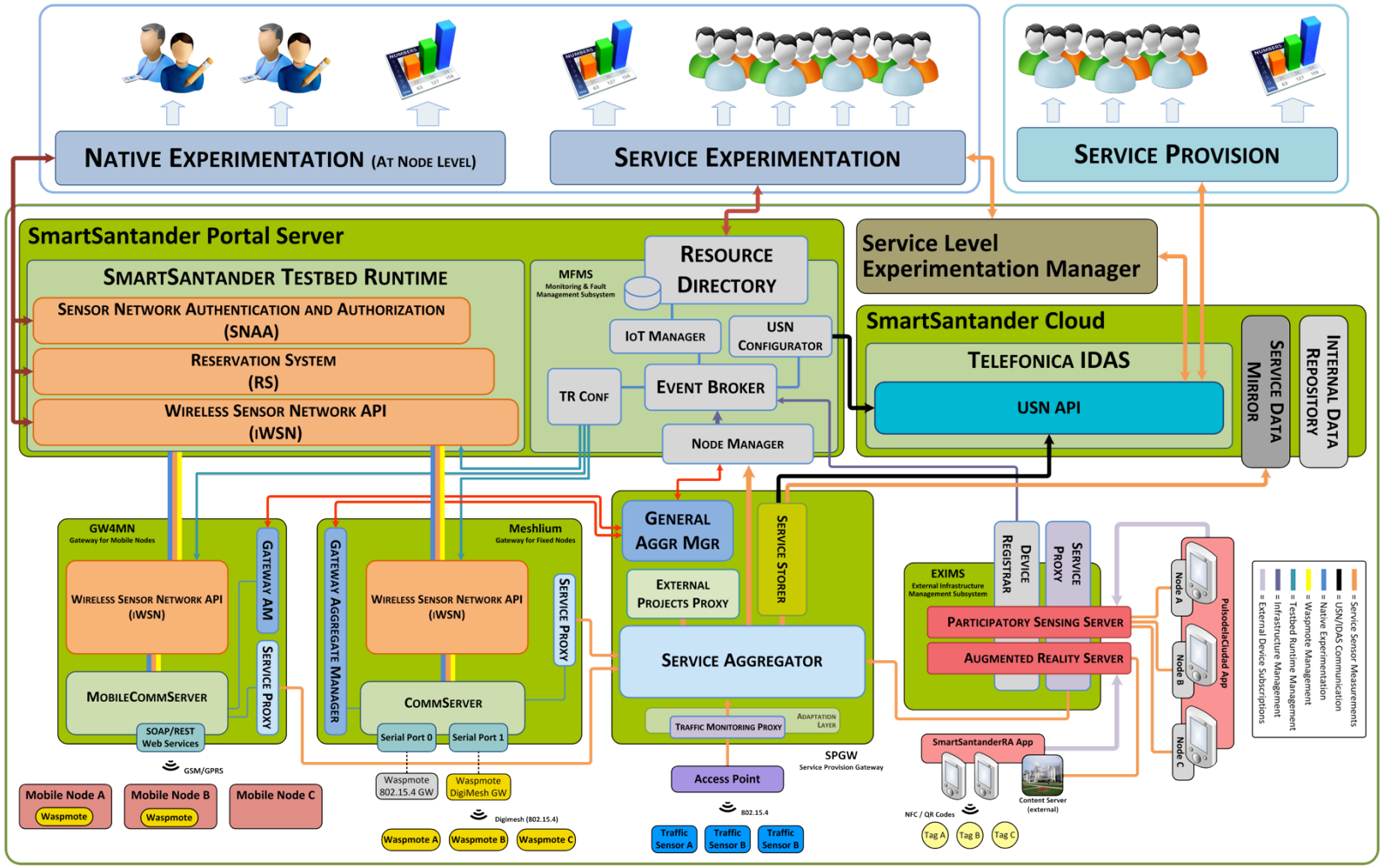
Traffic Monitoring Sensors Deployment

SmartSantander Applications

Participatory Sensing



SmartSantander software architecture



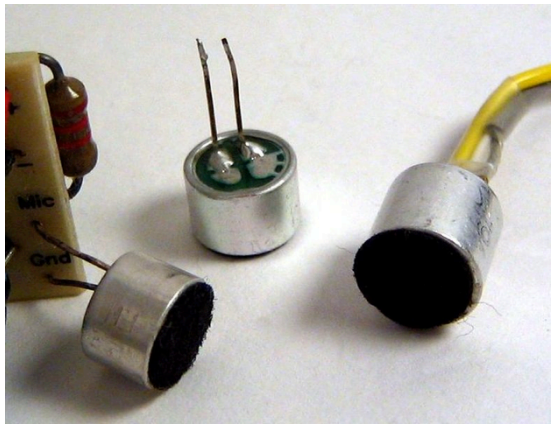
Audio Sensing Technologies from IoT domain

Motes (Sensor Nodes)

*Def.: "is a node in a WSN that is capable of gathering sensory information, performing **some** processing and do **certain** communication with other connected nodes in the network"*

Current IoT Motes Specs

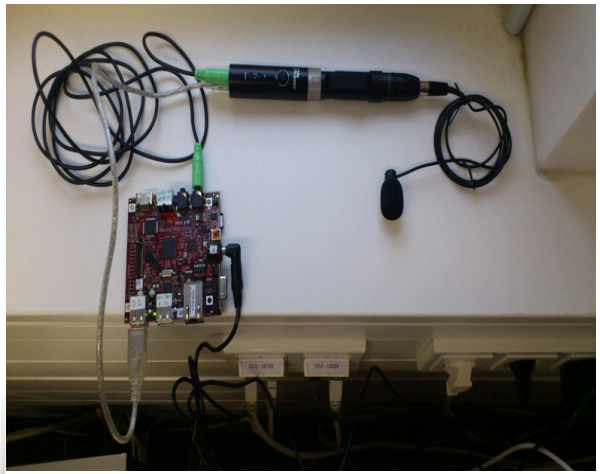
- Fundamental Energy/Power constraints
- Low processing power
- Low storage capabilities
- Low-cost sensors
  (e.g. electrect microphone)



Audio Sensing Technologies from Acoustic Sensing domain

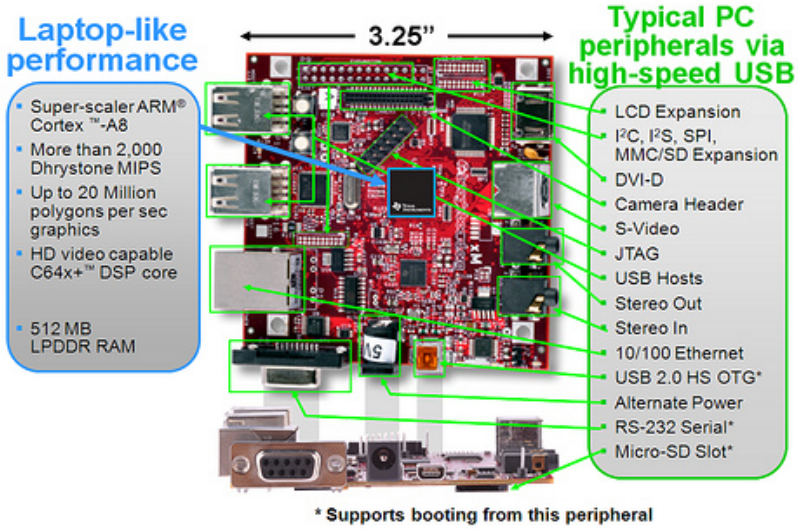
APUs – Acoustic Processing Units

- Computer-like performance processing platform able to run robust accosting sensing framework;
- "Soundboard" - high quality sound, customized and stackable sound card;
- High-quality & responsive microphones;



- Bea
  acti

AUDITORY VALLEY



Complementary Technologies

Today's audio-ready IoT Technologies

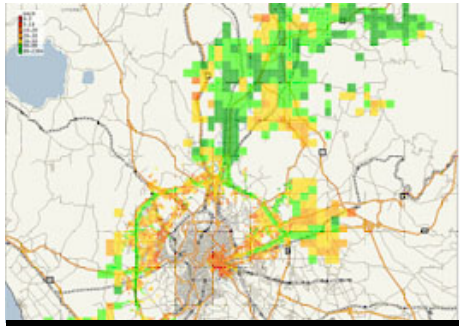
- *Less Capable*
- *Low energy*
- *Cheaper to get*
- *Much deployed*

Today's Acoustic Sensing Technologies

- *Powerful*
- *Power greedy*
- *More costly*
- *Fewer available*

Combining the complementary Acoustic Sensing and Internet-of-Things technologies of today for value

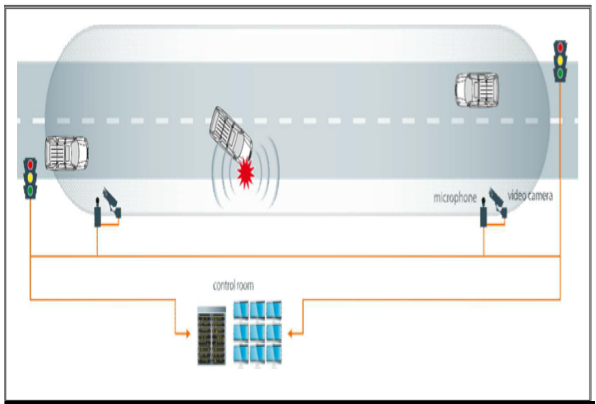
Vast Application Potential



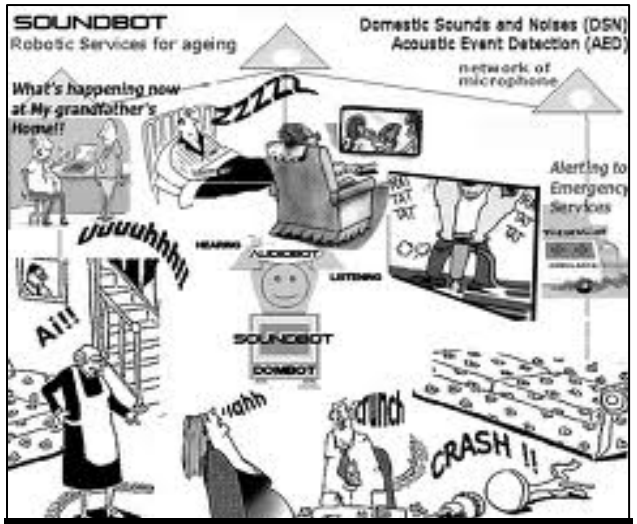
Sound Mappings

Traffic Management

Energy-efficiency



Traffic Accidents

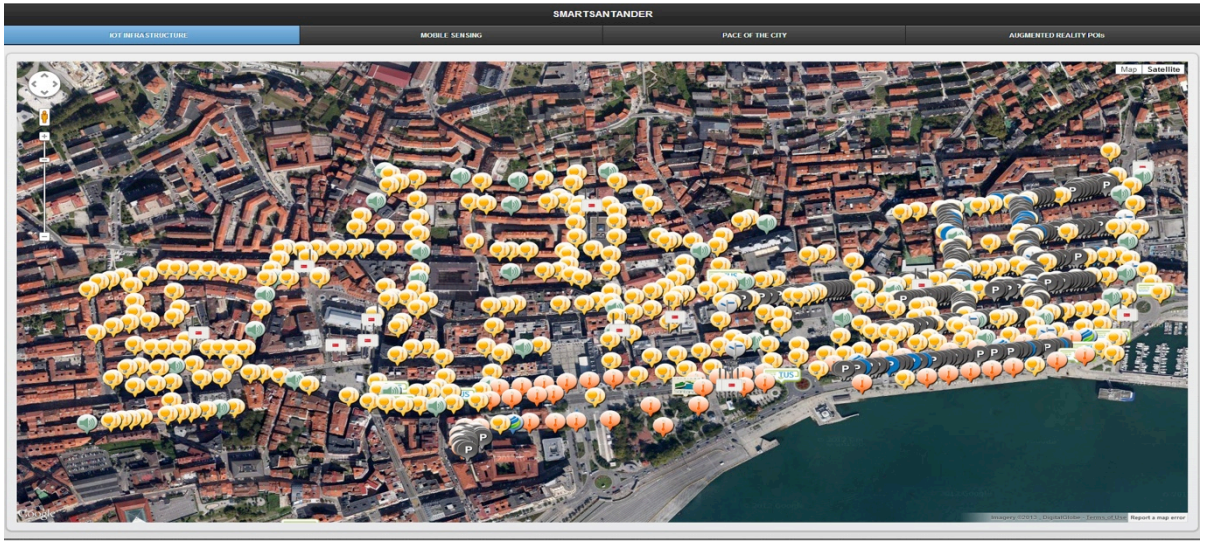


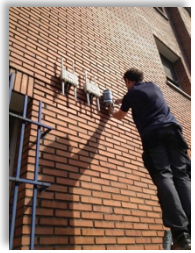
Ambient Assisted Living

(Audio) Surveillance

SmartSantander meets EAR-IT

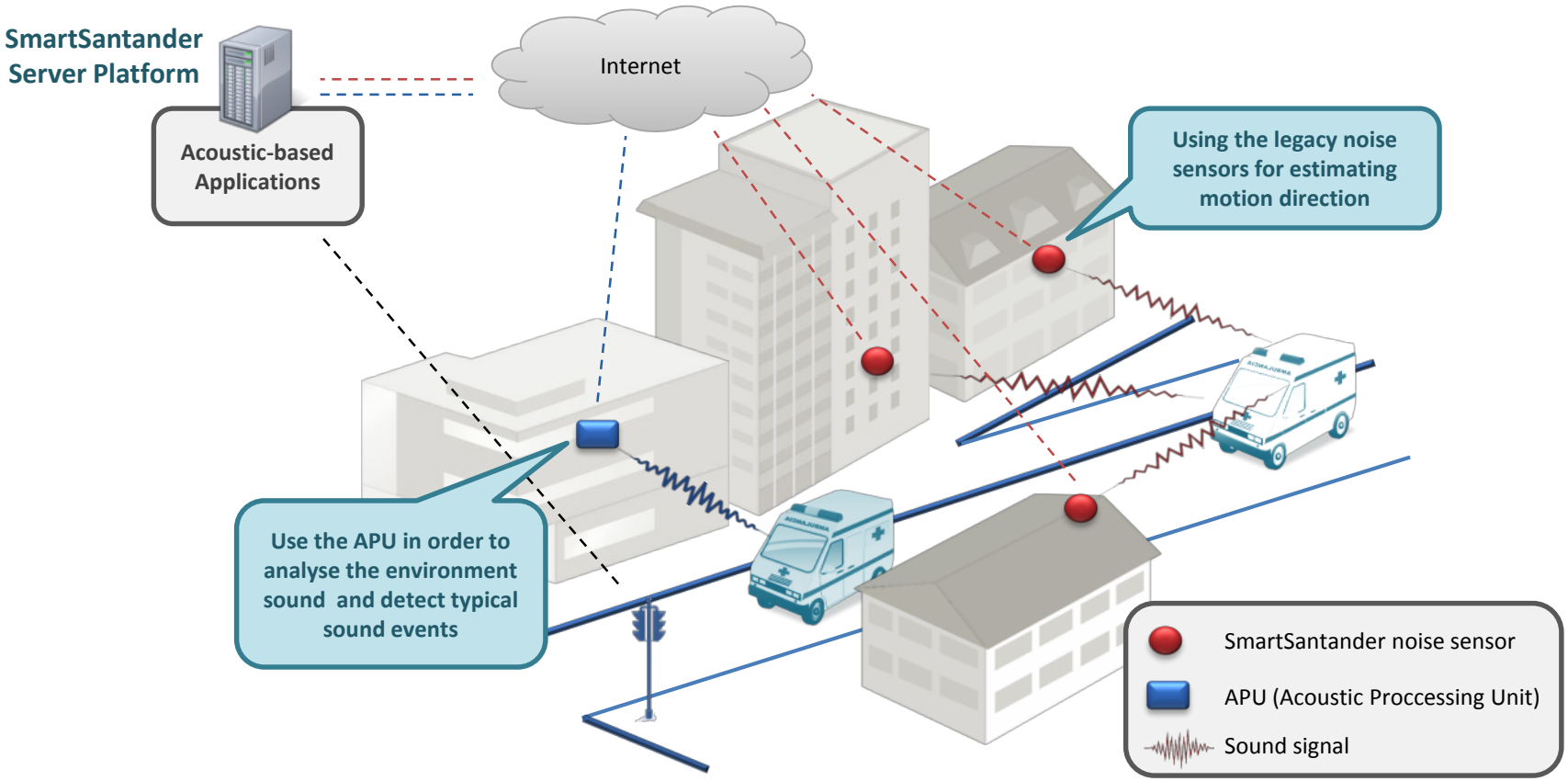
Upon concrete noise pattern detected by the APU, legacy sensors collect data for several purposes ⇒ Two use cases as a starting point.



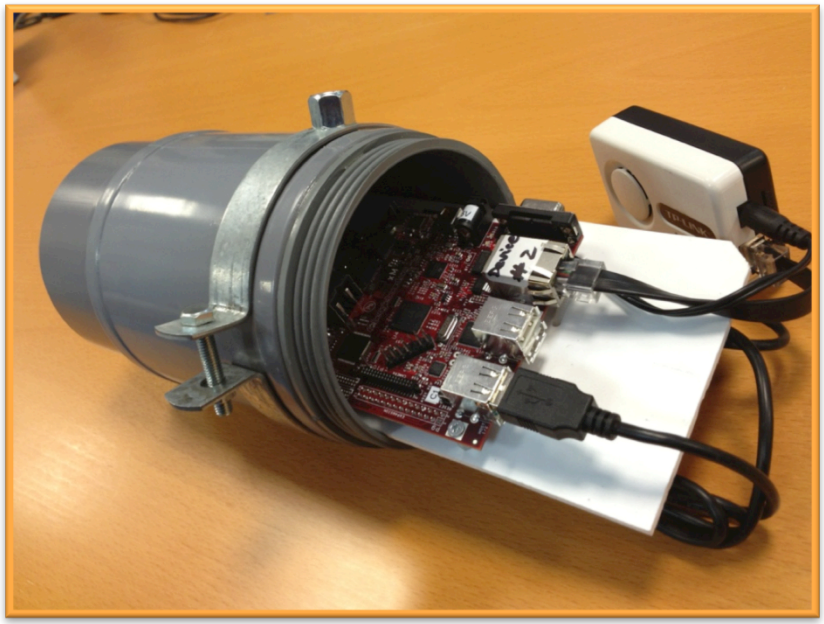


EAR-IT Use Case 1: Emergency Detection

Use the APU to detect an alarm ⇒ Legacy SmartSantander noise sensors to get the direction of such an event (police car, ambulance,…).

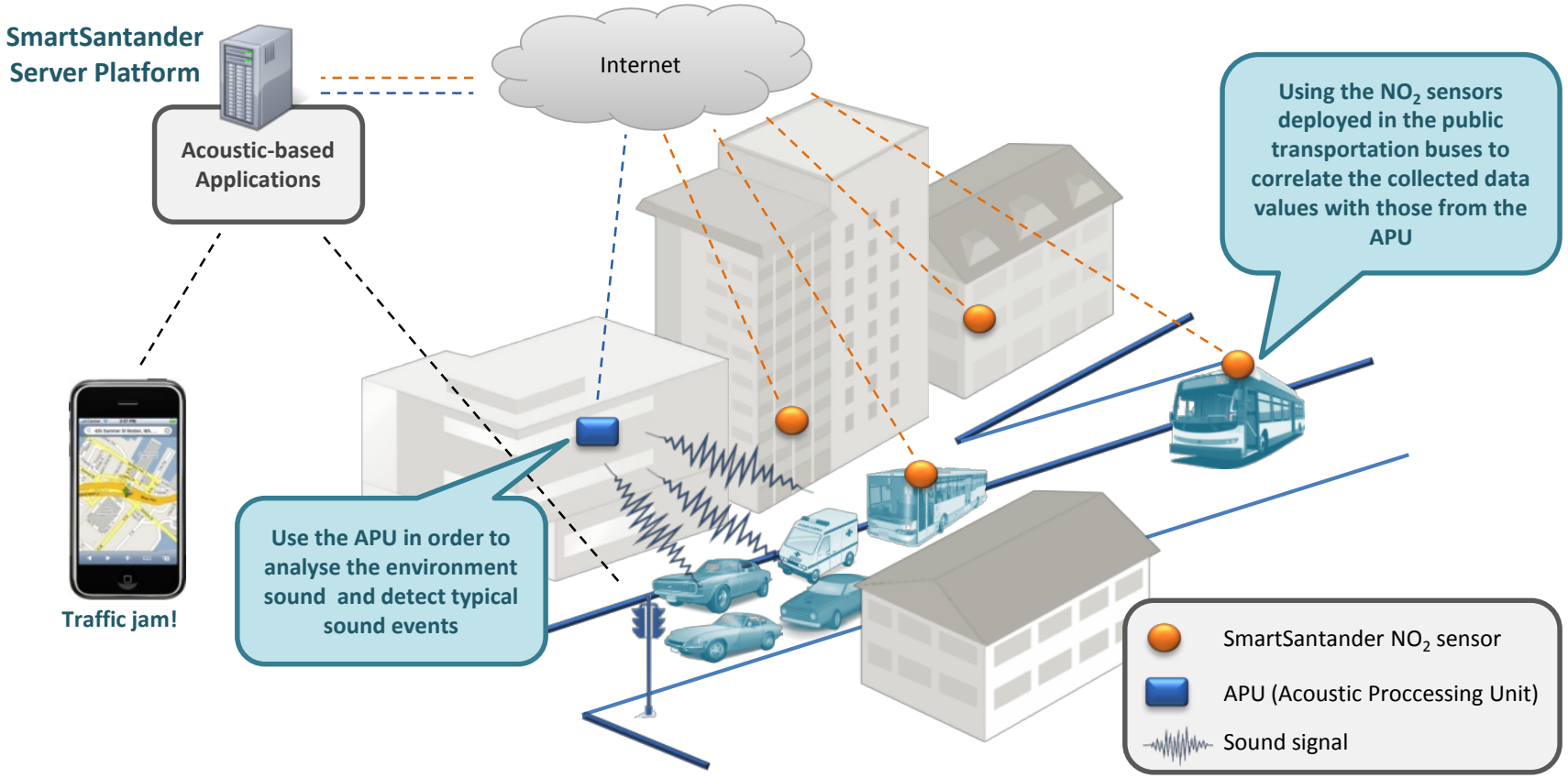


Emergency Detection Deployment



EAR-IT Use Case 2 : Traffic Monitoring

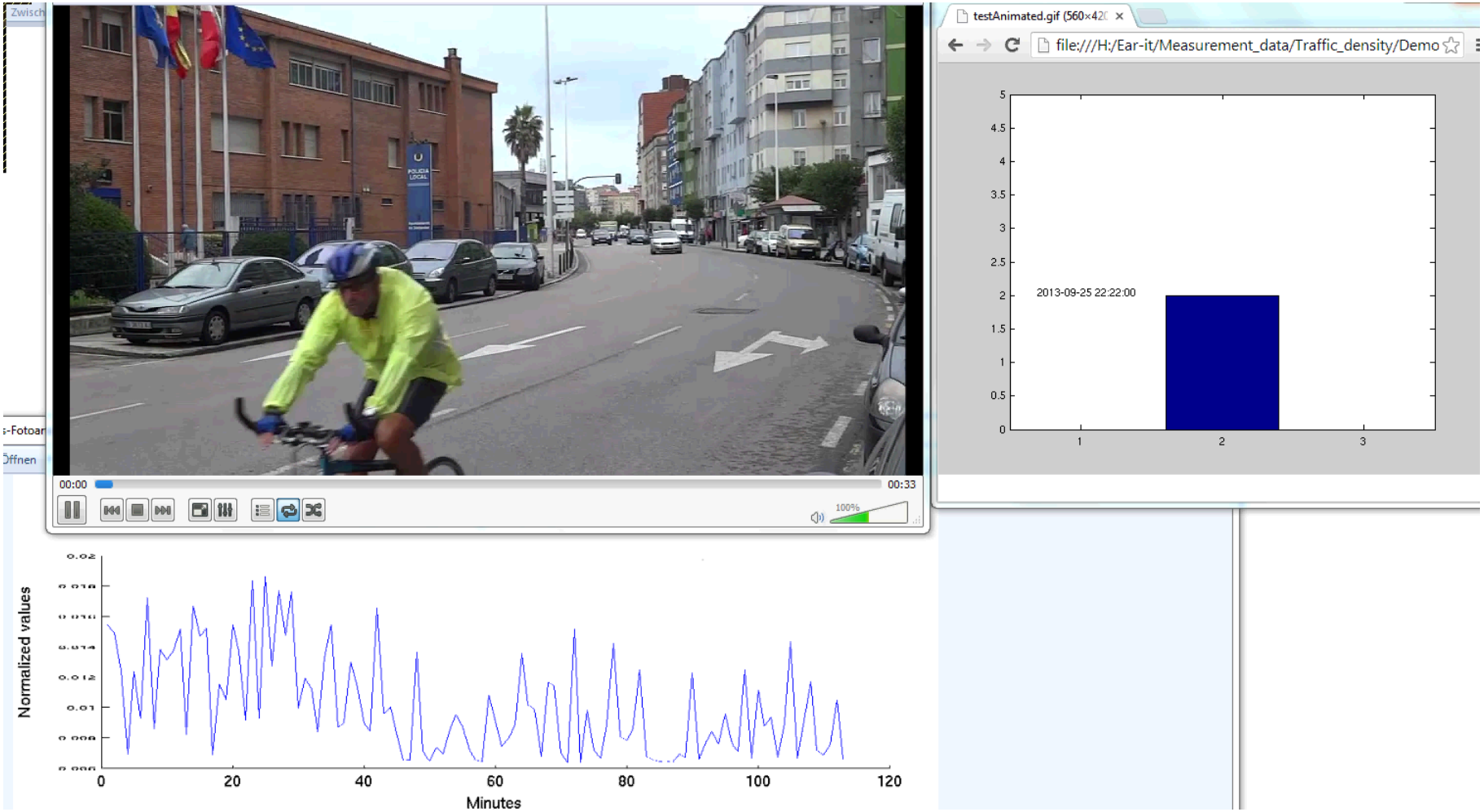
Use the APU to measure the traffic density and correlating it with pollution values (NO_2, CO,…) collected by legacy fixed and mobile nodes in the area.



EAR-IT Use Case 2 : Traffic density estimation

- The whole SmartSantander infrastructure is used in the deployment (IoT-s, APU, database, remote control)
- Traffic monitoring IoT-s are used for development and validation
- The examined street is a one-way road with 3 lanes

Traffic Density Monitoring Deployment


00:00
00:33
100%
testAnimated.gif (560×42
file:///H:/Ear-it/Measurement_data/Traffic_density/Demo
2013-09-25 22:22:00
Normalized values
Minutes
0
20
40
60
80
100
120

Audio streaming on IoT nodes

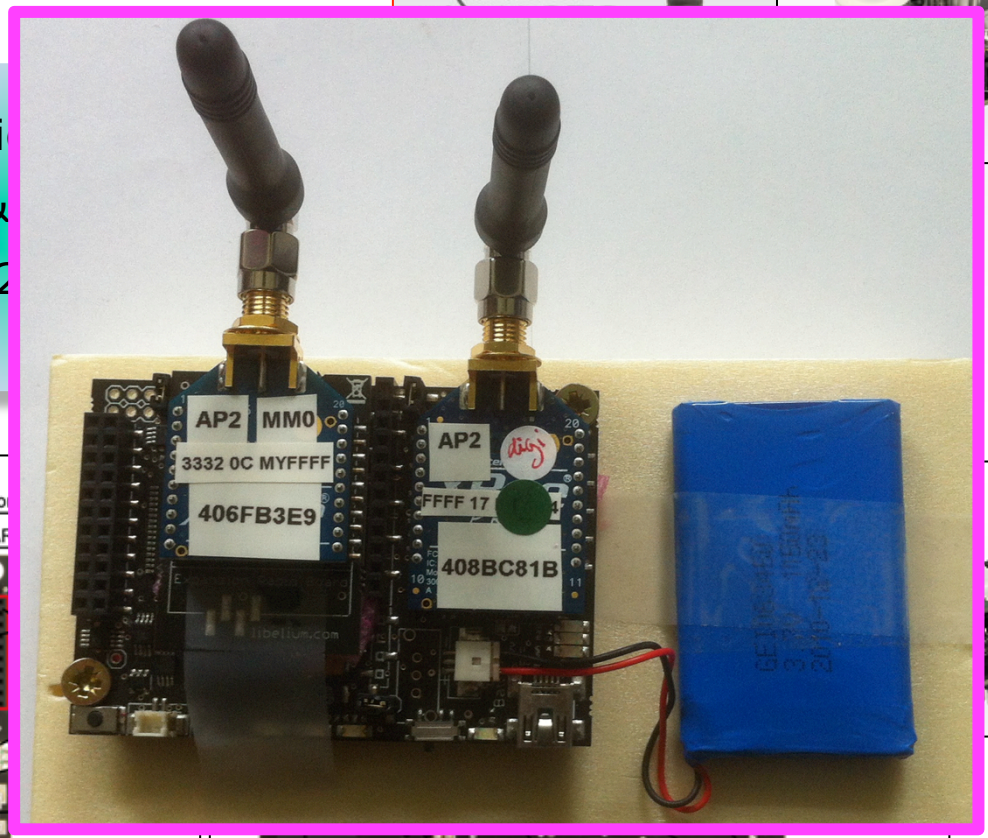
Congduc Pham

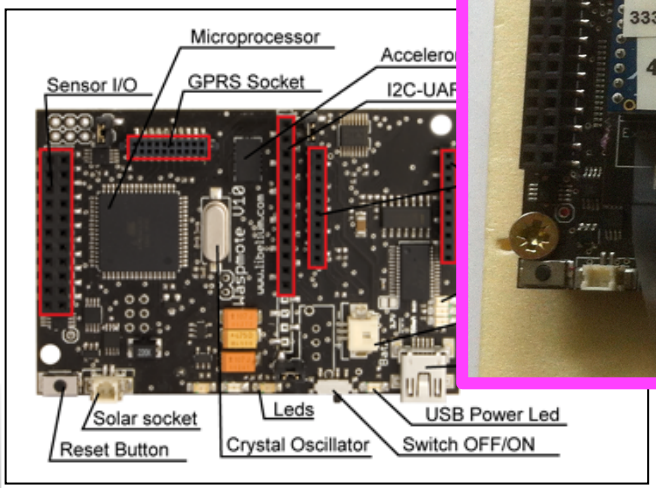
EAR-

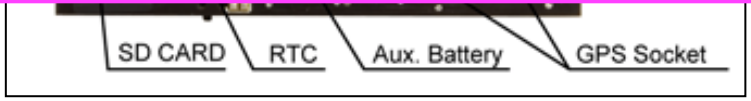
SmartSantander IoT node

libelium
comunicaciones inalámbricas distribuidas

ATmega1281 mi
8Mhz, 4K RAM &
2.4GHz IEEE 802







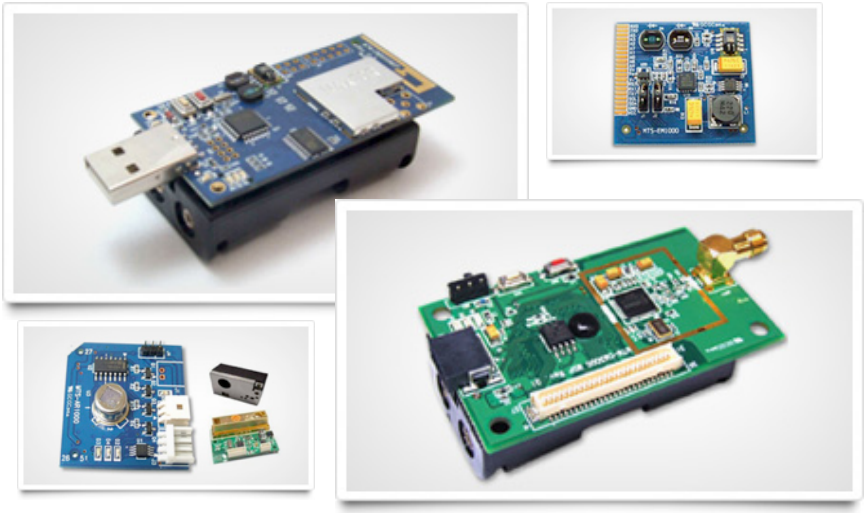
Gases

- Carbon Monoxide – CO
- Carbon Dioxide – CO2
- Oxygen – O2
- Methane – CH4
- Hydrogen – H2
- Ammonia – NH3
- Isobutane – C4H10
- Ethanol – CH3CH2OH
- Toluene – C6H5CH3
- Hydrogen Sulfide – H2S
- Nitrogen Dioxide – NO2
- Temperature
- Humidity

- Pressure/Weight
- Bend
- Vibration
- Impact
- Hall Effect
- Tilt
- Temperature (+/-)
- Liquid Presence
- Liquid Level
- Luminosity
- Presence (PIR)
- Stretch

IMAGES ARE FROM LIBELIUM COMPANY

HobNet test-bed at UNIGE

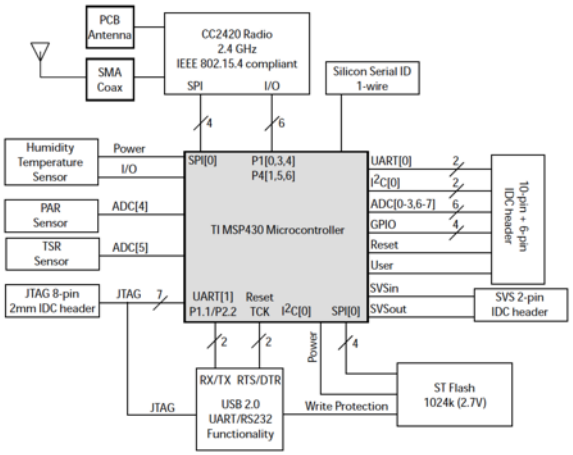


MSP430F1611
microcontroller

8Mhz, 48K flash, 10K RAM

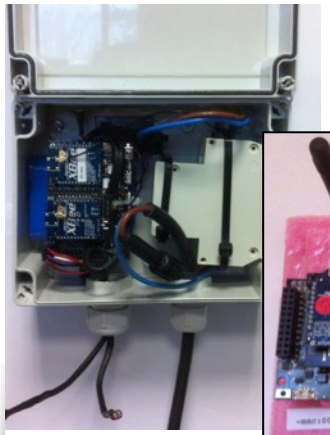
2.4GHz IEEE 802.15.4
CC2420

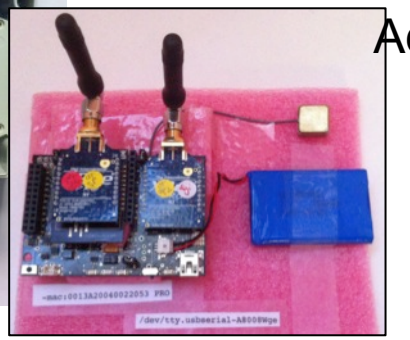
Programmed under TinyOS



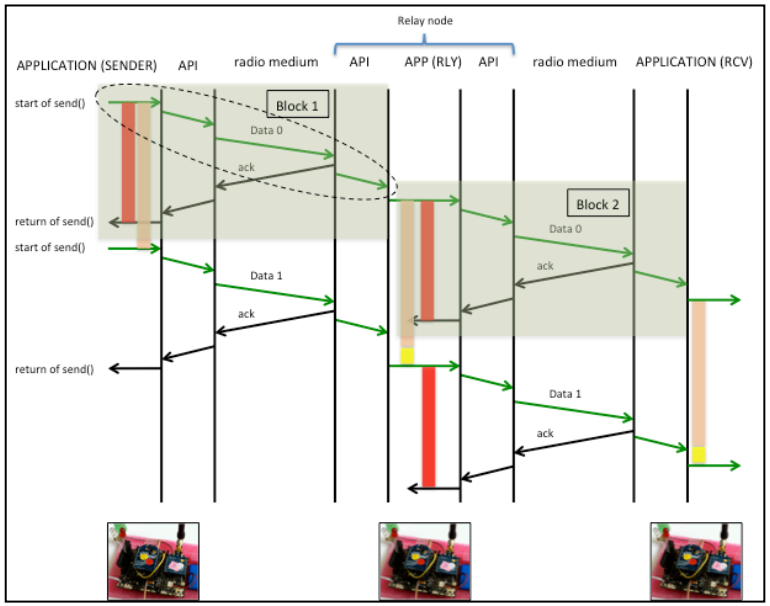
Qualification phase 1

- Phase 1
  - Determine upper bounds on performances of a single IoT node
  - Determine upper bounds on performances of multi-hop transmissions

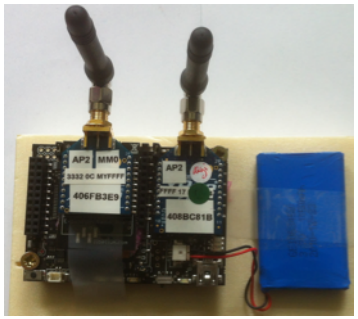




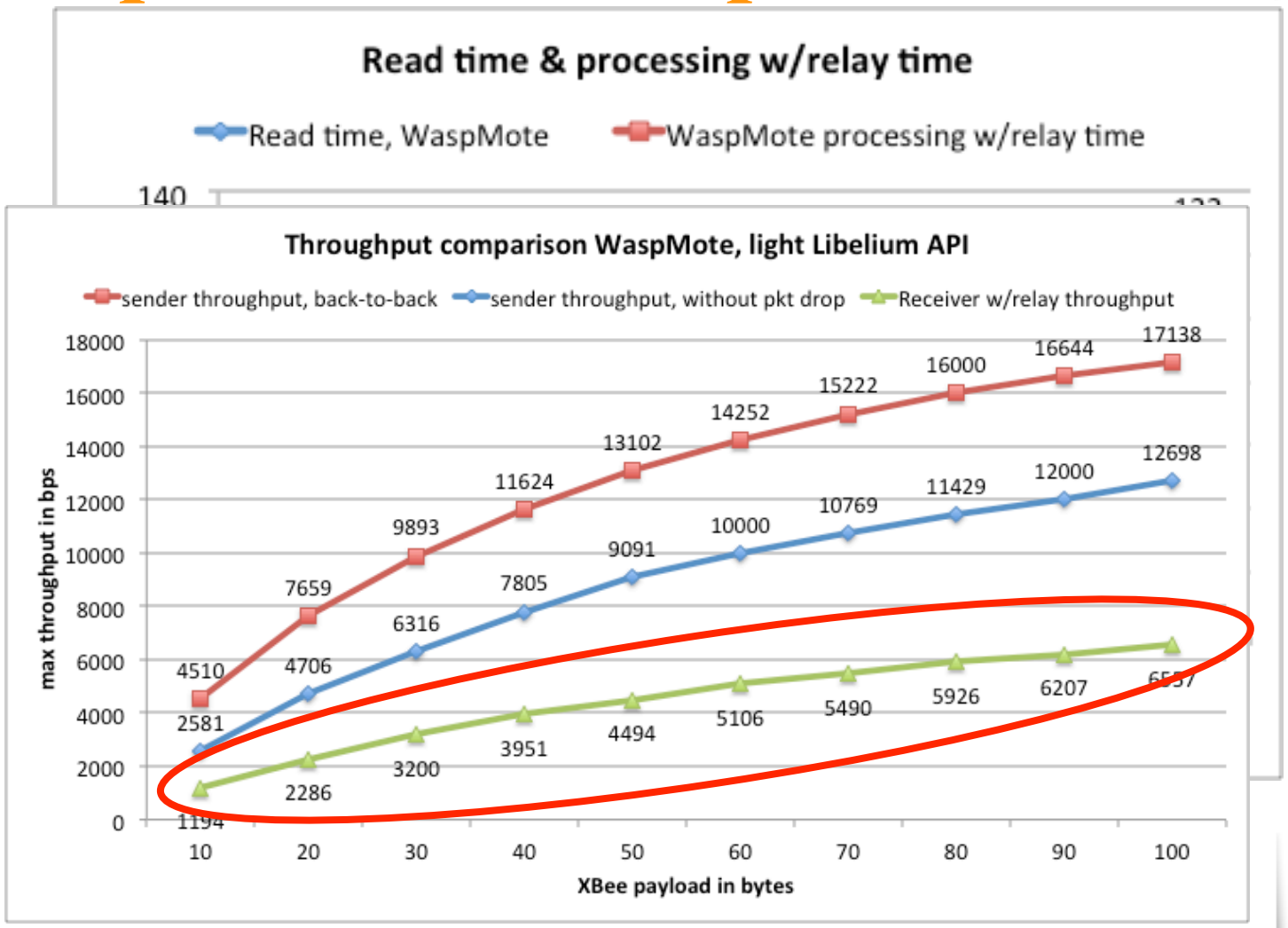
Traffic Generators
Sniffers
Advanced timing



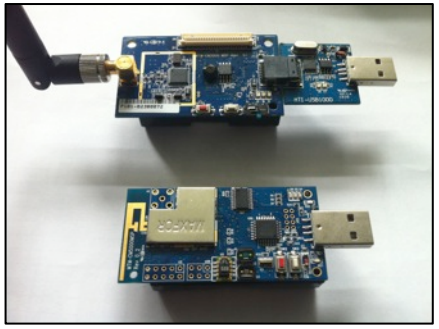
WaspMote multi-hop overheads



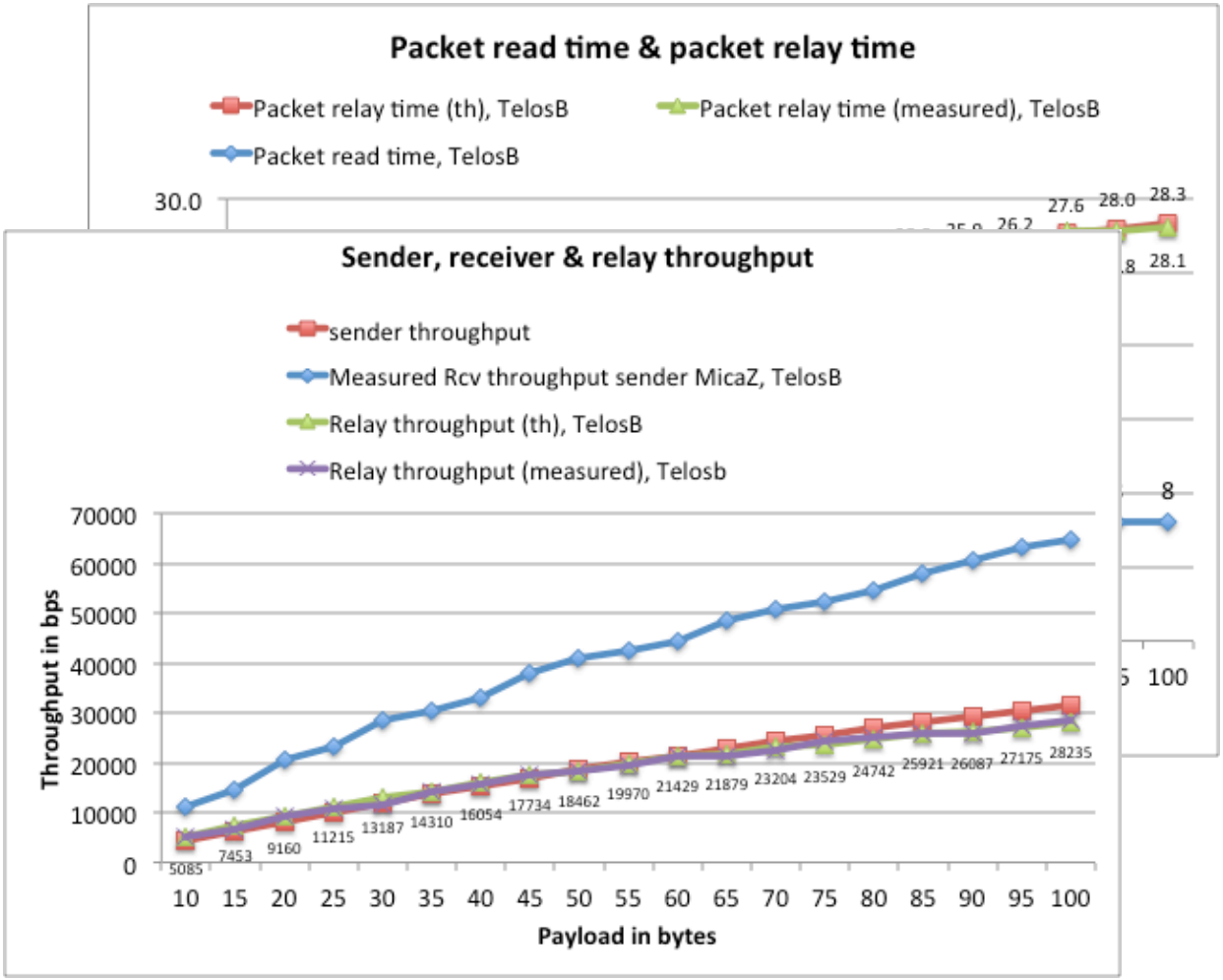
Libelium WaspMote



AdvanticSys multi-hop overheads

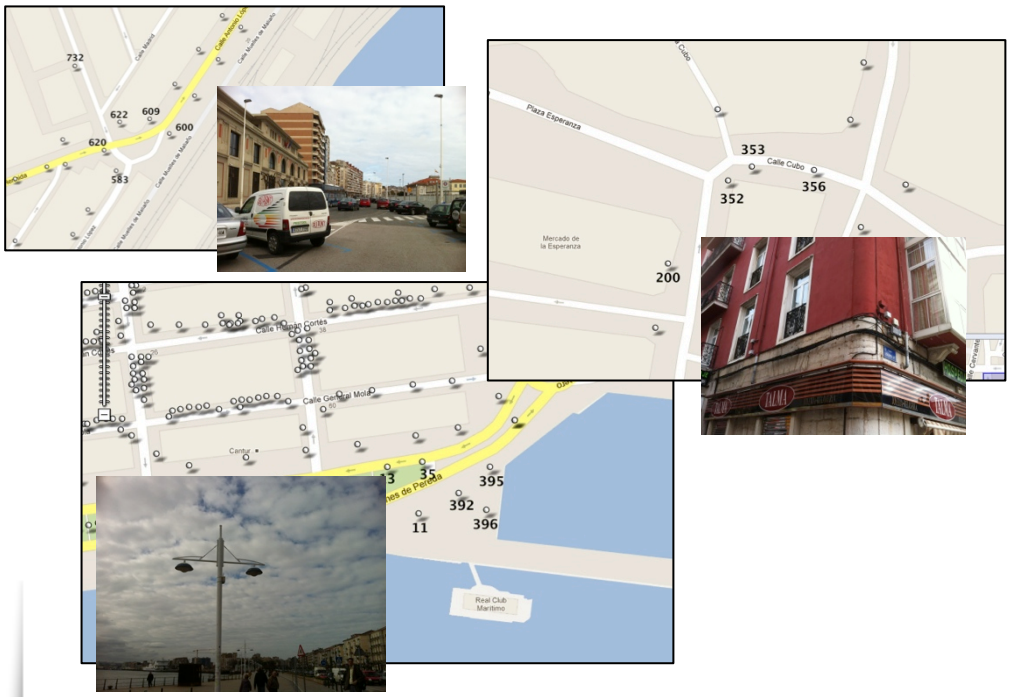


AdvanticSys
CM5000, CM3000



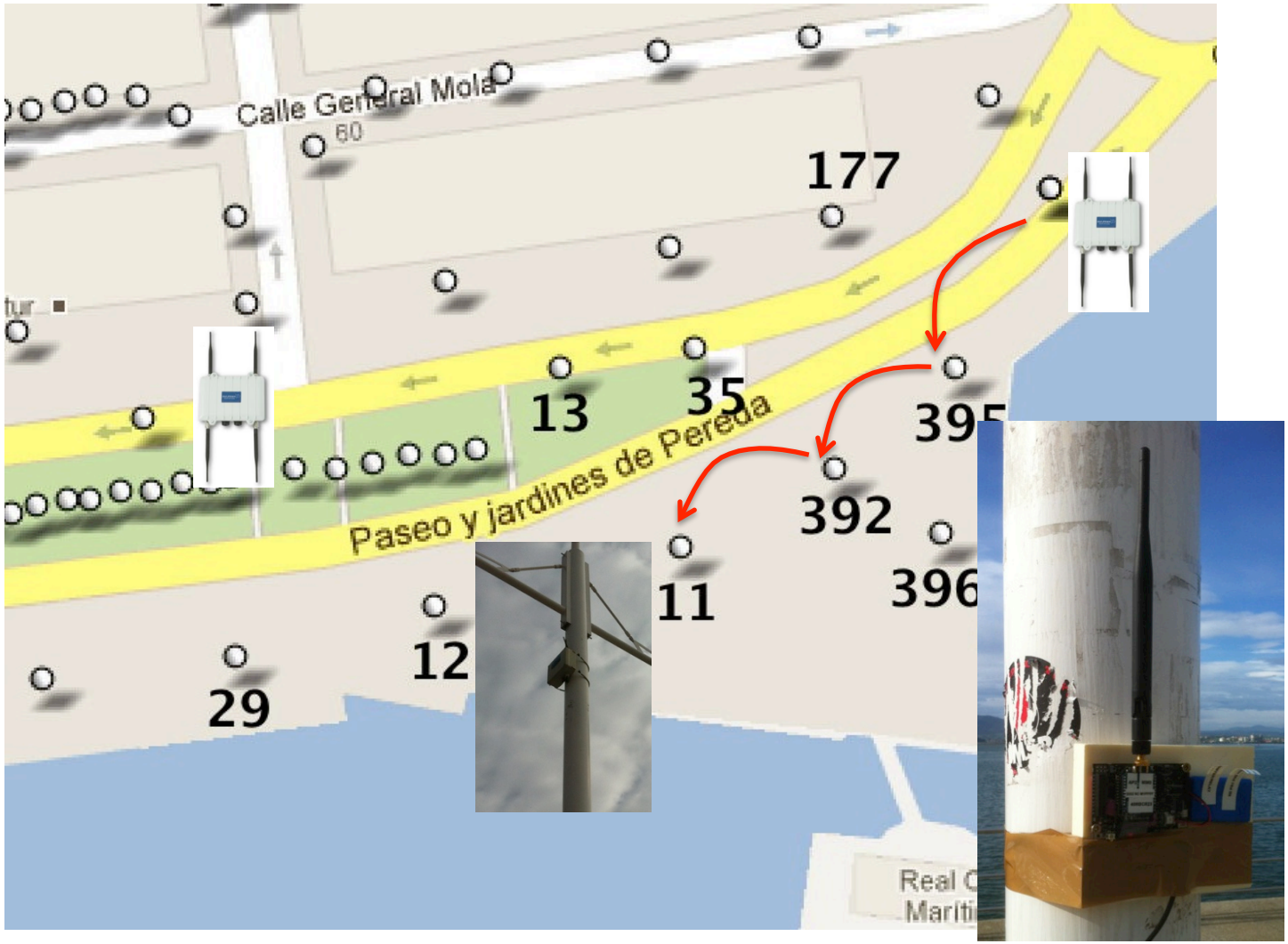
Qualification phase 2

- Phase 2
  - Performances in a networked environment: node density, traffic loads



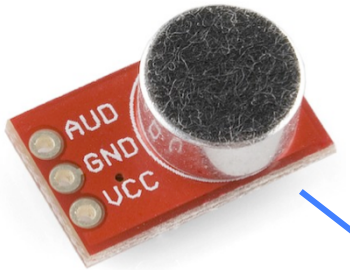
- Use representive locations in Santander for on-site test campaigns
- Deploy on IoT nodes traffic generators & sniffers
- Use mobile traffic generators & sniffers for dynamic traffic patterns
- Throughput, packet losses, latency,…

Test on SmartSantander

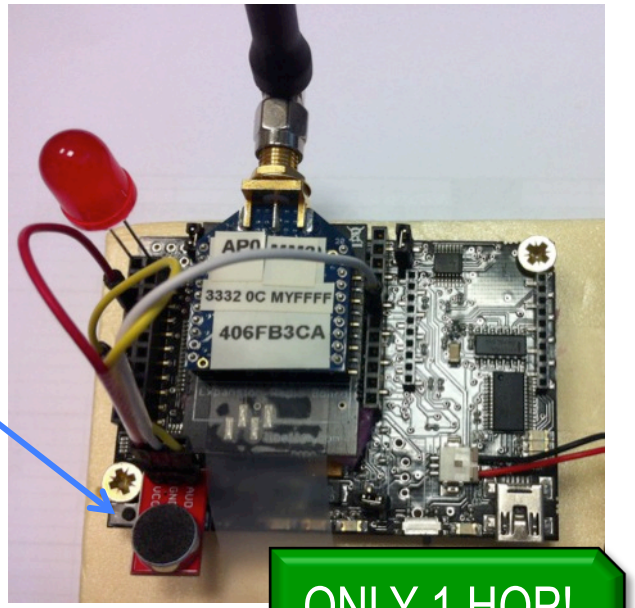


WaspMote+XBee in raw mode

- Electret mic with amplifier

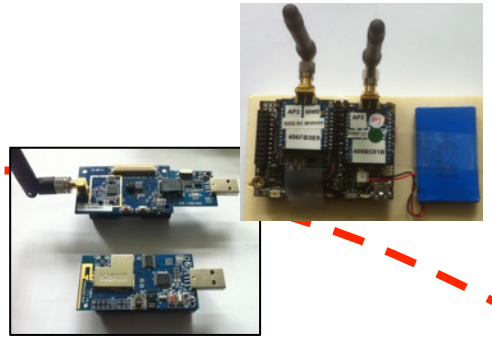


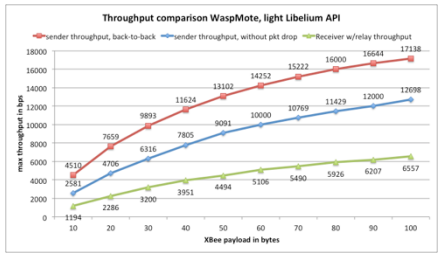
- XBee in AP0 mode (transparent mode)
- 8-bit 4Khz sampling gives 32000bps
- 8Khz sampling gives 64000bps, requires custom API



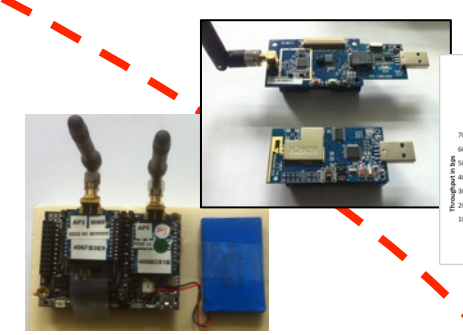
ONLY 1 HOP!

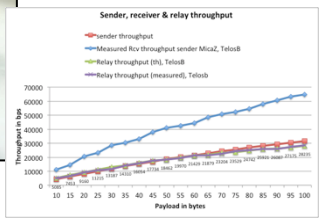
Multi-hop audio constraints



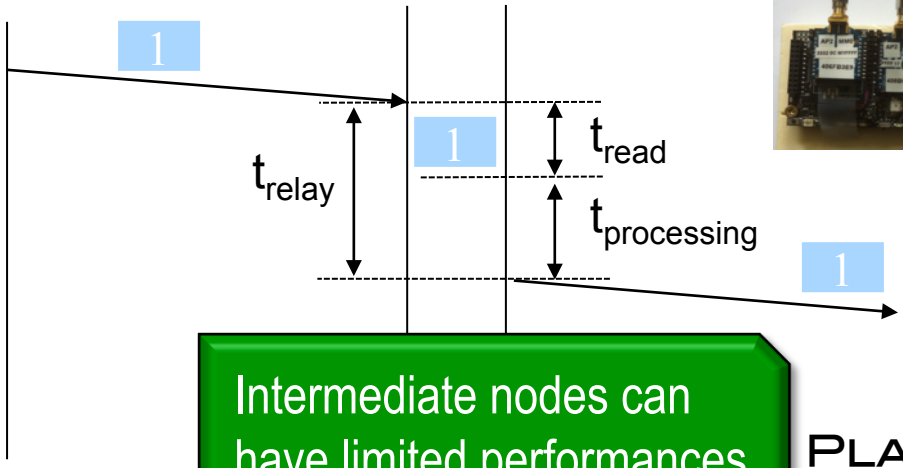


RELAY





RELAY

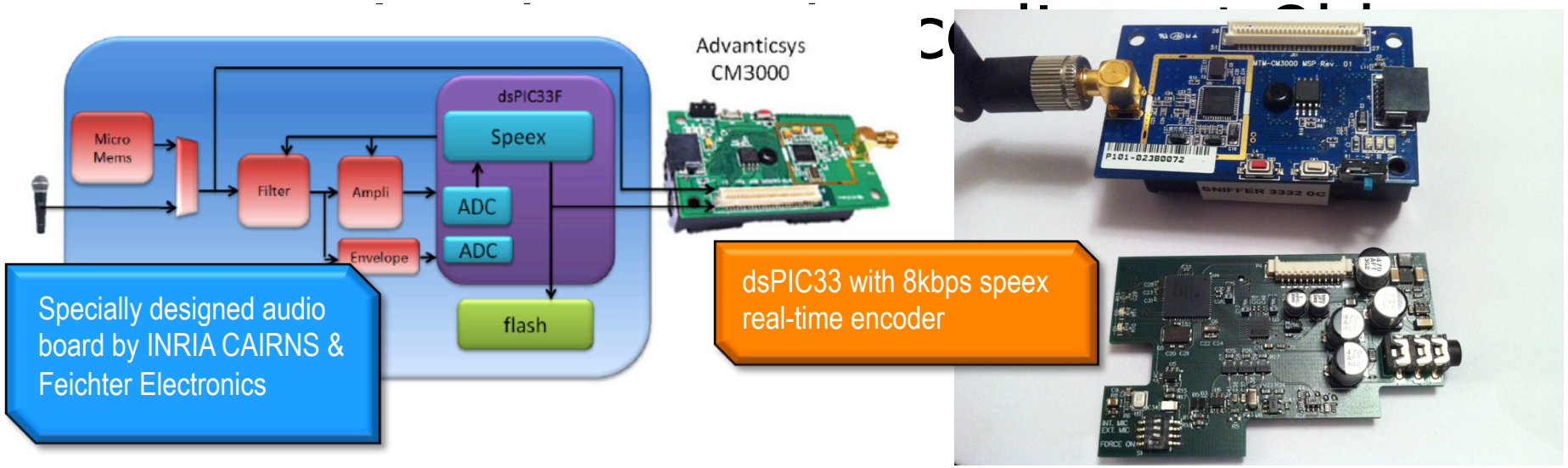


Intermediate nodes can have limited performances

PLAY RECEIVED FILE

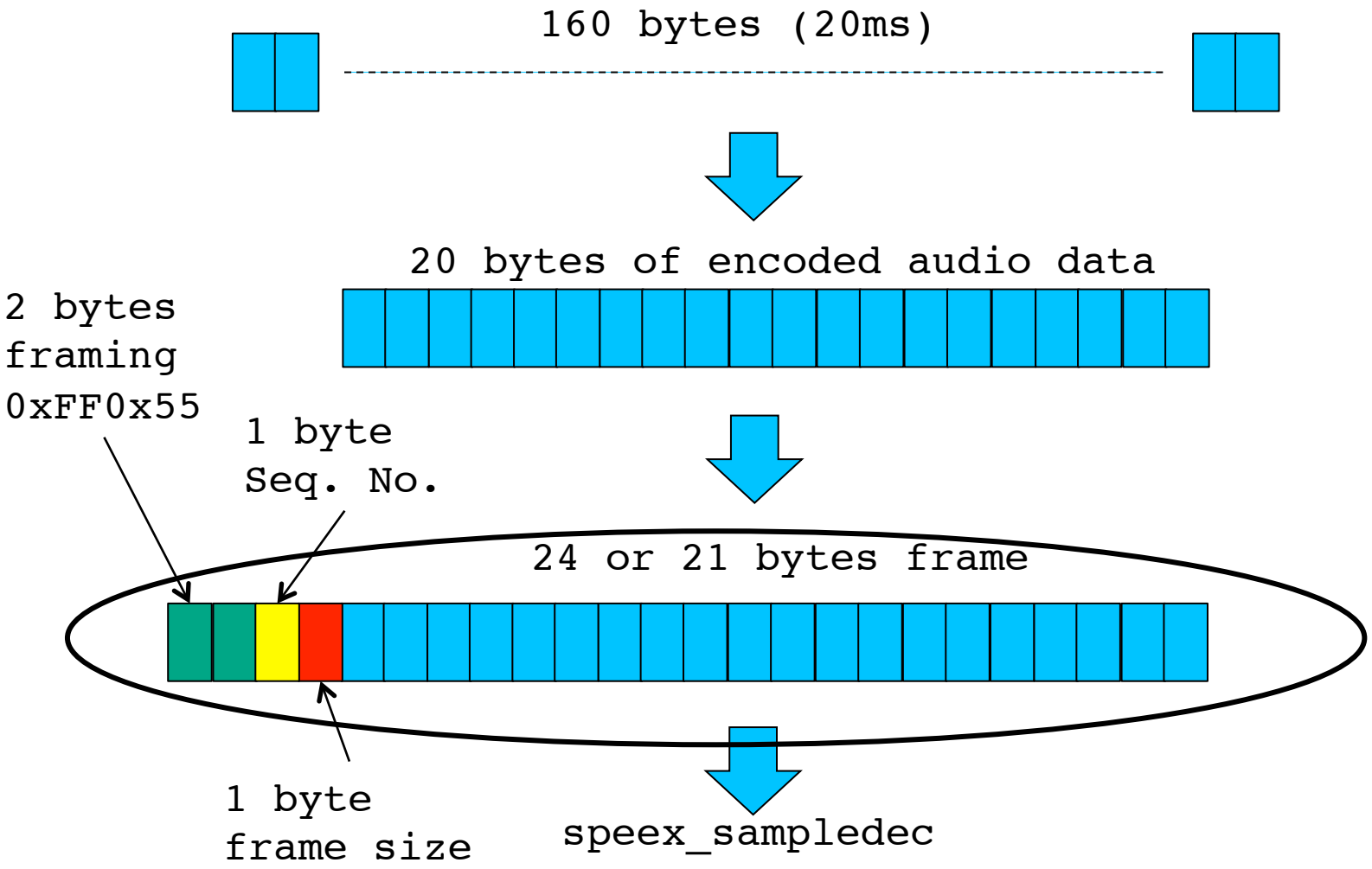
Multi-hop audio solution

- Use dedicated audio board for



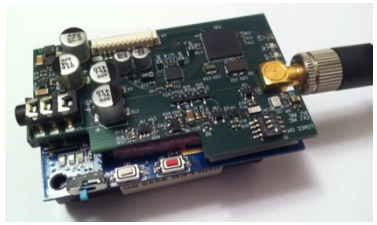
- Allows for multi-hop, encoded audio streaming scenarios

speex at 8kbps



1-hop test-bed w/audio board

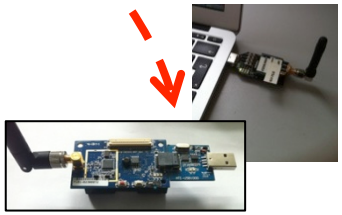
0x0090



SPEEX AUDIO ENCODING
8KBPS

A1/2/3/4 aggregate audio frames
D0100 set the 16-bit dest. mac addr
C0/1 power off/on the audio board

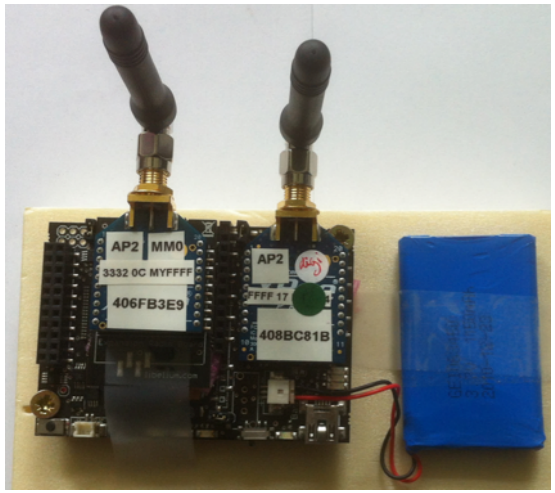
0x0100



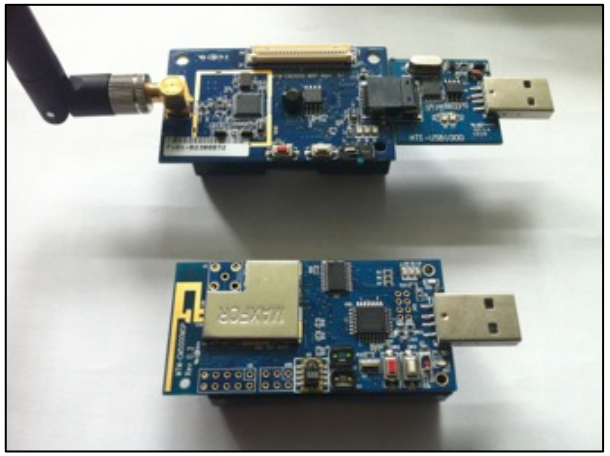
```
python 115200SerialToStdout.py | ./speex_sampledec_wframing essai.raw |
play --buffer 100 -t raw -r 8000 -s -2 -
```

DECODE & PLAY
RECEIVED AUDIO

Relay nodes



LIBELIUM
WASPMOTE



ADVANTICSYS
CM5000, CM3000

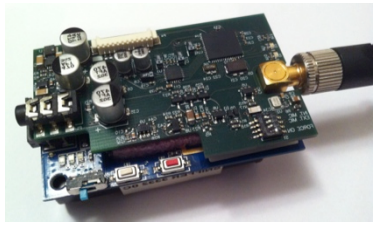
Fully configurable:

Destination node
Additional relay delay
Clock synchronization

```
R0/1 enable/disable relay mode
D0013A2004086D828 set the 64-bit dest. mac addr
D0080 set the 16-bit dest. mac addr
```

2-hop test-bed w/audio board

0x0090



SPEEX AUDIO ENCODING
8KBPS

A1/2/3/4/6 aggregate audio frames
D0200 set the 16-bit dest. mac addr
C0/1 power off/on the audio board

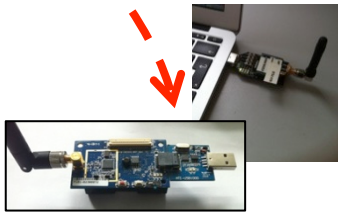
R0/1 enable/disable relay mode
D0100 set the 16-bit dest. mac addr

0x0200

RELAY

0xC823

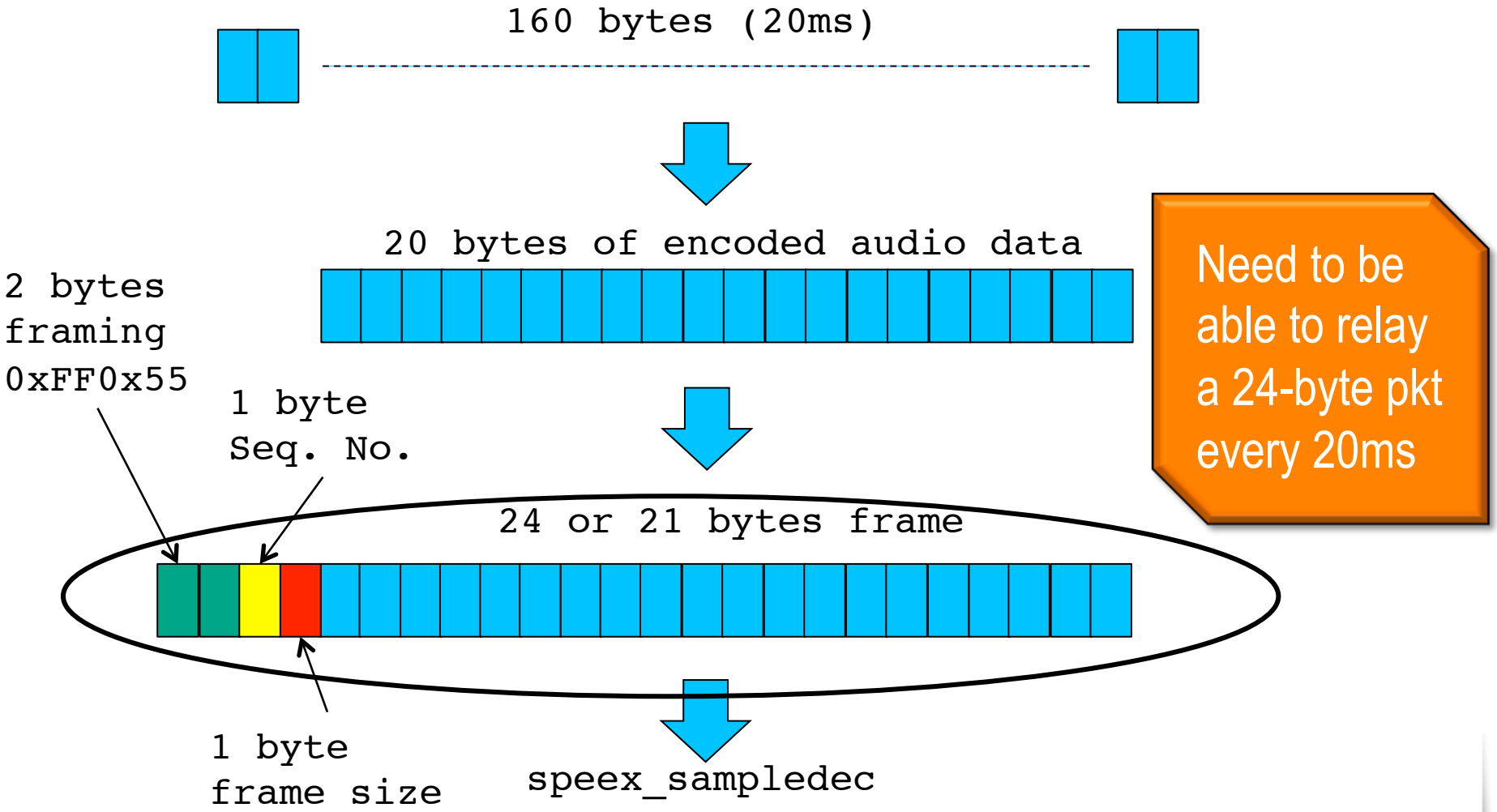
0x0100



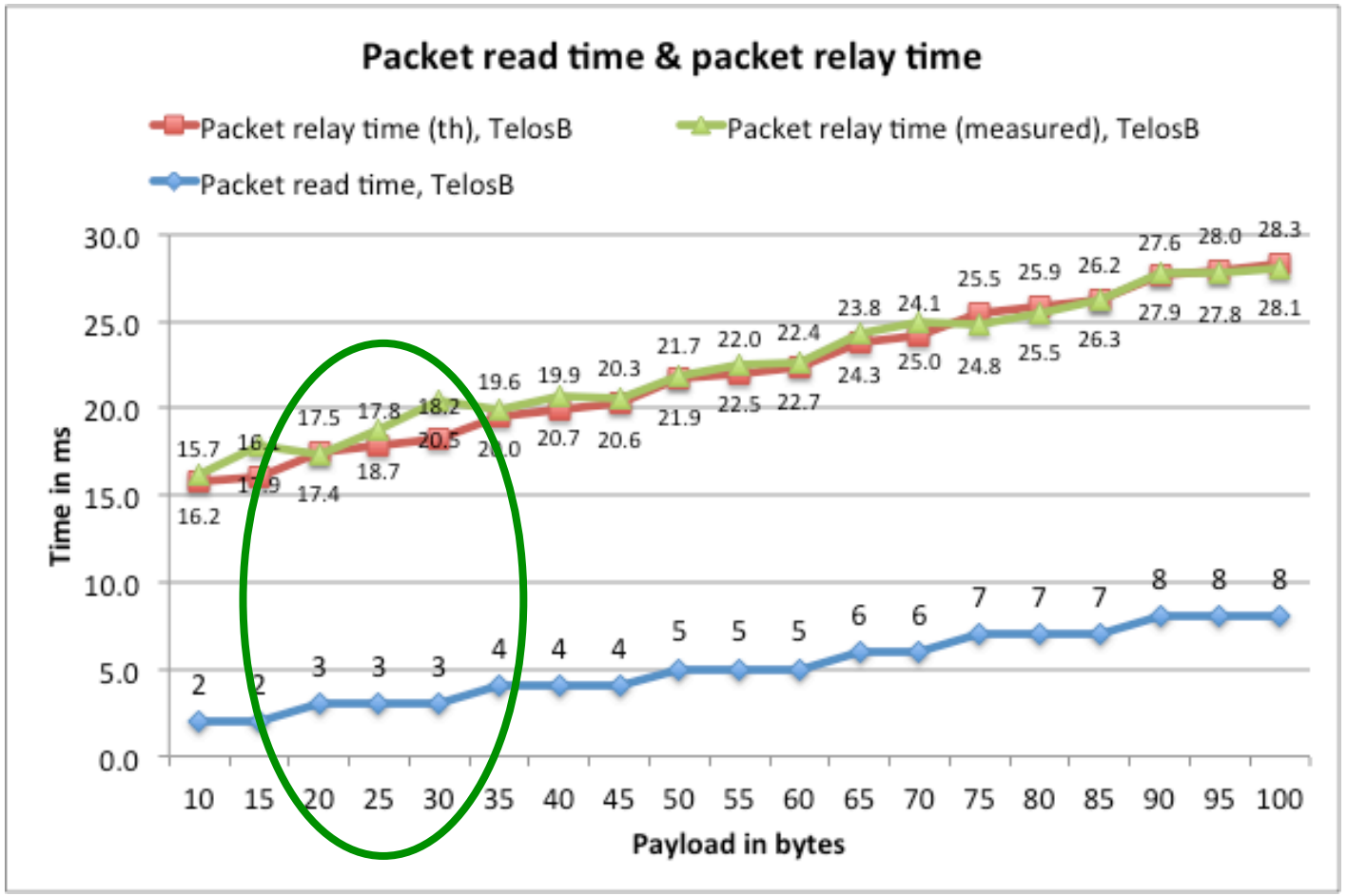
DECODE & PLAY
RECEIVED AUDIO

```
python 115200SerialToStdout.py | ./speex_sampledec_wframing essai.raw |
play --buffer 100 -t raw -r 8000 -s -2 -
```

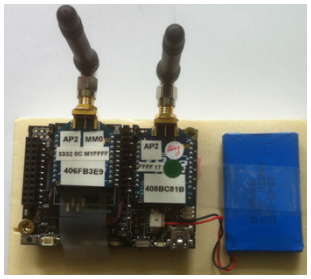
speex at 8kbps requirements

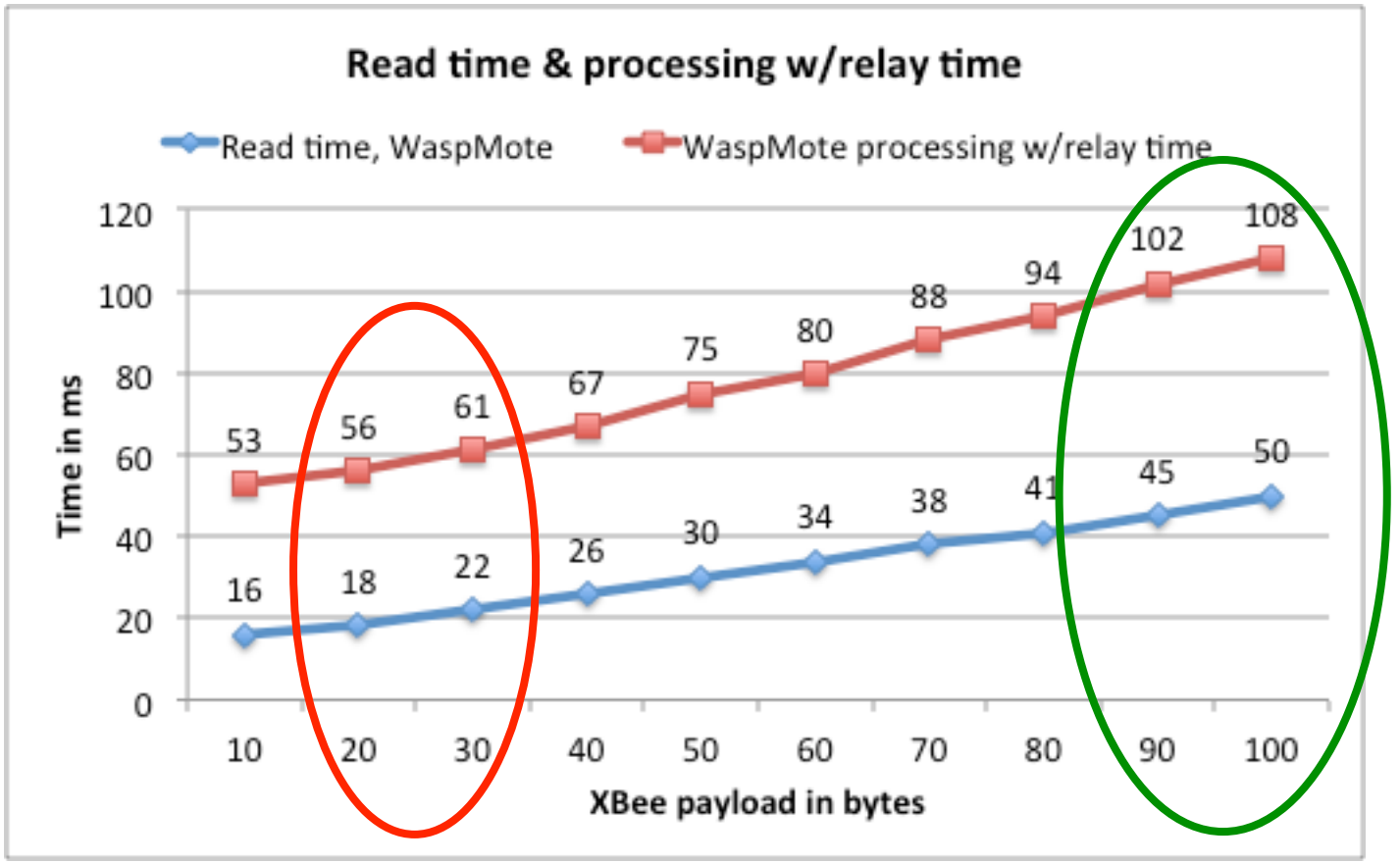


Relay node performances

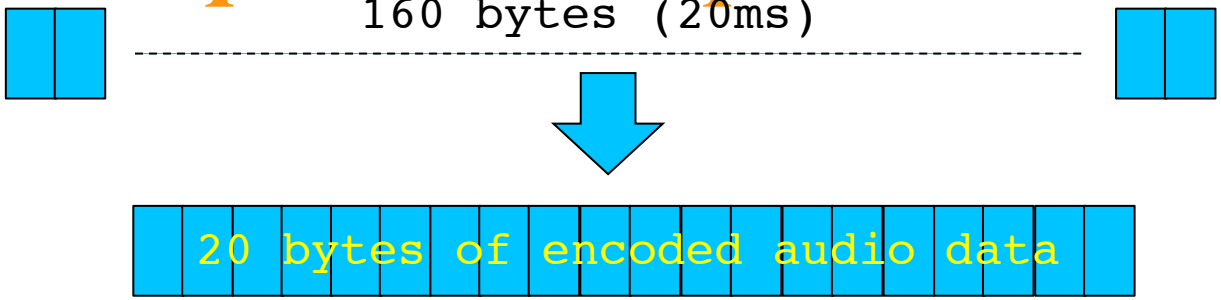


Relay node performances

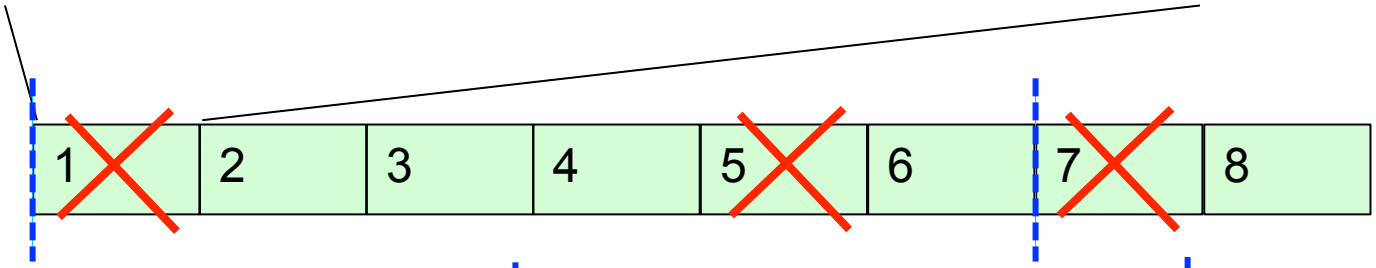


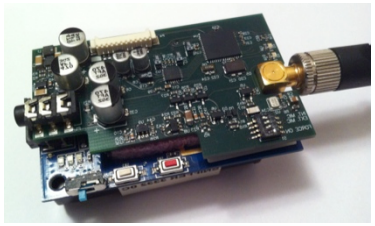


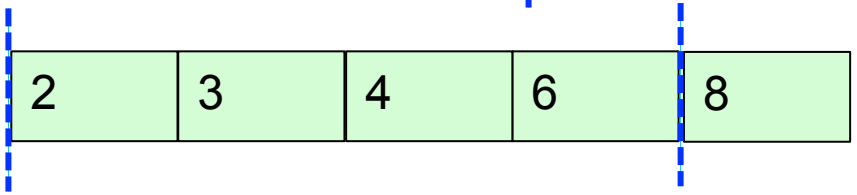
speex at 8kbps on slow relay nodes



Add framing bytes





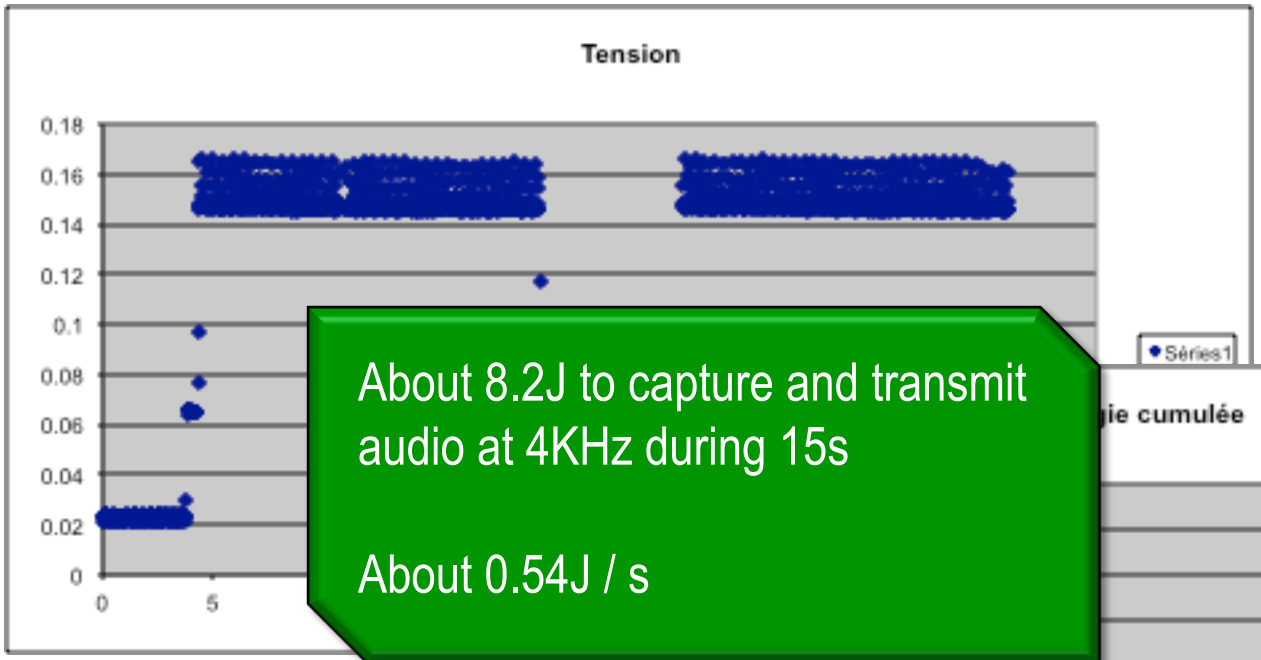


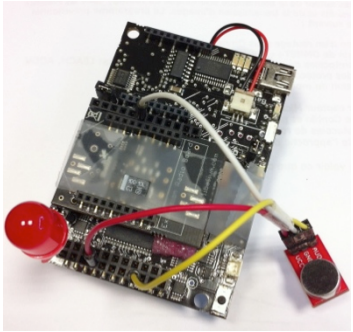
A6 aggregate audio frames

Capture 6 audio frames (120ms) but only send 4

Need to be able to relay 96-byte pkt every 120ms

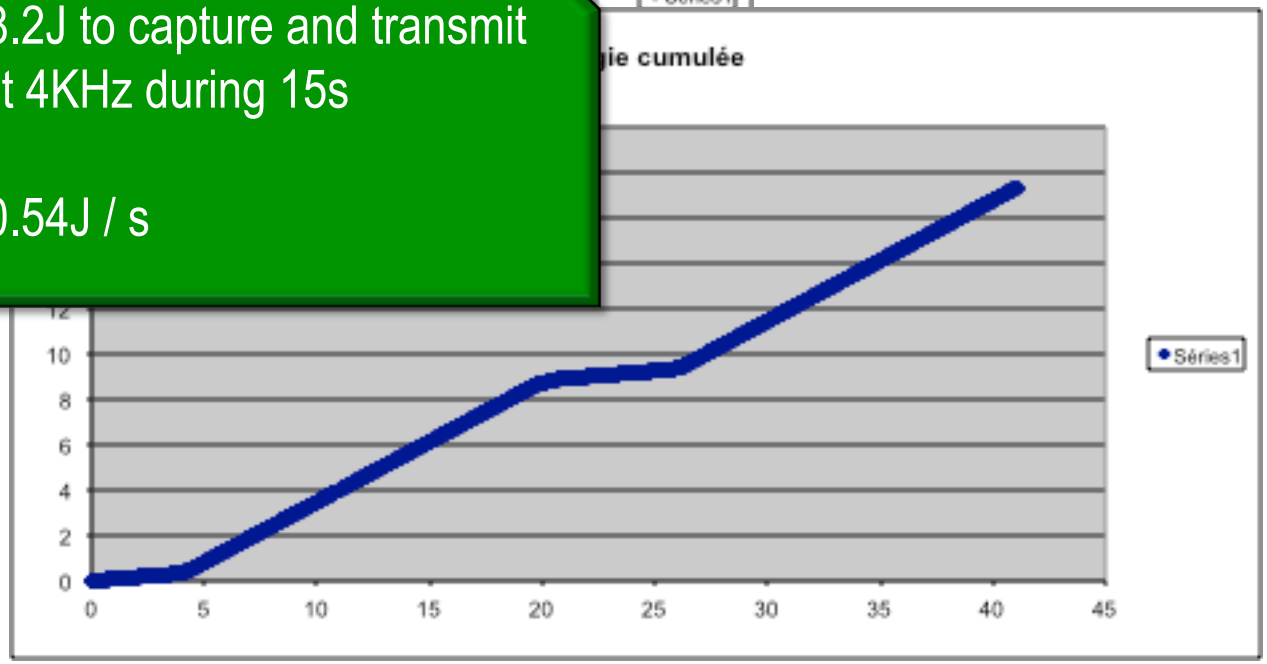
Energy consumption (1)



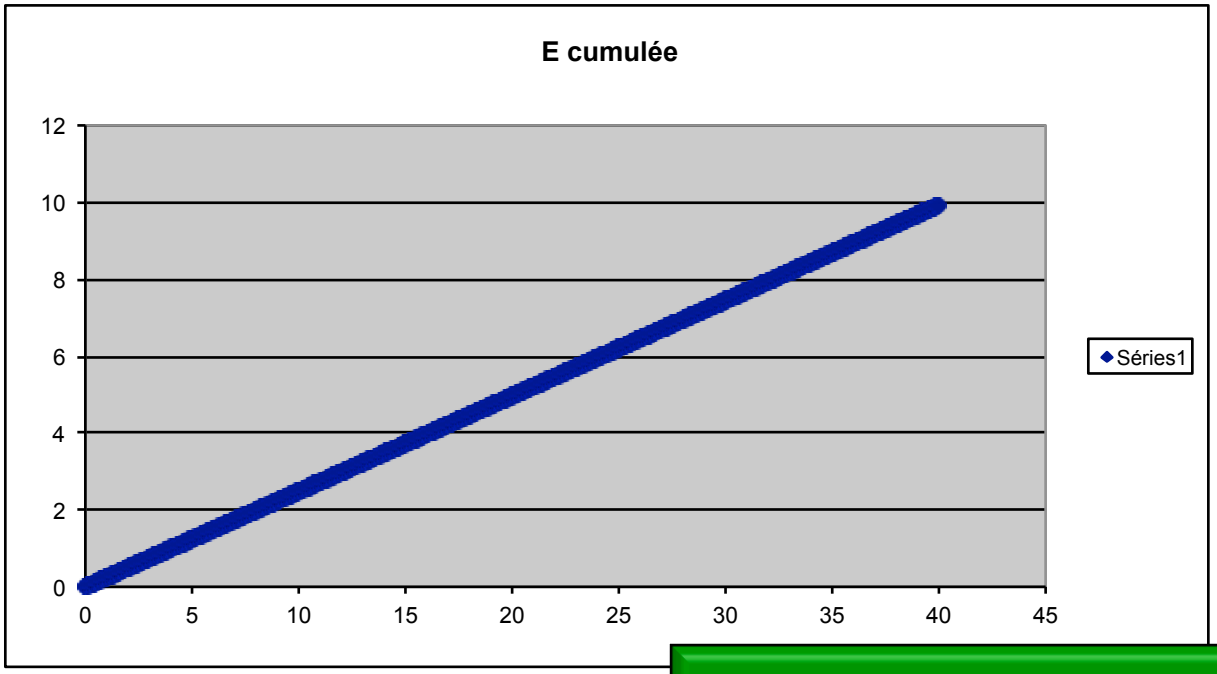


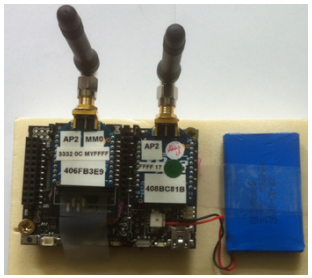
About 8.2J to capture and transmit audio at 4KHz during 15s

About 0.54J / s



Energy consumption (2)





Energy to relay 100 packets of size 30 bytes: about 10J

About 0.1J / packet


EAR-IT
the sounds of smart environment
SEVENTH FRAMEWORK PROGRAMME
Thank you
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