EAR-IT

the sounds of smart environment

Benchmarking Low-Resource Device Test-Beds for Real-Time Acoustic Data

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TridentCom, Guangzhou, China. May 5-7, 2014

Forewords

- Philippe Cousin from EGM is co-leading the EU-China Future Internet common Activities and Opportunities (ECIAO) Support Action in FP7-ICT-2013-10

EU-China FIRE

- Strengthen EU-China joint research efforts on the Future Internet by **developing interoperable solutions and common standards**
- **Reinforce academic and industrial cooperation** on Future Internet experimental research, through a better networking between European and Chinese actors
- Exchange **good practices for IPv6** deployment and support the creation of interconnected IPv6 pilots between Europe and China
- Build a **partnership between European and Chinese organis**
to foster cooperation in the domain of Future Internet research experimentation and IPv6.

- Please visit http://www.euchina-fire.eu and fill-in the survey to help us know you

EU-China FIRE survey

Take a short survey on EU-China cooperation on future Internet and contribute to the EU-China FIRE project!

1. How important is EU-China cooperation on Future internet?

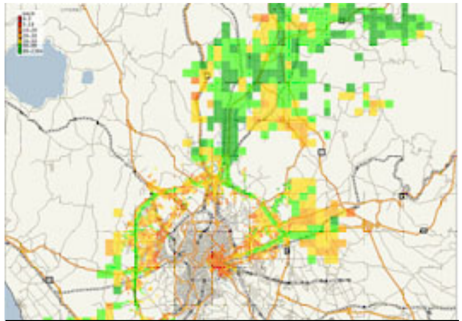
Not Important	Somehow important	Quite important	Rather important	Very important
○	○	○	○	○

2. What are in your opinion the main benefits of EU-China cooperation on Future Internet?

- ☐ Moving towards global standards
- ☐ Promotion of common topics of interest
- ☐ Stronger research cooperation
- ☐ Exchange of best practices

Other (please specify)

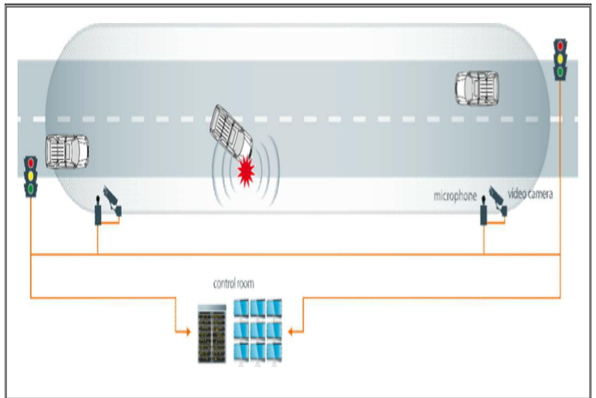
Exploiting Acoustic data



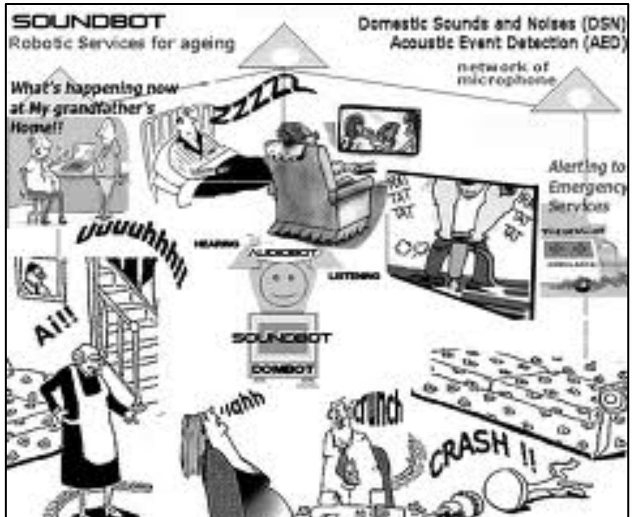
Sound Mappings

Traffic Management

Energy-efficiency



Traffic Accidents



Ambient Assisted Living

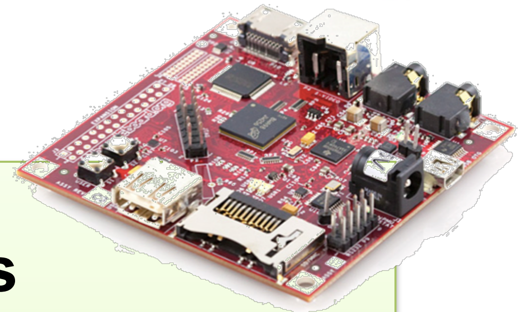
(Audio) Surveillance

Use of Complementary Technologies

www.ear-it.eu

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

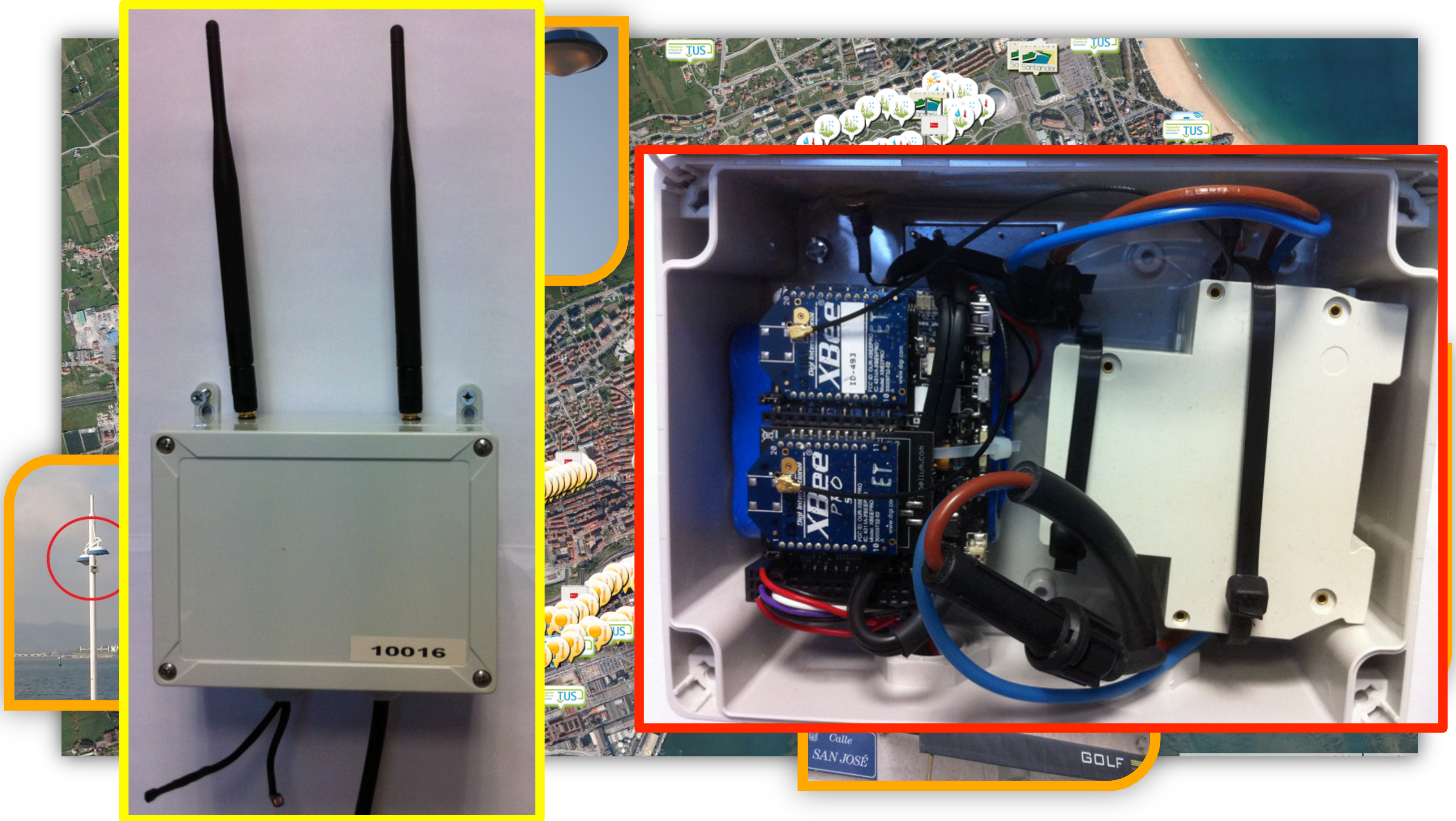
SmartSantander test-bed

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 test-bed
Santander’s sensor network deployment



the sounds of smart environments

SmartSantander IoT node

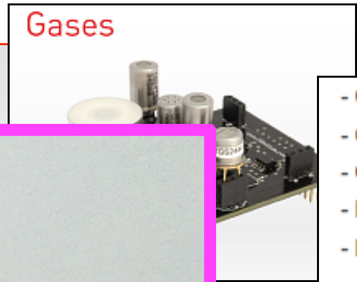
libelium
comunicaciones inalámbricas distribuidas

ATmega1281 mic

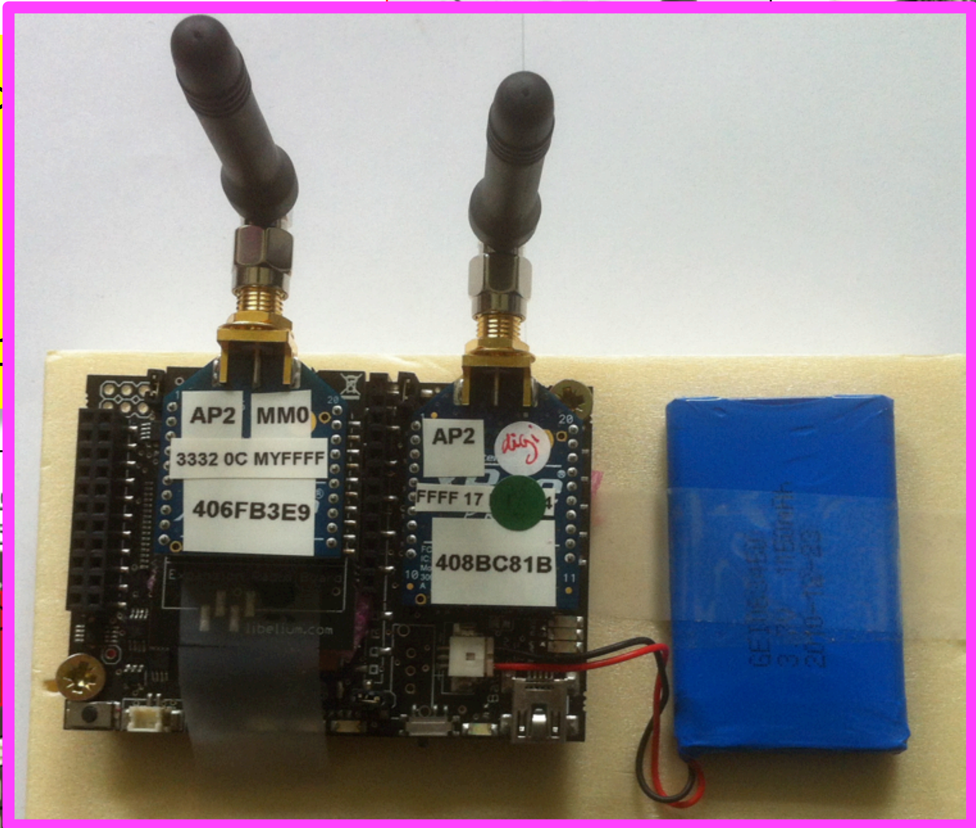
8Mhz, 4K RAM &

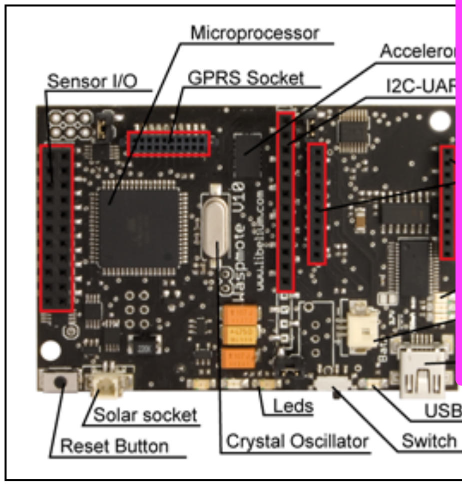
2.4GHz IEEE 802

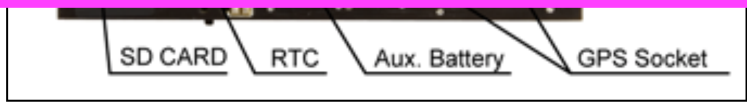
Libelium API v03

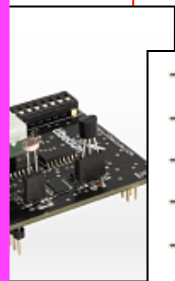


- Carbon Monoxide – CO
- Carbon Dioxide – CO2
- Oxygen – O2
- Methane – CH4
- Hydrogen – H2
- Ammonia – NH3
- Isobutane – C4H10
- Ethanol – CH3CH2OH
- Toluene – C6H5CH3
- Hydrogen Sulfide – H2S
- Nitrogen Dioxide – NO2
- Temperature
- Humidity







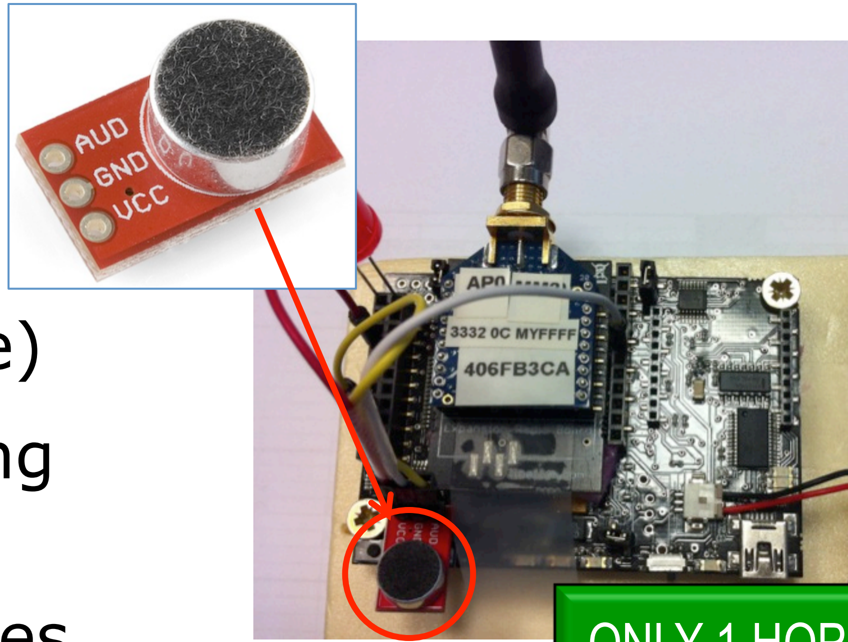


- Pressure/Weight
- Bend
- Vibration
- Impact
- Hall Effect
- Tilt
- Temperature (+/-)
- Liquid Presence
- Liquid Level
- Luminosity
- Presence (PIR)
- Stretch

IMAGES ARE FROM LIBELIUM COMPANY

WaspMote+XBee in raw mode

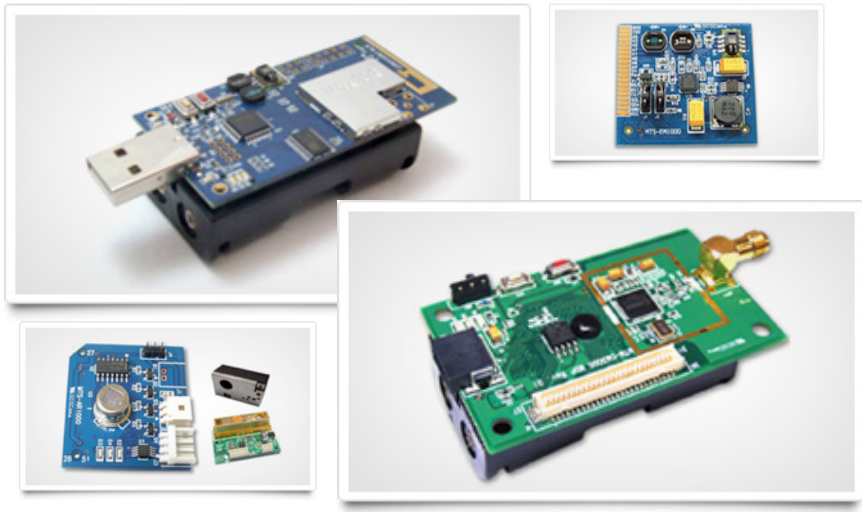
- Electret mic with amplifier
- XBee in AP0 mode (transparent mode)
- 8-bit 4Khz sampling gives 32000bps
- 8Khz sampling gives 64000bps, requires custom API



ONLY 1 HOP!

100 8-bit samples (12.5ms or 25ms)

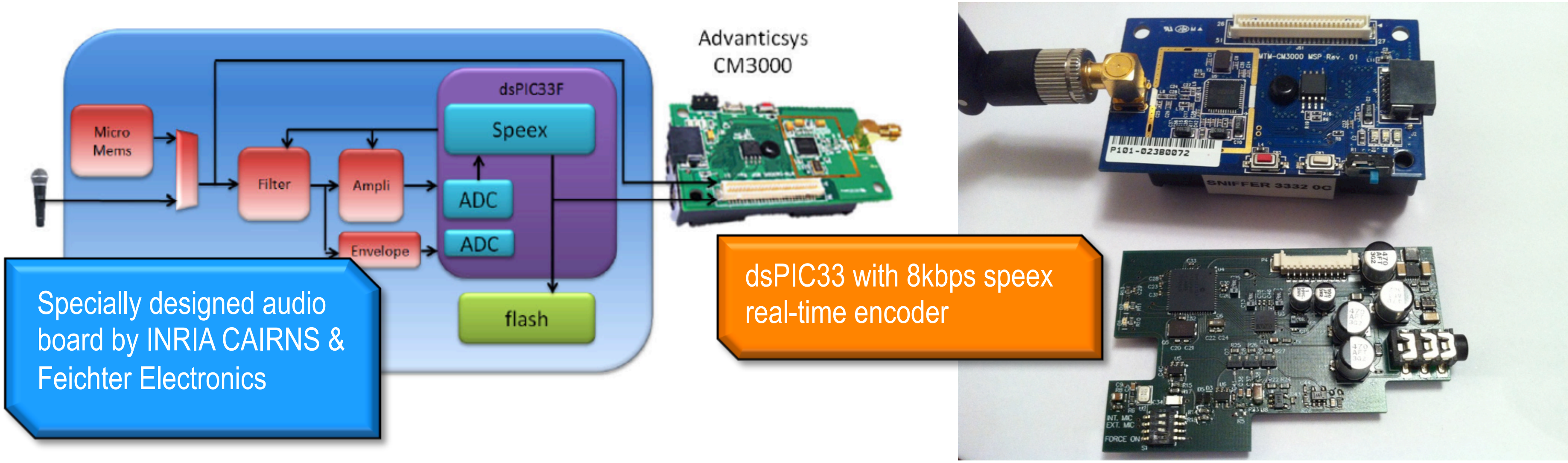
HobNet test-bed at UNIGE



- MSP430F1611 microcontroller
- 8Mhz, 48K flash, 10K RAM
- 2.4GHz IEEE 802.15.4 CC2420
- Programmed under TinyOS
- Similar to TelosB

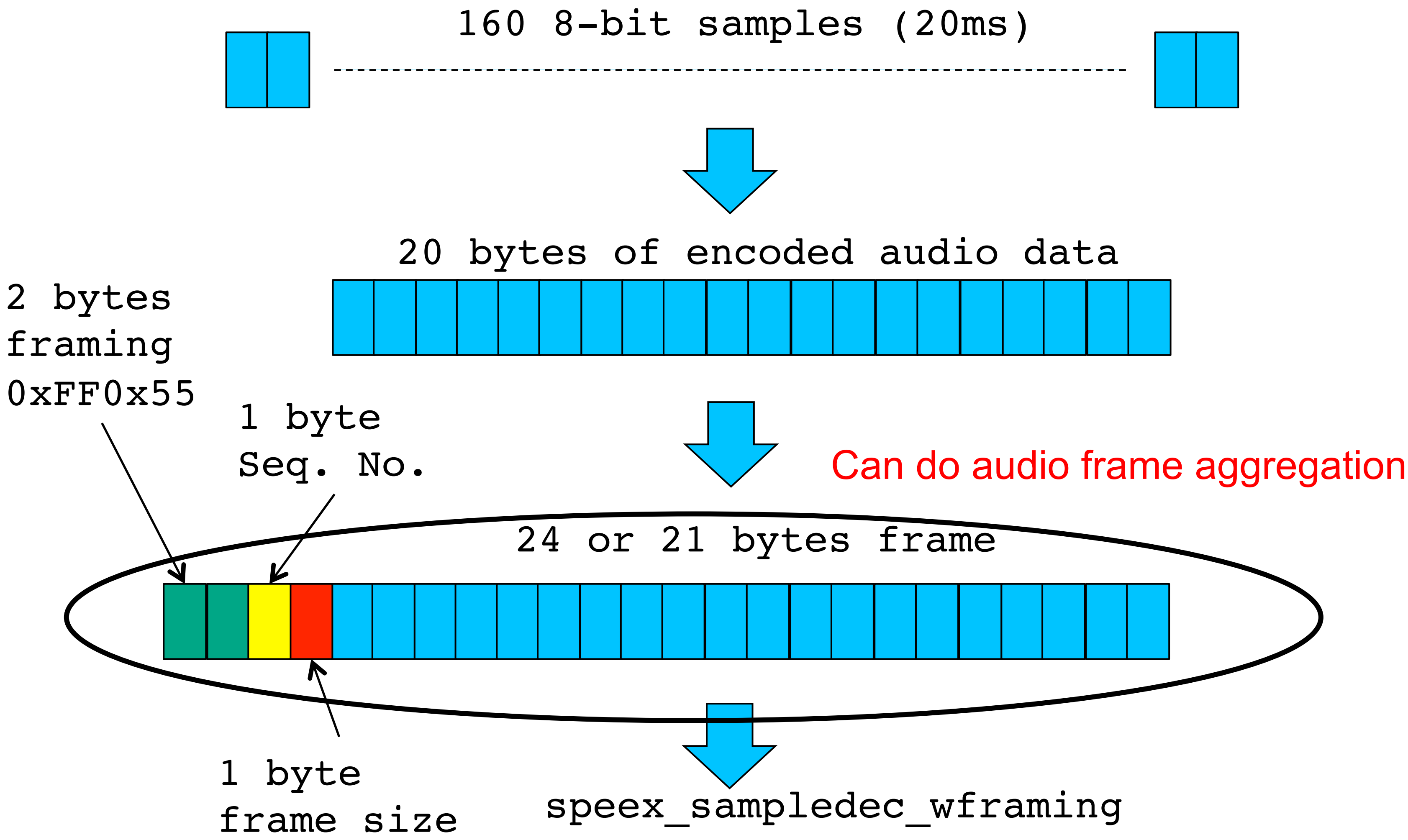
Development of audio board

- Use dedicated audio board for sampling/storing/encoding at 8kbps



- Allows for multi-hop, encoded audio streaming scenarios

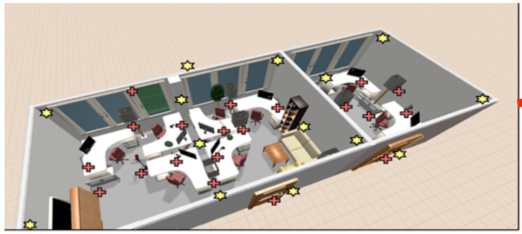
speex at 8kbps

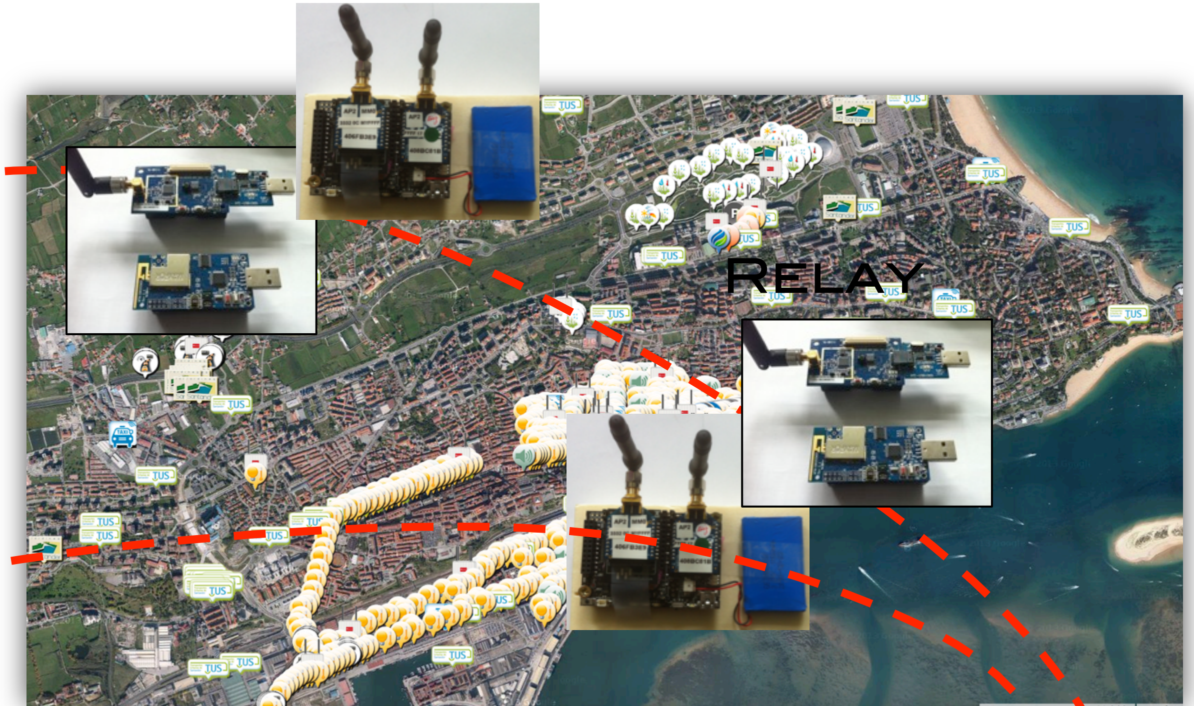


Summary of audio constraints

Codec	Minimum sending rate
Raw 4KHz 8KHz	 100 bytes every 25ms 100 bytes every 12.5ms
Speex 8000bps A1 A2 A3 A4	 24 bytes every 20ms 48 bytes every 40ms 72 bytes every 60ms 96 bytes every 80ms

To what extend audio traffic can be supported?





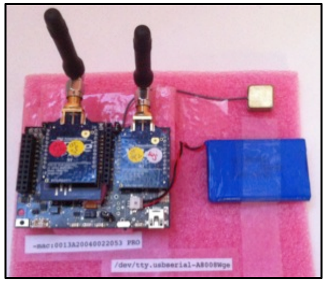
PLAY/STORE RECEIVED AUDIO DATA

Performance indicators

- Need to define and determine performance indicators
  - IoT node performance indicators
  - Network performance indicators
- Quality and usability indicators are also necessary
  - Audio quality indicators
  - Energy indicators

Benchmark methodology (1)

1. Determine IoT node performance, lab tests
    - Upper bounds performances for sending and receiving
    - Upper bounds performances for relaying



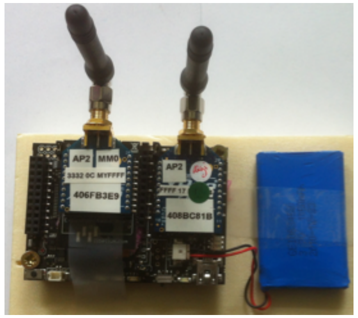
Traffic Generators
Advanced timing

2. Determine sensitivity of codec against packet losses, with various packet size, lab tests
    - audio benchmarking, apply controlled packet error rates
    - MOS-LQO computation

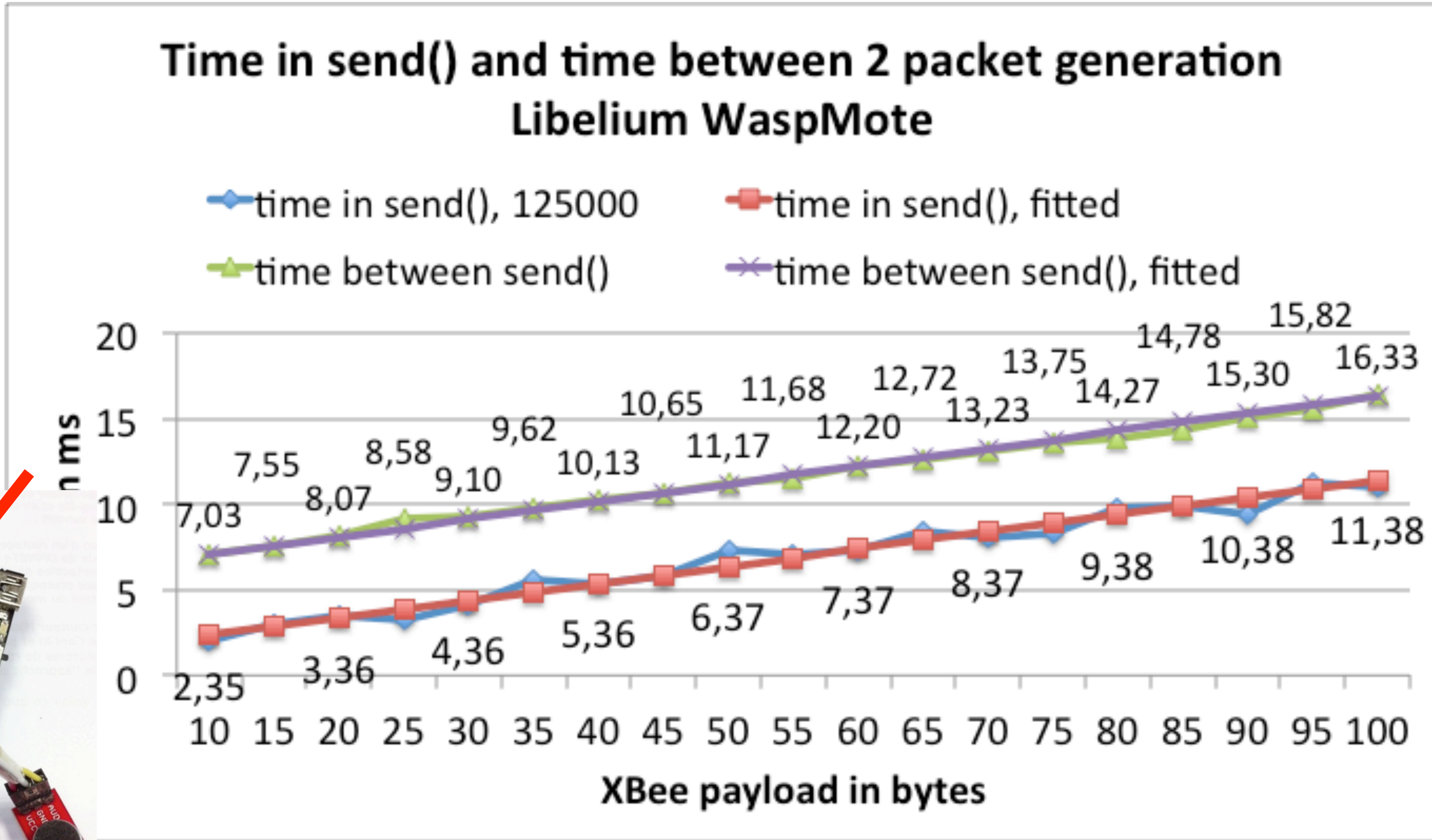
Benchmark methodology (2)

3. Determine channel condition in selected areas, in-situ tests
    - Synthetic workload to determine packet loss rates
4. Determine latencies and jitter in multi-hop scenario, lab tests & in-situ tests
    - Controlled transmission of packetized/encoded audio
    - Measure latencies and jitter at intermediate nodes
5. Determine energy consumption
    - When idle
    - When capturing and sending audio
    - When relaying

IoT node sending performance

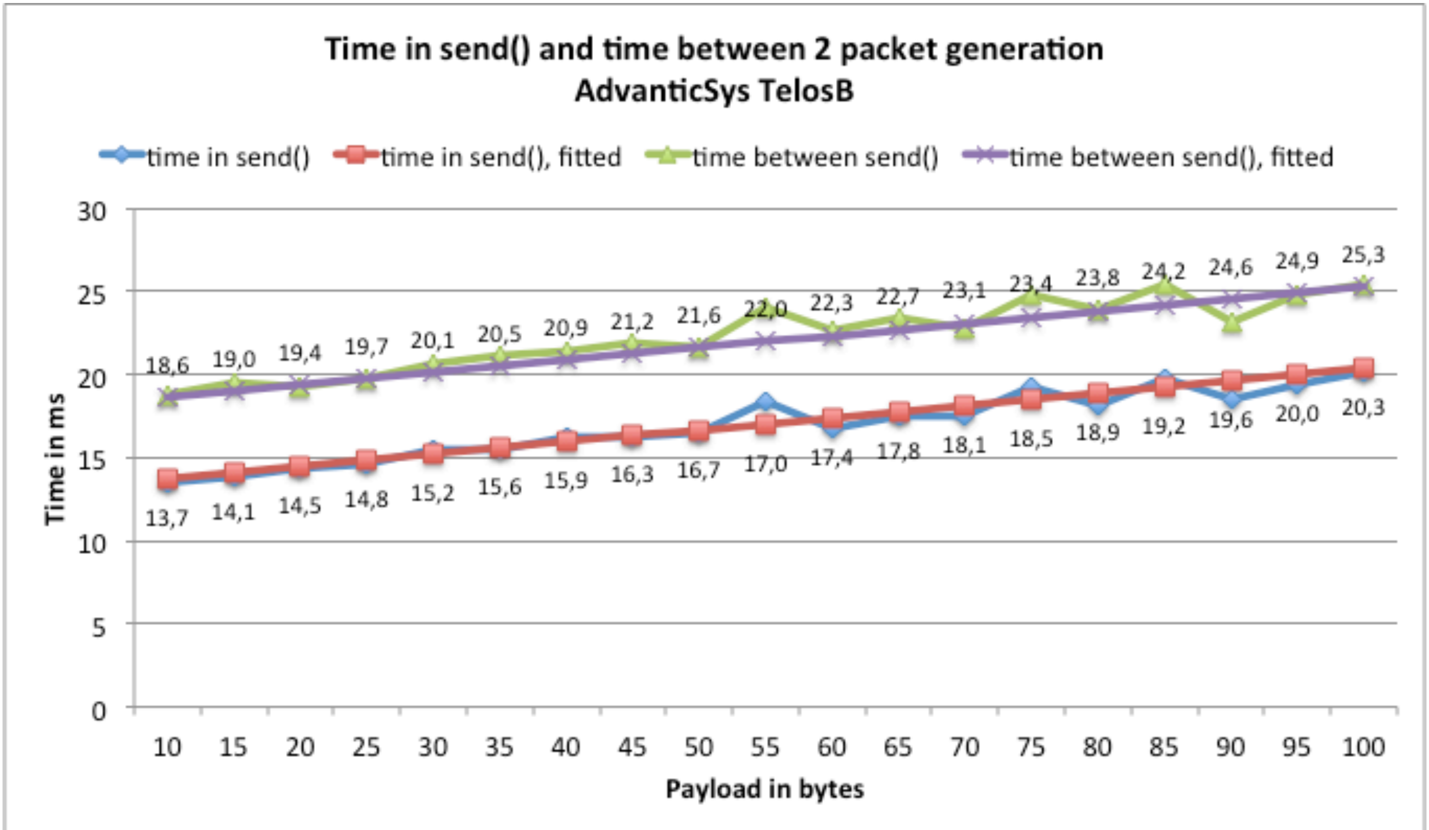


Libelium WaspMote

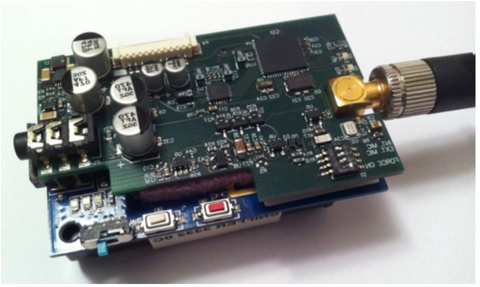


No capture and transmission at the same time if using only mote ucontroller!

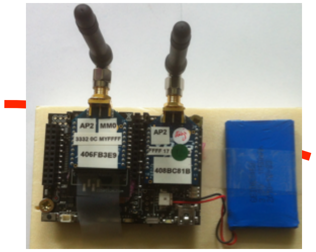
IoT node sending performance



Multi-hop audio

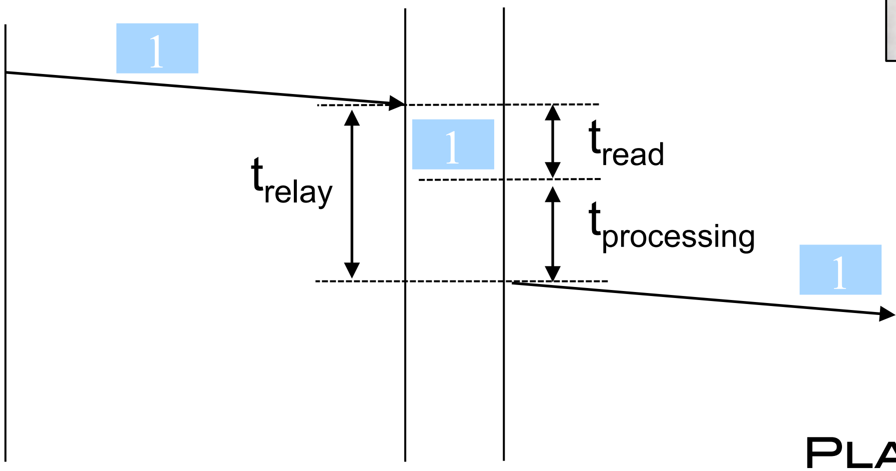


Sends audio data



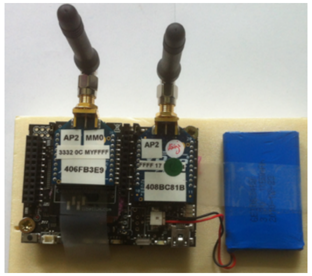
Relay

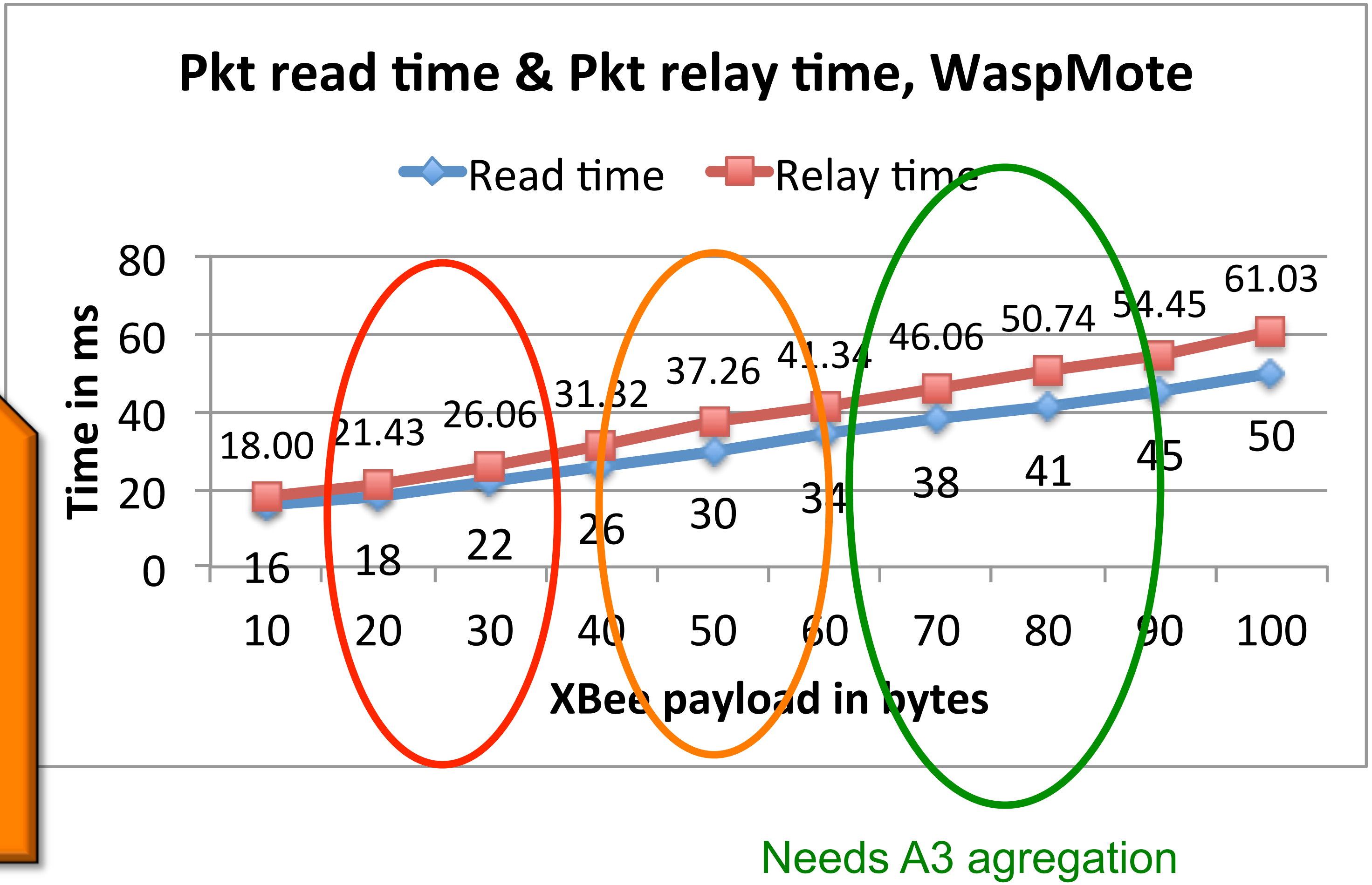
Relay



Play received file

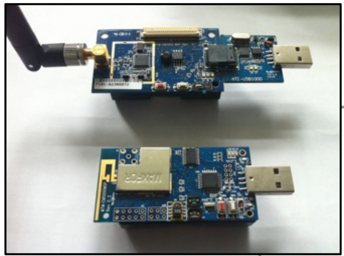
Relay node performances

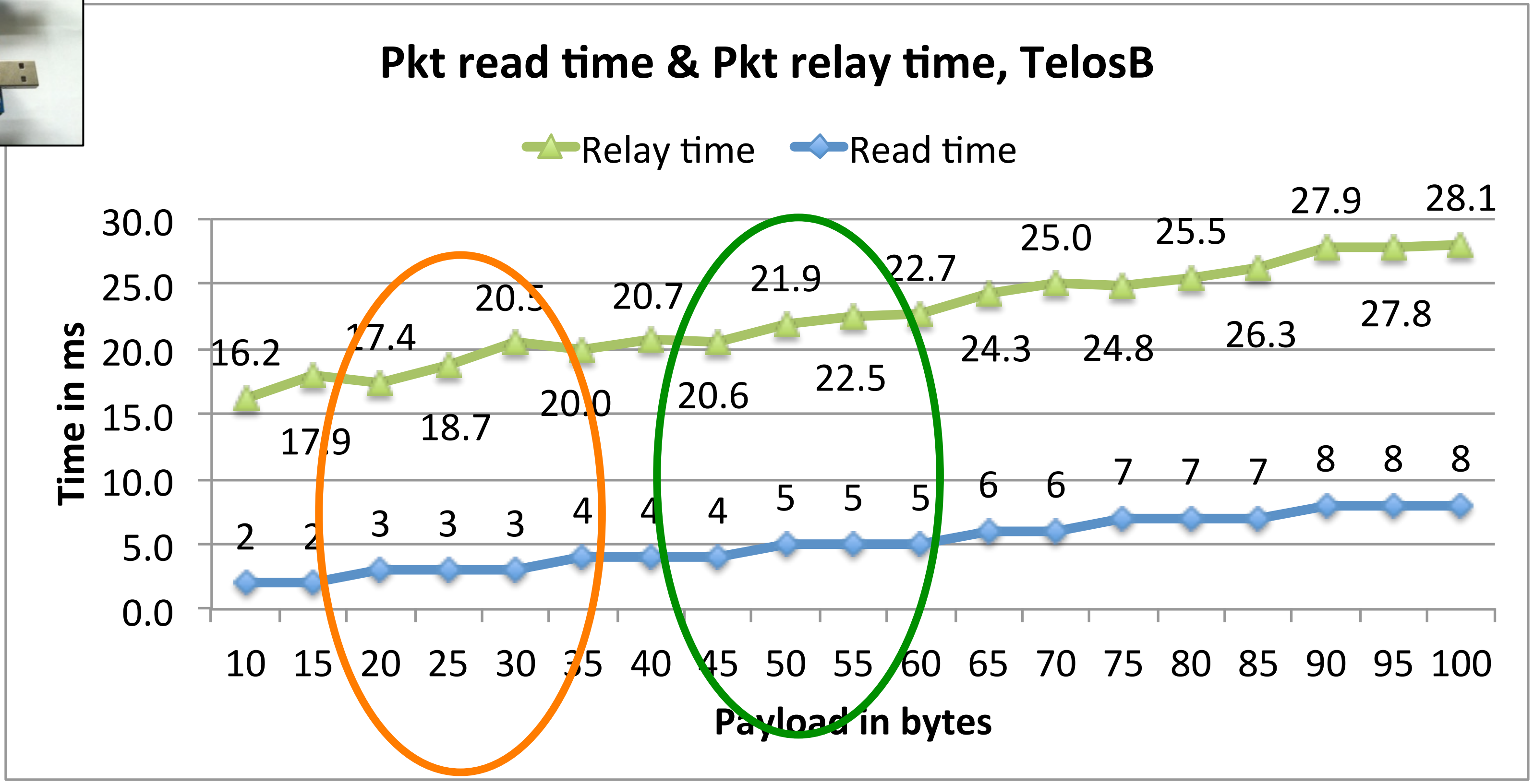




SPEEX codec at 8kbps requires to be able to relay a 25-byte packet every 20ms

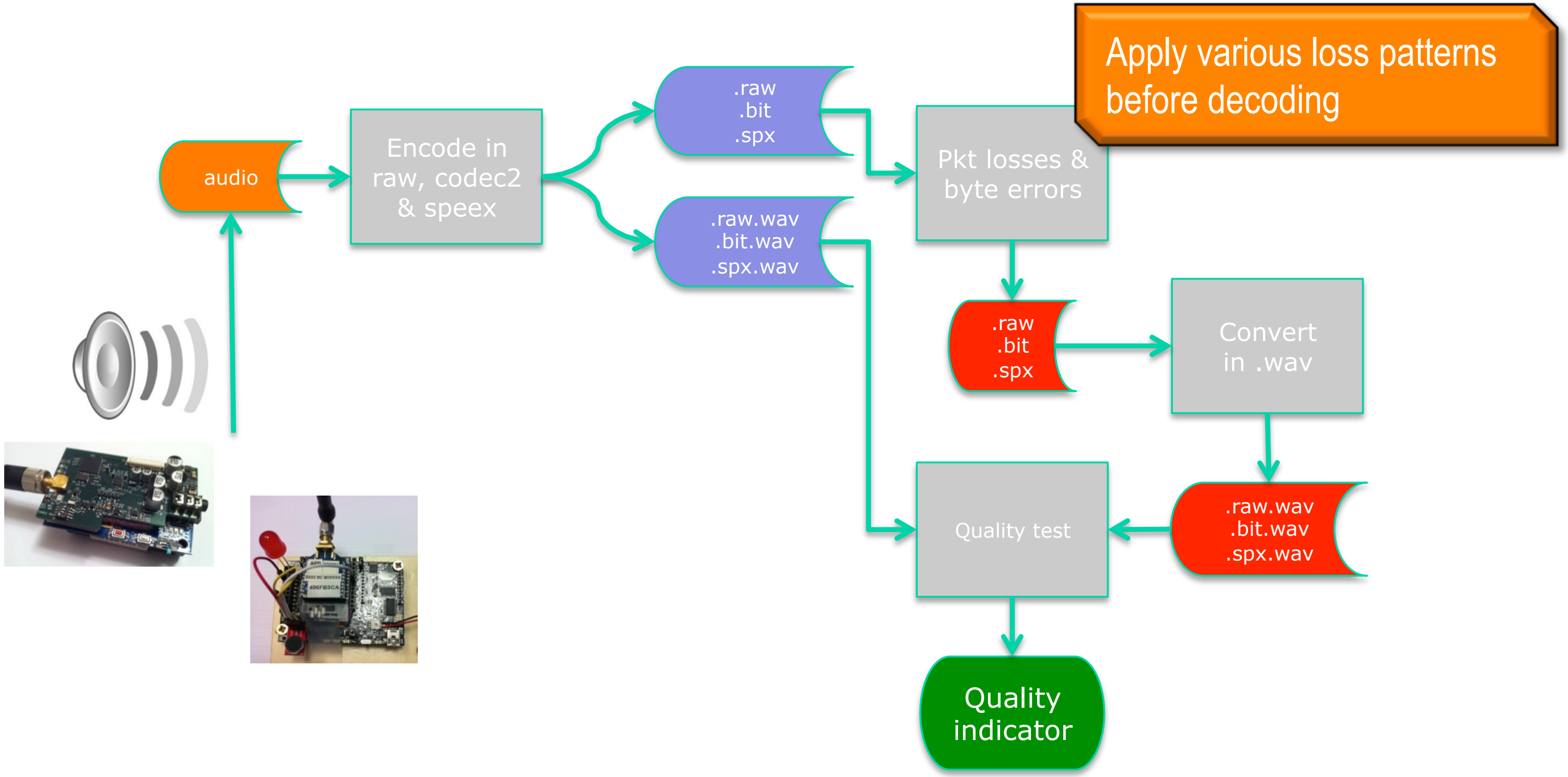
Relay node performances





Needs A2 agregation

Sensitivity of codecs



Audio quality: PESQ & MOS (1)

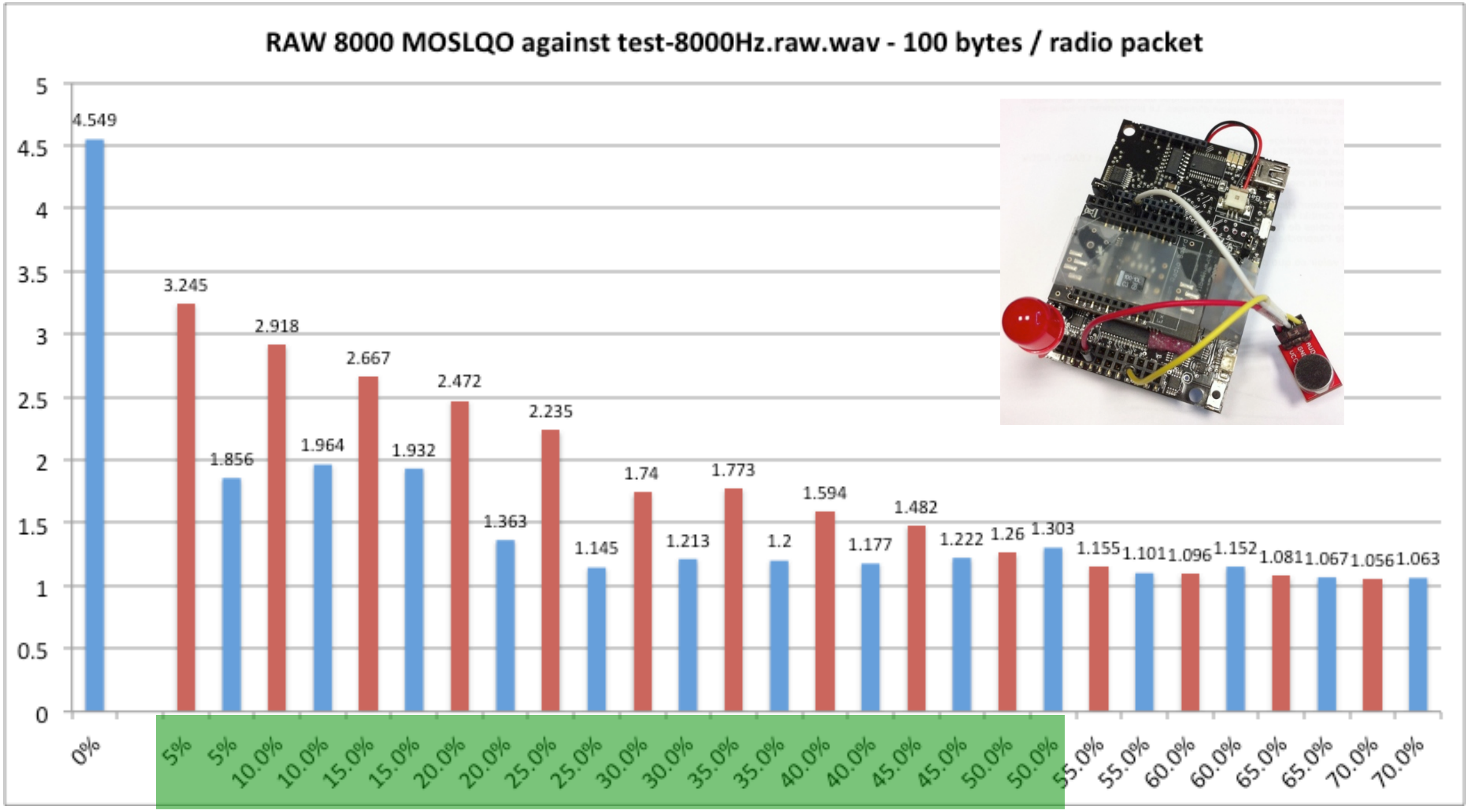
- ITU-T P.862 Perceptual evaluation of speech quality (PESQ): An objective method for end-to-end speech quality assessment of narrow-band telephone networks and speech codecs.
- We can use ITU-T PESQ tool to determine the MOS value for loss-free encoded audio (codec2, speex, …). MOS-LQO values greater than 2.6 are considered good.

Audio quality: PESQ & MOS (2)

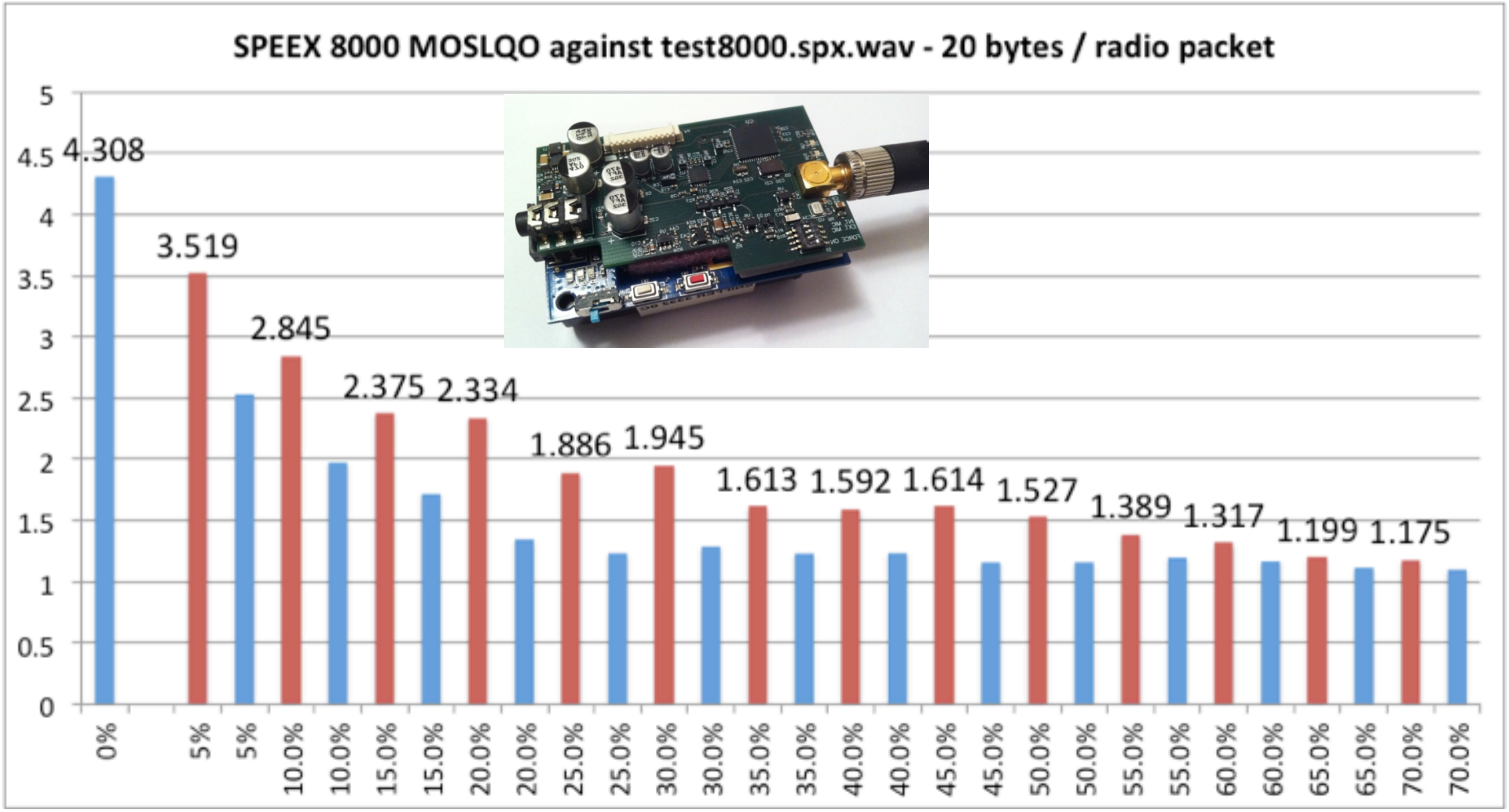
- 5=Excellent, 4=Good, 3=Fair, 2=Poor, 1=Bad

REFERENCE	DEGRADED	PESQMOS	MOSLQO	SAMPLE_FREQ
test.wav	test.wav	4.500	4.549	8000
test.wav	test4000Hz.raw.wav	0.769	1.115	4000
test.wav	test8000Hz.raw.wav	4.5	4.549	8000
test.wav	test2150.spx.wav	2.757	2.472	8000
test.wav	test5950.spx.wav	3.428	3.454	8000
test.wav	test8000.spx.wav	3.652	3.757	8000
test.wav	test11000.spx.wav	3.941	4.093	8000
test.wav	test13000.spx.wav	3.941	4.093	8000
test.wav	test15000.spx.wav	4.085	4.235	8000

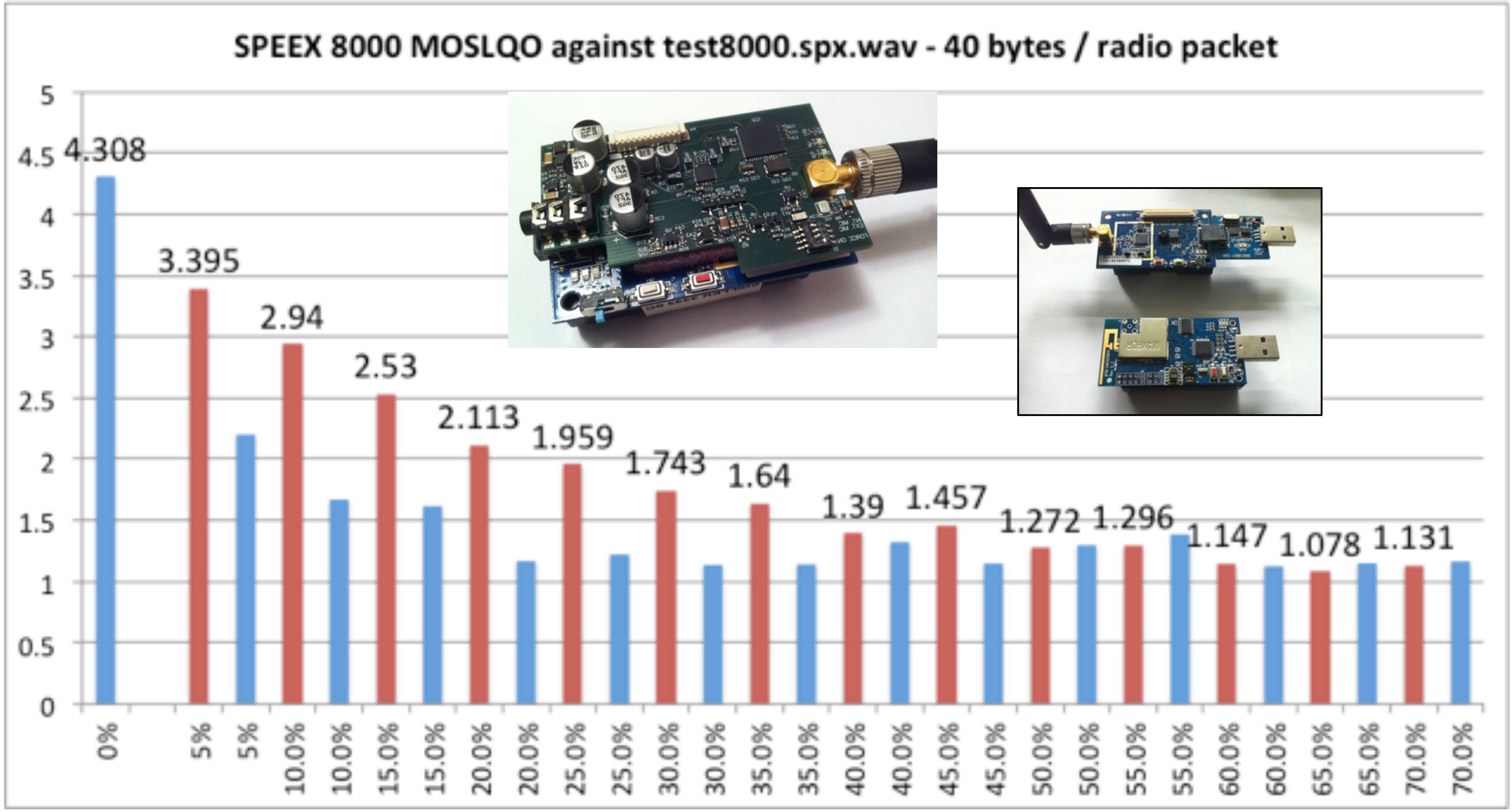
Test8000.raw



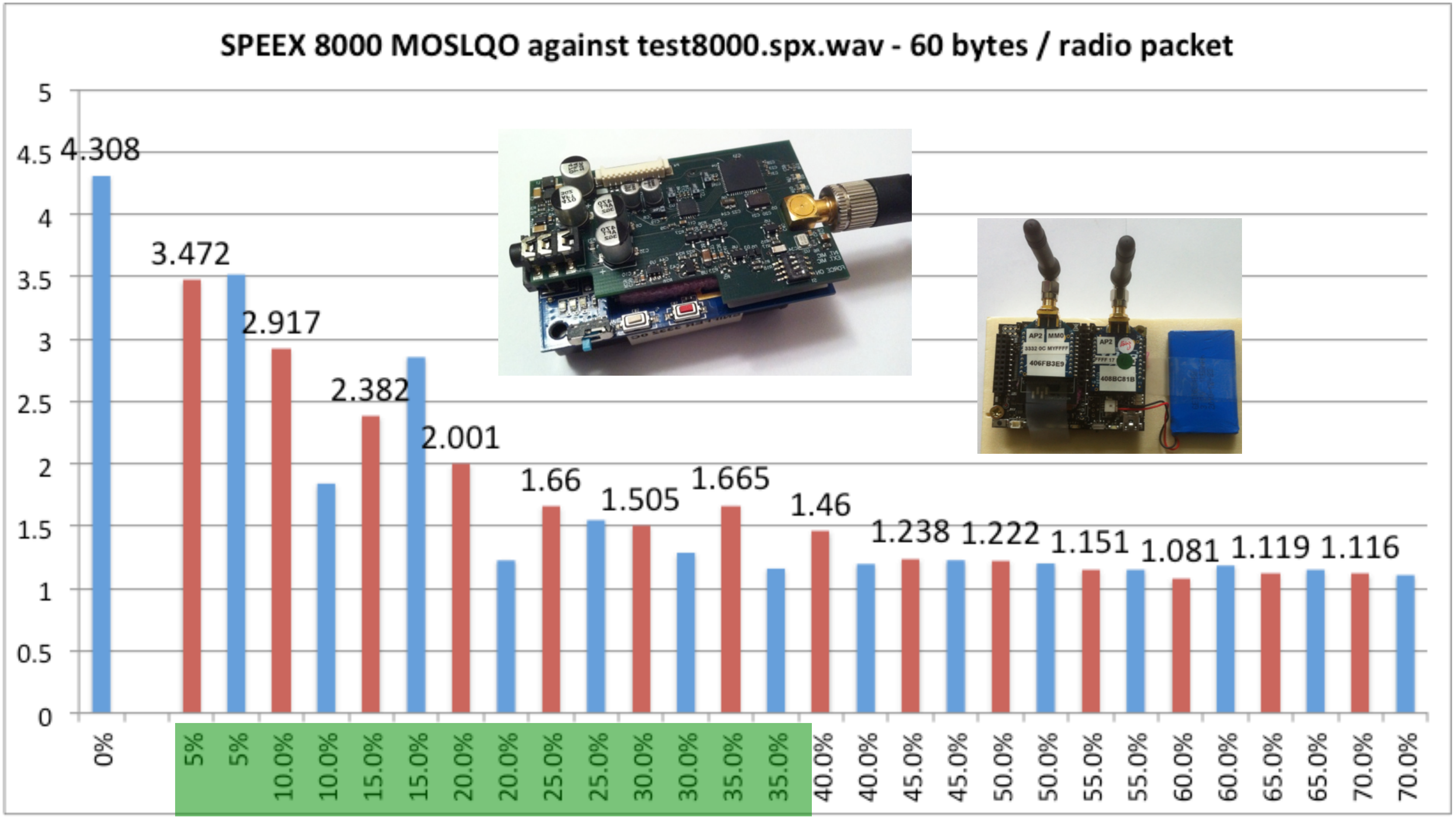
Test8000.spx, 20B/pkt (A1)



Test800.spx, 40B/pkt (A2)

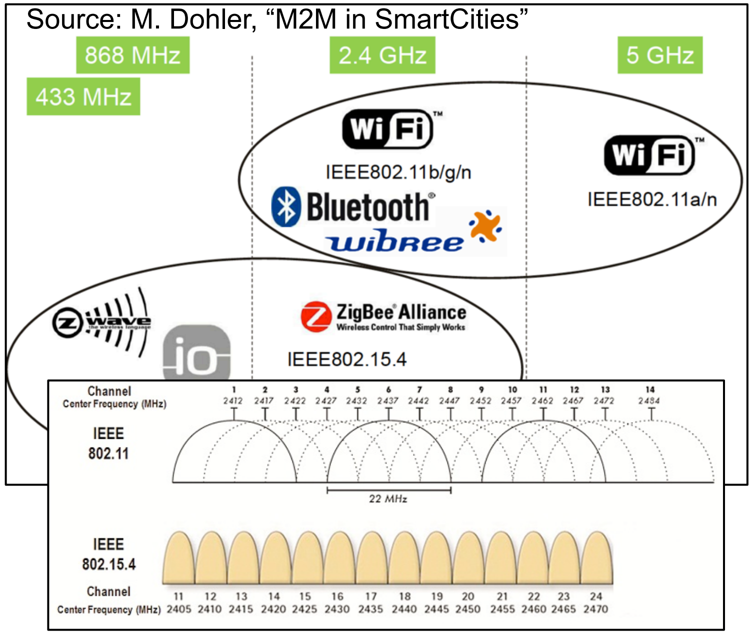


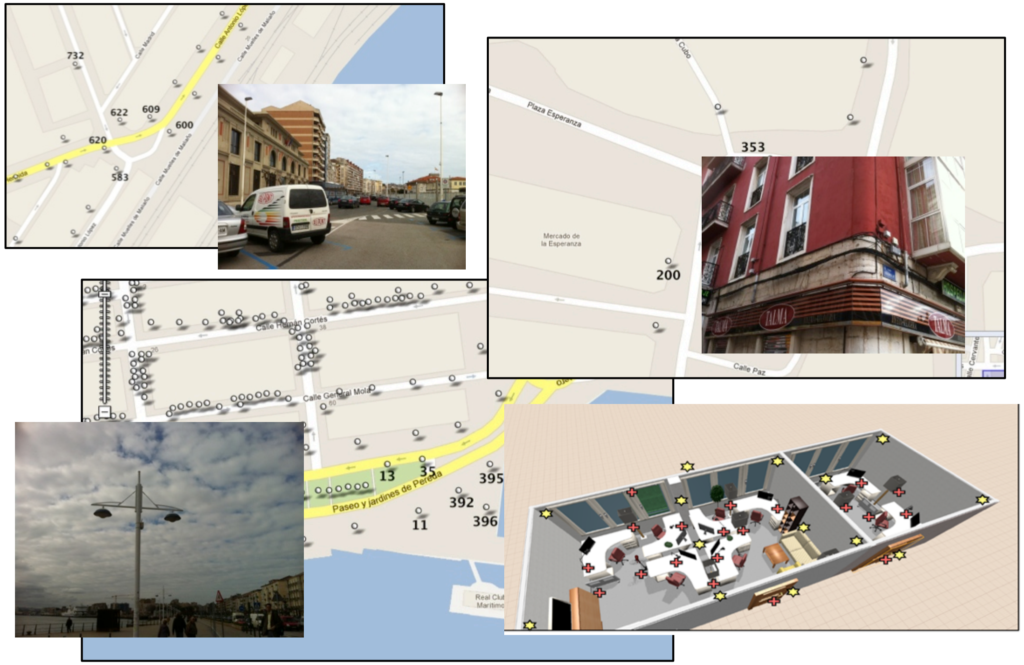
Test800.spx, 60B/pkt (A3)



Channel condition in selected areas

IN-SITU TESTS





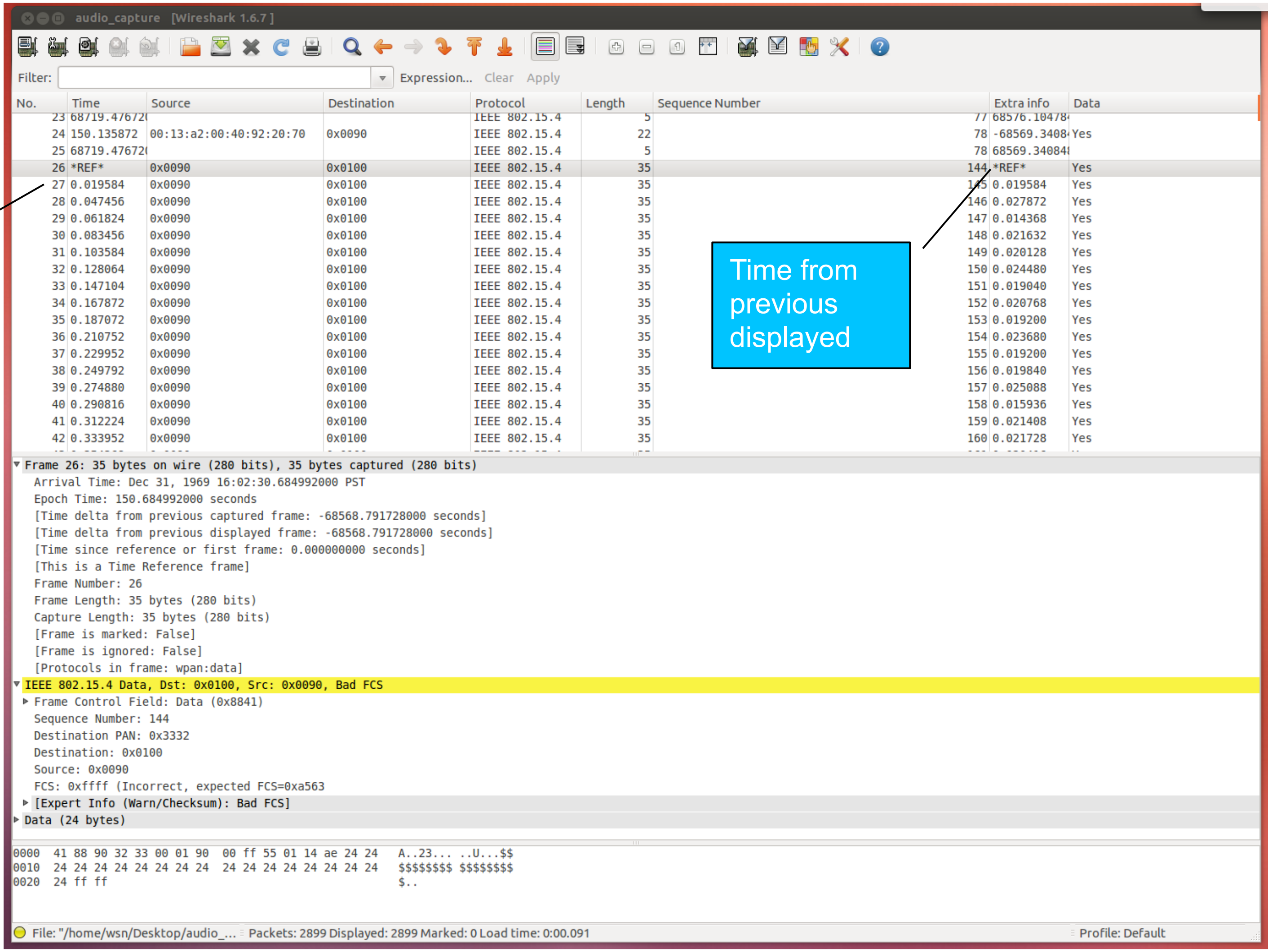
- Use representive locations in Santander & Geneva buildings
- Deploy IoT nodes traffic generators & sniffers
- Determine packet loss patterns and rates

Frame analysis

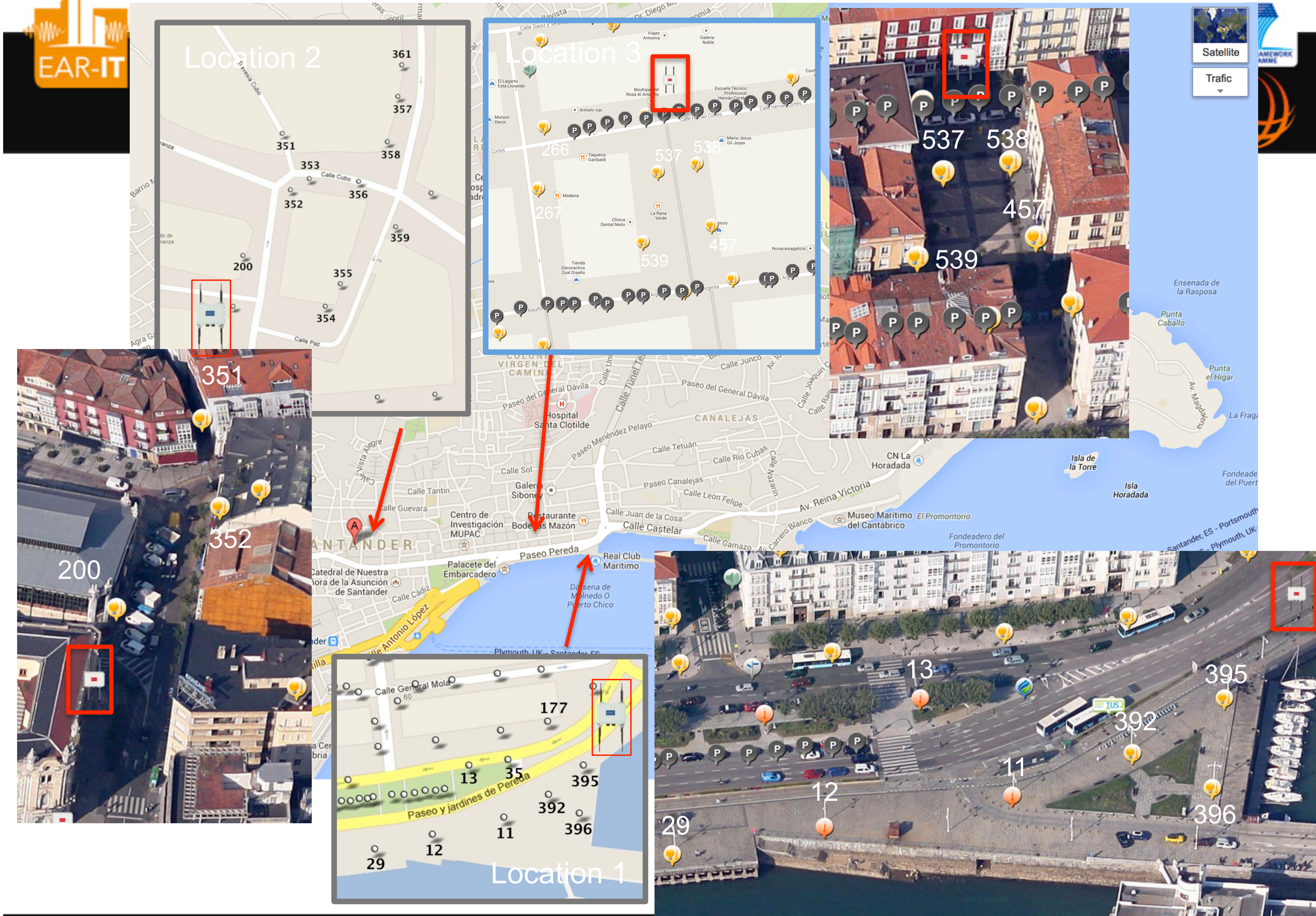
- Use `wireshark` as frame analysis tool
- AdvanticSys TelosB mote as promiscuous sniffer mote, connected to `wireshark` to display captured frames
- Frame reception time can be visualized for statistic collection
  - Transmission latencies
  - Frame jitter

Example: latency 1-hop

Time from reference time



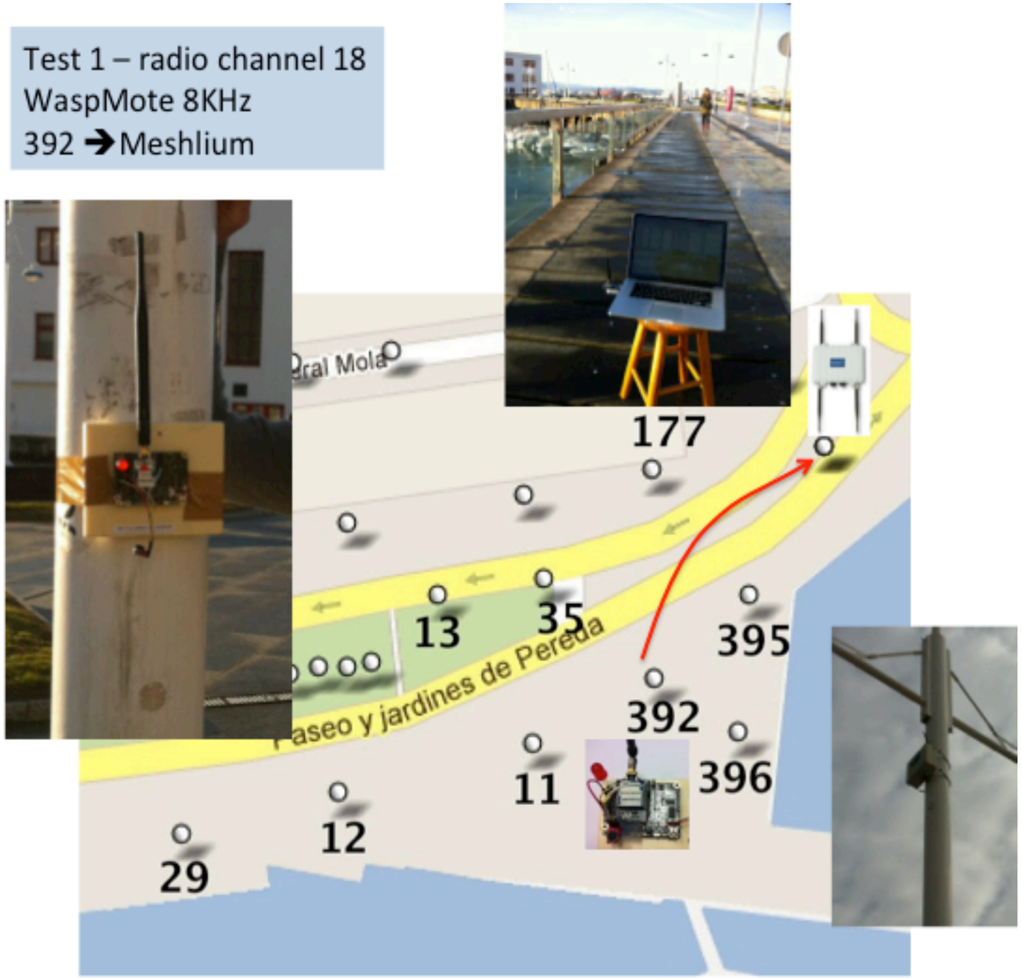
Time from previous displayed



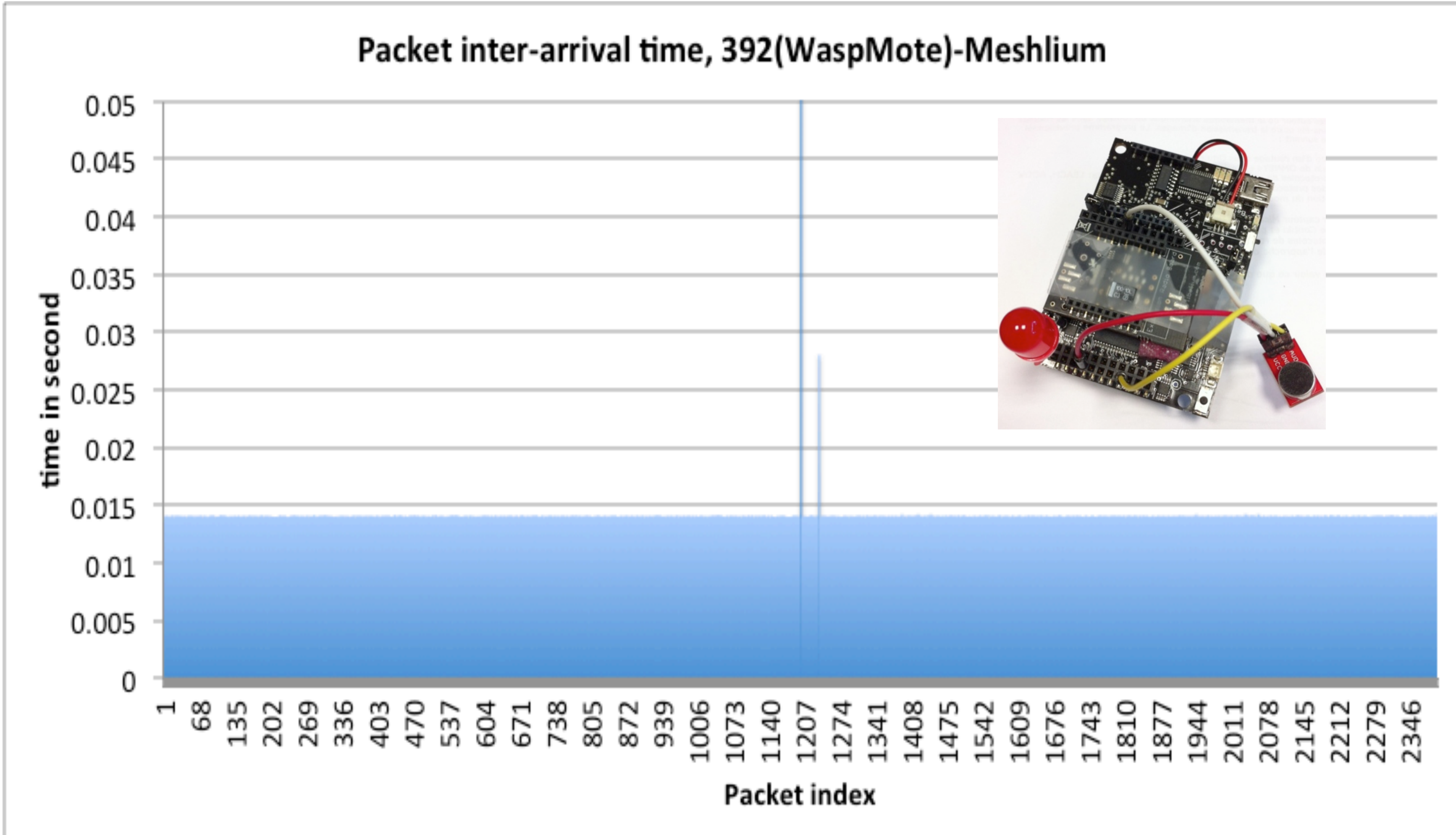
Location 2
361
357
351
358
353
Calle Cubo
356
352
359
200
355
354
Calle Paz
Location 3
266
537
538
267
539
457
537
538
457
539
351
352
200
Paseo del General Dávila
Hospital Santa Clotilde
CANALEJAS
Calle Tetuán
Calle Río Cubas
Paseo Canalejas
Calle León Felipe
Av. Reina Victoria
Calle Juan de la Cosa
Calle Castelar
Paseo Pereda
Real Club Marítimo
SANTANDER
Centro de Investigación MUPAC
Restaurante Bodegas Mazón
Palacete del Embarcadero
Catedral de Nuestra Señora de la Asunción de Santander
Museo Marítimo del Cantábrico
CN La Horadada
Isla de la Torre
Isla Horadada
Ensenada de la Rasposa
Punta Caballo
Punta el Higar
La Fraga
Satellite
Trafic
Calle General Mola
177
13
35
395
392
396
11
12
29
Paseo y jardines de Pereda
Location 1
13
395
392
11
12
29
396

1-hop audio in LoS

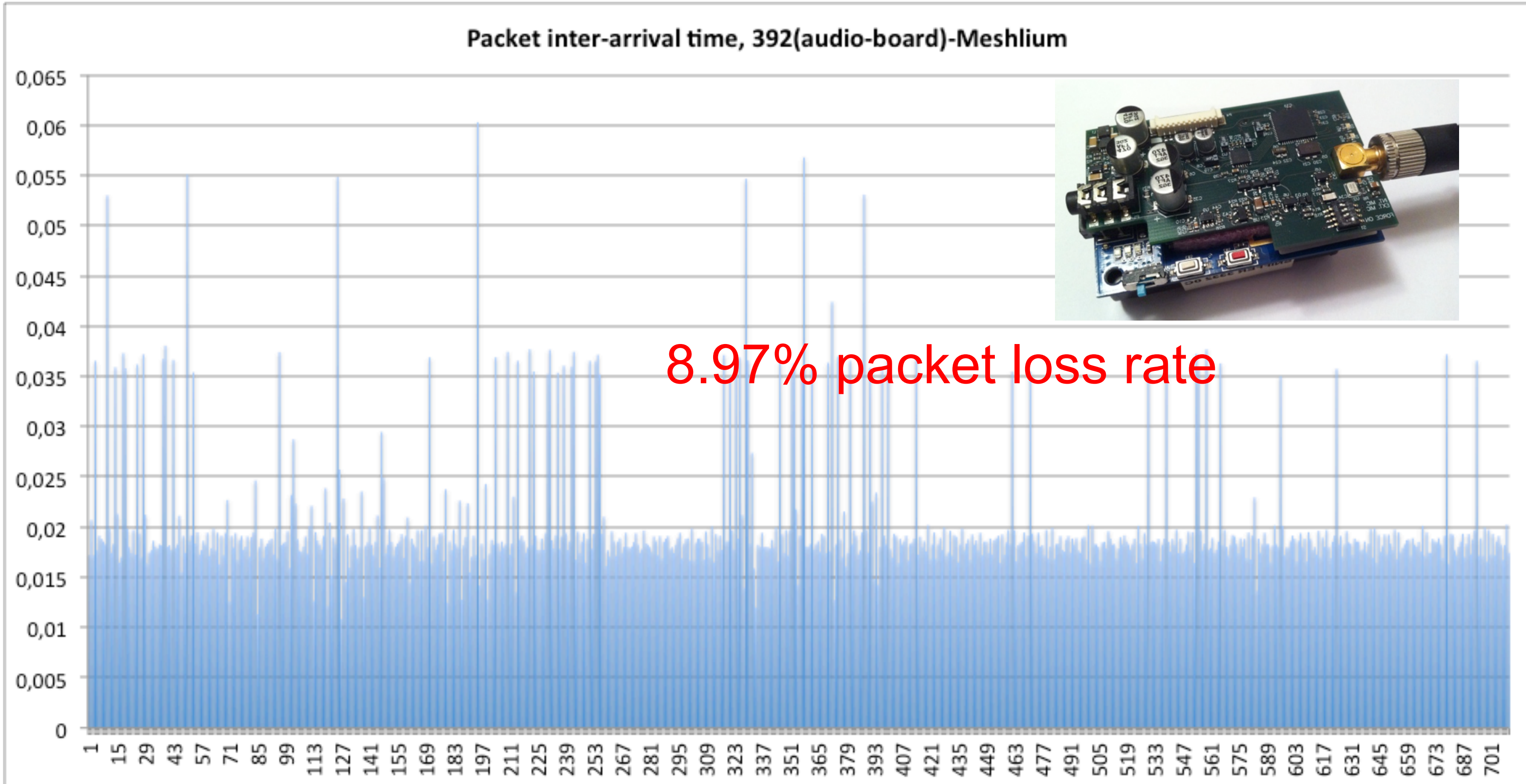
Test 1 – radio channel 18
WaspMote 8KHz
392 → Meshlium



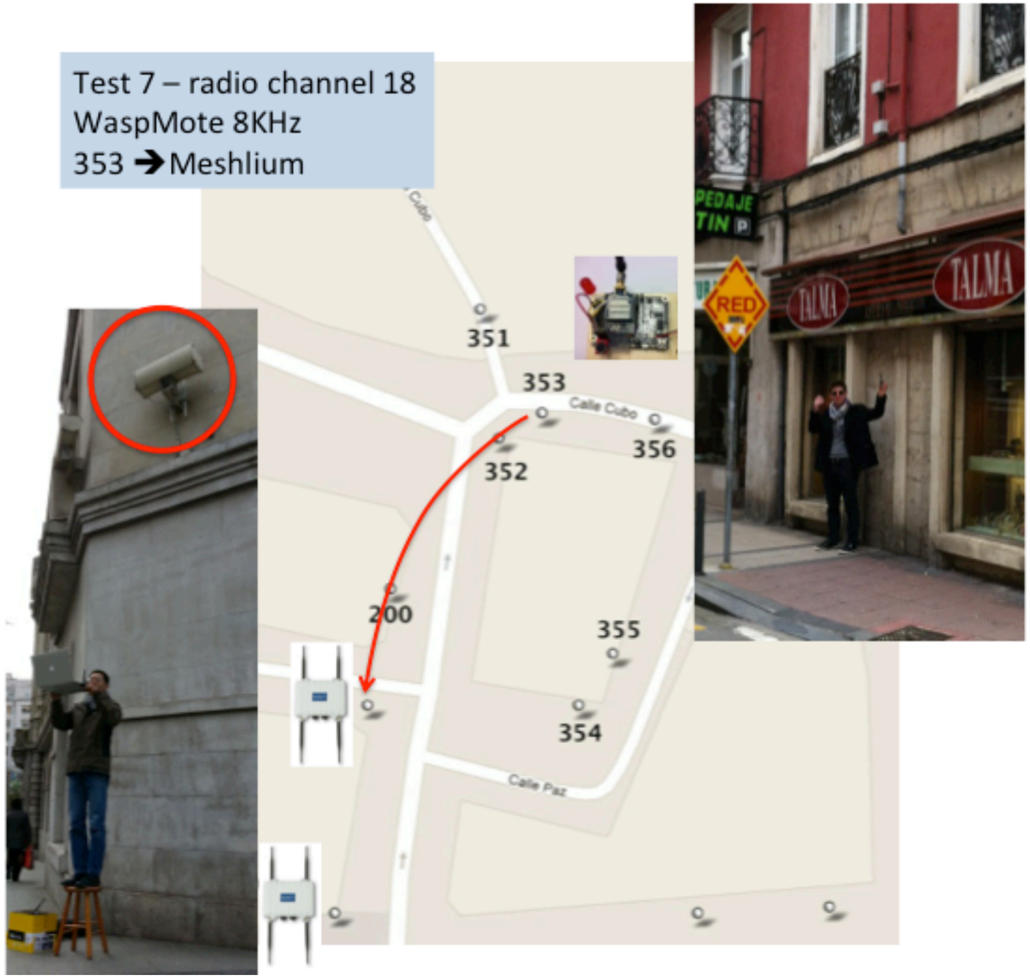
1-hop WaspMote audio



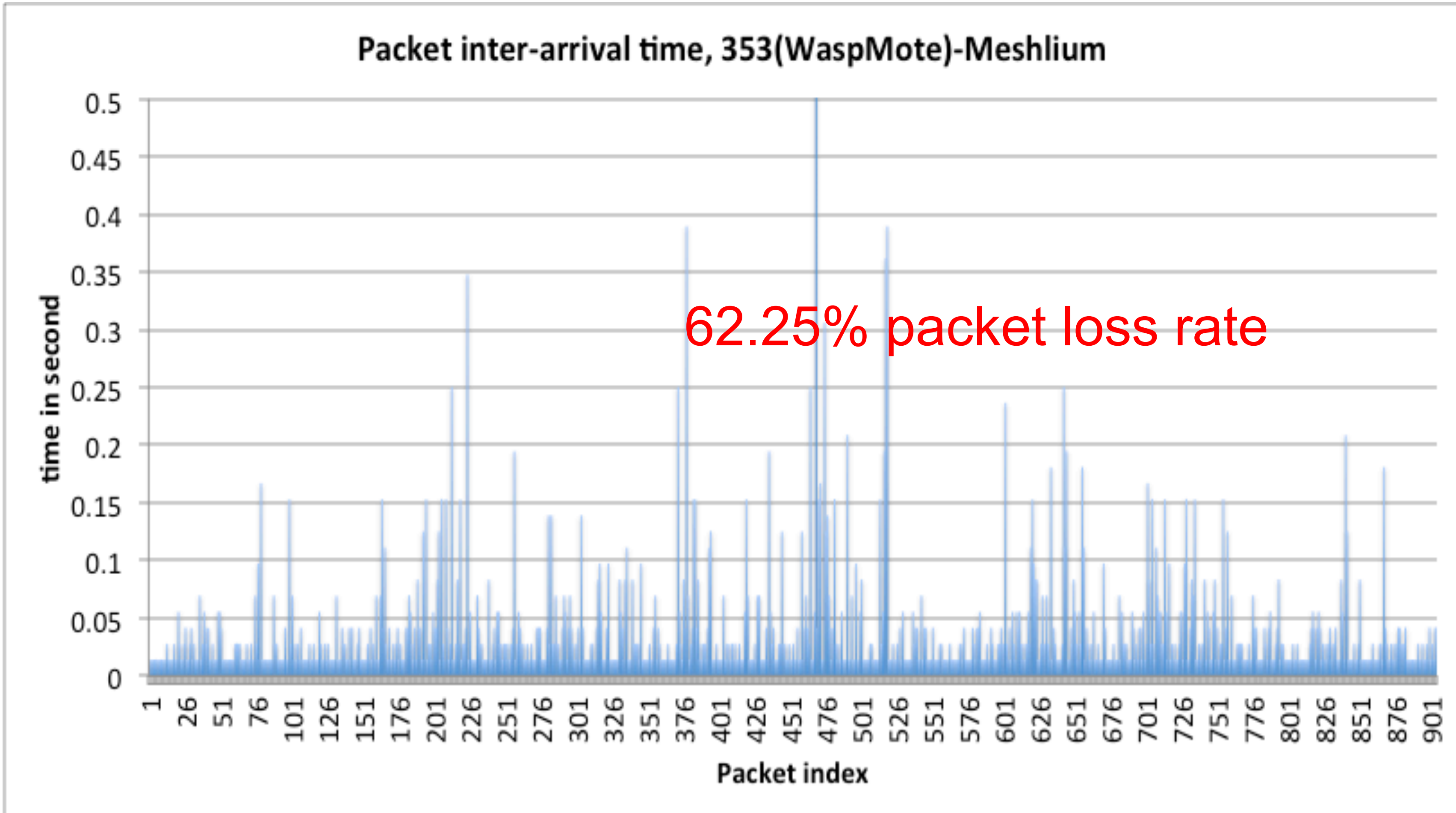
1-hop Advanticsys audio board



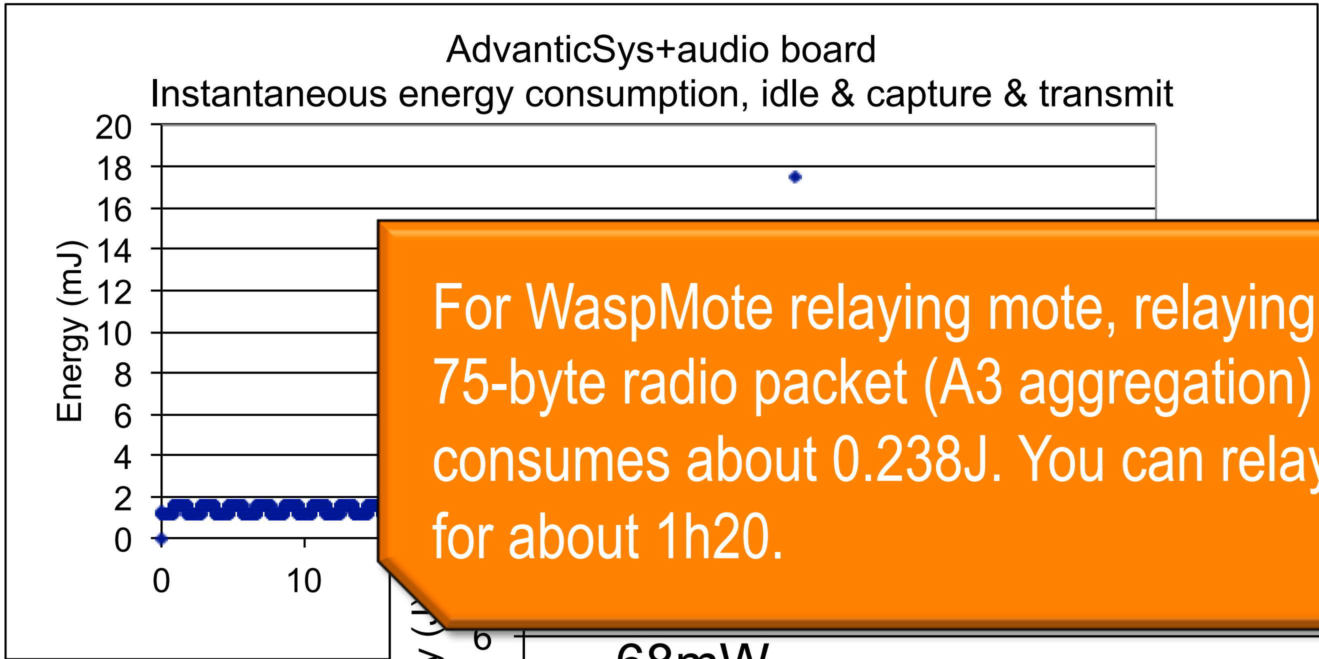
1-hop audio in non LoS

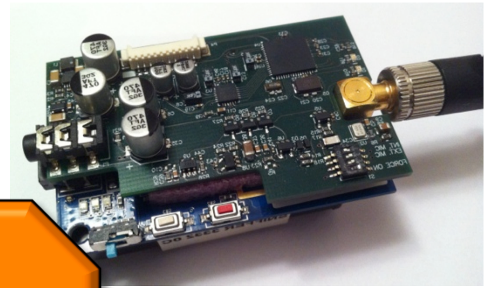


1-hop WaspMote audio

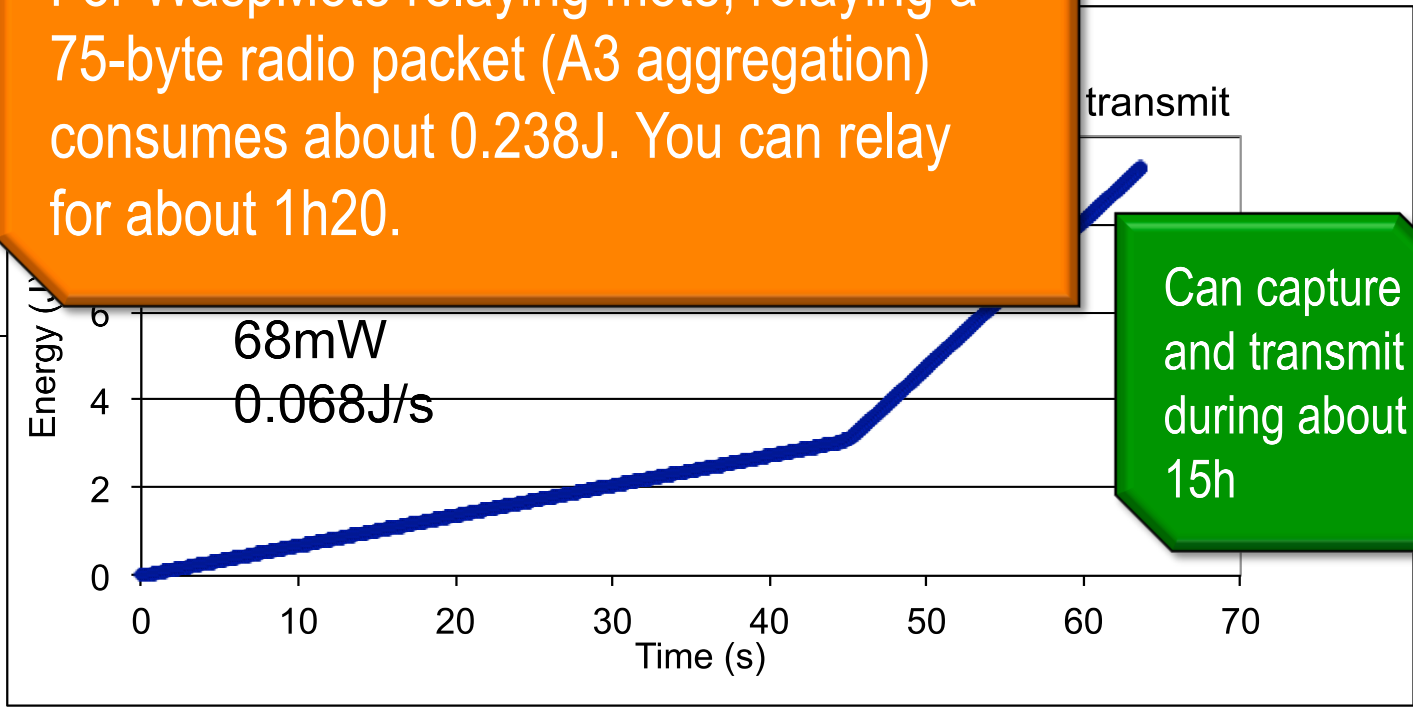


Energy consumption





For WaspMote relaying mote, relaying a 75-byte radio packet (A3 aggregation) consumes about 0.238J. You can relay for about 1h20.



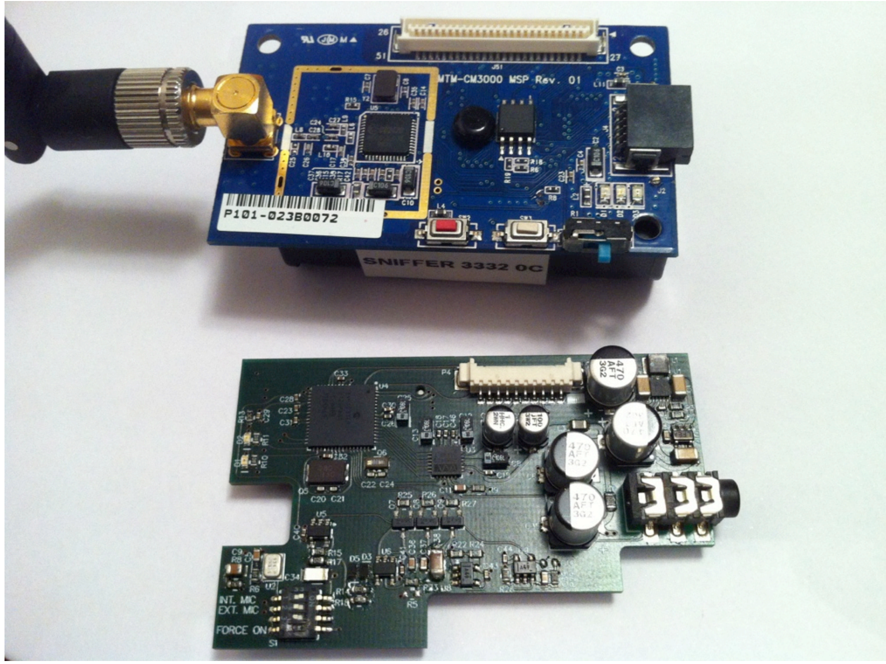
Can capture and transmit during about 15h

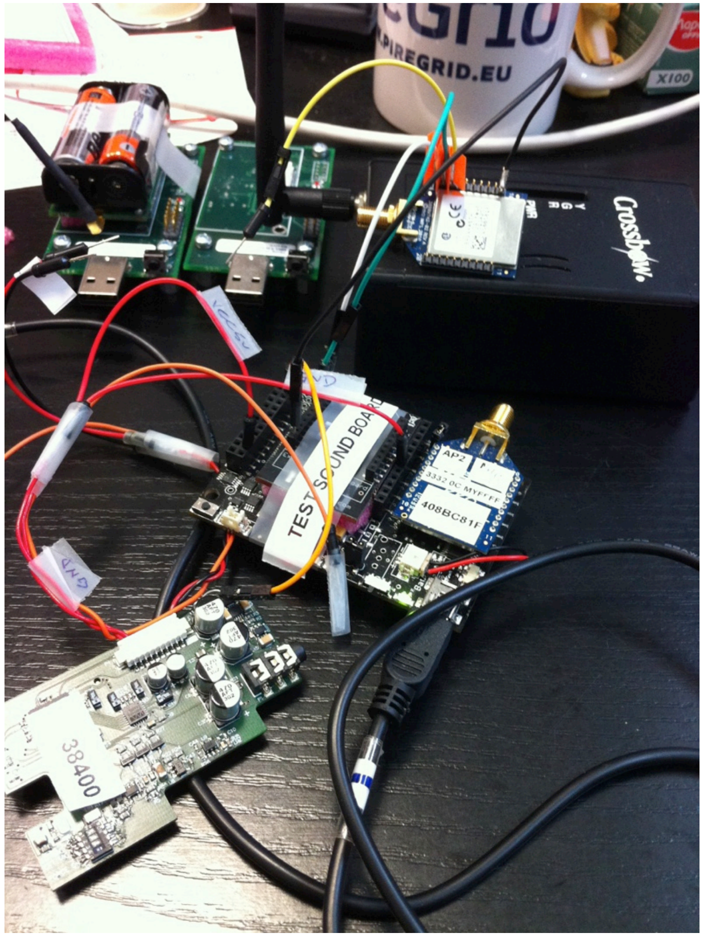
18720 Joules

Conclusions

- Low-resource devices (sensor, IoT, …) are currently deployed in a number of projects, especially in SmartCities context
- Benchmarking such test-beds is of prime importance for understanding the infrastructure limitations
- The EAR-IT project focuses on acoustic data, deployed on large scale test-beds
- We shown main performance bottenecks, defined performance indicators as well as quality and usability indicators
- Synthetic workload and in-situ tests have been performed to quantify the test-bed capacity and to propose adequate mechanism to provide near real-time acoustic data
- Same methodology can be applied to other test-beds

Developped audio board





Do not hesitate to contact us


EAR-IT
the sounds of smart environment
SEVENTH FRAMEWORK PROGRAMME

Questions ?