EAR-IT the sounds of smart environment

WP1.3 Methodology and tools for measurements and benchmarking on the use of acoustic sensors

C. Pham (University of Pau, EGM) and P. Cousin (EGM)

Objectives of WP1.3

- Present methodology and tools for measurements and benchmarking for a number of performance indicators
- Describe the benchmark campaigns in Santander's SmartSantander and Geneva's HobNet test-beds for NETWORK indicators
- Present energy consumption measures for ENERGY indicators

Outline

- Presentation of the benchmarking methodology, procedure and tools
- Review of minimum NETWORK & AUDIO requirements
- Presentation of benchmark campaigns for NETWORK & AUDIO indicators
- Presentation of ENERGY indicators
- Conclusions

Benchmark methodology (1)

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

Have been realized in WP1.1 and WP1.2

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. Verify sending time and pkt jitter at audio source
4. Determine latencies and jitter in multi-hop
   - Controlled transmission of packetized/encoded audio
   - Measure latencies and jitter at intermediate nodes
5. Determine channel condition in selected areas
   - 1-hop packet loss rates
6. Determine energy consumption
   - When idle, When capturing and sending audio, When relaying
7. Develop and provide benchmark tools

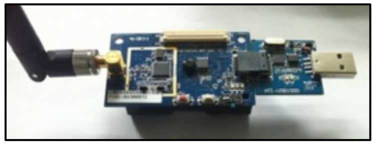
Indicators

- NETWORK indicators
  - Packet jitter at the source
  - Packet relaying time at relay nodes
  - Packet relaying jitter at relay nodes
- AUDIO indicators
  - Packet loss rates at 1-hop
  - Packet loss rates at 2-hop
- ENERGY indicators
  - Energy consumption at the audio source
  - Energy consumption at the relay nodes

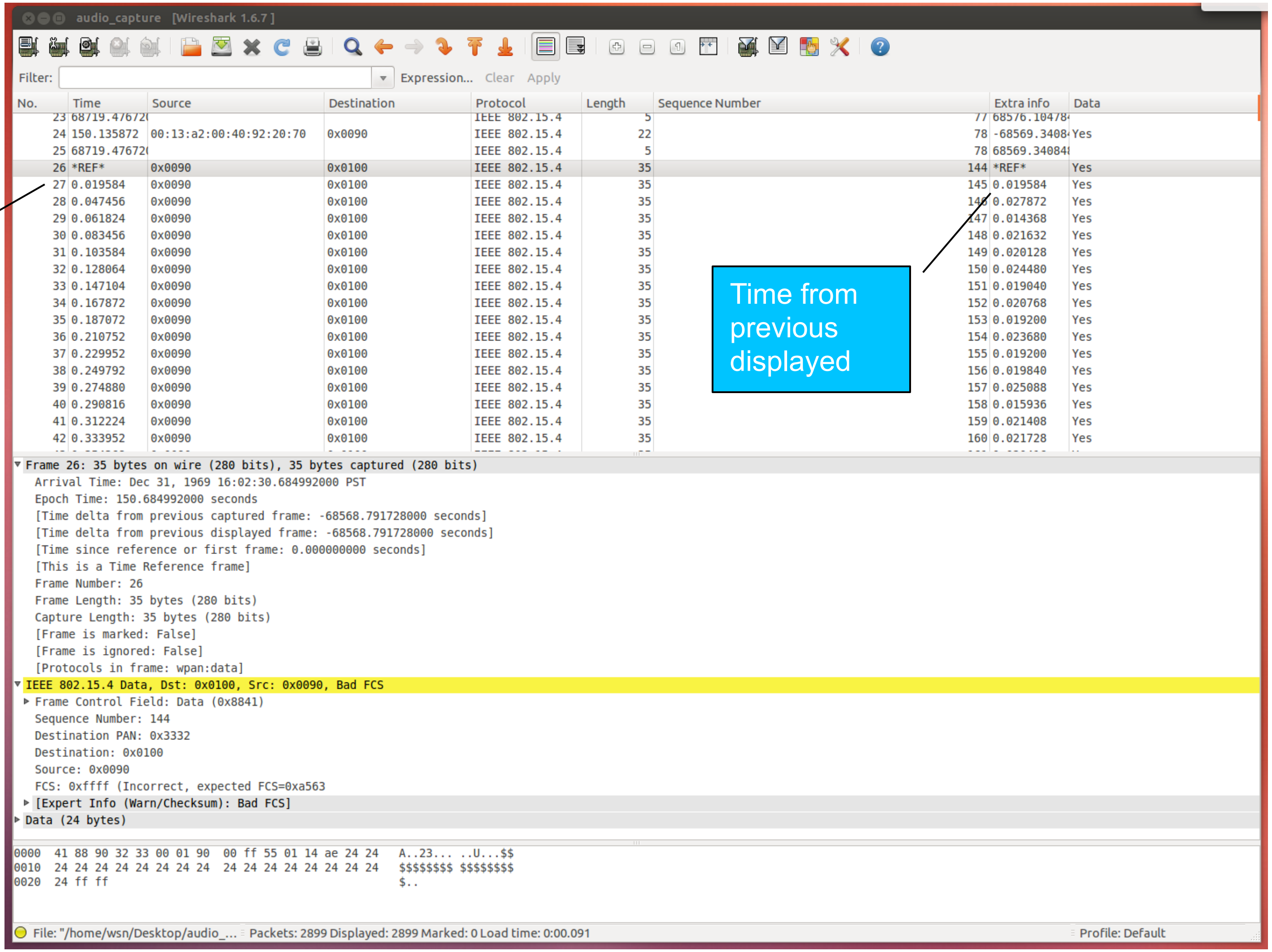
Frame analysis tool

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

Example: latency 1-hop

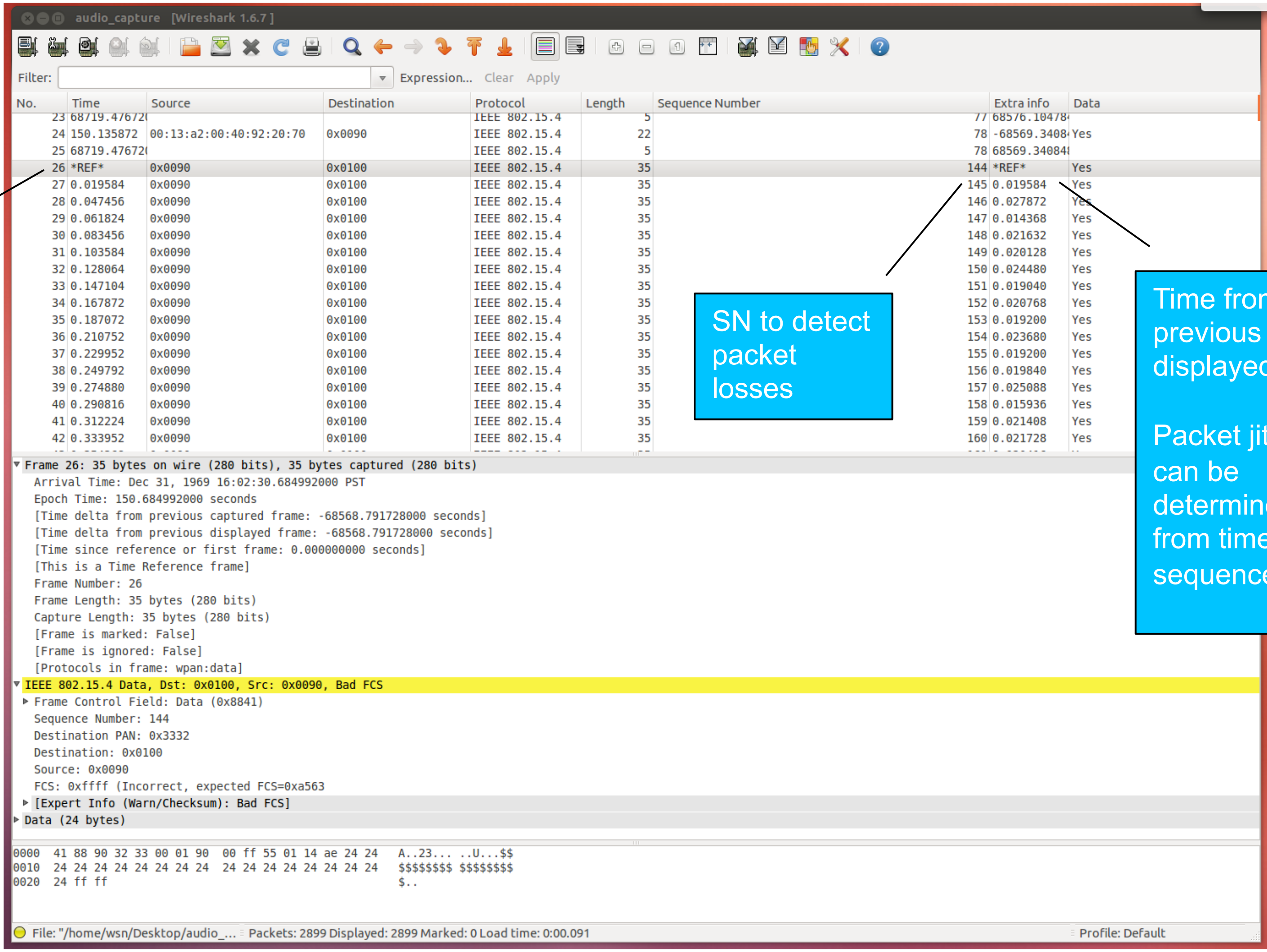


Time from reference time



Time from previous displayed

Example: packet losses & jitter



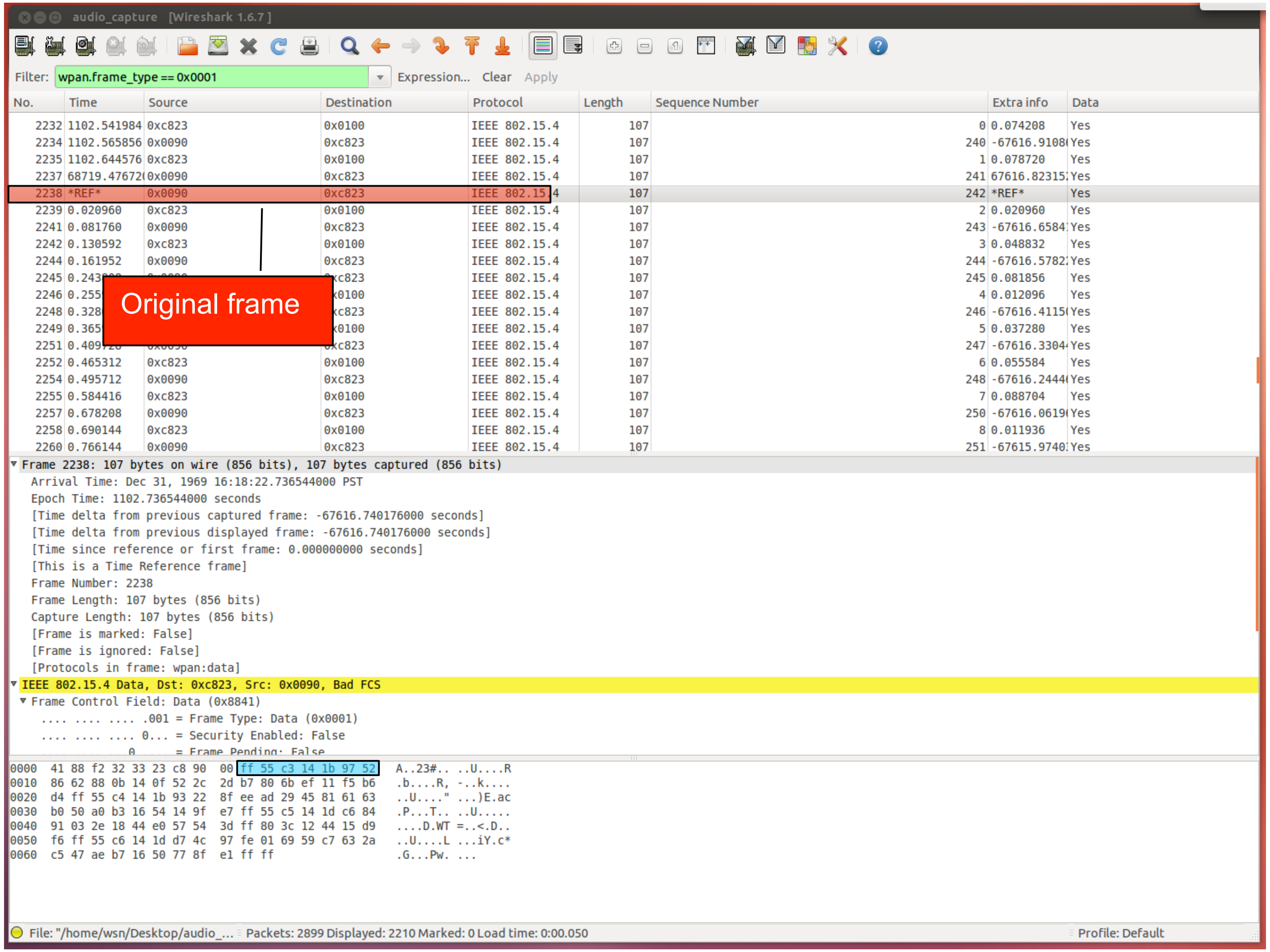
Time from reference time

SN to detect packet losses

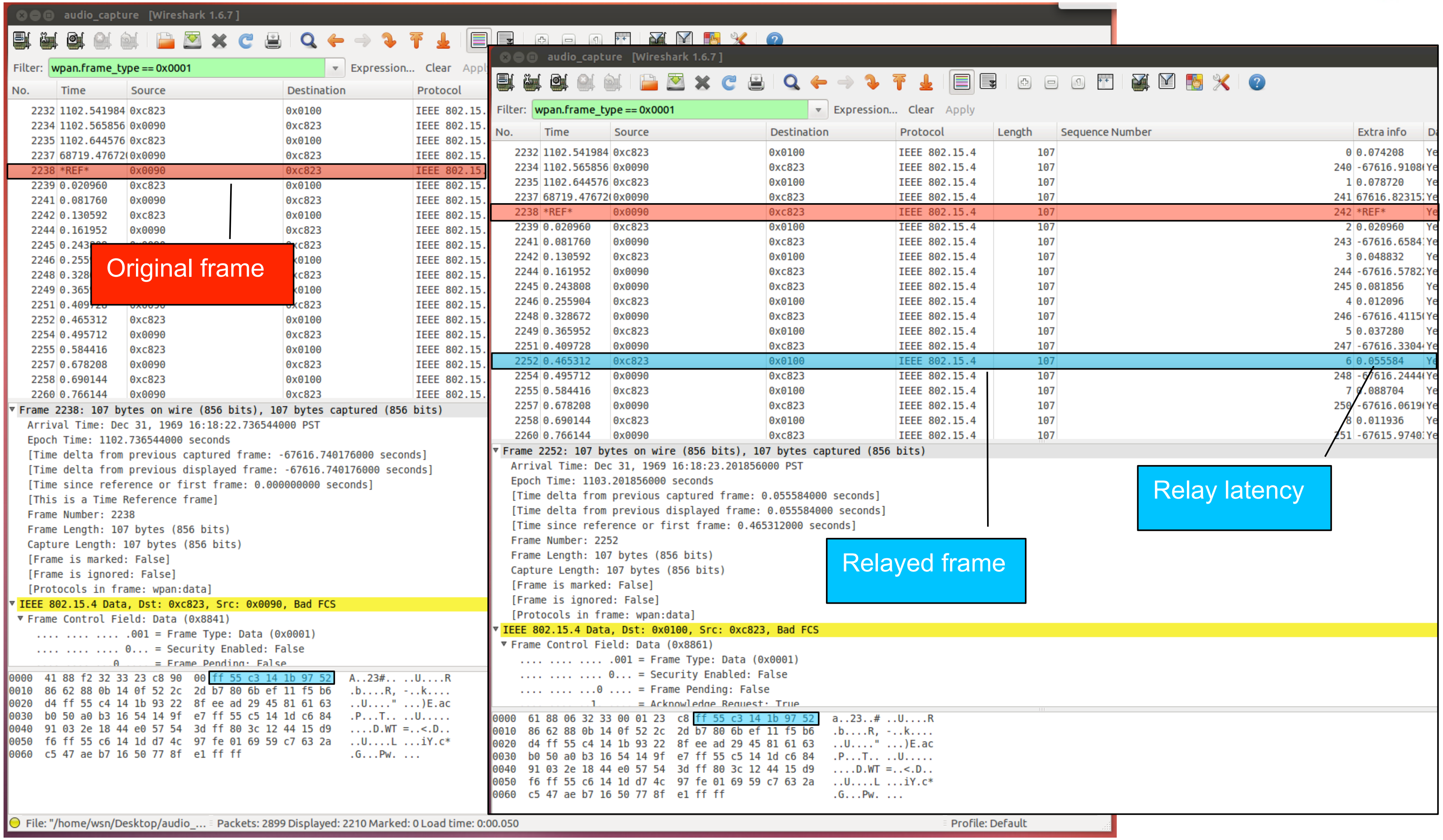
Time from previous displayed

Packet jitter can be determine from time sequence

Example: relay latency

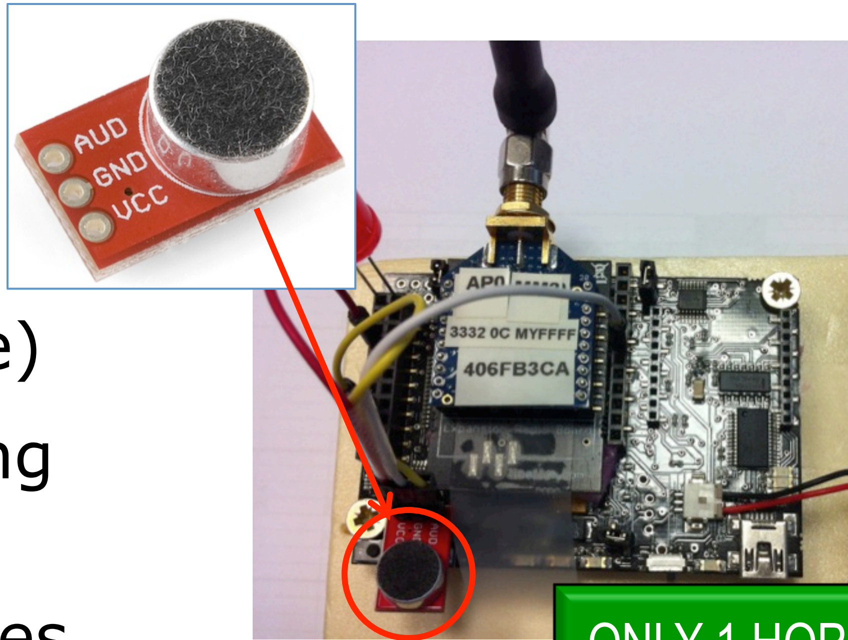


Example: relay latency



Raw audio IoT

- Electret mic with amplifier
- XBee in AP0 mode (transparent mode)
- 8-bit 4Khz sampling gives 32000bps
- 8Khz sampling gives 64000bps
- Periodic ON/OFF (15s)

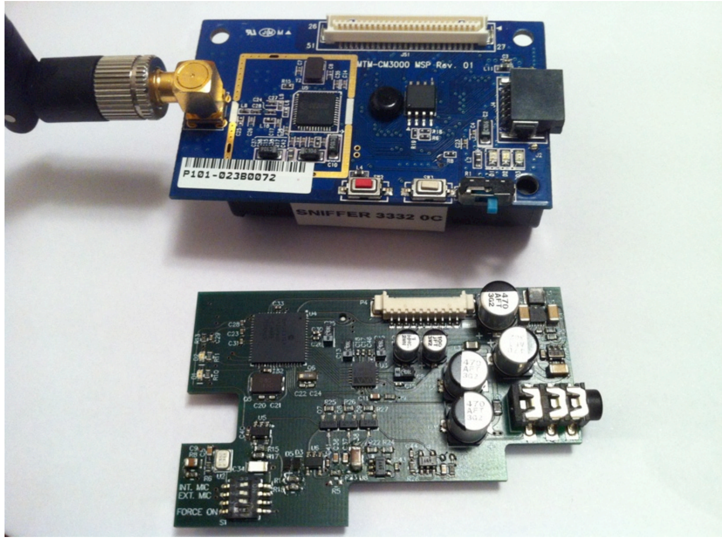


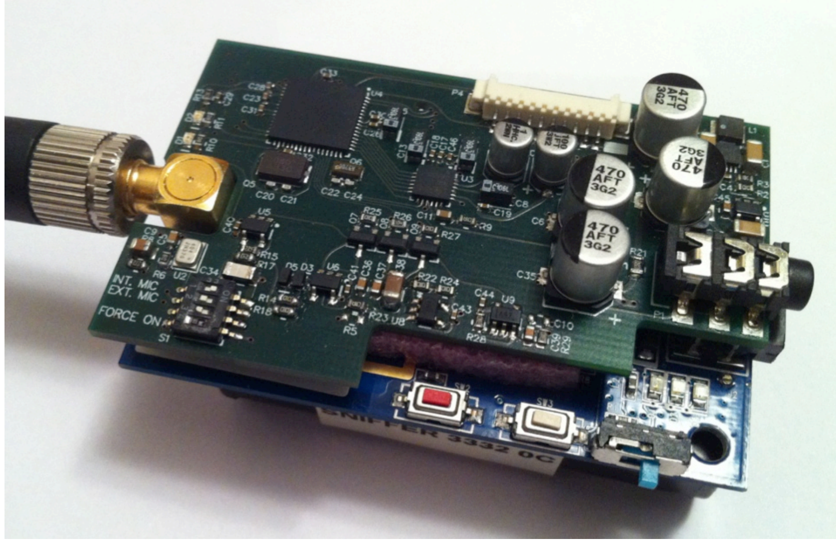
ONLY 1 HOP!

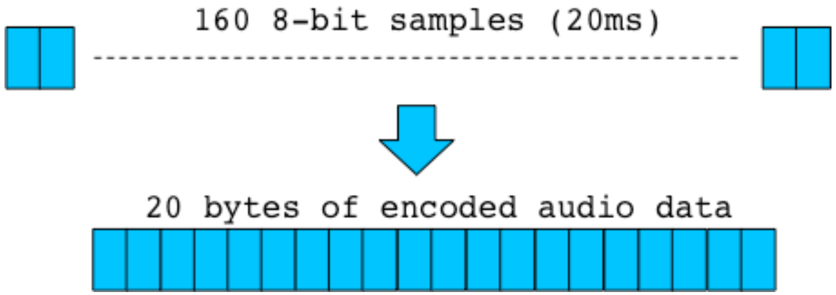
100 8-bit samples (12.5ms or 25ms)

Compressed audio IoT

- Encode with Speex codec at 8kbps







Configuring & controlling the audio source

- The audio source can be controlled wirelessly with text-based message
  - "@/A" for aggregation mode
  - "@/D" to set destination address
  - "@/C" to start/stop audio capture

```
A1/2/3/4 aggregate audio frames
D0013A2004086D828 set the 64-bit dest. mac addr
D0080 set the 16-bit dest. mac addr
C0/1 power off/on the audio board
```

- Use a 802.15.4 gateway to send control messages

Review of minimum requirements

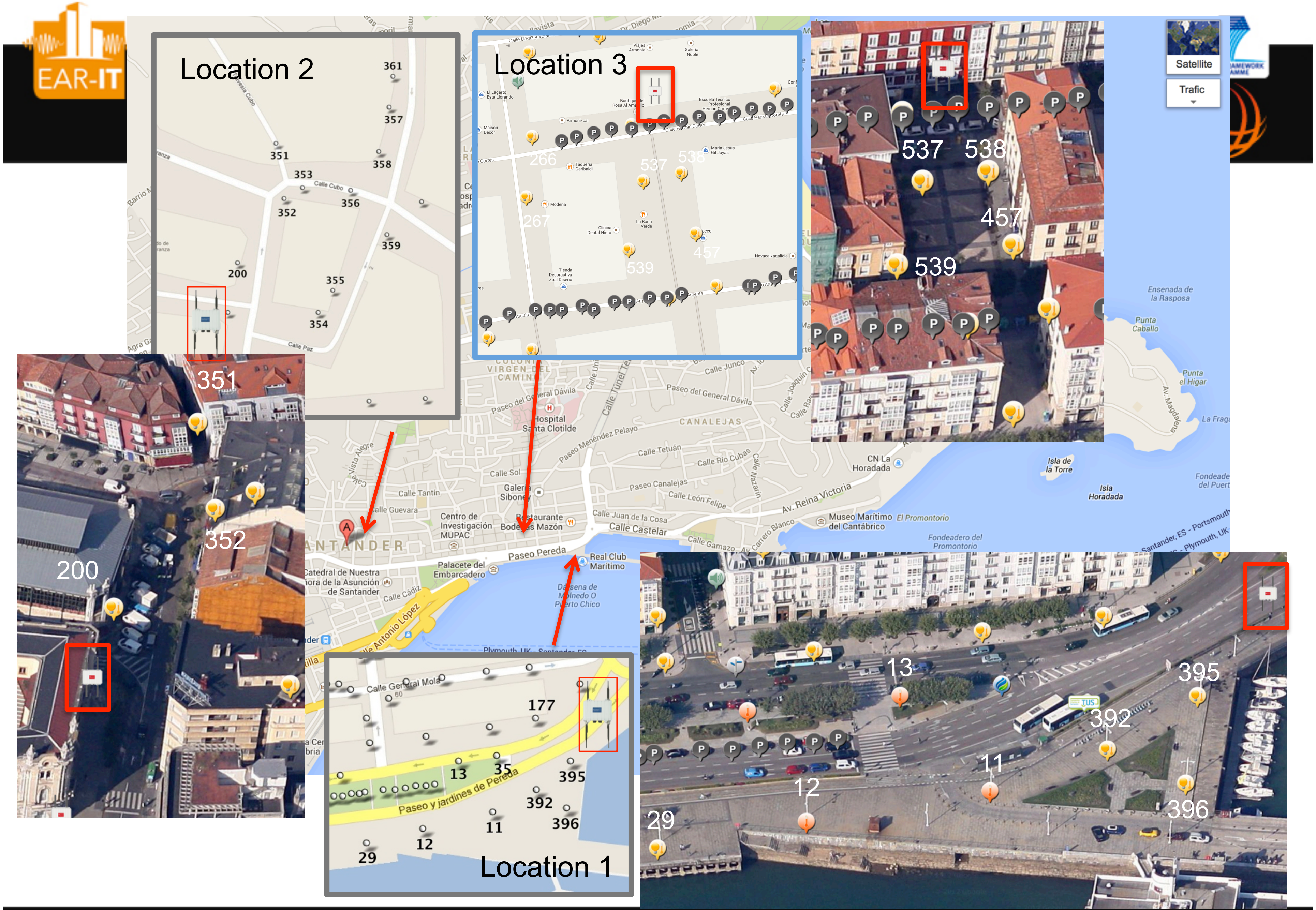
Codec	Minimum sending rate
Raw 4KHz 8KHz	 100 bytes every 25ms 100 bytes every 12.5ms
Speex 8000bps A1 A2 A3 A4	 24 bytes every 20ms 48 bytes every 40ms 72 bytes every 60ms 96 bytes every 80ms
Codec2 2400bps A1 . . An (1≤n≤11) 3200bps A1 . . An (1≤n≤9)	 9 bytes every 20ms . . 9*n bytes every n*20ms 11 bytes every 20ms 11*n bytes every n*20ms

Codec	Maximum packet loss rate for speech understanding
Raw 4KHz & 8KHz	50%
Speex 8000bps	35%
Codec2	
2400bps	20%
3200bps	30%

Benchmarks in Santander
February, 2014

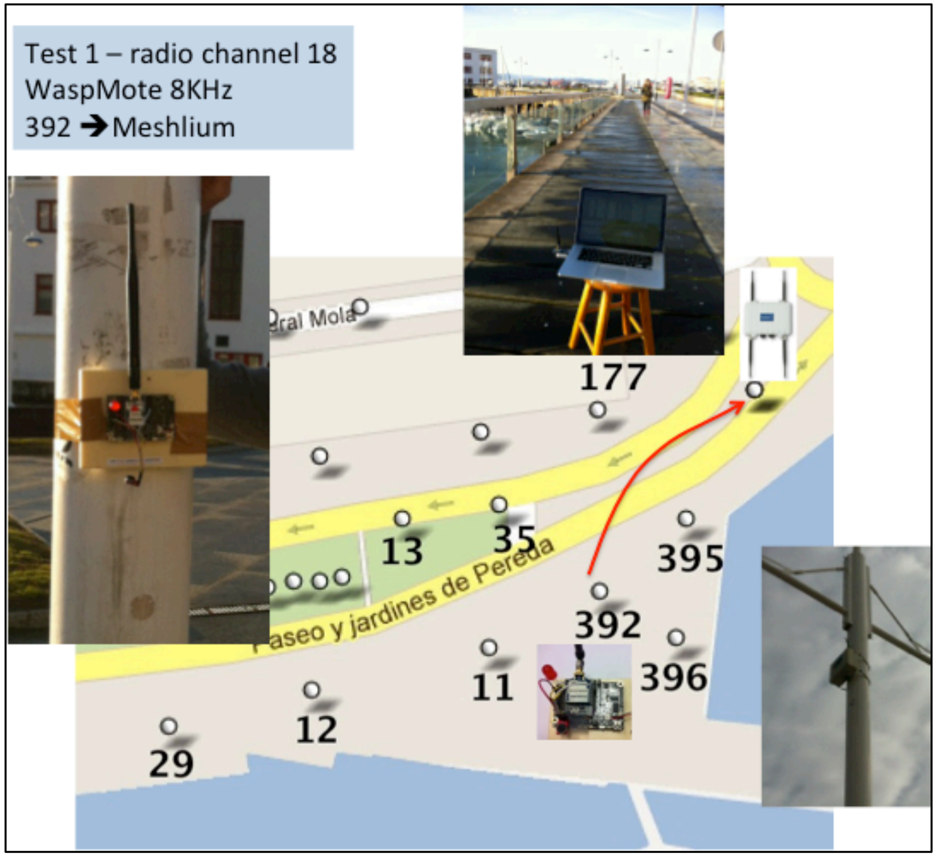
Benchmarks in Santander

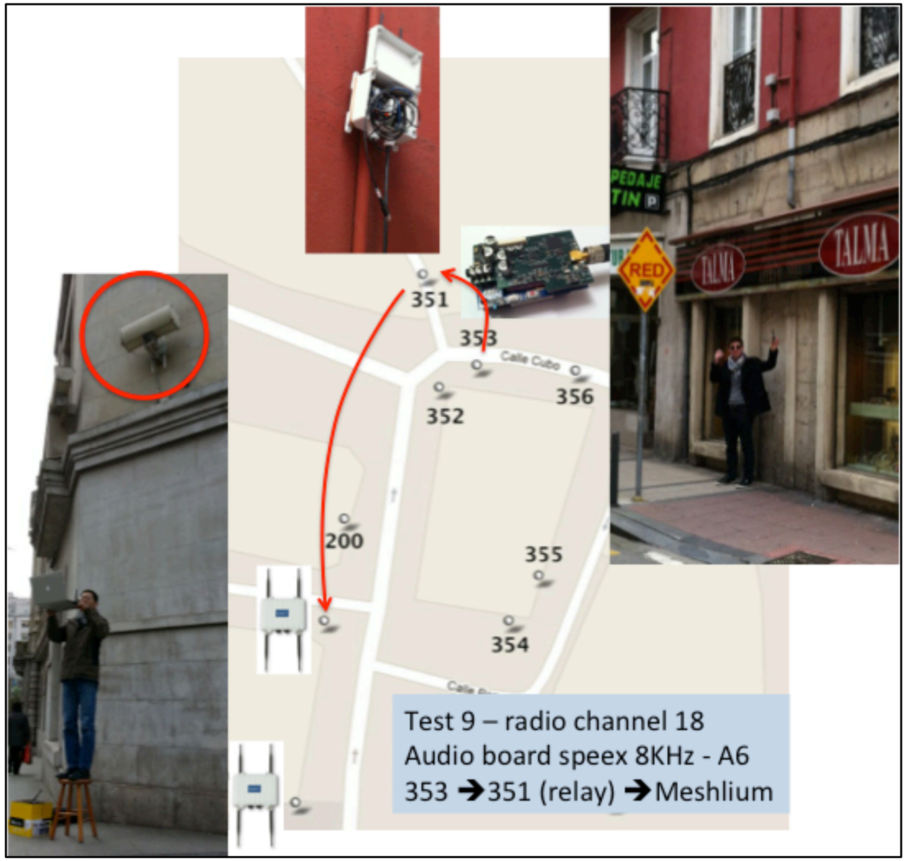
- 11 tests in 3 locations
- 1-hop and 2-hop tests
- Raw audio and compressed audio
- LOS and NLOS transmission
- Open space and dense urban area
- NETWORK indicators and AUDIO indicators



Tests in Santander

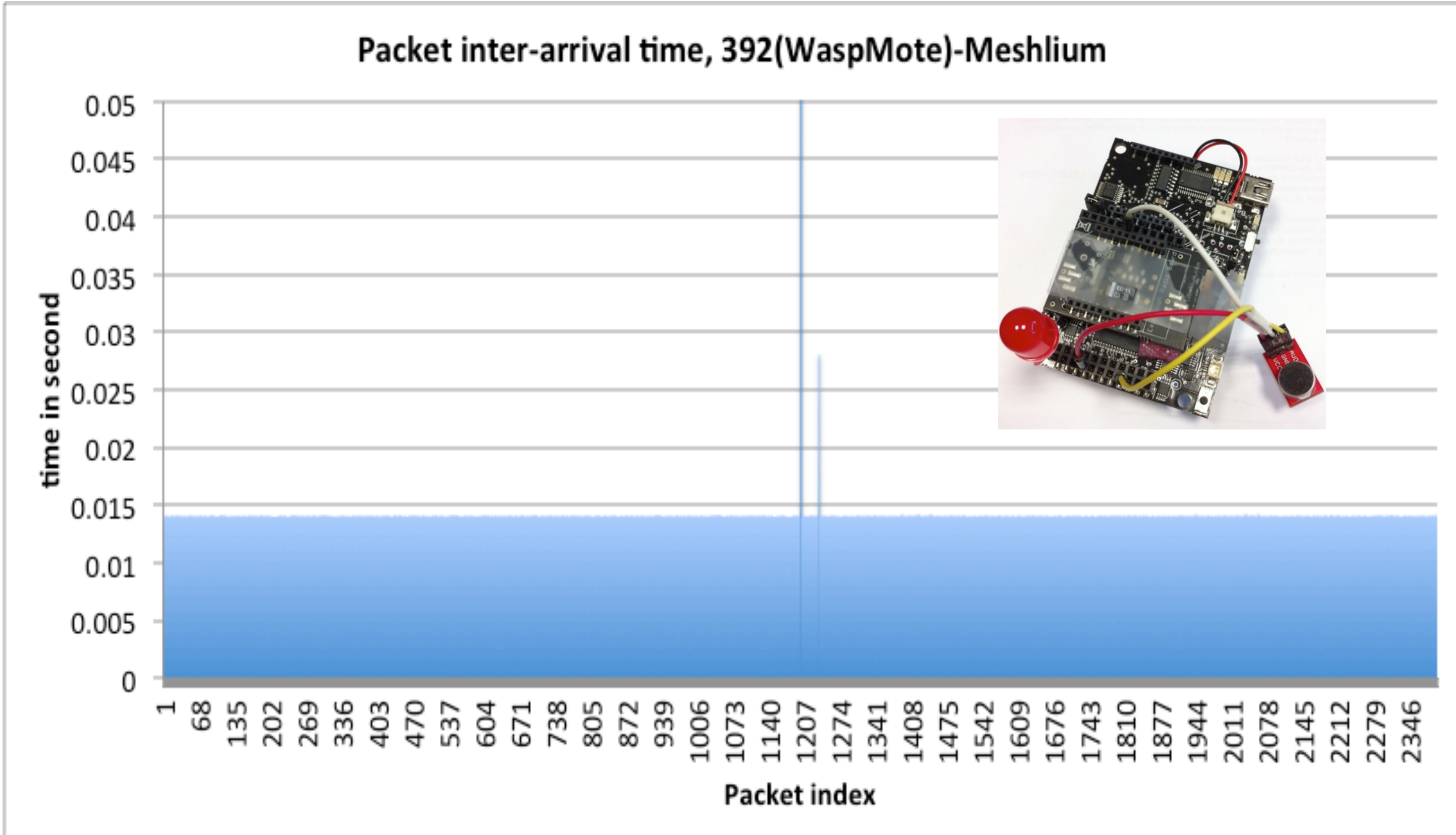
Some benchmark settings



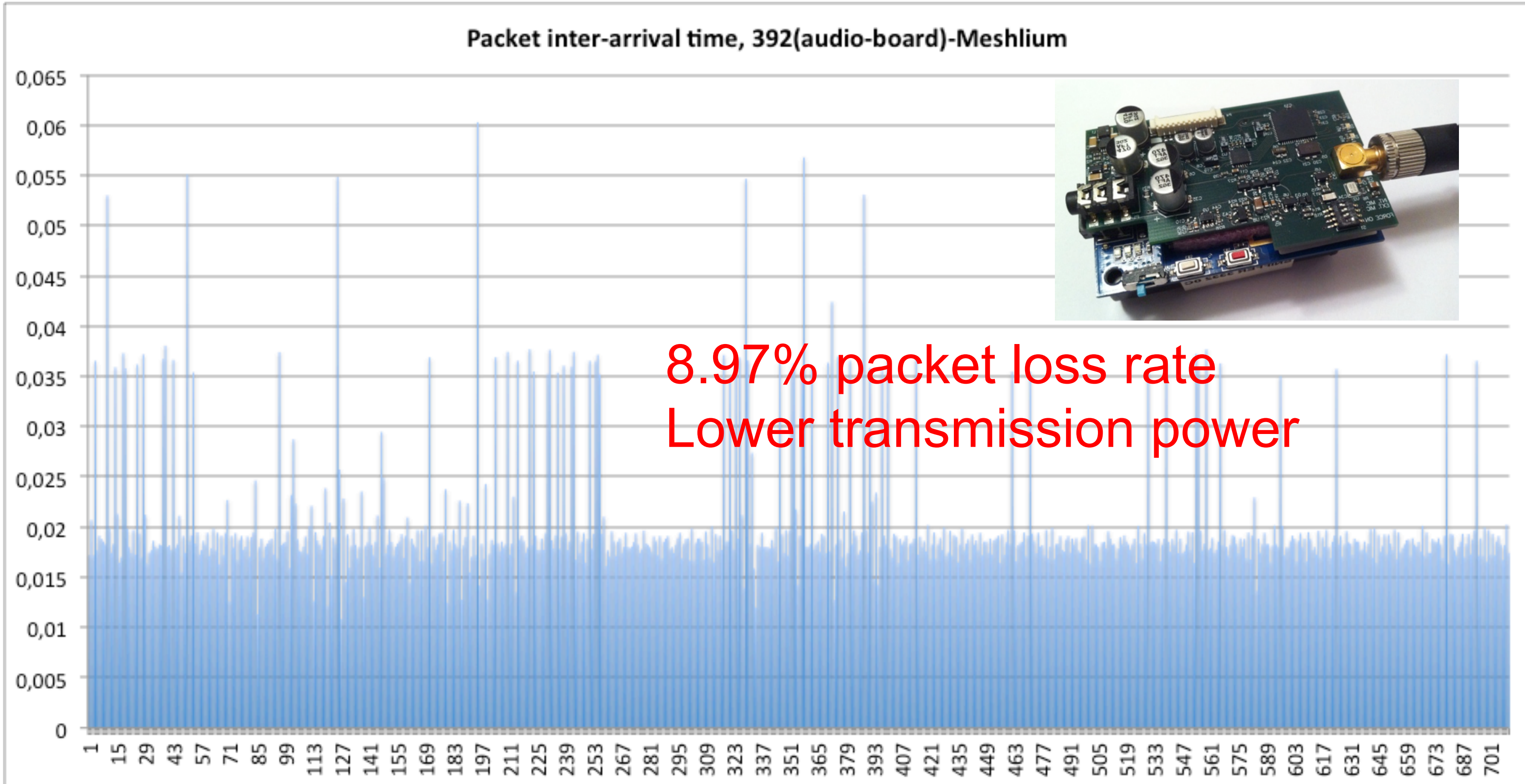


Benchmark campaign pictures

1-hop raw audio, LOS

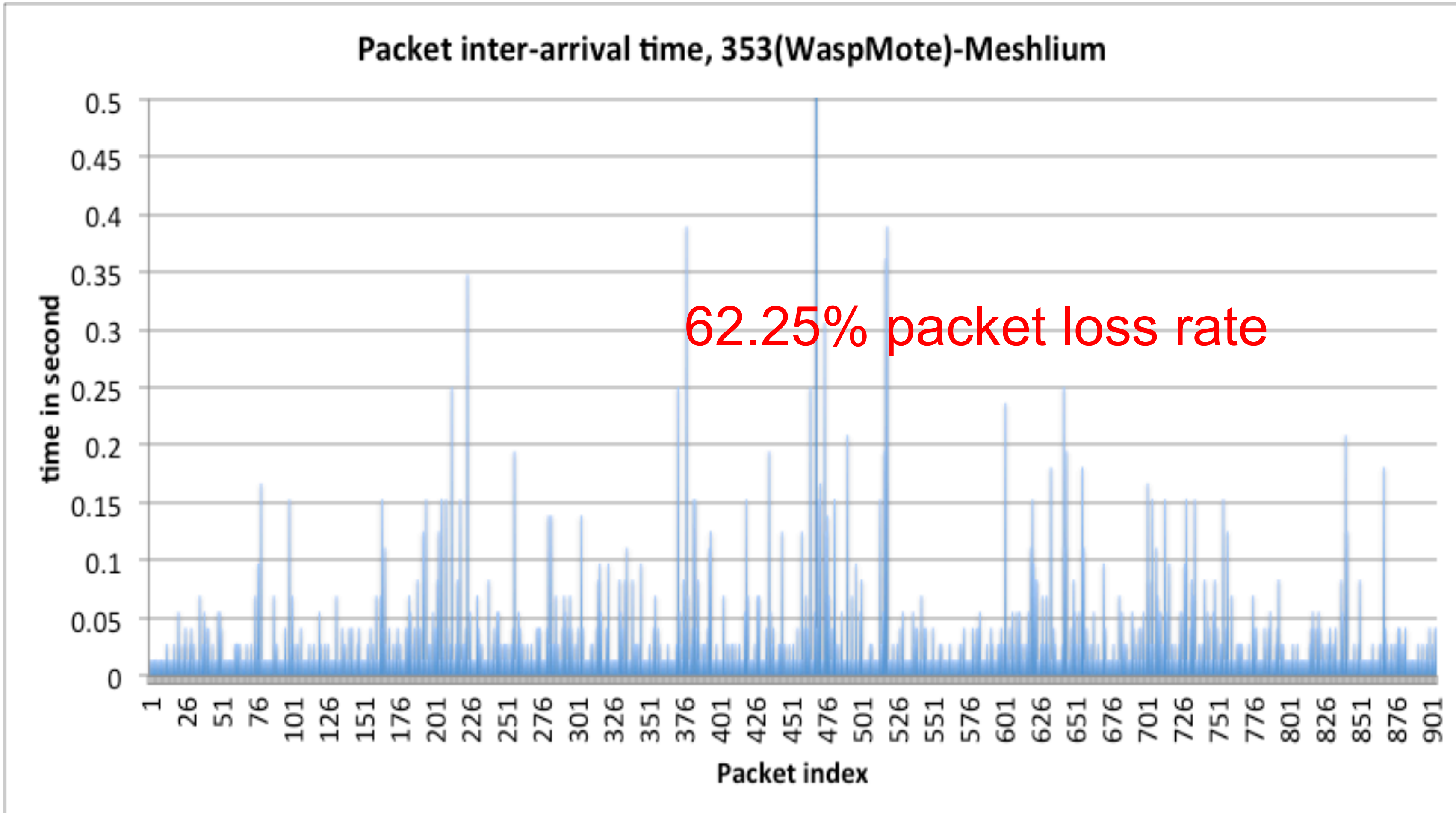


1-hop compressed audio, LOS

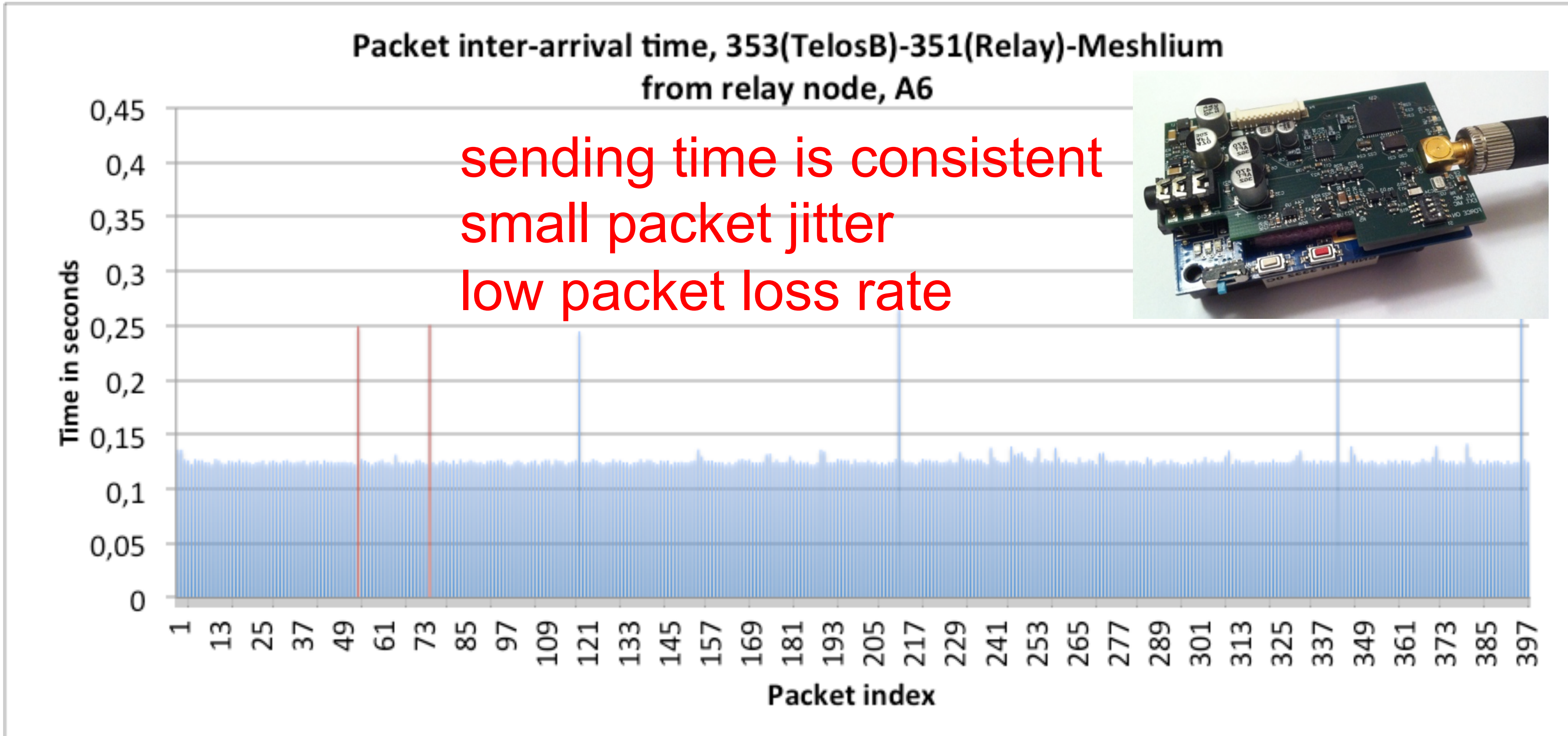


8.97% packet loss rate
Lower transmission power

1-hop WaspMote audio, NLOS



2-hop compressed audio, NLOS



Summary for Santander

Santander, SmartSantander test-bed			
test scenario	Pkt jitter at source	pkt jitter at relay	pkt loss rate
1-hop LOS open s			0% - 12% (2)
1-hop LOS urban			35% (2)
1-hop NLOS urba			60% - 92% (2)
2-hop open space			5% - 23% (3)
2-hop urban			53% (3)

(1) The packet jitter at th … a very simple playout buffer.

(2) The packet loss rate … acket loss rate can be very high.

(3) At 2-hop or more, usi … an greatly be improved. However, the choice of t … ent, the packet loss rate can still be high and mor …

(4) The packet relaying t … ccording to the maximum relaying capabilities, an … losses at intermediate relay nodes.

(5) The packet relay jitter is very … imple playout buffer.

The SmartSantander test-bed in Santander is capable of supporting streamed audio both in open space and urban environment when LOS transmission is possible. In NLOS conditions, care must be taken to choose relay nodes. In all cases, the packet jitter at the source and at the relay nodes is very small.

Benchmarks in Geneva
March, 2014

Benchmarks in Geneva

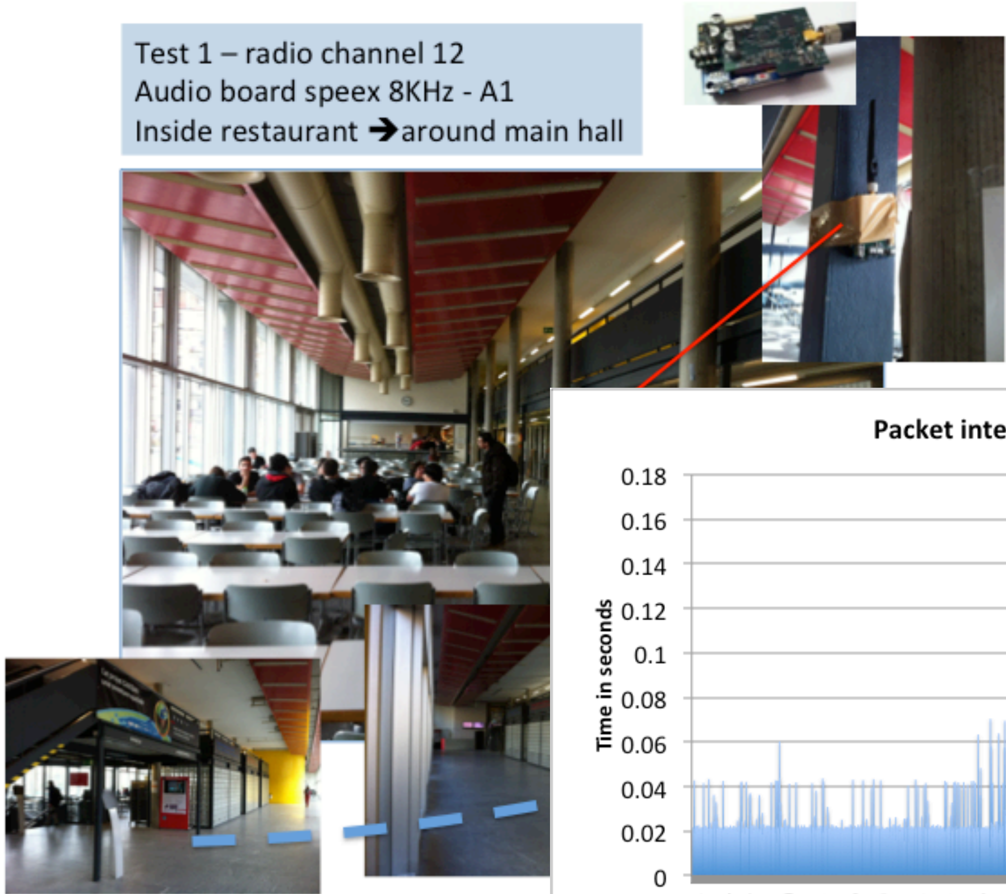
- HEPIA building
- 7 tests in 3 locations of HEPIA
- Various in-door conditions, LOS and NLOS transmission
- 1-hop and 2-hop tests
- Raw audio and compressed audio
- NETWORK indicators and AUDIO indicators

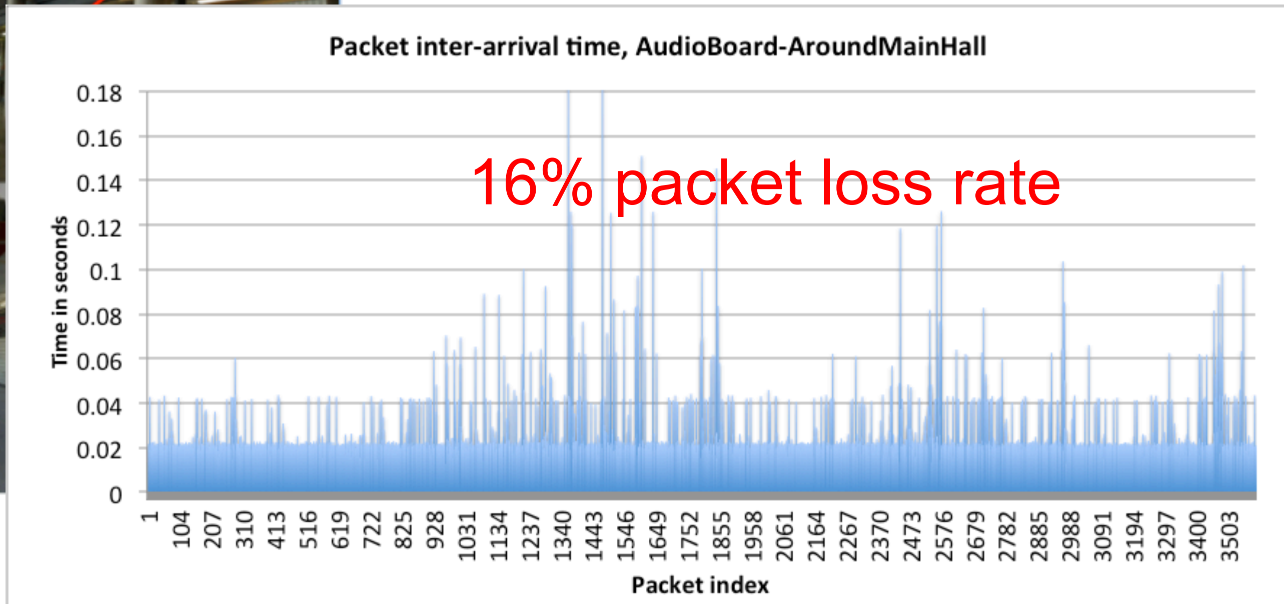

2
3
1
hepia
Le projet CAESAR
une aventure spatiale
AULA

Benchmark campaign pictures

1-hop compressed audio

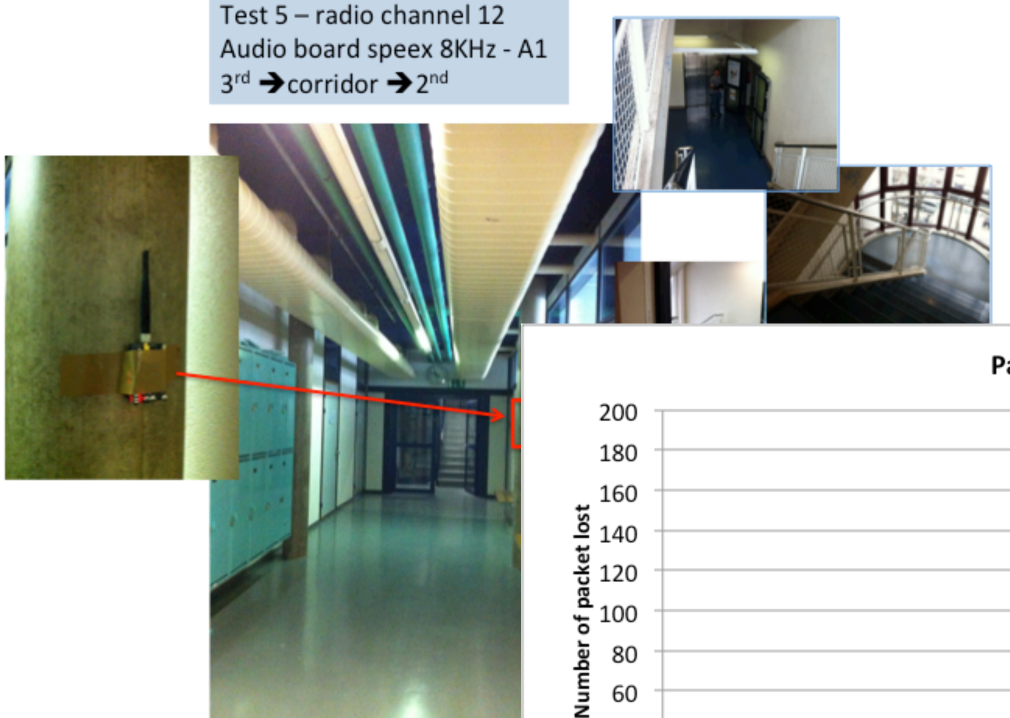
Test 1 – radio channel 12
Audio board speex 8KHz - A1
Inside restaurant → around main hall

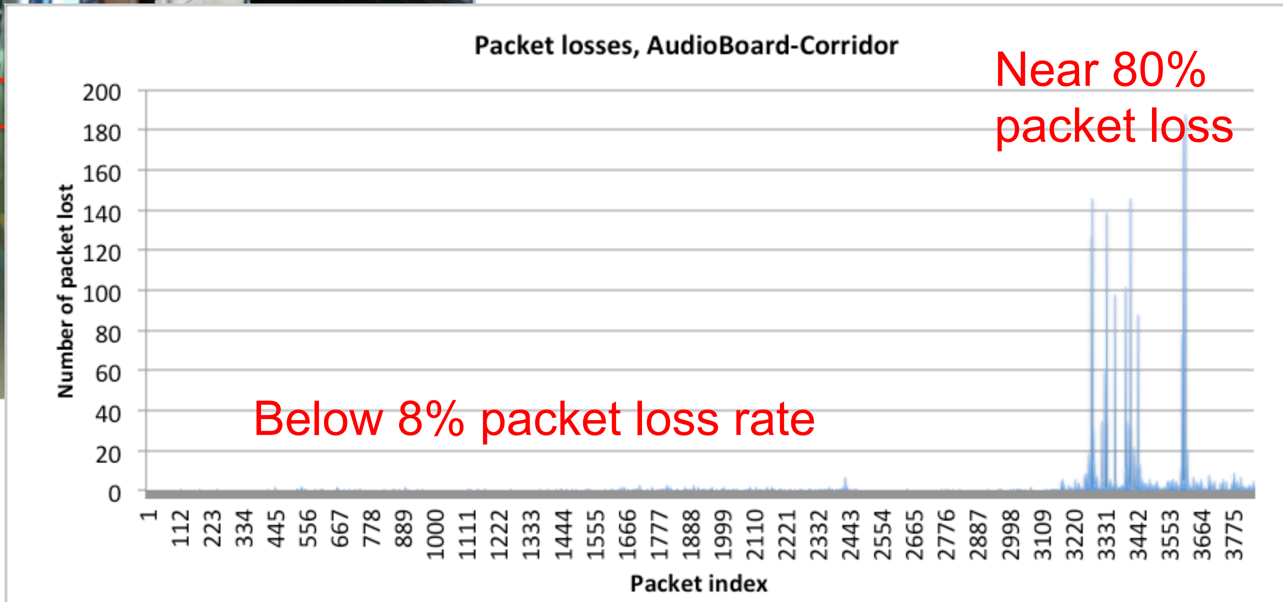




1-hop compressed audio

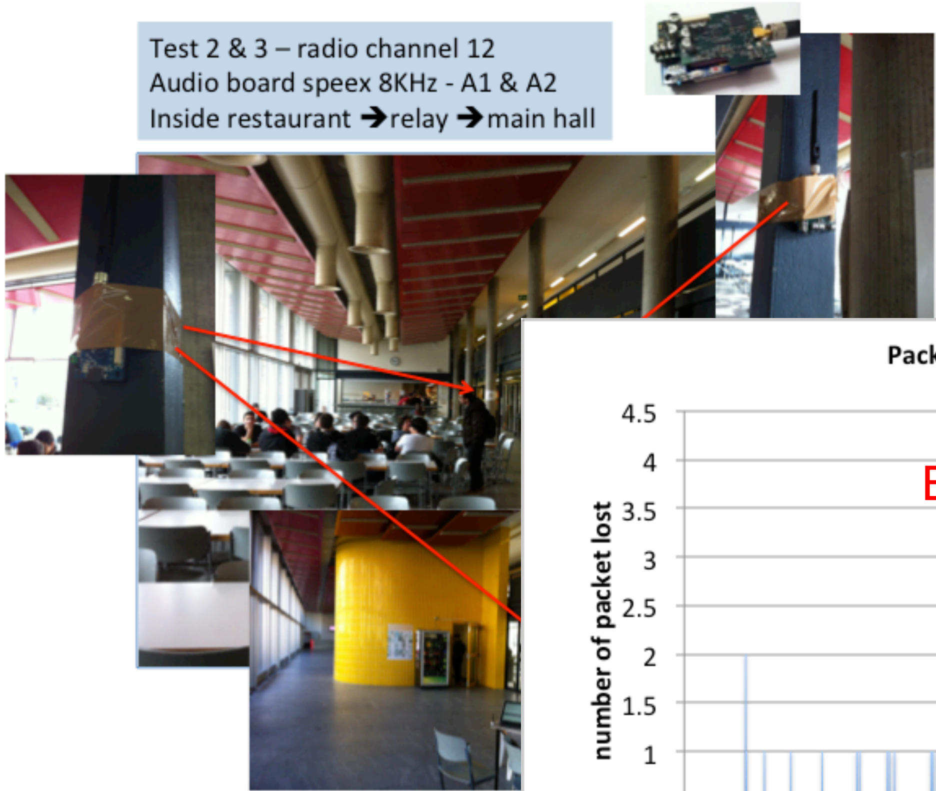
Test 5 – radio channel 12
Audio board speex 8KHz - A1
3rd ➔corridor ➔2nd

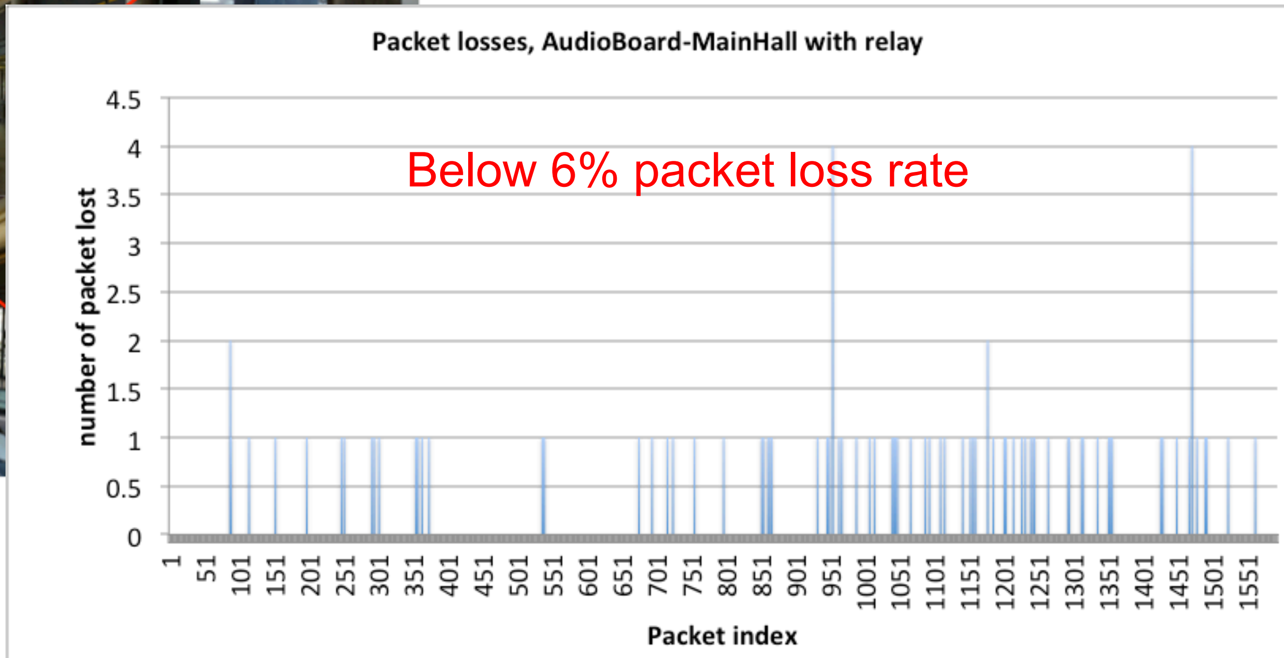




2-hop compressed audio

Test 2 & 3 – radio channel 12
Audio board speex 8KHz - A1 & A2
Inside restaurant →relay →main hall





Summary for Geneva

Geneva, HEPIA building			
test scenario	Pkt jitter at source	pkt jitter at relay	pkt loss rate
1-hop no occlusion	very small (1)	NA	0% - 8% (3)
1-hop occlusion	very small (1)	NA	16% - 81% (4)
2-hop			5% - 30% (2)

The Geneva's HEPIA test-bed in Santander is capable of supporting streamed audio in LOS transmission. In NLOS conditions, care must be taken to choose relay nodes. In all cases, the packet jitter at the source and at the relay nodes is very small.

(1) The packet jitter at th … a very simple playout buffer.

(2) At 2-hop or more, usi … an greatly be improved. This is particularly impor … oice of the relay nodes can have a big impact of

(3) In indoor environmen … ound in open space environment (actually the

(4) In indoor environmen … ally the reception quality.

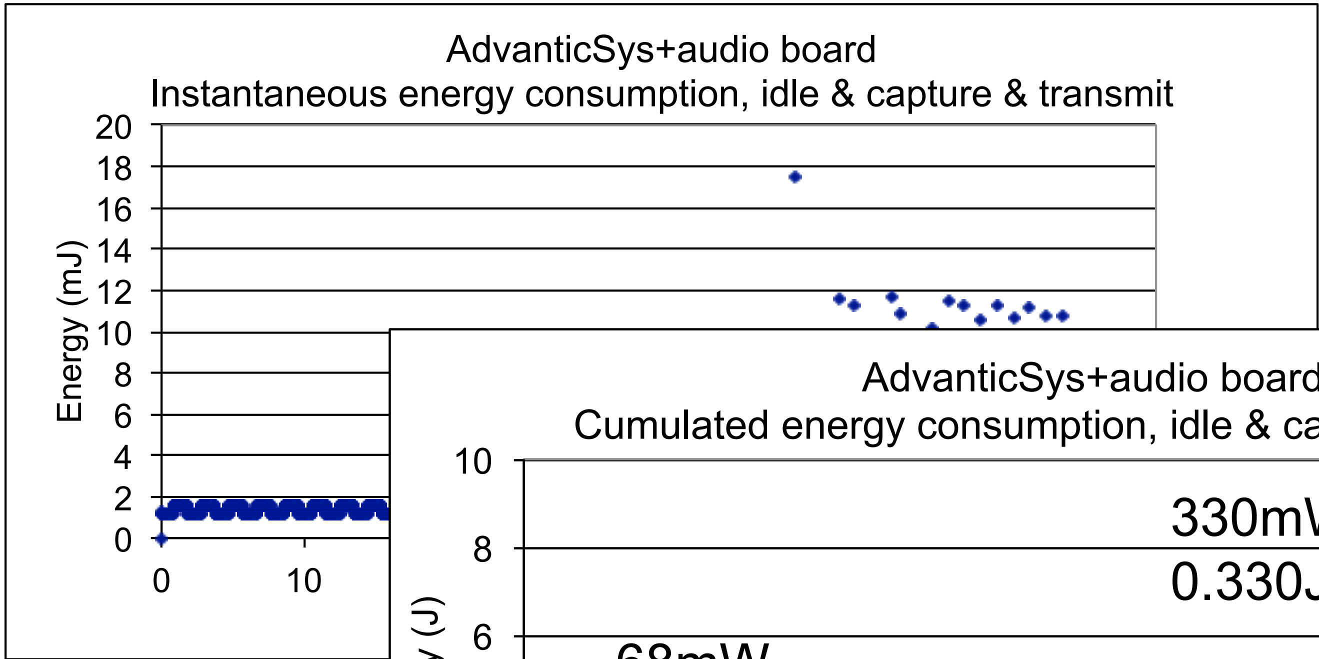
(5) The packet relaying tim … ccording to the maximum relaying capabilities, an appro … losses at intermediate relay nodes.

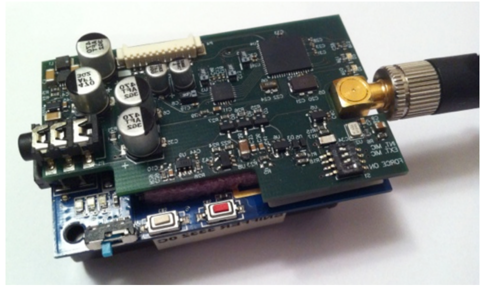
(6) The packet relay jitter is very small and can be easily compensated at the destination with a very simple playout buffer.

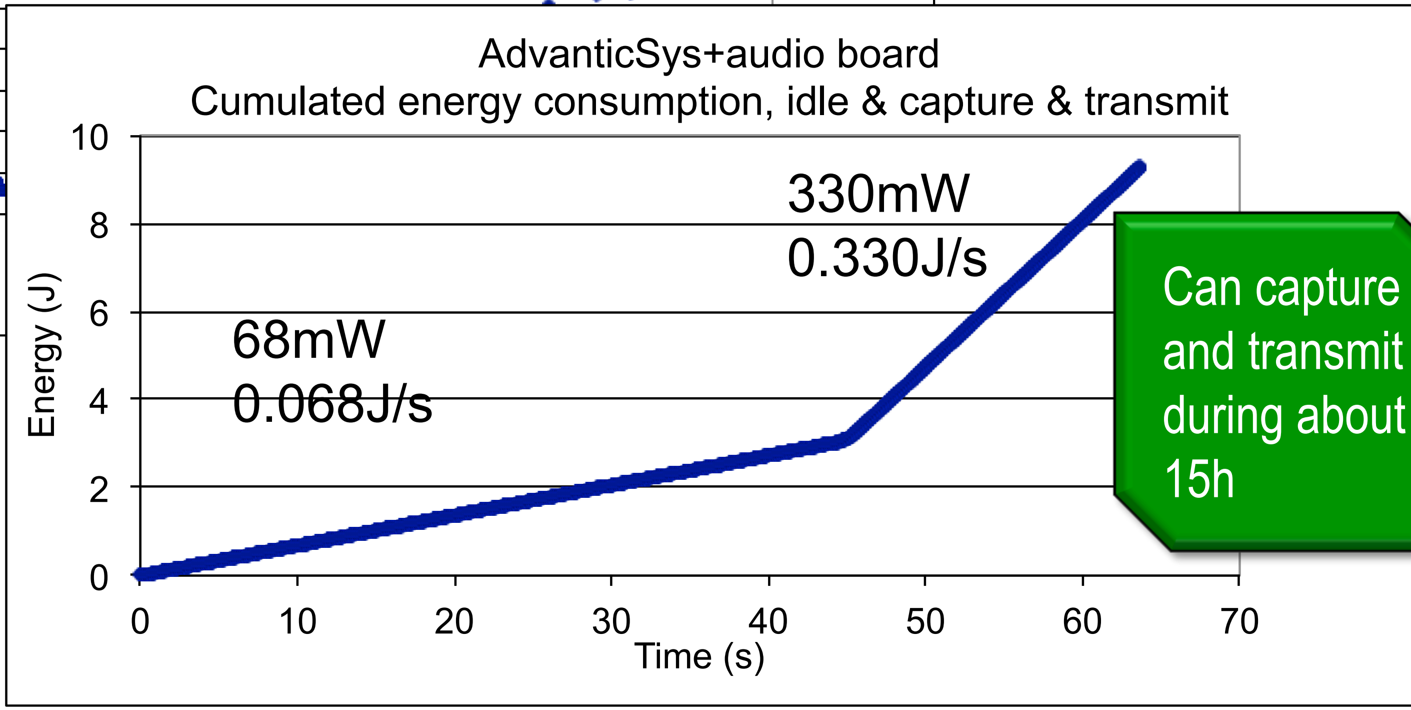
Energy consumption measures

Lab settings

Audio board energy consumption



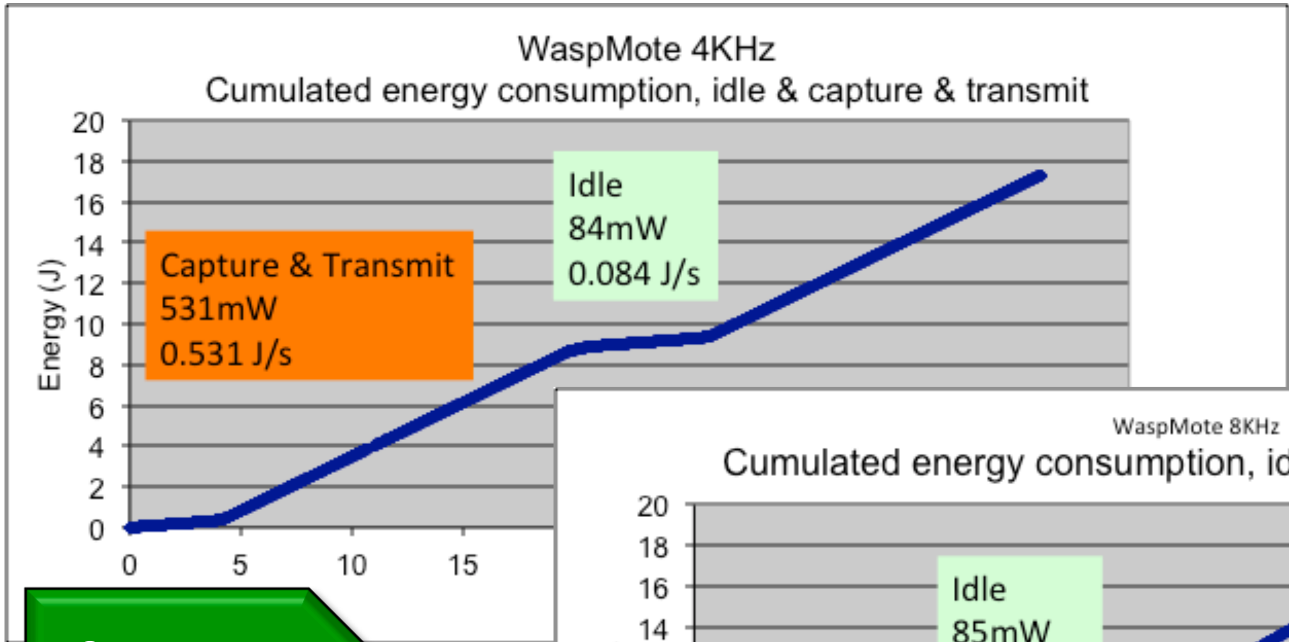




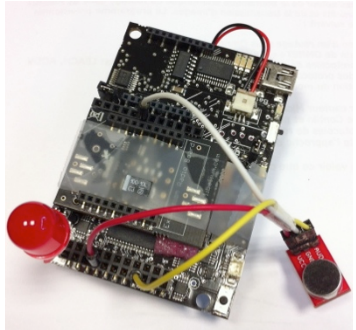
Can capture and transmit during about 15h

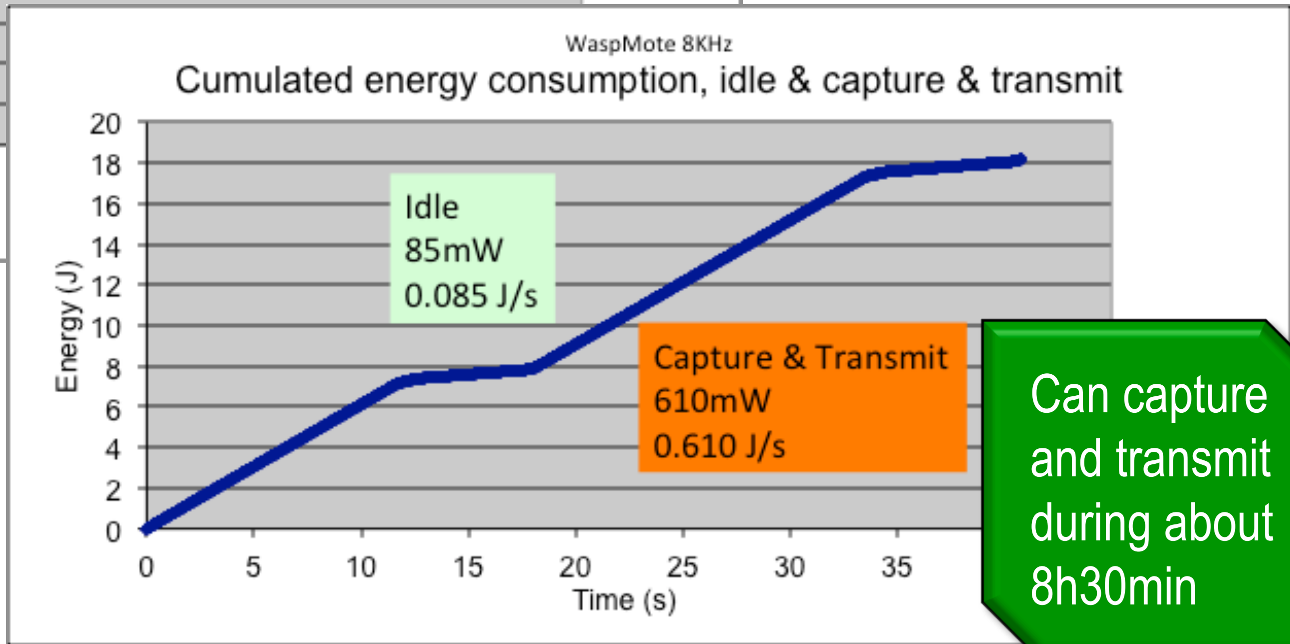
18720 Joules

Raw audio energy consumption



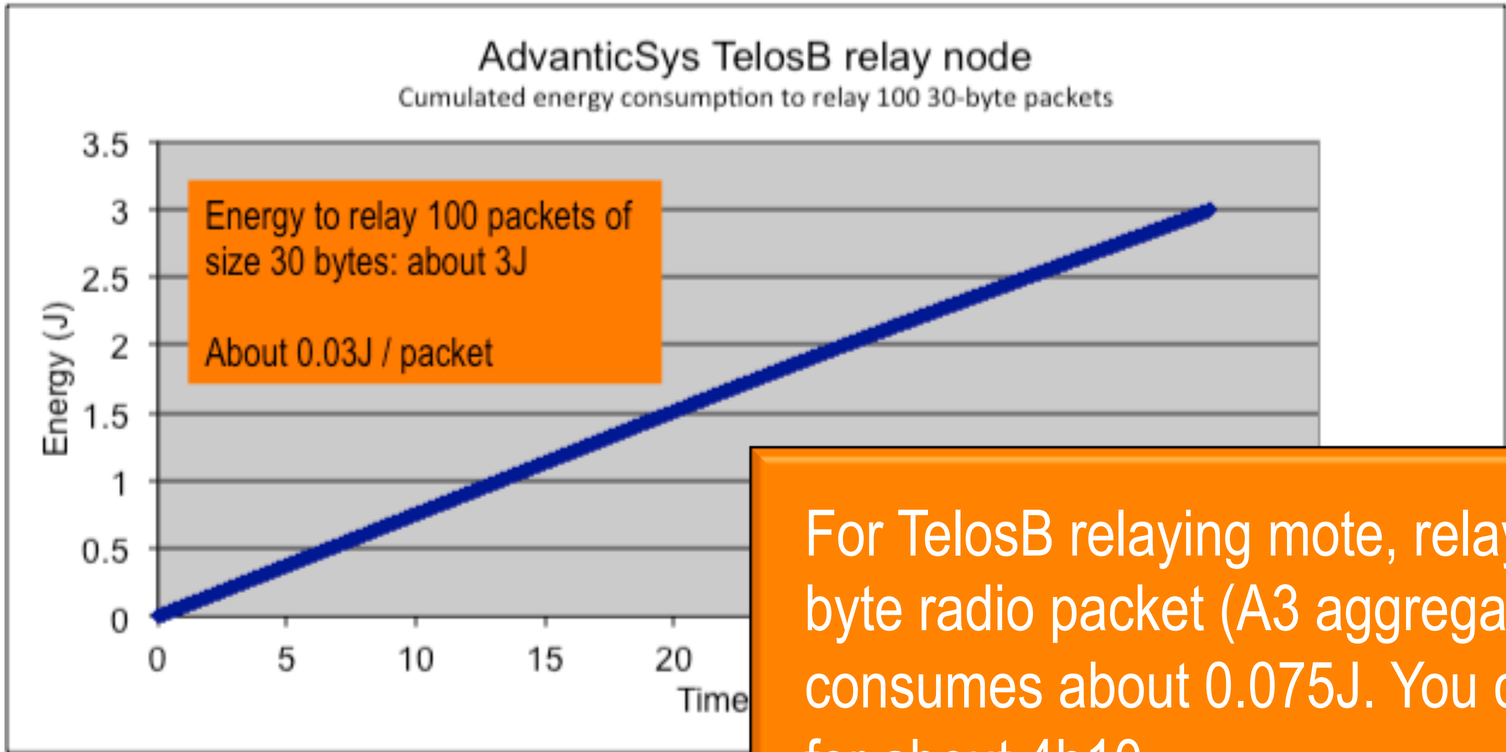
Can capture and transmit during about 9h47min



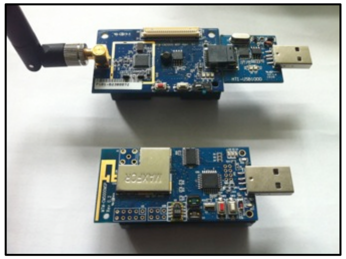


Can capture and transmit during about 8h30min

TelosB relay

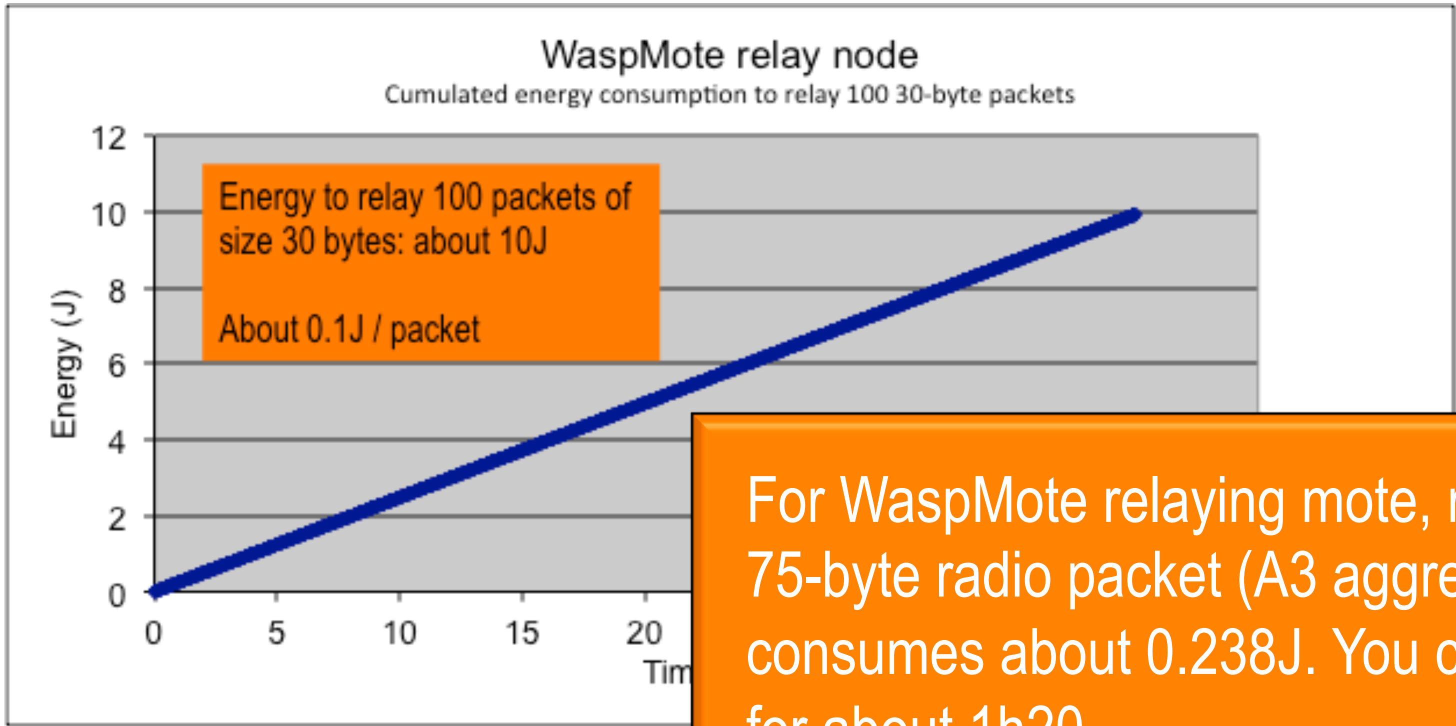


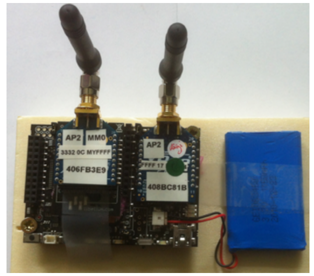
For TelosB relaying mote, relaying a 75-byte radio packet (A3 aggregation) consumes about 0.075J. You can relay for about 4h10.



AdvanticSys TelosB

WaspMote relay





Libelium WaspMote

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

Call for benchmark

- We have defined a benchmark procedure and made available promiscuous sniffer tools and Excel templates
- Univ. of Surrey test-bed for packet loss rate
- EGM TST-based mote test-bed for sending and relaying time
- http://www.ear-it.eu/audio-benchmarking

Developed hardware & tools

- Raw audio and compressed audio platforms. Full design of audio board. Control software for audio board
- Traffic generators based on real audio hardware
- Promiscuous packet sniffer control software and link with wireshark
- Radio gateway software to control wireless devices
- Fully controllable relay nodes for multi-hop
- Excel templates and script for benchmark analysis

Conclusions

- Experimental tests in Santander and Geneva test-bed have validated the benchmark procedure
- We determined value for NETWORK, AUDIO and ENERGY indicators.
- Audio sources have very small packet jitter and fully satisfied the constraints of audio transmission
- Relaying time are consistent with measured values, again with very small jitter
- According to the maximum relaying capabilities, an appropriate aggregation level at the source can be used to reduce the packet losses at intermediate relay nodes
- LOS transmissions show small packet loss rates therefore audio quality is high
- NLOS transmissions (oftenly the case in in-door) is very challenging and relay nodes have to be carefully chosen

Conclusions (con't)

- EAR-IT WP1 demonstrated that low-power acoustic IoT nodes can provide complementary acoustic information
- Audio streaming capabilities on limited-resource IoT infrastructures have been demonstrated
- WP1.3 also provided
  - useful & important experimental competencies in IoT network qualification and benchmarking
  - set of tools for benchmarking other test-beds

Questions ?