Some thoughts and feedback from extensive experimentations with a large scale IoT testbed

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Credits

- Isabel Vergara, PhD now at CEA LETI
- Ana Bildea, PhD now at Arago Systems
- Michał Król, PhD student
- Andres Cantor, João Zeni, Antoine Ubrich, Yongkan Huang, and other interns
- Étienne Dublé, Olivier Alphand, Andrzej Duda
- Quentin Lampin, Frédéric Evennou, Dominique Barthel, Orange Labs
- Many others

Our usage these last 4 years

- Very early users
  - Things have changed a lot since then
- Projects funding our work
  - ANR Aresa2, ANR Iris, ICT Calipso
  - Wireless sensor networks related obviously
- Software we have used
  - Contiki OS, TinyOS, FreeRTOS, bare bone

Keep in mind

- We focus on large scale experiments
  - Several hundred nodes
  - Running for days
  - Generating loads of data
- Senslab / IoT-lab is very good at that
  - But even with such a great tool, we found that it remains a challenge to do it well

Experiments we made

- Routing
  - Waypoint routing, Featurecast, (comparison with previous work)
- MAC protocols
  - Wake on Idle, Sleep on Idle, (comparison with previous work)
- Transmissions
  - Bit Error Rate and Packet Error Rate analysis

Results ?

- It worked, we made publications, deliverables, etc.
- But since we learn from our mistakes, lets focus on

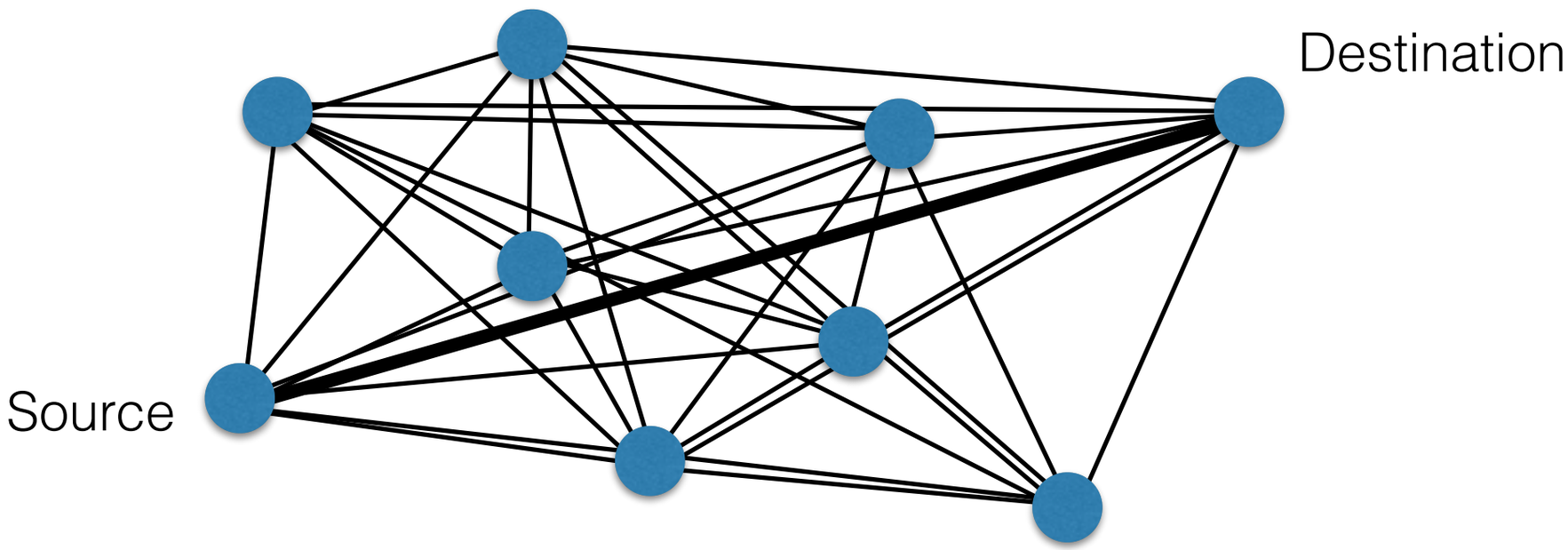
where we struggled

what was missing

and what has failed

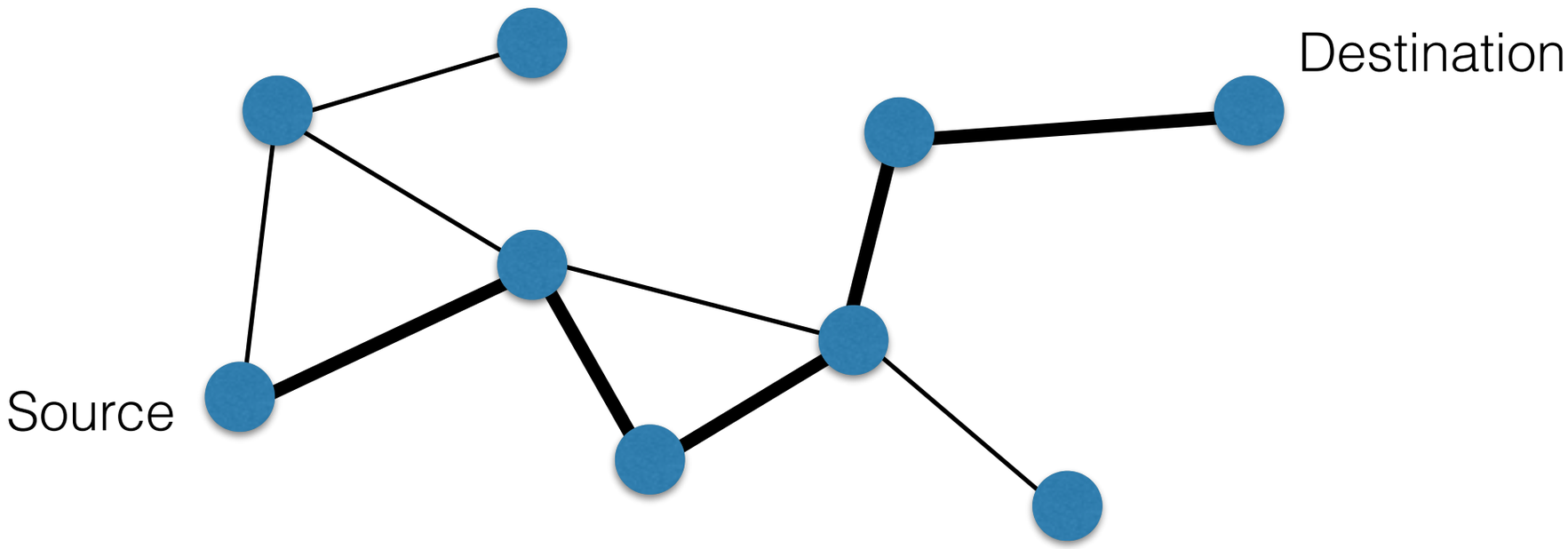
Routing

- Study mechanisms to route packets in the networks
- Long range transmissions relative to testbed range
- Fully connected network, single hop, no routing !



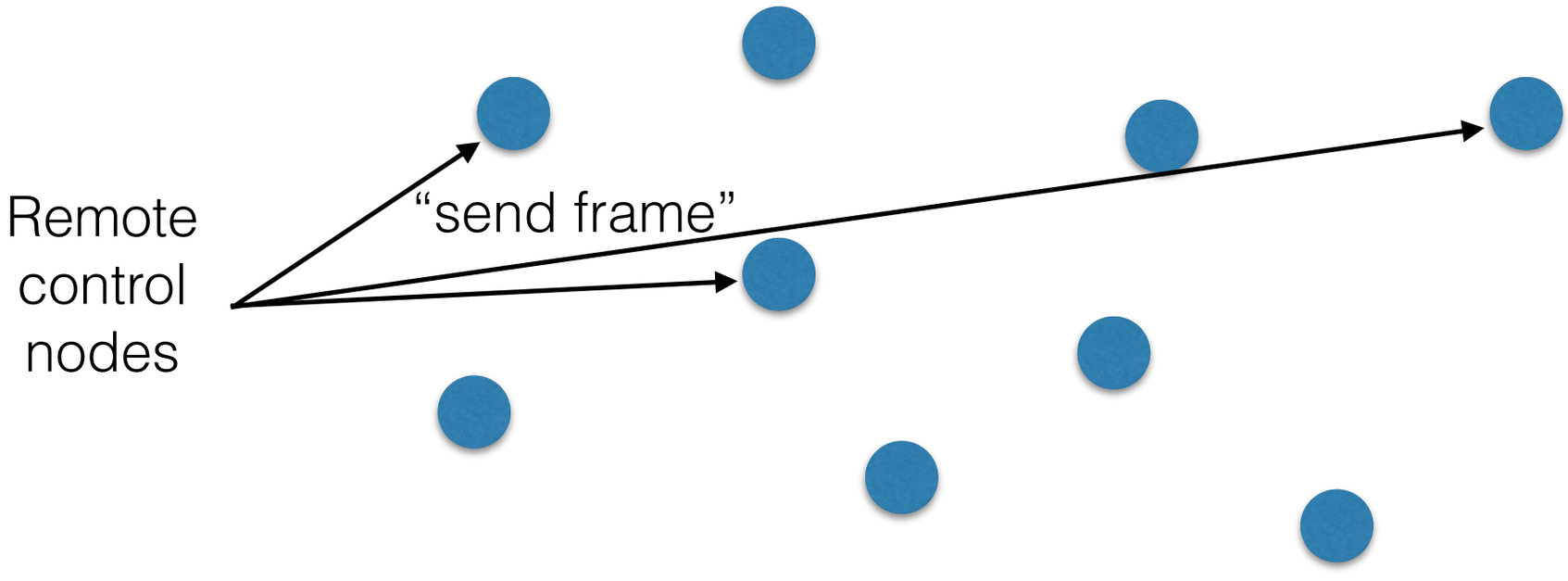
Large topologies

- We expect many hops to test routing protocols
- Depends on the transmission range
- TX power reduction, impact on experiments ?



Traffic

- Generate traffic patterns, distributions
  - No advanced arithmetics in MCUs
  - Coordination among nodes
- Create defects

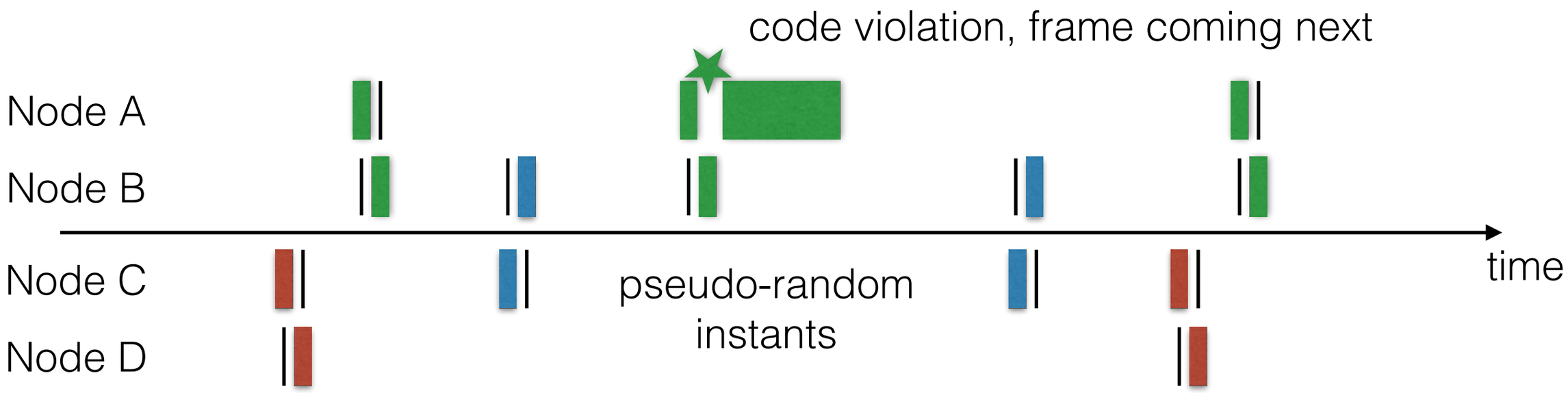


MAC protocols

- Analog signaling for energy efficient synchronized communications
- No need to decode frames, only sensing
- Need very flexible radios like CC1101 to experiment some ideas

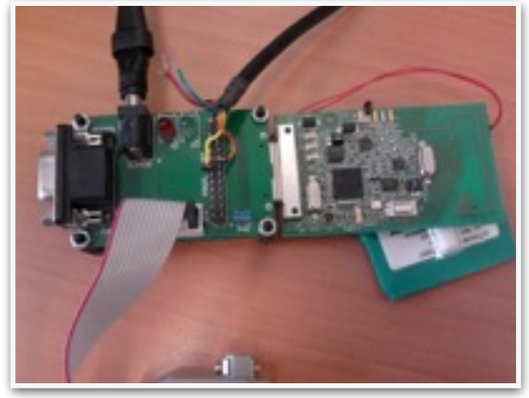
Wake on Idle

- Neighbor maintenance and medium access
- Pair of nodes tracks each other using analog signaling at pseudo-random instants
- Medium access using code violation



Complex implementation

- Remote debug is impractical in the dev. phase
- Local debug on desktop is very limited and very bulky
  - 2-3 nodes max and as many serial interfaces for debug control and traces



http://www.senslab.info

- Port / adapt previous work for comparison purposes
  - Quite tedious

Channel characterization

- Study Bit Error Rate
  - Use CC1101 infinite mode to generate very long sequences
- Study Packet Error Rate
  - Relation between BER and PER
  - Derive packet receive ratio from RSSI and LQI

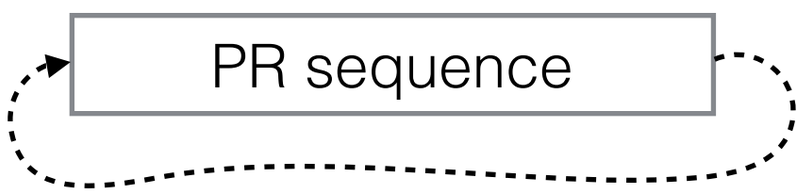
BER experiments

- Very large scale
  - Send from each node to all the others
    - x100 receivers
- Serial link way too slow compared to radios
  - Use reduced wireless bitrate
- 450 GB of traces collected — raw decoded bits

Idea

- Transmit pseudo-random sequence cycle
- Analyse received data to detect bit errors
- Collect other data periodically for eventual further analysis
  - RSSI, temperature, …

TX



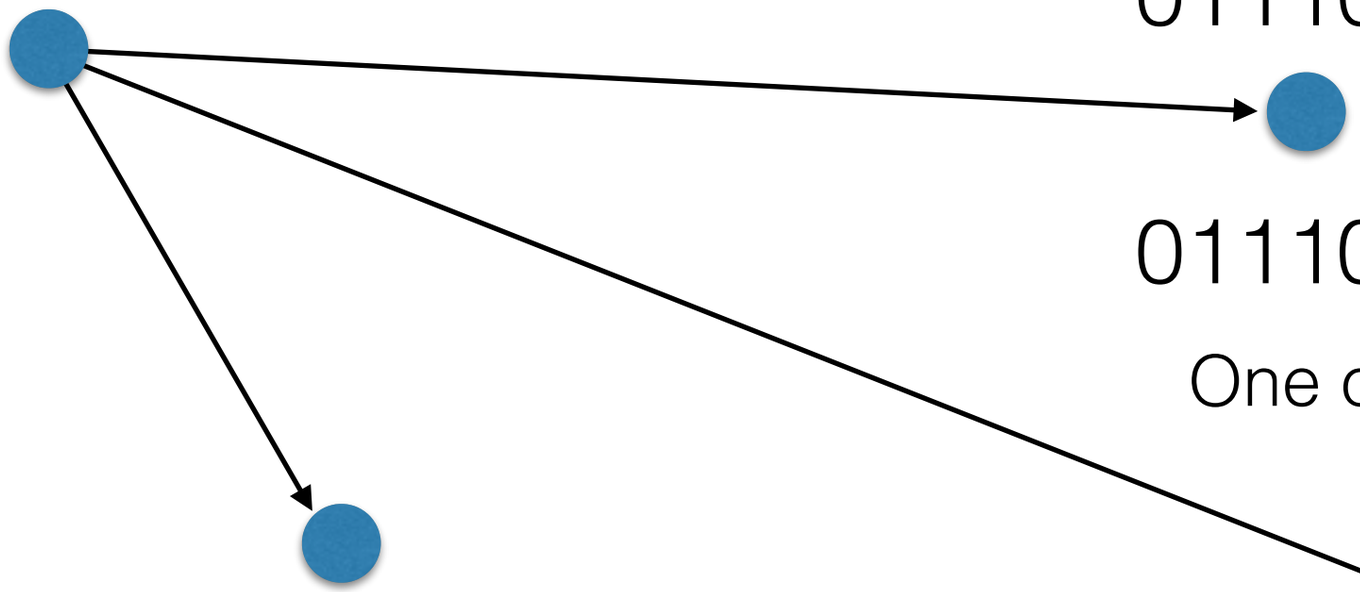
cycle PR sequence
embed and protect sequence number

RX

locate PR sequences
extract sequence number
compute BER

Raiders of the lost bits

Node A TX
01110110100111O110



Node B RX
01110110101111011101

BER is huge

01110110100X1110110

One or several bits missing

Node C RX
01110110100111O110

BER = 0

Node D RX
01110110110111O110

BER ≈ 10^{-7}

Automation

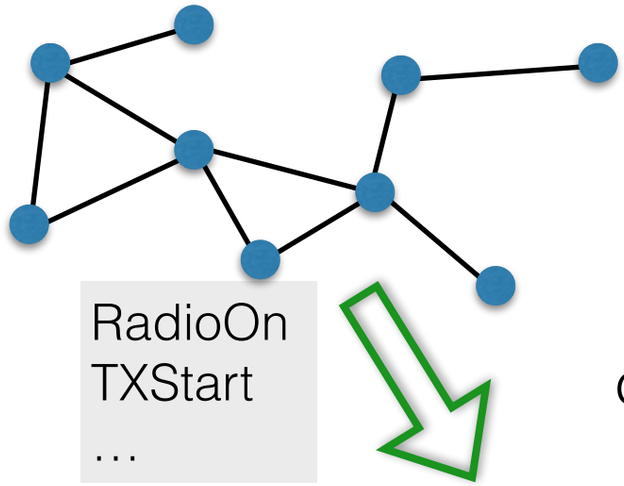
- Large scale means
  - A lot of runs, with varying parameters
    - Scriptable experiments
      - Traffic generation, synthetic behavior, perfect behavior
        - Remotely controlled generic firmware
      - Random node crashes
        - Resume experiments
- Experiment control with a Python framework

Experiment setup

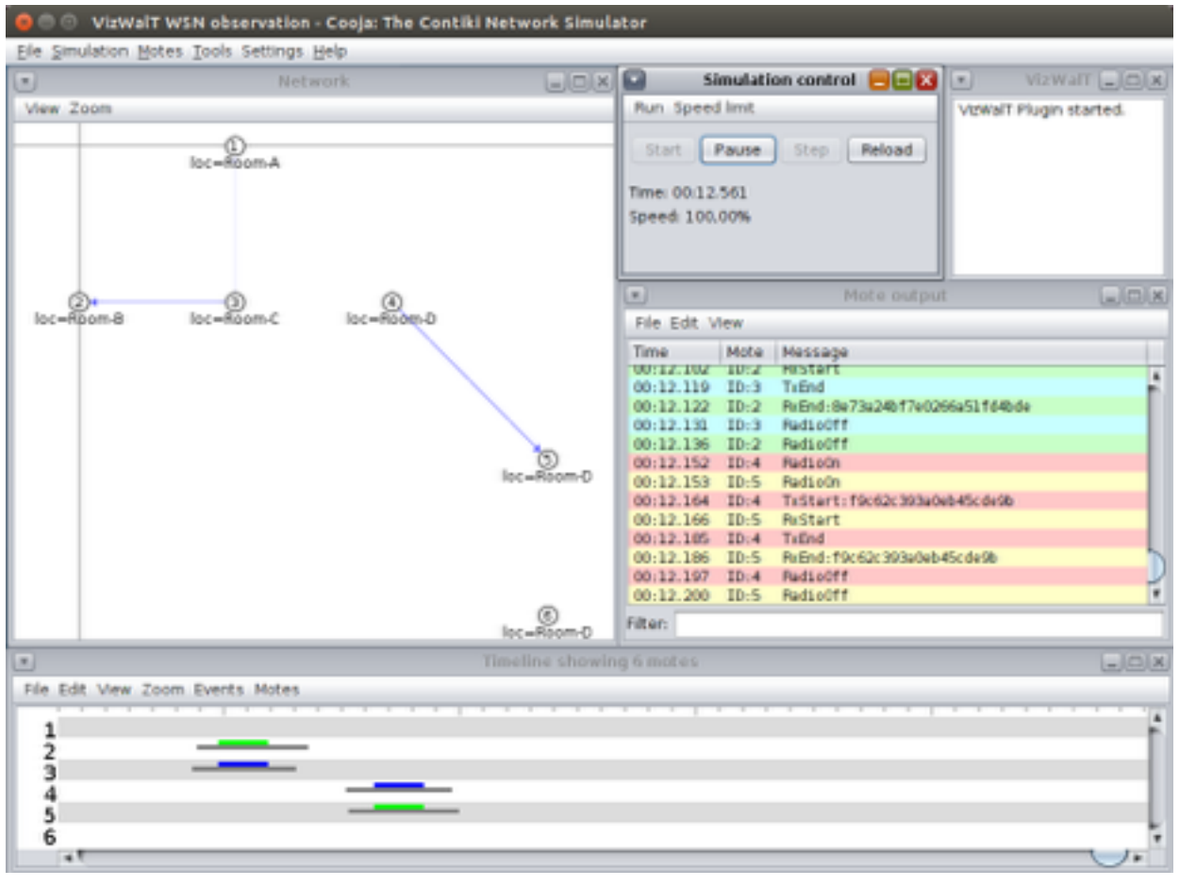
- Debugging low level functions on the desktop is fine
  - Usual stuff: JTAG, SWD, debugger, etc.
- Debugging and validating an entire protocol / application on a remote platform is tedious
  - No direct access, node reservation
  - No easy integrated build and test
- Need for a small size platform: WalT

Traces and visualization

- Collect
  - Events in nodes
    - Instrumented Contiki OS
  - All the traffic in the network
    - Need fast links from nodes to the infrastructure
- Visualize traces with usual tools
  - VizWalT plugin for Cooja
    - Inject real traces in Cooja



Full trace collected from nodes



Thanks