



# Extending and Improving Personal Area Networks on ns-3



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# Personal Area Networks

Connection of a group of devices that ranges from a few centimeters to a few meters.

- Often used with sensors
- Typically powered by batteries
- Used in “IoT” applications: Home automation, farming, WSN in general.

Technologies:

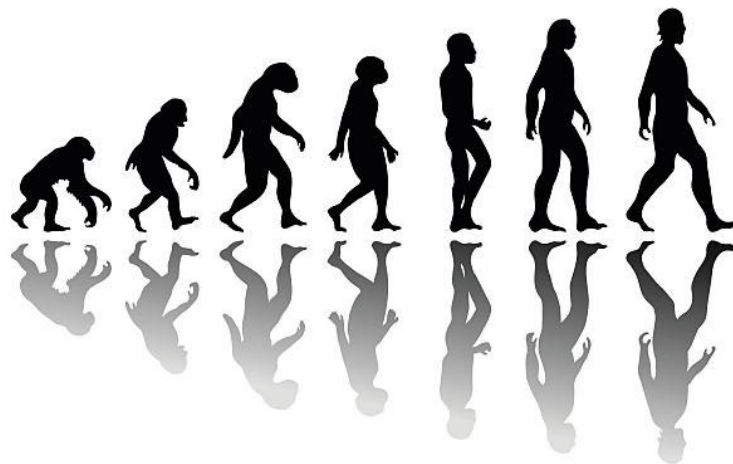
- WiFi (IEEE 802.11)
- Bluetooth and BLE (IEEE 802.15.1)
- 5G (Nb-IoT)
- Lr-WPAN (IEEE 802.15.4)
- WBAN (IEEE 802.15.6)
- Lora



# History of ns-3's Lr-wpan module

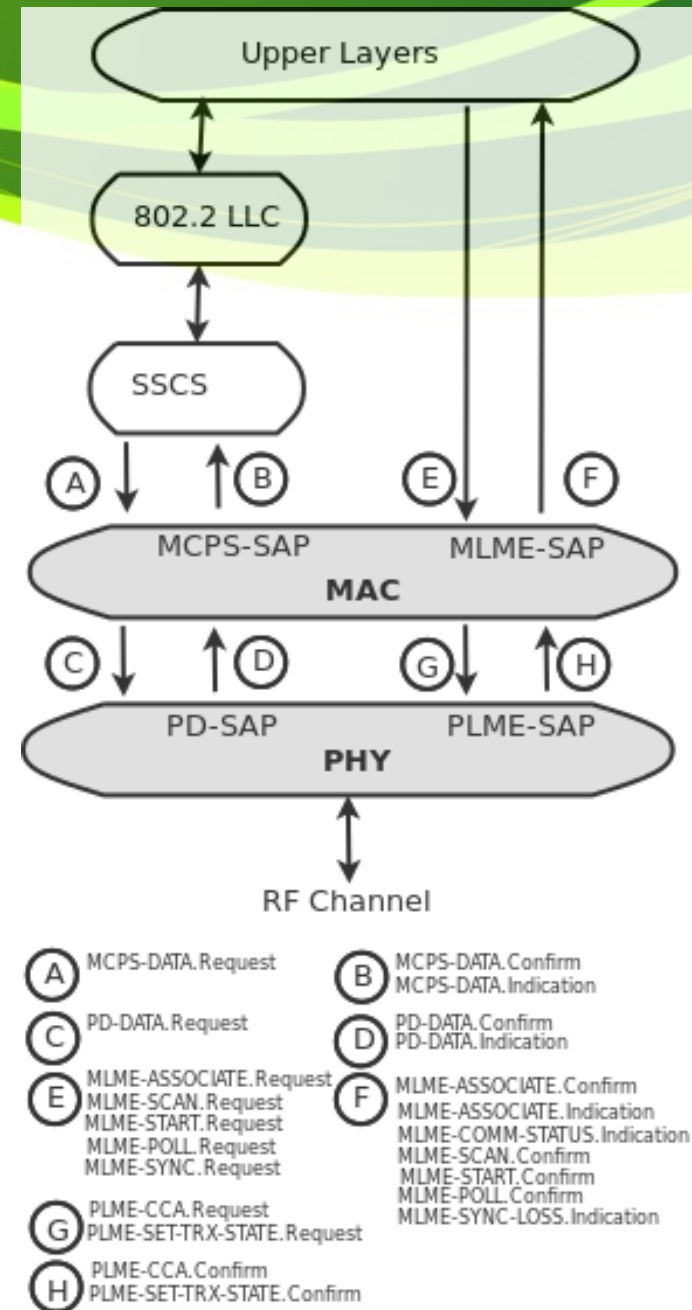
- Developed by Gary Pei et al. , 2011
- Based on IEEE 802.15.4-2006 std. and the ns-2 module
- Included a PHY with O-QPSK 250 kbps
- Supported a basic MAC with an unslotted CSMA/CA
- Basic documentation

 ns-3



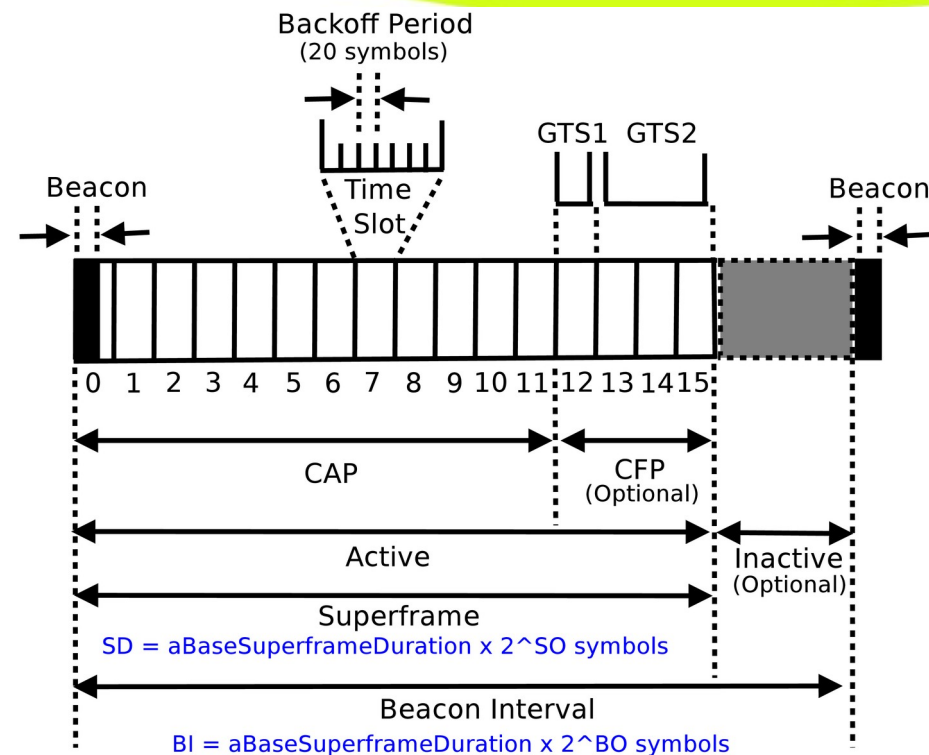
# Some changes since then

- Updates and refactor to IEEE 802.15.4-2011 (Pagination, primitives, documentation)
- Beacon Mode (slotted CSMA/CA)
- Bootstrap (Network scan and Association)
- Sensitivity configuration support



# Beacon Mode

- Legacy “MAC mode”
- Used for comparison purposes and development of “advance behaviors” (TSCH, DSME, LLDN)
- Beacon frames are still relevant even if the beacon mode is not often used.



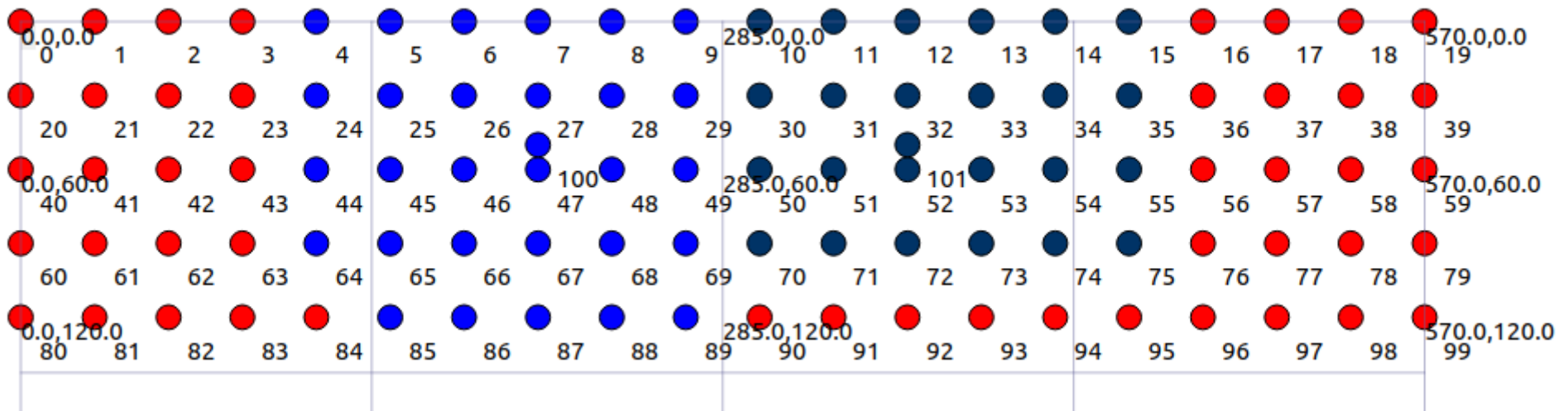
- Alberto Gallegos Ramonet and Taku Noguchi. 2020. LR-WPAN: Beacon Enabled Direct Transmissions on Ns-3. In 2020 the 6th International Conference on Communication and Information Processing (ICCIP 2020). Association for Computing Machinery, New York, NY, USA, 115–122. <https://doi.org/10.1145/3442555.3442574>.

- Alberto Gallegos Ramonet, and Taku Noguchi. "IEEE 802.15. 4 now and then: Evolution of the LR-WPAN standard." 2020 22nd International Conference on Advanced Communication Technology (ICACT). IEEE, 2020.



# Network Bootstrap

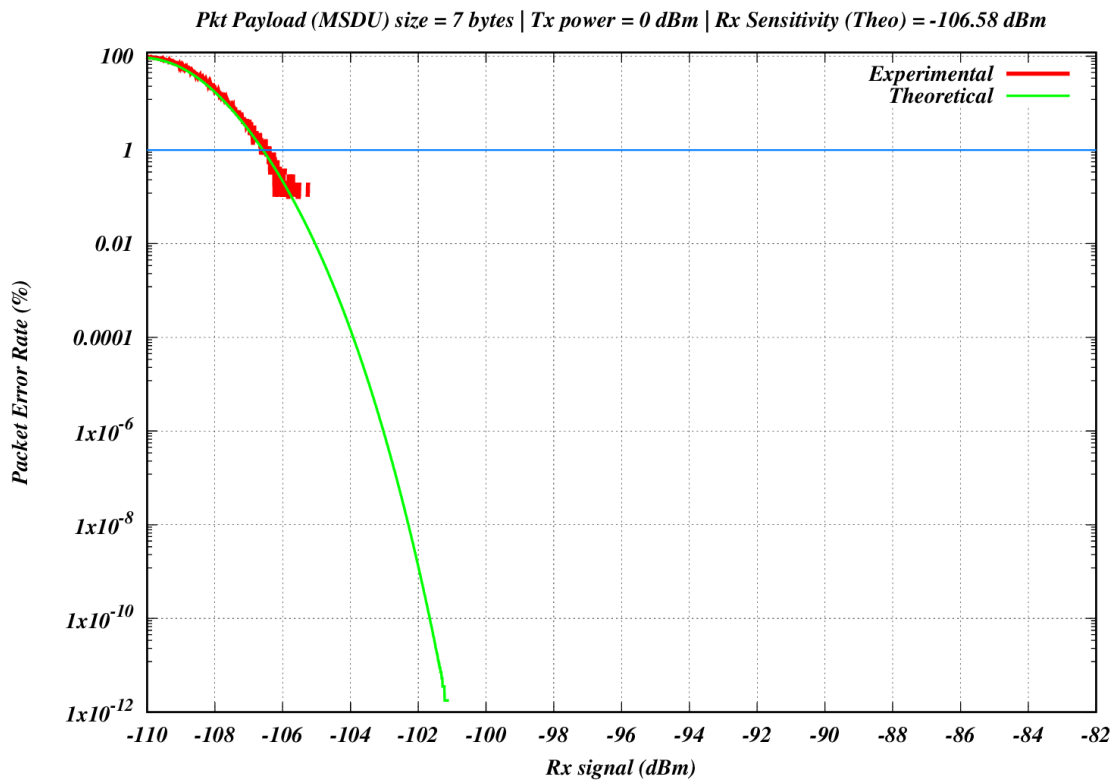
- Required multiple primitives and command frames
- Support for extended addresses (EUI-64 addresses)
- 4 types of scanning (passive, active, energy detection, orphan)
- Mac association procedure and short address assignment



[src/lr-wpan/examples/lr-wpan-bootstrap.cc](http://src/lr-wpan/examples/lr-wpan-bootstrap.cc)

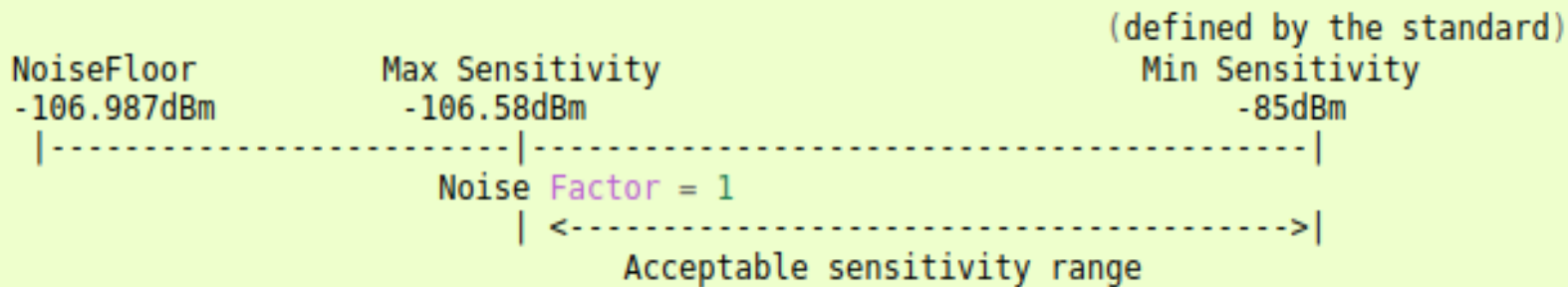


# Sensitivity

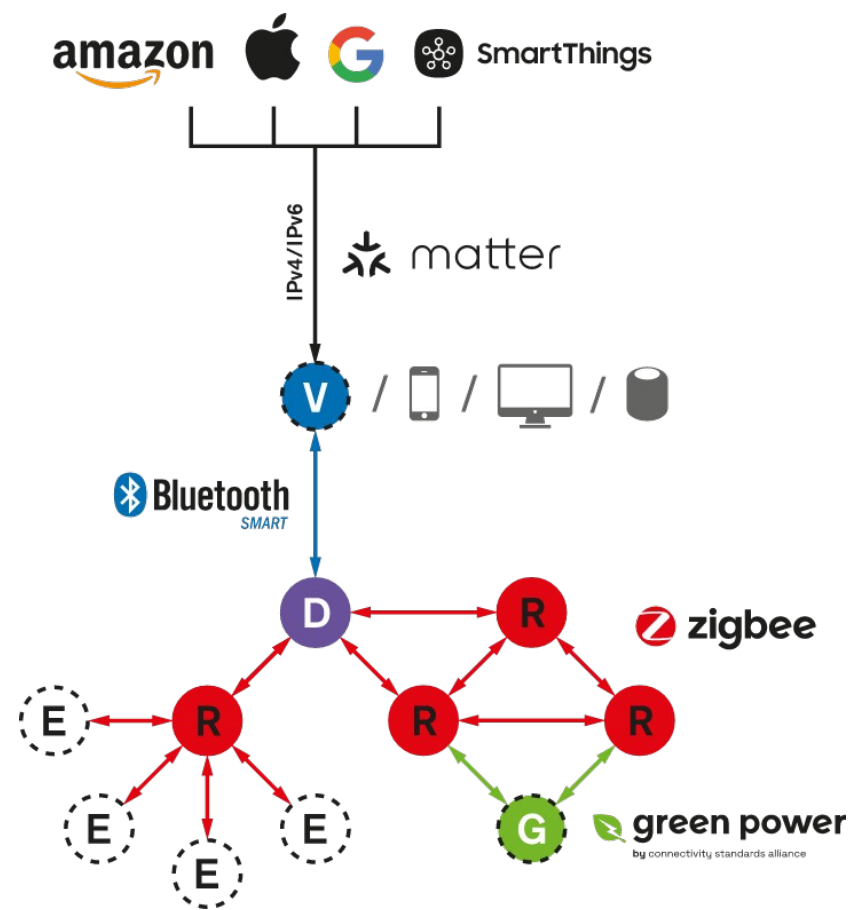


Adjustable noise figure to simulate radios with different Rx sensitivity.

Standard:  
1 % PER using 20 byte frames. Sensitivity should be at least -85 dBm for O-QPSK 250 kbps.



# What is next and why does it matter?



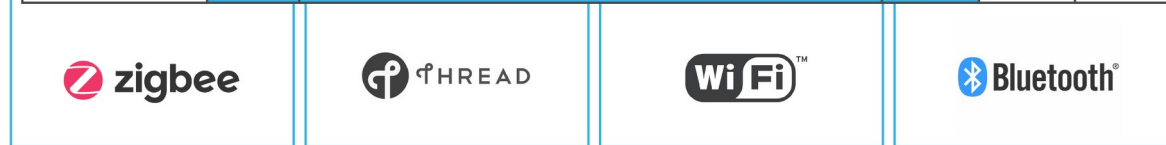
Ecosystems and Cloud



Application Layer



Network/Transport Layer

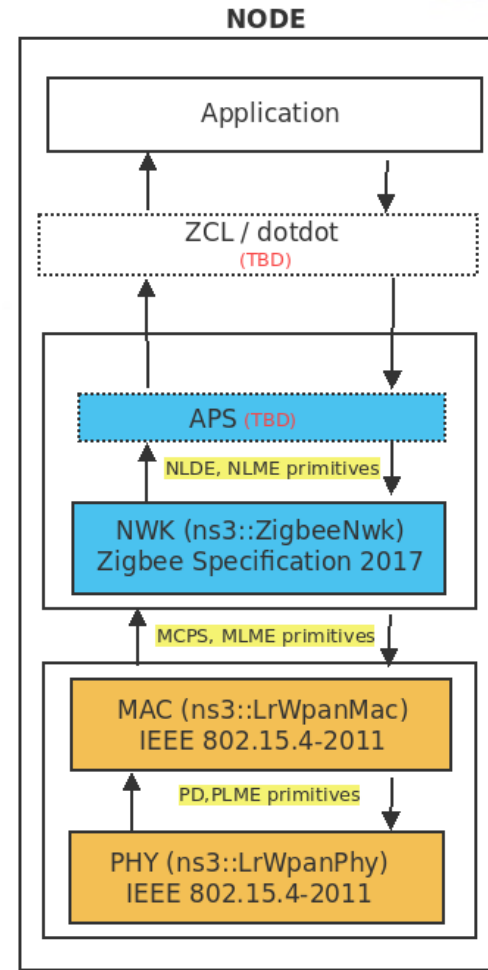
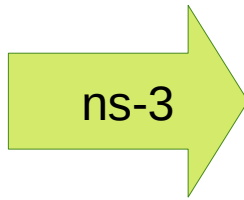
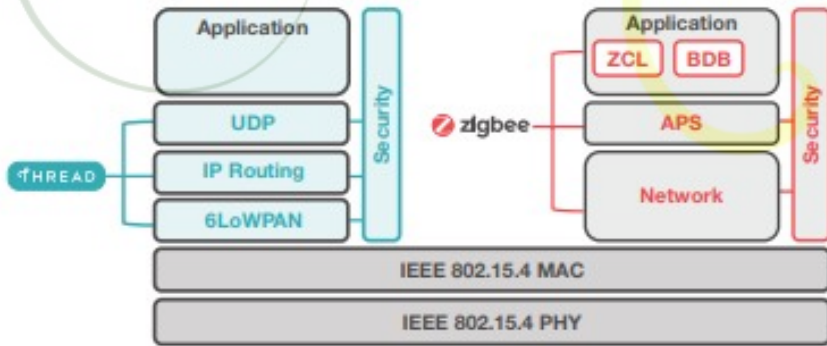


Radio: Physical/Link Layer (MAC/PHY)





# Zigbee for ns-3 (Under development)



ns3::ZigbeeStack

ns3::LrWpanNetDevice

Objective: Zigbee NWK and APS support  
(Stack profile 0x002, 2017 revision)

- A non-IP-dependent PAN
- Help to spot problems within ns-3's MAC
- Open the path for Application layer protocol support (dotdot, ZCL, matter bridge)



[https://gitlab.com/nsnam/ns-3-dev/-/merge\\_requests/1004](https://gitlab.com/nsnam/ns-3-dev/-/merge_requests/1004)

# Future work and conclusions

After 20 years Lr-wpan and Zigbee remain relevant for PAN and IoT applications, interest continue growing and support is present in the form of Zigbee 2023 , Thread and Matter. Ns-3 is capable of continuing support for these PAN protocols.

## Future Work:

- Additional PHY modulations/band support (ASK, BPSK,O-QPSK)
- PHY preamble support
- Code Optimization / PHY evaluation
- MAC additions (Indirect transmissions, disassociation, etc)
- PHY sleep state
- LrWpanRadioEnergy model
- Zigbee NWK (Routing)
- IEEE 802.15.6 (WBAN) - <Available soon (ns-3 App store)>



<https://gitlab.com/nsnam/ns-3-dev/-/issues/693>