



# A communication stack over PLC for multi physical layer IPv6 Networking

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# Motivation

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- Bring an **open standardized** communication protocol stack over PLC
- **Bridge PLC with RF**
  - Take the best of PLC and RF world
  - Enhance Home Area Networking and Smart Grid

# Background

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- Major developments in WSN :
  - IEEE 802.15.4 Standard
  - 6LoWPAN (IETF RFC 4944)
  - RoLL
- Widely on RF

**W(ireless)SN → W(ired)SN ?**

# 802.15.4 PHY & MAC for LR-WPAN

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- LR = Low Rate (<250 kb/s)
- PAN = Personal Area Network (Short range)
- Small computation capabilities (8 bit  $\mu$ C)
- Unreliable Medium
- Low Power (2 AA batteries for RF)

**Does it makes sense for PLC applications?**

# 802.15.4 for ~~LR-WPAN~~ PLC

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- LR = Low Rate (<250 kb/s, 10 kb/s)
- PAN = Personal Area Network (Short range, House)
- Small computation capabilities (8 bit  $\mu$ C)
- Unreliable Medium
- Low Power (~~2 AA batteries~~ Main Powered )

# PLC Technology

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- Homeplug standard:
  - AV: OFDM modulation / 200Mb/s
  - GP: OFDM modulation / 3 Mb/s
- WPC™ Transceiver from Watteco:
  - Specific modulation
  - 10 kb/s

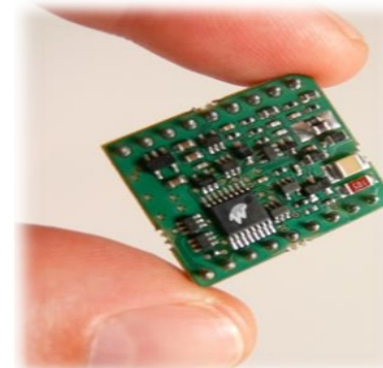
## **BUT :**

- Expensive (a few \$)
- Power greedy ( a few W & most part always ON)
- Large Size



## **AND :**

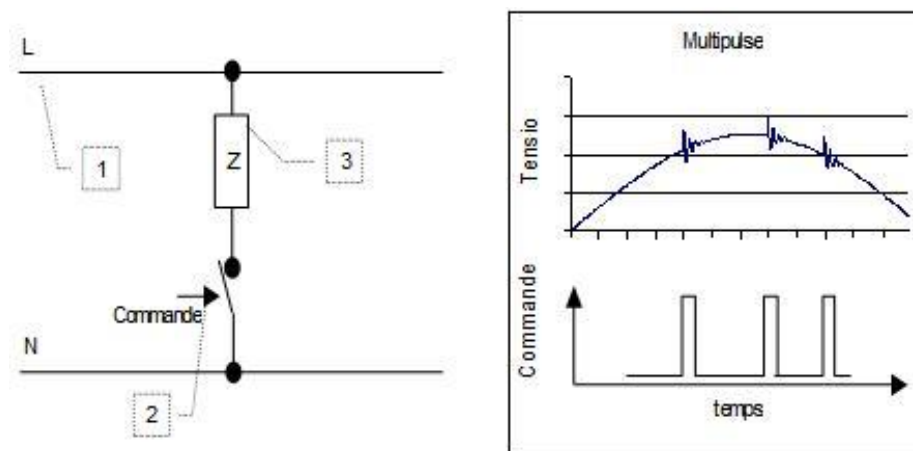
- 1\$ transceiver
- 10 mW
- Prototype 25 mm<sup>2</sup> large
- Single chip coming soon  
    <<1\$, a few mW, a few mm<sup>2</sup>



**Integrated in your homeplugs, light bulbs...**

# WPC™ Technology

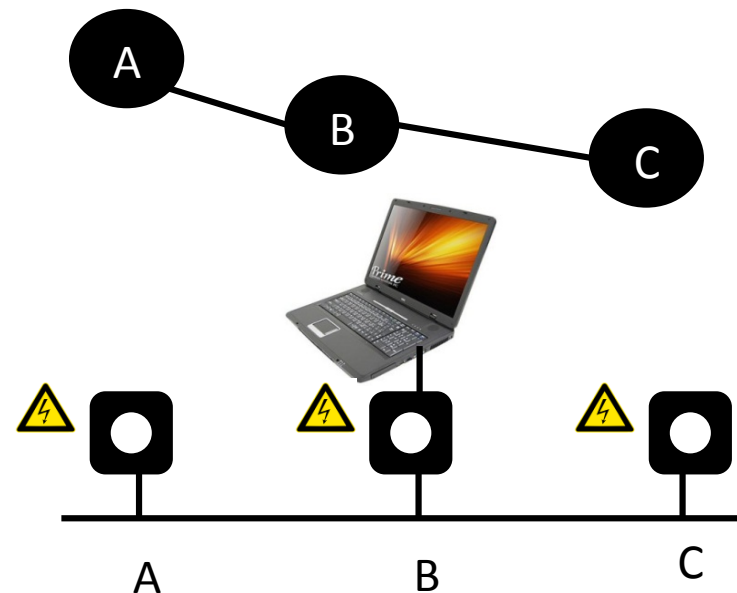
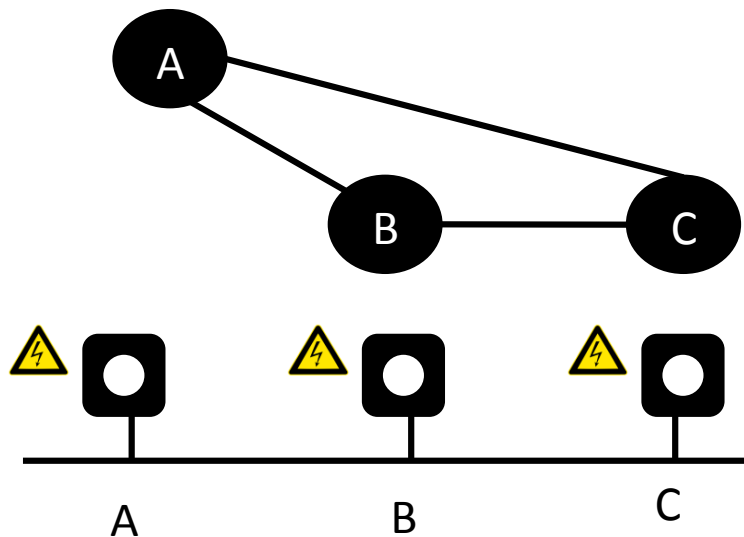
- Coupling method



- « Hit on a pipe with a hammer »
- No continuous carrier sense
- No power injected

# Unreliability

- Powerline is subject to « real life » activity
- A physical connexion doesn't ensure reliability

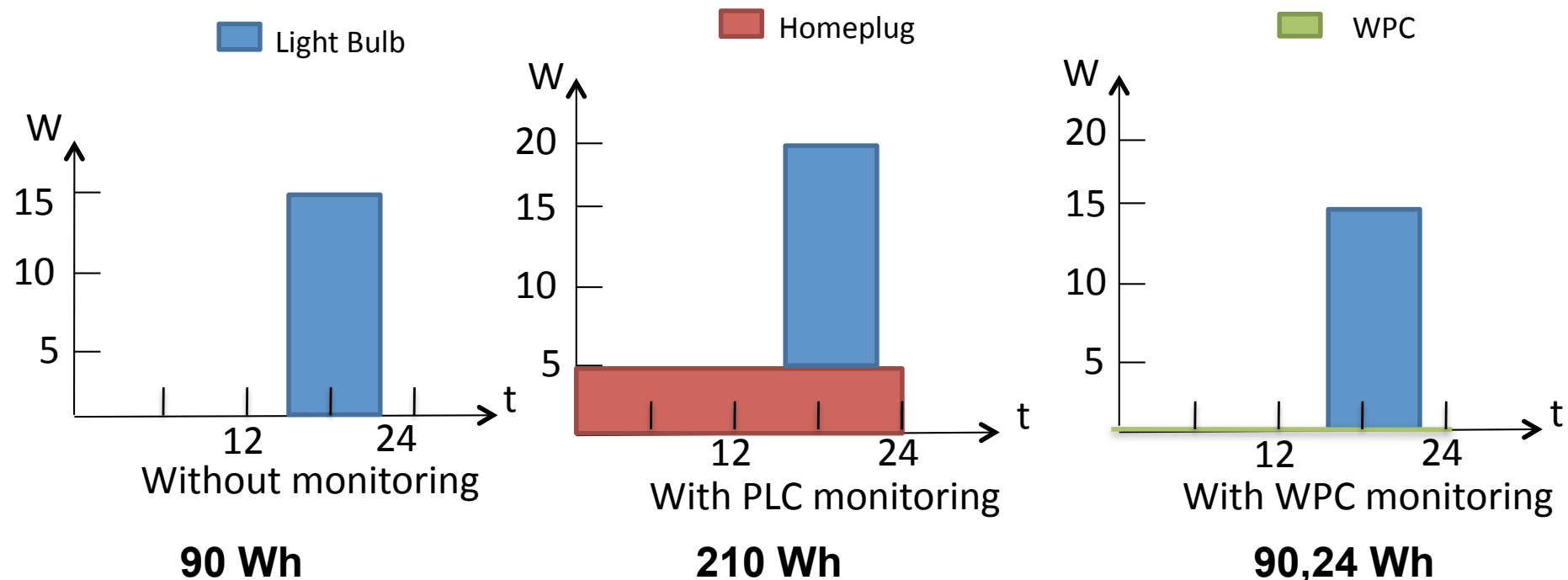


**Need for Mesh Topology over PLC**



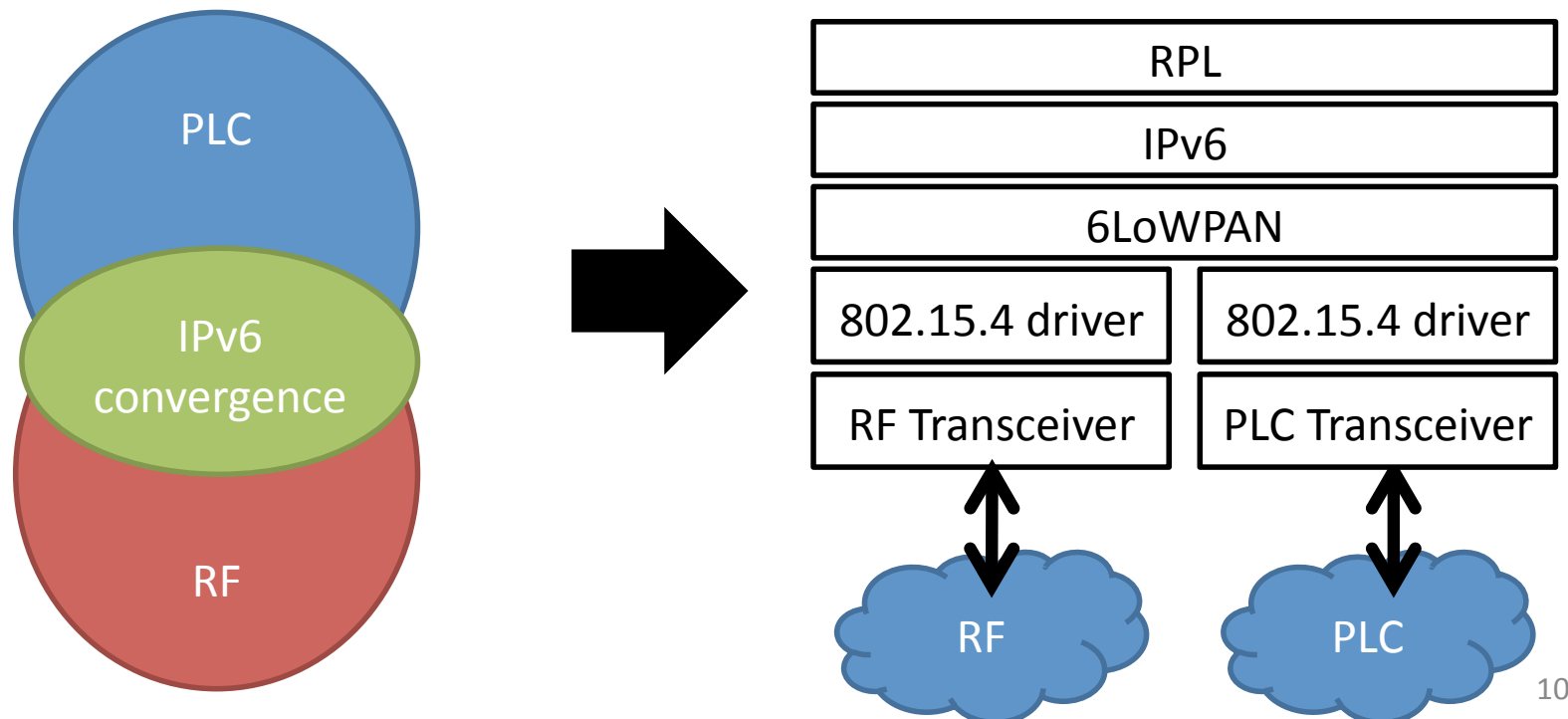
# Low Power in PLC

- Continuous power supply (no lifetime issue)
- BUT power consumption has to be low



# MAC Layer Context

- 802.15.4 context is the same as our PLC context
- Enable efficient interoperability



# 802.15.4 Adaptation over PLC

|                               | LR – WPAN                                                                                         | PLC-PAN                                          |
|-------------------------------|---------------------------------------------------------------------------------------------------|--------------------------------------------------|
| Data-rate                     | Over-the-air data rates of 250 kb/s, 100kb/s, 40 kb/s, and 20 kb/s                                | 10 kb/s                                          |
| Star, P2P or Mesh             | OK                                                                                                | OK                                               |
| CSMA-CA                       | OK                                                                                                | OK                                               |
| Fully acknowledged            | OK                                                                                                | OK                                               |
| Link quality indication (LQI) | OK                                                                                                | OK                                               |
| Channels                      | 16 channels in the 2450 MHz band, 30 channels in the 915 MHz band, 3 channels in the 868 MHz band | 1 channel (2 - 4 Mhz)<br>(4 channel in progress) |
| Power ressource               | - - (Limited to battery)                                                                          | + + (Main powered)                               |
| Mobility                      | + + (No Cord)                                                                                     | - - (Limited to the cord)                        |

→ Introduce PLC to the Internet of Things

# IPv6

- IPv6 Specification (RFC2460)
- IPv6 Neighbor Discovery (RFC4861)
- ICMPv6 (RFC4443)
- Stateless Address Auto-configuration (RFC4862)
- 16.444 kB of ROM and 2.622 kB of RAM

*Full TCP/IP for 8-Bit Architectures  
(Mobisys 2003)*

*IP is Dead, Long Live IP for Wireless  
Sensor Networks (Sensys 08)*

# 6LoWPAN

- IPv6 over 802.15.4 networks (RFC4944)
- Header Compression (6lowpan-HC draft)
- Neighbor discovery (6lowpan-ND draft)
- 4.922 kB of ROM and 291 Bytes of RAM.

# Routing Protocol for LLNs (RPL)

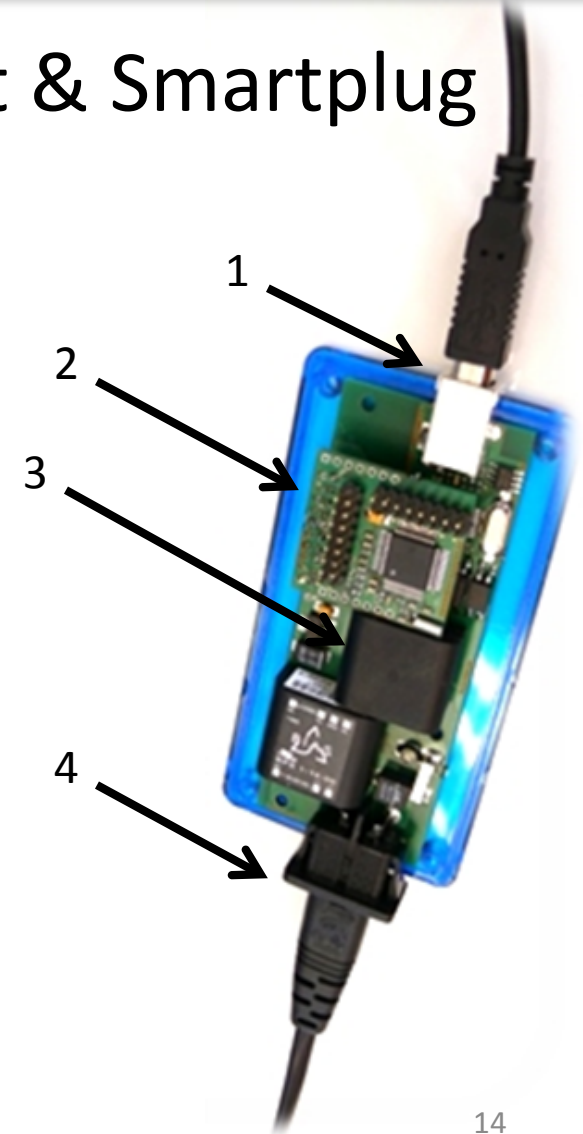
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- ROLL Working Group
- Enable MP2P, P2MP and basis P2P mechanism
- **Link Layer agnostic (Enable Multi physical routing)**
- Objective Function mechanism
- 7.057 kB of ROM and 442 Bytes of RAM

# Experiment

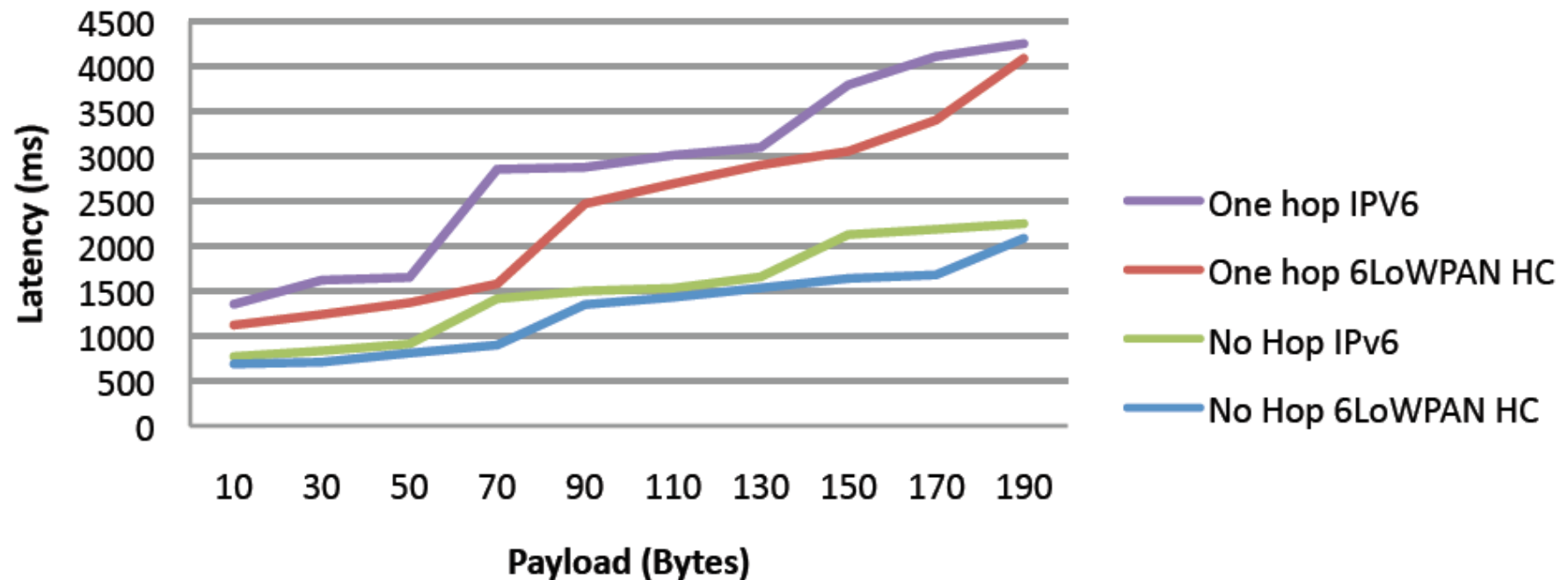
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- Hardware : WPC Development kit & Smartplug
  - USB interface (1)
  - Microcontroller (2)
  - WPC™ Transciever (3)
  - AC power (4)
- Software :
  - Contiki 2.4  
(6LoWPAN/IPv6/RPL)



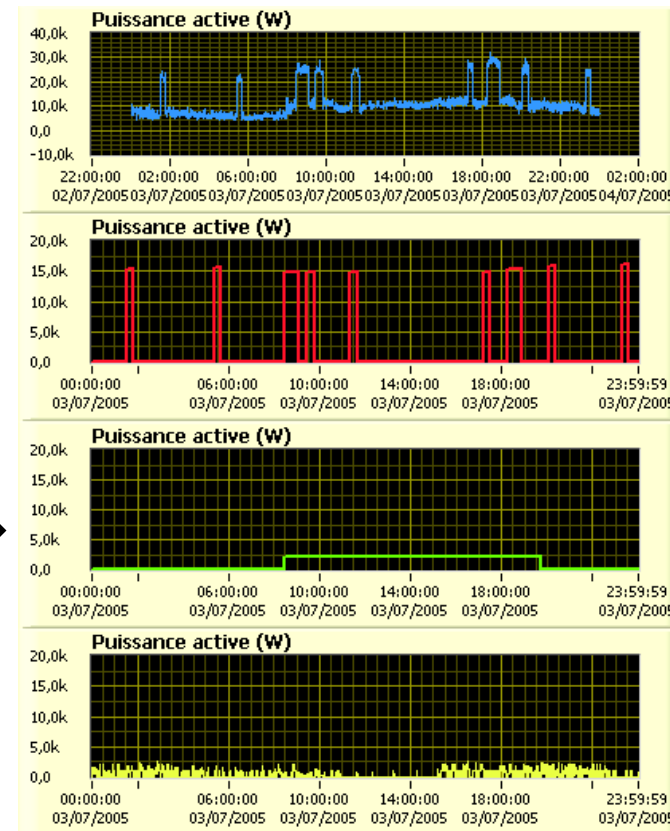
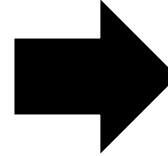
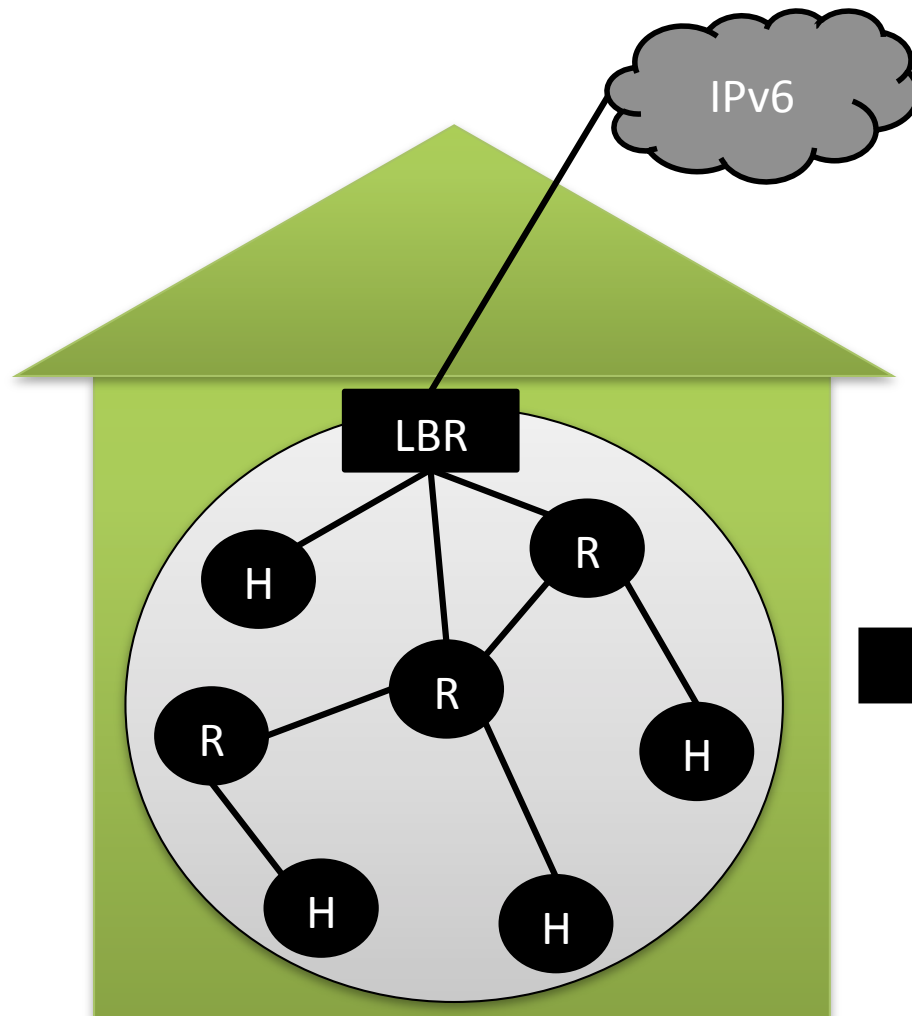
# Performance

- 6LoWPAN HC benefits



Every Byte has a cost in LLN

# Power Management



Global Load Curve (L.C.)

Boiler L.C.

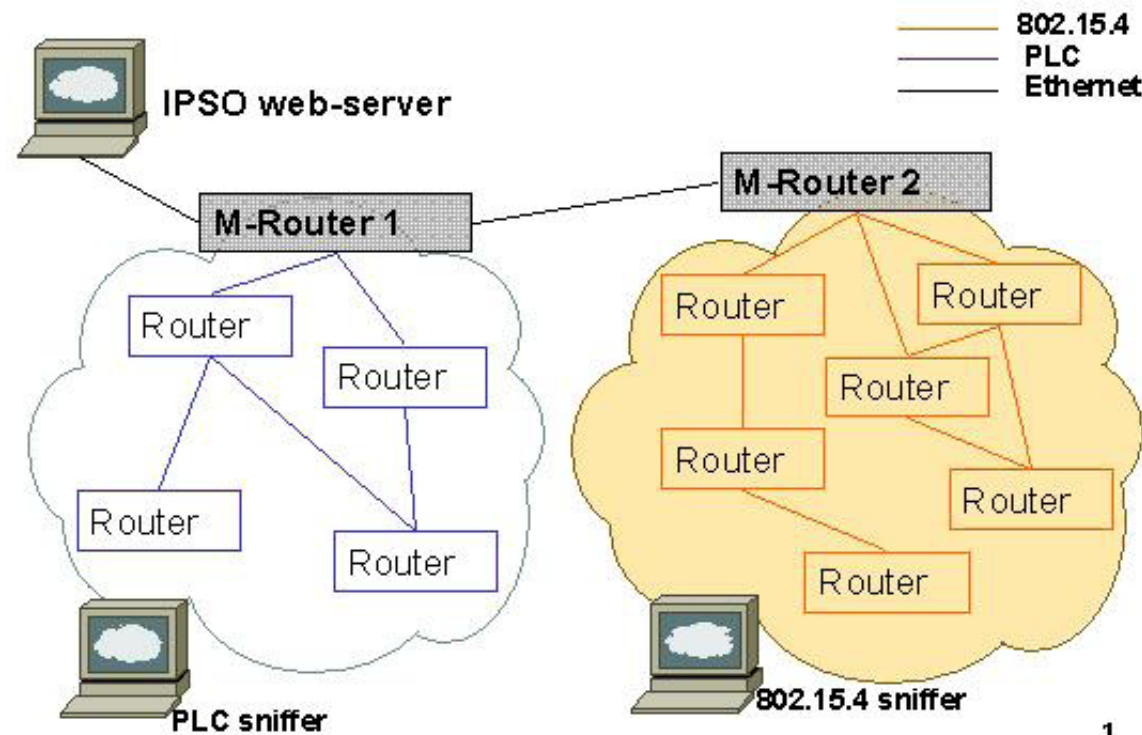
Swimming Pool L.C.

HVAC L.C.



# IPSO Interop Testbed

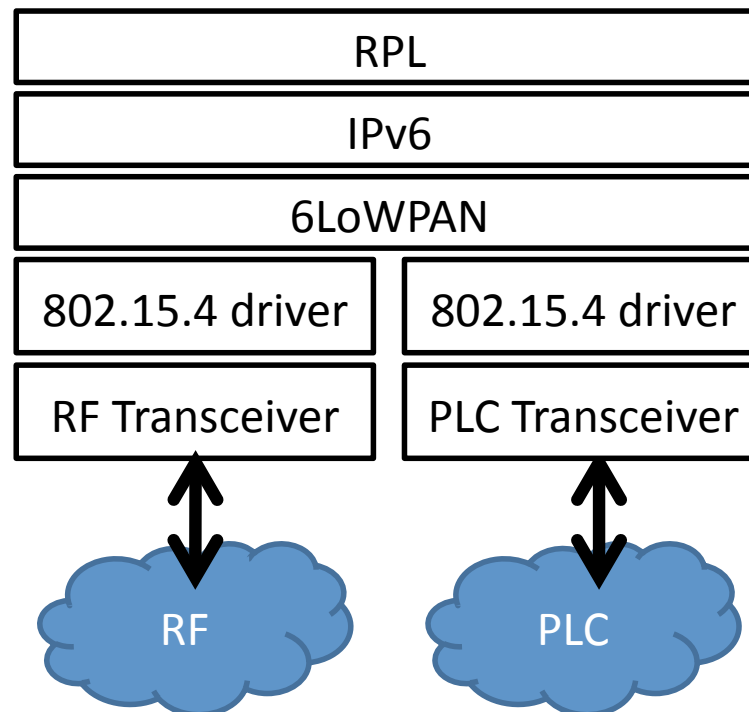
RPL Test Set-up (March 2010)



# Conclusion & Future Work

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- We provided an open communication stack over PLC for multi physical layer IPv6 Networking
- Simulation
- Heterogeneous Routing (Metrics, Constraints...)



# Thank you for your attention

