

# Energy Efficient Implementation of IETF Protocols on Constrained Devices

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# The Problem

- No sustained energy supply in many application scenarios



AA Battery



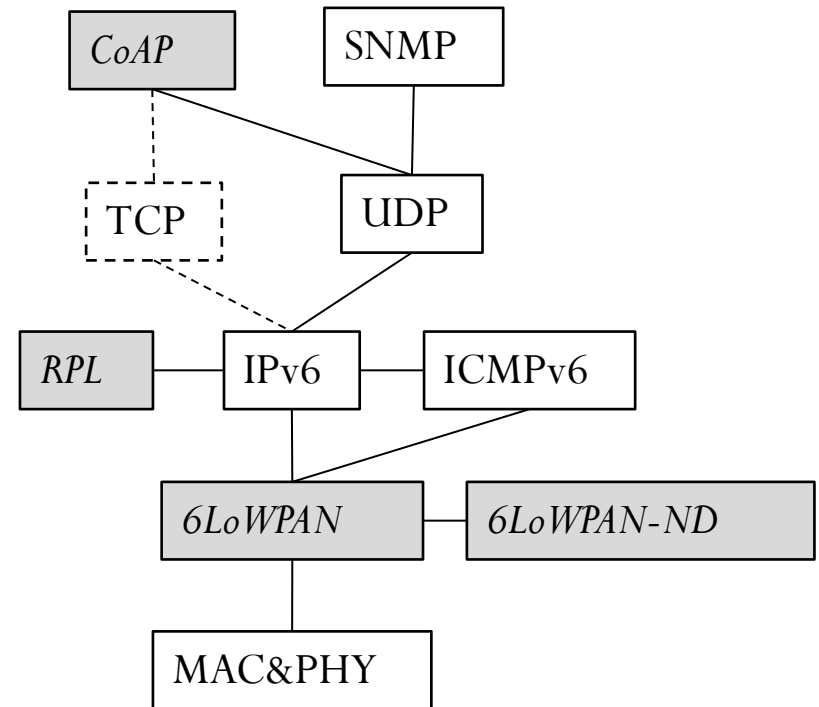
Power cord

- What's the implication of battery-powered devices on the IETF protocol design and implementation?

# Typical Device Configuration

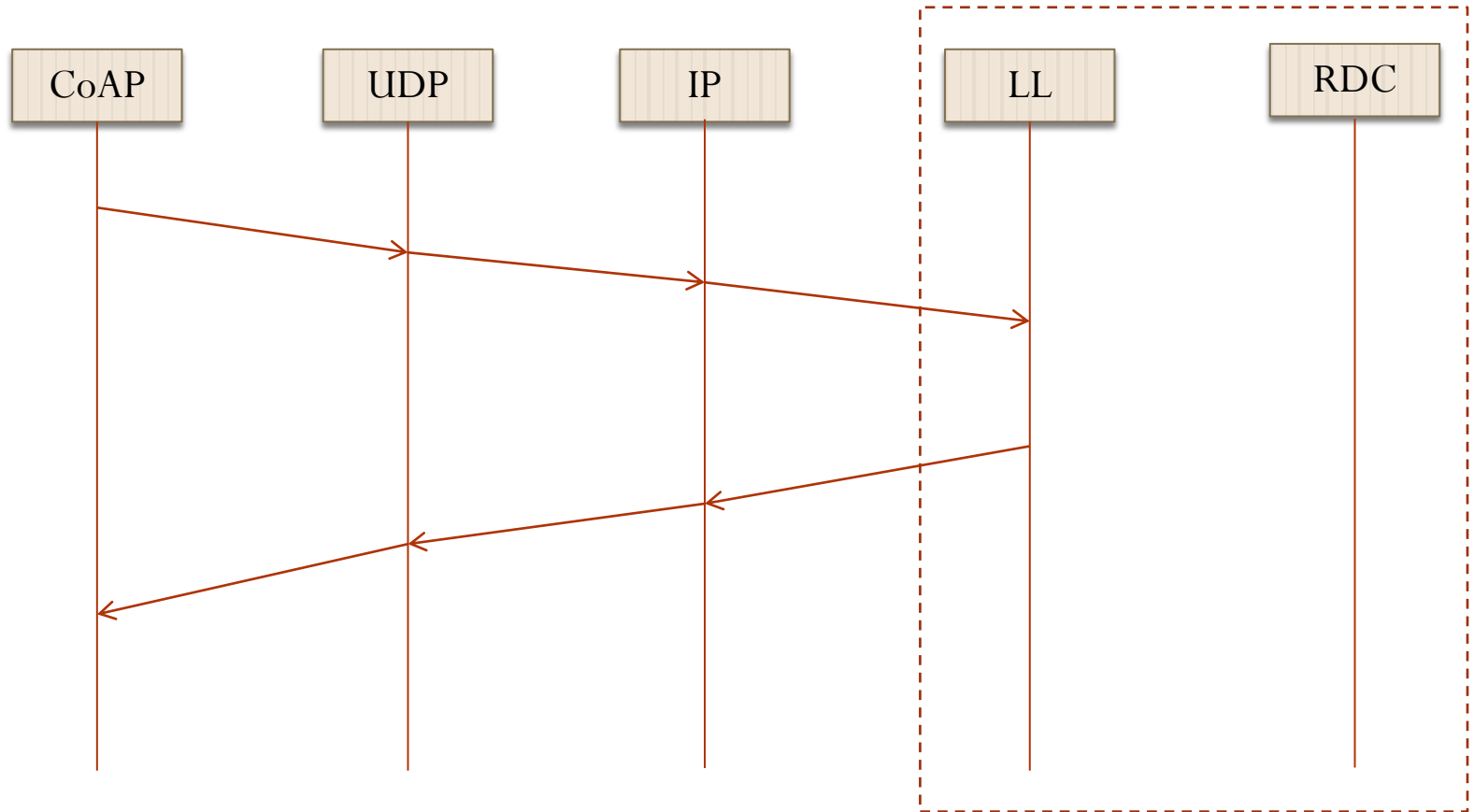
<i>Layer</i>	<i>Protocols</i>
APP	CoAP
TSV	UDP
NET	IPv6
Adaption	6LoWPAN
MAC	CSMA
RDC	ContikiMAC or A-MAC
PHY	IEEE 802.15.4

## Lightweight Internet Protocols



# The Fact of Consuming and Producing

- The network and upper layer protocols are customers of the lower layer



So obviously, we developers need to know the lower layer better

<b>Activity</b>	<b>Energy (uJ)</b>
Wake-up, no signal detected	12
False positive wake-up	100
Broadcast reception	178
Unicast reception	222
Broadcast transmission	1790
Non-synchronized unicast transmission	1090
Synchronized unicast transmission	120
Unicast transmission to awake receiver	96

\* Adam Dunkels, Joakim Eriksson, Niclas Finne, Nicolas Tsiftes, “Powertrace: Network-level Power Profiling for Low-power Wireless Networks”, SICS Technical Report T2011:05

# Network Layer

- 6LoWPAN
  - Trades communication for computation
  - Designed for short frames of low-power radios
- 6LoWPAN-ND
  - Reduce broadcast messages for ND, its addressing mechanisms, and duplicate address detection
- RPL
  - ICMP messages dominate power consumption to keep the routing state, may decrease with stable topology

# Transport

- UDP
  - No specific design for energy saving
- TCP
  - Reduce state during transmission
  - Simplify window control to reduce in-flight packets
- These are software engineering techniques...

# App

- CoAP
  - RESTful with binary header
  - Observe extension to avoid polling
  - RD for resource state maintenance
  - Mechanisms to deal with sleepy nodes to avoid frequent wake ups
- Many good discussions in related drafts
  - [draft-arkko-lwig-cellular-00](#)
  - [draft-kovatsch-lwig-class1-coap-00](#)



# Cross-Layer Considerations

- PHY to NWK layer: Using cooperative diversity in routing design to reduce power consumption
- MAC to Transport layer: Congestion control and scheduling to reduce unnecessary data re-transmission
- APP layer consideration? CoAP observe period design considering duty cycle, etc.

# Summary

- All Internet protocols, which are in the scope of the IETF, are customers of the lower layers (PHY, MAC, and Duty-cycling). In order to get a better service, the designers of higher layers should know them better.
- The IETF has developed multiple protocols for constrained networked devices. A lot of implicitly included design principles have been used in these protocols.
- Effective methods to be energy-friendly: to save wakeups, save unnecessary states maintenance, be less chatty

# Next Step

- Questions for the group
  - Interesting ?
  - Useful ?
- Questions for ourselves
  - Collect more information to make it solid and ready for WG consideration