Low-Power Interoperability for the IPv6 Internet of Things

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Introduction

- The Internet of Things is a current ‘buzz’ term that many see as the direction of the “Next Internet”.
- This includes activities such as Smart Grid and Environmental Monitoring.
- This is a world of ubiquitous sensor networks that emphasizes energy conservation!
- This paper provides an overview of the low-power IPv6 stack.

Steps for IoT Interoperability

1. Interoperability at the IPv6 layer
   - Contiki OS with uIPv6 stack provides IPv6 Ready stack.
2. Interoperability at the routing layer
   - Interoperability between RPL implementations in Contiki and TinyOS have been demonstrated.
3. low-power interoperability
   - Radios must be efficiently duty cycled.
   - Not yet done!!

Low-Power uIPv6 Stack

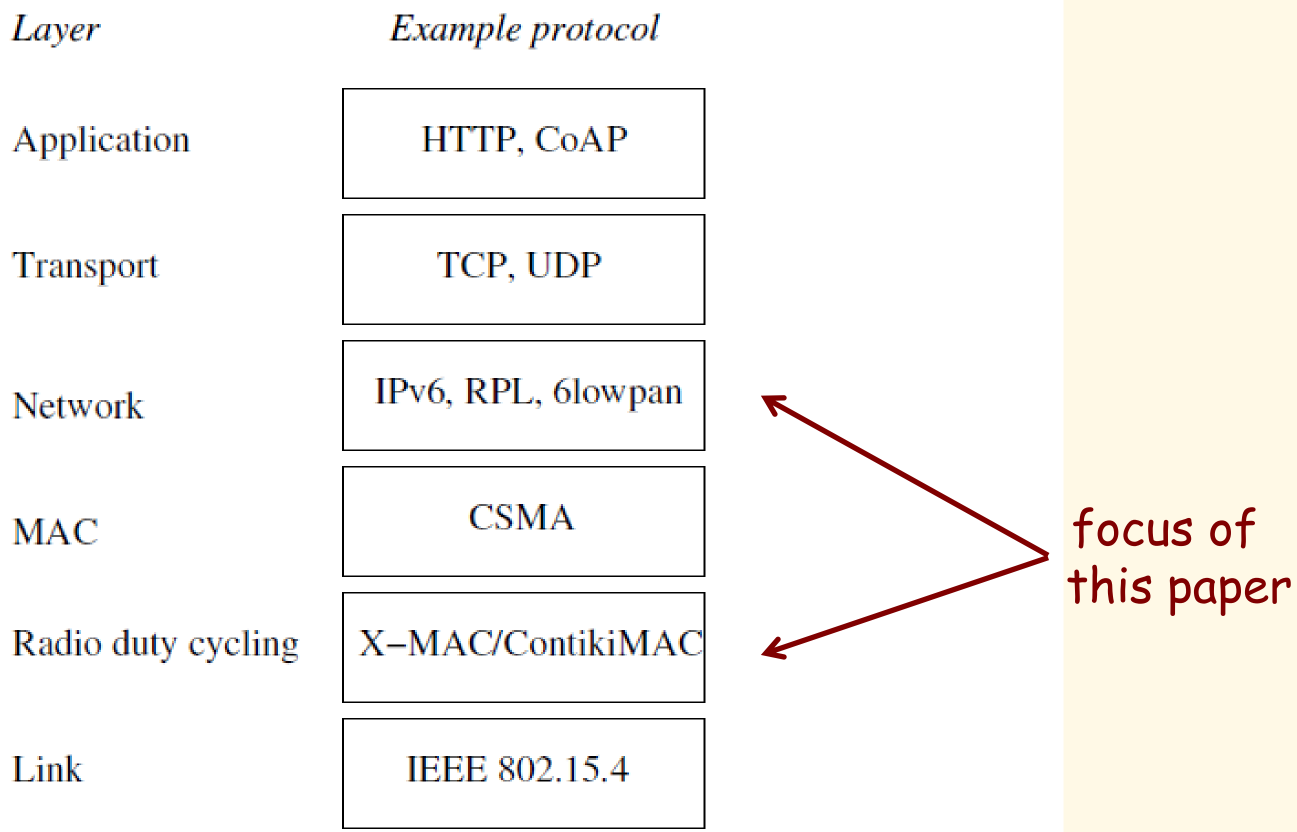

Figure 1. The low-power IPv6 stack consists of the standard IPv6 protocols at the network layer and transport layers, and of new protocols from the network layer and down.

Contiki MAC Layer Choices

- X-MAC
- Contiki-MAC
- LPP Low Power Probing

LPP (Low Power Probing)

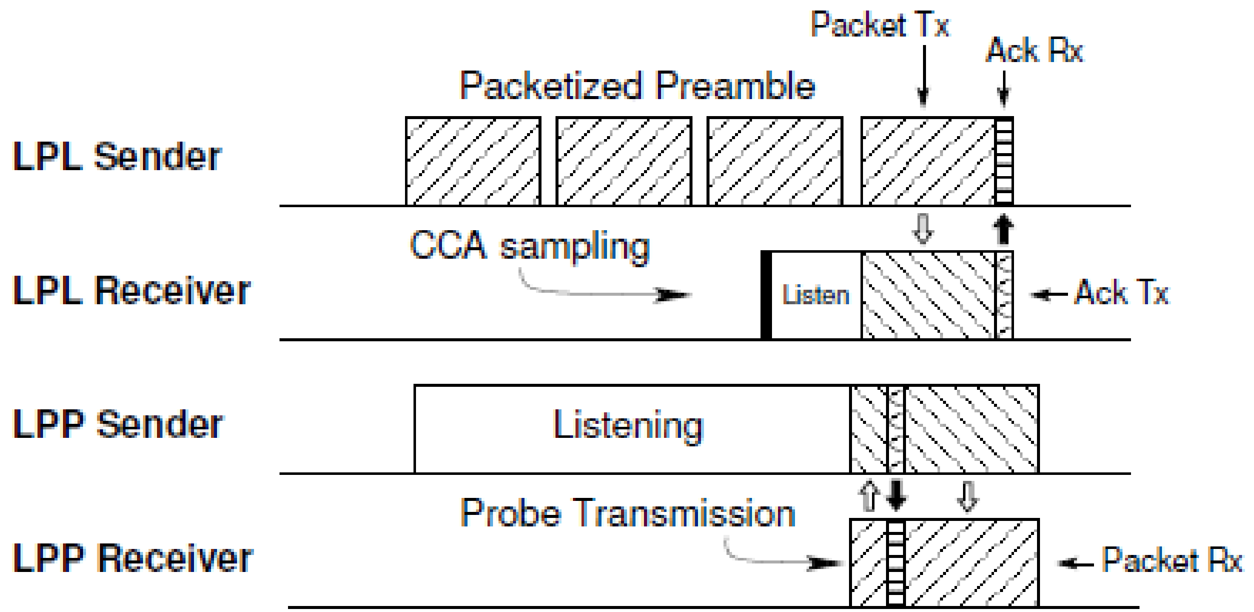

Figure 4. A simplified representation of LPL for packet-based radios and LPP. Preamble and packet durations are not drawn to scale.

Koala paper 2008

IPv6 for Low-Power Wireless

- IPv6 stack for low-power wireless follows IP architecture but with new protocols from the network layer and below.
- 6LoWPAN adaptation layer provides header compression mechanism based on IEEE 802.15.4 standard to reduce energy use for IPv6 headers.
  - Also provides link-layer fragmentation and reassembly mechanism for 127-byte maximum 802.15.4 frame size.

IPv6 for Low-Power Wireless

- IETF ROLL (Routing over Low-power and Lossy networks) group designed RPL (Routing Protocol for Low-power and Lossy networks) for routing in multi-hop sensor networks.
- RPL optimized for many-to-one traffic pattern while supporting any-to-any routing.
- Supporting different routing metrics, RPL builds a directed acyclic graph (DAG) from the root node for routing.
- Since CSMA and IEEE 802.15.4 are most common, the issue becomes the radio duty cycling layer.

Radio Duty Cycling Layer

- To reduce idle listening, radio transceiver must be switched off most of the time.
- Figures show ContikiMAC for unicast and broadcast sender {similar to X-MAC}.
- ContikiMAC sender "learns" wake-up phase of the receivers.
- Performance relationship between RPL and duty cycling layer yet to be studied.

ContikiMAC Unicast

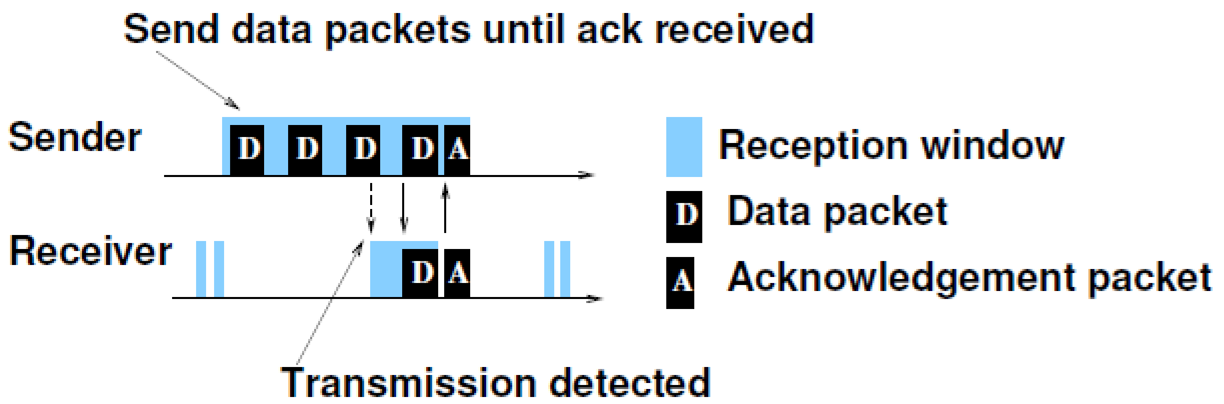

Figure 2. ContikiMAC, from Dunkels et al. [2].

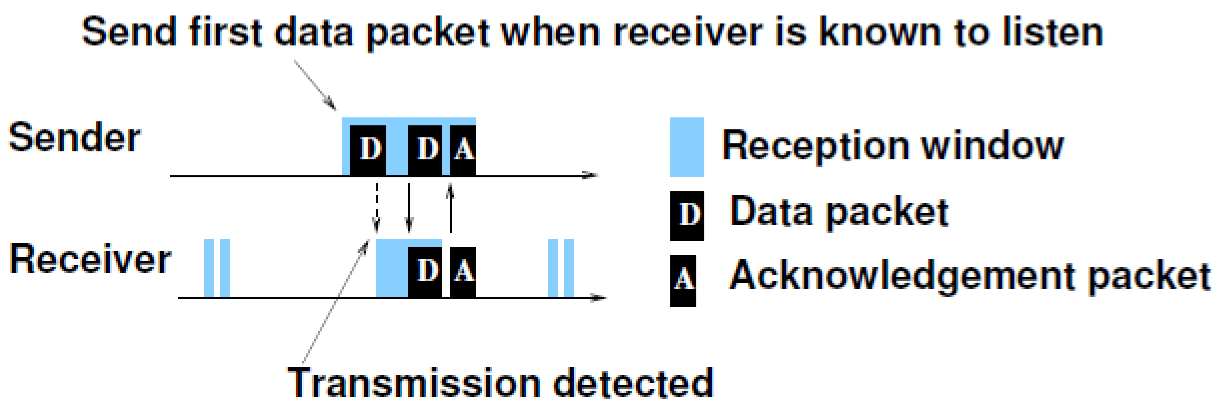

Figure 3. ContikiMAC sender phase-lock.

ContikiMAC Broadcast

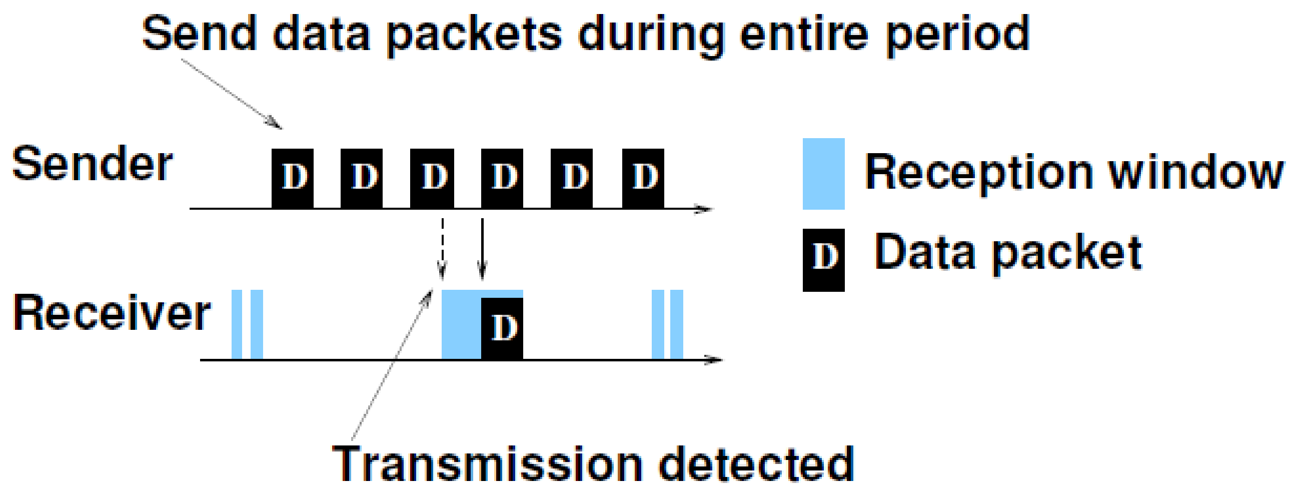

Figure 4. ContikiMAC broadcast.

ContikiMAC broadcast is the same as the *A-MAC* broadcast scheme.

Interoperability

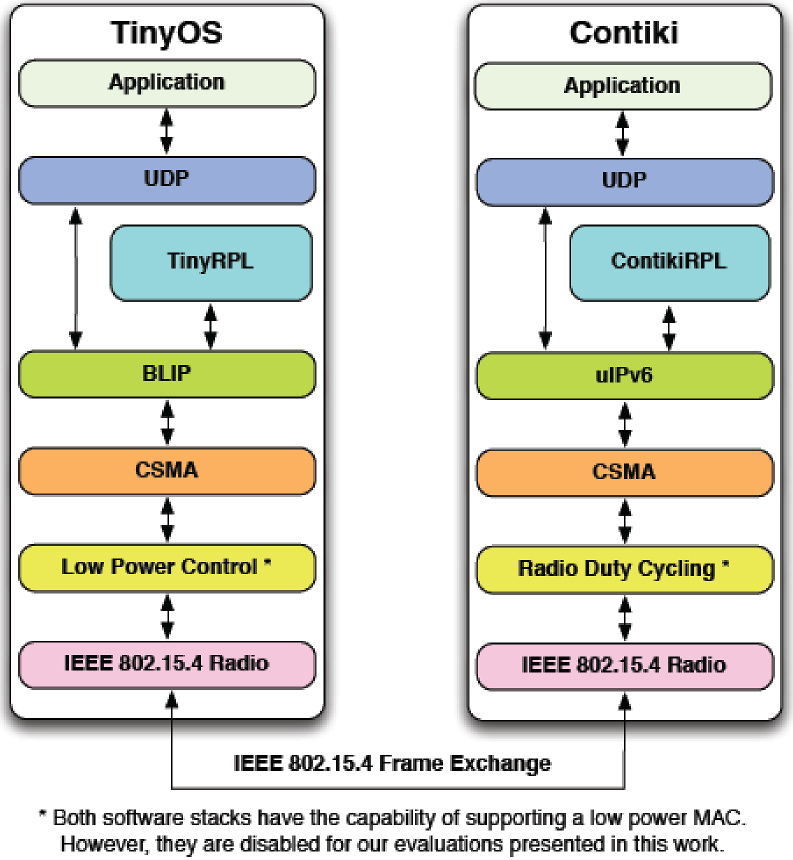

Figure 5. Contiki and TinyOS IPv6 interoperability, from Ko et al. [6]. We demonstrated interoperability at the network layer, the MAC layer, and the link layer, but without radio duty cycling.

REST/CoAP

DTLS/UDP

IPSec/IPv6

Adding Security

Low-Power Interoperability

- Interoperable radio duty cycling is essential!
- Thus far interoperability demos have ONLY been with always-on radio layer.
- Two implementations with good performance on their own can have sub-optimal performance when mixed.

Low-Power Interoperability

- Results suggest IoT implementations need to be tested for performance and NOT just correctness.
- Contiki simulation tool (Cooja) can be used to study challenges of low-power IPv6 interoperability.

Low-Power Interoperability

Three challenges:

1. Existing duty cycle mechanisms NOT designed for interoperability.
   - e.g., ContikiMAC and TinyOS BoX-MAC have no formal specifications.

   * Mentions 802.15.4e group for standardization

2. Duty cycling protocols are typically timing sensitive.
   - Makes testing of interoperability difficult.

Low-Power Interoperability

3. Current interoperability testing is done via physical meetings of separate protocol developers.
   - This bounds the testing time.
   - Hence, this strategy is not well-suited for interoperability testing of duty cycling protocols.

Conclusions

- While IPV6 provides IoT interoperability, attaining low-power interoperability for the Internet of Things is still an open problem because:
  - Existing protocols for LLNs are not designed for duty cycling.
  - Existing duty cycling protocols are NOT designed for interoperability.