Research Topic for the ParisTech/CSC PhD Program

Subfield: Computer science, networking

ParisTech School: Ecole Polytechnique

Title: Low power Wide Area Networks for Internet of Things

Advisor(s):

- Thomas Clausen (thomas.clausen@polytechnique.edu http://www.thomasclausen.net)
- Jiazi Yi (jiazi.yi@polytechnique.edu https://jiaziyi.com)
  https://www.epizeuxis.net

Short description of possible research topics for a PhD:
Low-Power Wide Area Networking (LPWAN) is a wireless technology poising itself to be to the "Internet of Things" what WiFi was to consumer networking. Unlike other wireless networking technologies such as WiFi, 4G, or Zigbee, LPWANs aim to provide connectivity to particularly power-constrained devices, trading off low data rates (and, possibly asymmetric links) for attaining long range (up to tens of km). Initial emphasis of the project will be the following LPWAN topic areas:

- *The Network Layer* Packet sizes, link asymmetry, delays, etc., makes IPv6 support all the way to the end devices a challenge: in most LPWAN architectures, the "I" in "Internet of Things" is a central server, bridging "the Internet" to a link-adapted communications stack on the "things". New One way to avoid that could be to have end-devices relay information between each other towards a gateway through multi-hop paths with shorter links, and using a higher data rate - **the challenge** being to discover and maintain such multi-hop paths, and to optimize their usage.
- The Data-Link Layer For implementation simplicity, LPWAN technologies often use Aloha as MAC protocol - known to result in inefficient channel usage in traffic-dense networks. A starting point for this can be to explore and adapt 802.15.4 scheduling mechanisms to also leverage LPWAN multi-hop topologies -- e.g. allowing topology-aware time-slot assignment to non-overlapping links.
- Further aspects Based on the findings from the previous topic areas, new challenges are likely to emerge also for upper layers, such as the examples given below: Data forwarding along multi-hop paths consisting of resource-constrained end devices, potentially introduces congestion as a problem to be addressed within the LPWAN - but, likely not by the same methods as were used "across the Internet". For example, part of this problem may be alleviated by a scheduling mechanism, introduced at the Datalink Layer. This may also inspire an entirely different transport semantics (e.g., as in CoAP), presenting a different service set to the application layer, possibly supporting decentralized data processing and/or "light learning" in the edge as a means to reduce network load and response time.

The topic areas mentioned above will be studied by building analytical models to understand theoretical boundaries. Network simulation tools will be used to evaluate protocol performance and simulate large scale scenarios. Real testbeds will be built to validate the correctness of the proposals.

Required background of the student: Computer networks, wireless communication, embedded systems, signal processing, information theory

A list of 5 (max.) representative publications of the group:

[1] Augustin, A.; Yi, J.; Clausen, T.; Townsley, W.M. A Study of LoRa: Long Range & Low Power Networks for the Internet of Things. Sensors 2016, 16, 1466.
[2] Yi, Jiazi; Clausen, Thomas; Herberg, Ulrich. Depth First Forwarding for Unreliable Networks: Extensions and Applications. Internet of Things Journal, IEEE, 2 (3), pp. 199–209, 2015.
[3] Thomas Clausen, Christopher Dearlove, Philippe Jacquet, Ulrich Herberg, IETF Proposed Standard RFC7181: The Optimized Link State Routing Protocol Version 2
[4] Clausen, Thomas; de Verdiere, Axel Colin; Yi, Jiazi; Igarashi, Yuichi; Lys, Thierry; Lavenu, Cedric; Herberg, Ulrich; Satoh, Hiroki; Niktash, Afshin; Dean, Justin. ITU G.9903 Narrow-band orthogonal frequency division multiplexing power line communication transceivers for G3-PLC networks: Amendment 1 -- The Lightweight On-demand Ad hoc Distance-vector Routing Protocol - Next Generation (LOADng)