Software Defined Low-Power and Lossy Wireless Networks

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Context

Advances in integrated circuits made it possible to include wireless transceivers, sensors, and actuators in one package, opening the way to network billions of everyday devices, from household electrical goods to wearable devices [1]. The networks formed by those devices are characterized by low-power consumption, low-datarate, lossy links, and short-range applications, hence the name of Low-Power and Lossy Wireless Networks (LLWN). Since then, numerous communication protocols have been proposed at each layer of the communication stack. For example, 47 MAC protocols are listed in [2], or more than 50 routing protocols are reported in [3]. As a result, it is very difficult to choose the protocol suite tailored for one application among this bunch of technologies and protocols. In addition, communication protocols are currently hardcoded in operating systems, and modifying a single parameter or switching from one protocol to another requires either recompiling and deploying new firmwares or provisioning operating systems with multiple concurrent protocols. This situation makes the adoption of new communication protocols, technologies, or services challenging.

Subject

In this PhD thesis, we will investigate how to make LLWN fully programmable, enabling ultimate flexibility, from the reconfiguration of the protocol suite at runtime to the deployment of any future wireless technologies on the same infrastructure. Programming the communication stack of wireless devices requires an interface to implement specific network functionalities or behaviors at runtime. Tinnirello et al. already paved the way with a reprogrammable MAC [4] that we extended to the LLWN context [5]. At the same time, the introduction of the P4 programming language [6] broadened the possibility of Software Defined Networking (SDN) in wired networks, enabling a custom data plane with full control of packet processing. However, this tool cannot directly manage the wireless interface, mainly the radio control, to reflect the behavior of any medium access control protocol. This PhD thesis will define a set of abstractions the wireless interface will expose and extend the instruction sets of P4 (or any alternative, such as eBPF [7]) to support them. A programmable pipeline for packet processing will also be enforced in the nodes. Regarding applicants' experience, contributions in Software Defined Radio (SDR) can also be considered to include lower layers of the communication stack. Finally, this PhD will focus on continuously optimizing the deployed configuration, leveraging Artificial Intelligence (AI) and edge computing, to reflect the current and future network conditions.

References

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