Course Takeaways

1. IoT network characteristics and specificities

Hint : *List the major peculiarities of IoT physical networks. If needed, you can take the case of Low-Power Wireless Personal Area Networks (LP-WPAN) that we considered during the course and explain how they differ from conventional computer networks and what are the specific constraints that they are subject to.*

IoT physical networks, such as Low-Power Wireless Personal Area Networks (LP-WPAN), have unique characteristics that distinguish them from conventional computer networks:

- Scalability: IoT networks must accommodate a large number of devices, often exceeding what traditional networks are designed to handle.
- Dynamic Topology: Devices in IoT networks frequently join or leave, requiring seamless and automatic reconfiguration.
- Energy Efficiency: IoT devices are typically battery-powered, necessitating low-power operation to extend their lifespan.
- Limited Bandwidth: LP-WPANs operate with minimal bandwidth to support low-data-rate applications efficiently.
- Small Payloads: Data is transmitted in compact frames, often focusing on event-driven communication rather than continuous streams.
- Latency Constraints: Many IoT applications require real-time communication, demanding low or predictable latency.
- Specialized Protocols: Protocols like IEEE 802.15.4, Zigbee, BLE, and 6LoWPAN are optimized for the specific constraints of IoT networks.
- Interference and Penetration: Low-frequency communication is used to mitigate penetration losses and interference.
- Cost Sensitivity: IoT networks prioritize affordability, using low-cost hardware and minimal infrastructure.

2. Rationale for adopting an IPv6 based architecture to support the communications of an IoT system or use case

Hint : *List the main benefits of adopting an IP based architecture in an IoT system, up the connected object (e.g. sensor, etc.).*

- Scalability: IPv6 provides a vast address space, ensuring every IoT device (e.g., sensors) can have a unique address.

Noël Jumin
Clément Gauché

- Interoperability: Standardized IP protocols allow seamless communication between diverse devices and systems.
- Dynamic Integration: Devices can automatically join the network using their MAC address to generate unique IPv6 addresses.
- End-to-End Communication: Direct communication without requiring Network Address Translation (NAT), simplifying data routing.
- Efficient Resource Utilization / Data Transmission: Optimized data transmission protocols, like 6LoWPAN, reduce bandwidth and energy usage.
- Mobility and flexibility: Better handling of dynamic and mobile IoT environments, such as wearable or vehicle-based devices.

3. IPv6 basics

Hint : First, from the experiments and traffic captures that you did during TD1, describe the different IPv6 initialisation steps that a host goes through, when switched on. Explain the rationale of the different steps, and the messages (with the types of IPv6 addresses) that are used to complete these steps. Then, derive some of the requirements of IPv6 (in terms of transmission capabilities of the physical network, and host availability) and enrich them with some other important characteristics of IPv6.

When a device initializes in an IPv6 network, it generates a unique address based on its MAC address. The Duplicate Address Detection (DAD) process ensures no address conflicts by checking the network’s multicast address. Neighbor discovery, similar to ARP in IPv4, builds a table of nearby devices for efficient communication. IPv6 requires robust transmission capabilities and host availability to maintain network reliability.
The TP1 highlighted the importance of understanding these initialization steps. IPv6’s expanded address space and efficient integration mechanisms make it well-suited for IoT networks. These features address IoT-specific needs, such as dynamic device addition and real-time communication.

4. IPv6 adaptation and extensions in order to enable its use atop a physical IoT network

Hint :Without delving into the details, and relying on the experiment that you undertook during TD2, list the main additions, adjustments and optimizations of IPv6 that were defined for an application in the context of an IoT network.

IPv6 headers are large (32 bytes for source and destination addresses), which can be problematic for low-power IoT networks. To address this, 6LoWPAN compresse IPv6 headers to reduce data size, improving efficiency. Compression can save up to 32 bytes, depending on the level used. For example, multicast addresses can be reduced from 16 bytes to just 1 byte. Routing protocols like RPL further optimize IoT networks by minimizing communication overhead and energy consumption. These adaptations ensure that IPv6 can operate efficiently on low-power networks with limited bandwidth. The IETF has standardized a protocol stack combining 6LoWPAN and RPL to support IoT.

5. The IETF IPv6 based stack for IoT

Hint :Depict the protocol tack proposed by the IETF for IoT and then briefly describe the main network functions performed by the new layers. Also, provide a few words to describe the proposed application level protocols.

The IETF proposes a protocol stack for IoT, combining 6LoWPAN for header compression and RPL for efficient routing in low-power networks. At the application layer, protocols like MQTT facilitate communication between devices. These layers address specific IoT needs, such as low latency, scalability, and energy efficiency. RPL enables devices to communicate over multi-hop routes, reducing energy use. 6LoWPAN ensures IPv6 headers are compressed for efficient data transfer. Together, these protocols create a cohesive stack optimized for IoT networks. The stack supports a wide range of applications, from smart homes to industrial automation.

6. Existing IPv6 based network technologies for IoT

Hint : List the existing IoT network technologies that are using IPv6 and their associated vertical(s) (application domain(s))

Several IoT network technologies leverage IPv6 for various application domains, ensuring scalability and interoperability:

1. 6LoWPAN: Used in sensor networks for environmental monitoring and smart agriculture. Its header compression ensures efficiency in low-power and low-bandwidth networks.
2. Thread: Commonly applied in smart home devices, such as lighting, security systems, and thermostats, enabling seamless communication among devices.
3. LTE-M: Utilized in wide-area IoT applications like asset tracking, smart metering, and industrial IoT due to its support for mobility and low power consumption.
4. NB-IoT (Narrowband IoT): Supports IPv6 for applications like smart cities, including parking management and utility monitoring.
5. Zigbee IP: Extends traditional Zigbee functionality with IPv6 support for smart homes and building automation.
6. Wi-SUN: Focused on smart grid applications, enabling IPv6-based communication for energy management and utility networks.
7. LoRaWAN (with IPv6 translation layers): Used in logistics and agriculture for long-range, low-power connectivity with IPv6 integration via gateways.

7. Is an IPv6 based stack relevant for your semester project ?

Hint : After briefly describing your semester project, elaborate very shortly on the relevance of adopting IPv6 in your semester project.

The **Wispers Project** aims to replace wired intracranial probes with wireless patches connected to a web application. While the project currently uses the low-level RuBee protocol with hardcoded identifiers, IPv6 could enhance its modularity. Adding a 6LoWPAN layer would enable automatic device integration and scalability. However, RuBee's low transmission frequency (131 kHz) limits frame size, so any additional headers must be carefully managed. IPv6's features, such as address automation and multicast support, align with the project's long-term goals. Despite the current limitations, adopting IPv6 could future-proof the system and support more complex applications.

8. IoT and sustainability

We can say that IoT plays a critical role in addressing environmental challenges by enabling energy-efficient solutions. Low-power connected devices monitor factors like energy consumption and CO2 emissions, helping companies adopt sustainable practices. Wireless energy supply technologies, such as powering sensors via Wi-Fi signals, offer innovative ways to reduce energy usage. IPv6 contributes to sustainability by eliminating the need for NAT devices, reducing network infrastructure energy consumption.
By optimizing communication and supporting eco-friendly technologies, IoT aligns with global sustainability goals. The focus on environmental impact reflects INSA's goal of training engineers who prioritize sustainability.

Noël Jumin
Clément Gauché