CT106-3-M-BIA - Building IoT Applications

CT127-3-M-ODL - BIA - Building IoT Applications

Topic 6 – IoT Transport & Internet Layer

TOPIC LEARNING OUTCOMES

At the end of this topic, you should be able to:

- Gain a comprehensive understanding of how the Transport and Internet Layer protocols enable communication and connectivity in IoT systems.
- Evaluate transport protocols used in IoT, such as TCP and UDP, considering their strengths, and weaknesses in relation to specific IoT applications.
- Gain knowledge of addressing schemes and routing protocols used in IoT networks, including IP addressing, 6LoWPAN, and RPL, to facilitate efficient and scalable communication.
- Understand various IoT network architectures, including star, mesh, and hybrid topologies, and how they impact the selection and implementation of transport and internet layer protocols.

Contents & Structure

- Transport Layer protocols
  - TCP and UDP
- Internet Layer protocols
  - IP addressing, 6LoWPAN, and RPL
- IoT network architectures
  - Star, mesh, and hybrid topologies

Transport Layer Protocols

Transport layer protocols define how data gets packaged, sent, and received. In IoT, the best protocol for your device depends on what needs to be sent and which quality is more important for your use case: speed or reliability.

TCP (Transmission Control Protocol)

- TCP sets the parameters for data exchanges between software applications, and confirms what is being sent, where it's coming from, where it's going, and whether or not it arrived correctly.
- TCP prioritizes accuracy over speed, ensuring that data arrives in order, with minimal errors, and without duplication.
- If data gets lost in transmission, TCP requests the data packets be resent.

UDP (User Datagram Protocol)

- User Datagram Protocol (UDP) is a communication standard for exchanging data over the Internet.
- UDP prioritizes speed over reliability, using a connectionless process to send data packets to a destination.
- Due to its low latency, UDP is ideal for time-sensitive use cases like video streaming, Voice over Internet Protocol (VoIP), video gaming, and Domain Name System (DNS) lookups.
- UDP doesn't correct errors, duplicates, or missing pieces. If a protocol uses UDP for transmitting data, data integrity is either unimportant or the application itself has a process for checking against errors.

UDP in IoT

- In IoT, UDP is less common than TCP. But UDP often appeals to IoT manufacturers because it uses fewer network resources to transmit and doesn't have to maintain a constant connection between the two endpoints.
- It uses less data and consumes less power.
- IoT devices often operate within Low power, Lossy Networks (LLNs). LLNs are optimized for power efficiency, so they have very few resources.
- Constrained Application Protocol (CoAP) was specifically developed to help these devices communicate, and it runs on devices that use UDP.

UDP vs. TCP

	UDP (User Datagram Protocol)	TCP (Transmission Control Protocol)
Reliability	Unreliable	Reliable
Connection	Connectionless	Connection-oriented
Message Delivery	Best-effort delivery	Guaranteed delivery
Error Checking	No error checking	Error detection and retransmission
Ordering	No guarantee of message order	Guaranteed message ordering
Overhead	Lower overhead	Higher overhead due to additional control mechanisms
Use Cases	Real-time applications, video streaming	File transfers, web applications, reliable data transfer
Latency	Lower latency	Higher latency due to handshaking and error checking
Bandwidth Utilization	More efficient utilization of network bandwidth	Less efficient utilization of network bandwidth

Internet Layer Protocols

The Internet/network layer packages transmissions and routes data packets from one network entity (such as a router, server, node, application, or device) to another, determining the path they will take to get there.

IP (Internet Protocol)

- Internet protocol (IP) is a set of rules that dictates how data gets sent to the Internet.
- It gives network entities an IP address, which allows other network entities to send them data packets even if they are not on the same network.
- The most widely used version of IP is Internet Protocol Version 4 (IPv4). IPv4 provides a 32-bit IP addressing system that has four sections.
- IPv6 defines a 128-bit address space, with 340 trillion IP addresses. An IPv6 address has eight sections. The text form of the IPv6 address is xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx, where each x is a hexadecimal digit, representing 4 bits.

6LoWPAN

- IPv6 over Low Power Wireless Personal Area Network (6LoWPAN) standard allows IPv6 to be used over **802.15.4** wireless networks.
- 6LoWPAN is a low-power wireless mesh network where every node has its own IPv6 address.
- This allows the node to connect directly with the Internet using open standards.
- 6LoWPAN came to exist from the idea that the Internet Protocol should be applied even to the smallest devices and that low-power devices with limited processing capabilities should be able to participate in the Internet of Things.

RPL

- RPL (Routing Protocol for Low-Power and Lossy Networks) is a routing protocol specifically designed for low-power and lossy networks in IoT.
- It is an IPv6-based routing protocol that enables efficient and reliable communication among resource-constrained devices in IoT deployments.
- RPL is designed to handle network conditions characterized by high packet loss rates, low data rates, and intermittent connectivity.
- RPL supports a variety of network topologies, including star, mesh, and tree structures.
- RPL is an open standard and is defined by the Internet Engineering Task Force (IETF) in RFC 6550.

Comparison of common Internet layer protocols

Protocol	Description	Characteristics	Use Cases
IPv4	Internet Protocol version 4	Widely adopted, 32-bit addressing, limited address space, packet fragmentation and reassembly	Legacy IoT systems, smaller-scale deployments
IPv6	Internet Protocol version 6	Next-generation IP protocol, 128-bit addressing, larger address space, improved security and mobility	Large-scale IoT deployments, future-proofing IoT infrastructure
6LoWPAN	IPv6 over Low-Power Wireless Personal Area Network	Adapts IPv6 for low-power wireless devices, header compression, optimized for constrained networks	Low-power IoT devices, sensor networks, smart home applications
RPL	Routing Protocol for Low-Power and Lossy Networks	Routing protocol for IoT networks, energy-efficient, support for different network topologies	Wireless sensor networks, smart city applications

IoT network architectures

- IoT network architectures refer to the various ways in which IoT devices and systems are interconnected and organized to facilitate communication and data exchange. These architectures determine how devices are connected, how data flows within the IoT network, and how the network is managed.
- Common IoT network architectures include:
  - Star Architecture
  - Mesh Architecture
  - Tree Architecture

Star Architecture

- In star architecture, all IoT devices are connected directly to a central hub or gateway. The hub serves as a central point for data collection, processing, and communication with external networks or the cloud.

Mesh Architecture

- In a mesh architecture, IoT devices are interconnected with each other to form a mesh network. Each device can communicate directly with other devices in the network, allowing for multiple communication paths. This architecture provides redundancy and self-healing capabilities.

Tree Architecture

- Tree architecture resembles a hierarchical structure, with a central hub or gateway connecting to multiple intermediate devices, which in turn connect to a larger number of end devices. Data flows from the end devices to the gateway through the intermediate devices.

Summary / Recap of Main Points

During this lesson, the following topics were covered:

- Transport Layer protocols
  - TCP and UDP
- Internet Layer protocols
  - IP addressing, 6LoWPAN, and RPL
- IoT network architectures
  - Star, mesh, and hybrid topologies

Review Questions

- How does the choice of transport layer protocol impact the performance and efficiency of IoT systems?
- Compare IPv4 and IPv6 in terms of addressing schemes and the number of available addresses.
- Define and compare star, mesh, and tree network architectures in IoT.

What To Expect Next Week

In Class

Preparation for Class