UNIT

2

# Internet of Things


## Unit 2. Communication Protocols and Sensor Networks

**Dr. Kiran Wakchaure**
**Assistant Professor**
**Sanjivani University**

## Session Content

- Understand basics of IoT

## Session Outcome

- Able to understand IoT and its advantages.

# Course Outcomes

| Course Outcomes: Upon completion of the course, students shall have the ability to | | |
|---|---|---|
| CO1 | Identify and describe the basic components and architecture of IoT systems. | U |
| CO2 | Explain the various communication protocols used in IoT and their applications. | U |
| CO3 | Develop simple IoT applications using Arduino and Raspberry Pi, integrating sensors and actuators. | AP |
| CO4 | Analyze the data flow and network requirements for different IoT applications. | A |
| CO5 | Evaluate the security and privacy challenges in IoT systems and propose potential solutions. | E |

# Teaching -Learning & Assessment Scheme

| Teaching -Learning & Assessment Scheme | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Learning Scheme | | | Credits | Assessment Scheme | | | Summative Assessment | Total |
| | | | | Formative Assessment | | | | |
| L | T | P | | CIA-I | CIA-II | Practical Assessment | End Semester Exam/ Project Evaluation | |
| 3 | 0 | 0 | 3 | 25 | 25 | 20 (100 Scaled Down to 20) | 30 (60 Scaled Down 30) | 100 |

# Course Contents

| Course Contents | | |
|---|---|---|
| **UNIT I** | **Introduction to IoT and Networking Basics** | **09 hrs** |
| Introduction to IoT, History and Evolution of IoT, IoT Architecture, Sensing, Types of Sensors, Sensor Characteristics, Actuation, Types of Actuators, Actuator Mechanisms, Basics of Networking, Network Models (OSI and TCP/IP), Network Topologies | | |
| **UNIT II** | **Communication Protocols and Sensor Networks** | **9 hrs.** |
| Communication Protocols and Sensor Networks, Communication Protocols, IoT Communication Models Protocols, Sensor Networks, Wireless Sensor Networks (WSN), Network Topologies in WSN, Energy Efficiency in WSN, Machine-to-Machine Communications, M2M Architecture, Applications of M2M | | |
| **UNIT III** | **IoT Programming and Integration** | **09 hrs** |
| IoT Programming and Integration, Interoperability in IoT, Standards and Protocols for Interoperability, Challenges in Interoperability, Introduction to Arduino Programming Basics of Arduino, Programming Environment, Integration of Sensors and Actuators with Arduino<br><br>Interfacing Techniques, Practical Applications, Introduction to Python Programming, Python Basics, Libraries for IoT, Introduction to Raspberry Pi, Raspberry Pi Hardware, Setting Up Raspberry Pi, Implementation of IoT with Raspberry Pi, IoT Projects with Raspberry Pi, Data Collection and Processing | | |

# Course Contents

| Course Contents | | |
|---|---|---|
| **UNIT IV** | **Advanced IoT Concepts** | **09 hrs** |
| Introduction to SDN, SDN Architecture, Benefits of SDN, SDN for IoT, Integration of SDN and IoT, Use Cases, Data Handling and Analytics, Data Storage Solutions, Data Processing Techniques, Cloud Computing, Cloud Services for IoT, Cloud Platforms (AWS, Azure, Google Cloud), Sensor-Cloud, Concept of Sensor-Cloud, Applications and Benefits, Fog Computing, Fog vs. Cloud Computing, Edge Computing,<br><br>Introduction to IoT Security and Privacy, Importance of security and privacy in IoT systems, Key challenges due to the distributed nature of IoT, Security vs. privacy in IoT: Definitions and differences, Security Solutions for IoT | | |
| **UNIT V** | **IoT Applcations** | 9 hrs. |
| IoT Applications and Case Studies, Smart Cities, IoT in Urban Planning, Smart Infrastructure Smart Homes, Home Automation Systems, Security Solutions, Connected Vehicles, Vehicle-to-Everything (V2X) Communication, Autonomous Vehicles, Smart Grid, IoT in Energy Management, Smart Metering, Industrial IoT, IoT in Manufacturing, Predictive Maintenance<br><br>Case Study: Agriculture, Precision Farming, IoT in Crop Monitoring, Case Study: Healthcare, Remote Patient Monitoring, IoT in Medical Devices<br><br>Case Study: Activity Monitoring, Wearable Devices, Health and Fitness Tracking | | |

# Reference Books


**Text Book:**

1. Bahga, A., & Madisetti, V. (2014). Internet of things: A hands-on approach. VPT. ISBN: 978-0996025515
2. Buyya, R., & Dastjerdi, A. V. (2016). Internet of things: Principles and paradigms. Morgan Kaufmann. ISBN: 978-0128053959
3. Greengard, S. (2015). The internet of things. MIT Press. ISBN: 978-0262527736
4. Minoli, D. (2013). Building the internet of things with IPv6 and MIPv6: The evolving world of M2M communications. Wiley. ISBN: 978-1118473474
5. Hersent, O., Boswarthick, D., & Elloumi, O. (2012). The internet of things: Key applications and protocols (2nd ed.). Wiley. ISBN: 978-1119994350
6. Pethuru, R., & Anupama, C. R. (2017). The internet of things: Enabling technologies, platforms, and use cases. CRC Press. ISBN: 978-1498761284

**Reference Book:**

1. Fraden, J. (2010). Handbook of modern sensors: Physics, designs, and applications (4th ed.). Springer. ISBN: 978-1441964656
2. Kurose, J. F., & Ross, K. W. (2012). Computer networking: A top-down approach (6th ed.). Pearson. ISBN: 978-0132856201
3. Bahga, A., & Madisetti, V. (2015). Internet of things: A hands-on approach. Orient Blackswan Private Ltd. ISBN: 978-8173719547
4. Hanes, D., Salgueiro, G., Grossetete, P., Barton, R., & Henry, J. (2017). IoT fundamentals: Networking technologies, protocols, and use cases for the internet of things. Pearson. ISBN: 978-0134307084
5. Perros, H. G. (2021). An introduction to IoT analytics. CRC Press. ISBN: 978-0367686314
6. Relevant articles from journals related to IoT.

# Internet

**Key Elements of the Internet**

**Hardware Components**

**1.End Devices (Clients and Servers):**

1. Examples: Computers, smartphones, tablets, and IoT devices.
2. Clients request information (e.g., accessing a website), and servers provide the requested data (e.g., hosting the website).

**2.Routers:** Direct data packets between networks and devices. They ensure data takes the most efficient path to its destination.

**3.Switches:** Operate within local networks, connecting multiple devices within a LAN (Local Area Network).

**4.Modems:** Convert digital data from a device into signals that can be transmitted over telephone or cable lines and vice versa.

**5.Internet Backbone:** Composed of undersea cables, satellites, data centers, and large-scale routers that form the core infrastructure of the internet.

**6.Data Centers:** Facilities housing servers that store and process vast amounts of information, such as websites, cloud services, and databases.

# Internet

**Software Components**

**1.Protocols:**

1. Define how data is transmitted and received. Examples include:
    1. **TCP/IP**: Ensures reliable transmission.
    2. **DNS**: Converts domain names into IP addresses.
    3. **HTTP/HTTPS**: Used for accessing web pages.

**2.Browsers and Applications:**

1. Examples: Google Chrome, Firefox, and mobile apps.
2. Provide user interfaces for accessing internet resources.

**3.Operating Systems and Middleware:**

1. Manage network connections and facilitate communication between hardware and applications.

# Internet

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# Internet

**Steps Involved in Internet Communication**

**Step 1: User Initiates a Request**

•Example: You type a website URL (e.g., www.google.com) in a browser.

•This request is sent using **HTTP/HTTPS** protocols.

**Step 2: DNS Lookup**

•The **Domain Name System (DNS)** converts the URL (www.google.com) into an IP address (e.g., 142.250.190.78).

•This IP address is necessary for locating the server hosting the website.

**Step 3: Data Packets Creation**

•Your device divides the request into smaller **data packets**.

•Each packet is assigned a sequence number and includes:

- •Destination IP address (server's address).
- •Source IP address (your device's address).

**Step 4: Routing**

•Packets are sent to the nearest **router**.

•Routers analyze the destination IP and forward the packets through the most efficient path across networks.

# Internet

**Step 5: Reaching the Server**

•The data packets travel through multiple routers and network nodes until they reach the destination server hosting the requested website.

**Step 6: Server Processes the Request**

•The server receives the packets, processes the request (e.g., retrieving the webpage), and sends a response back.

**Step 7: Returning Data to the User**

•The server breaks its response into packets and sends them back through the network.

•These packets follow the reverse route (or a different route if necessary) to your device.

**Step 8: Reassembly**

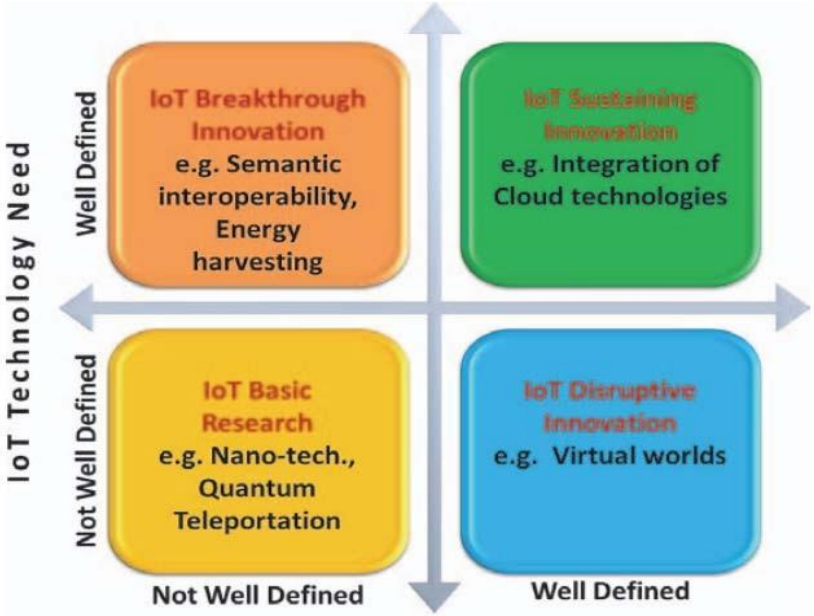
•Your device reassembles the data packets in the correct order using **TCP**.

•If any packets are lost, the server retransmits them.

**Step 9: Rendering the Content**

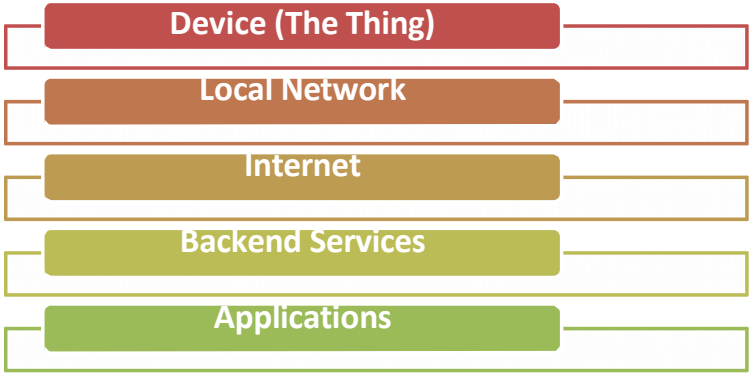
•The browser interprets the received data (HTML, CSS, JavaScript) and renders the website for you to view.

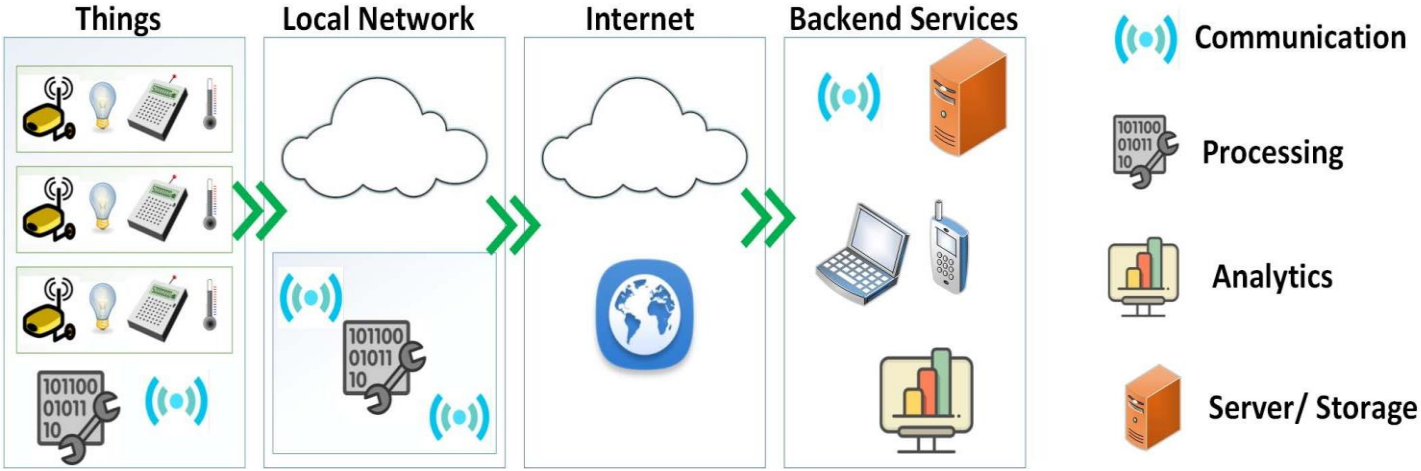
# Convergence of Domains




**Source:** O. Vermesan, P. Friess, "Internet of Things – Converging Technologies for Smart Environments and Integrated Ecosystems", River Publishers, Series in Communications, 2013

# IoT Components



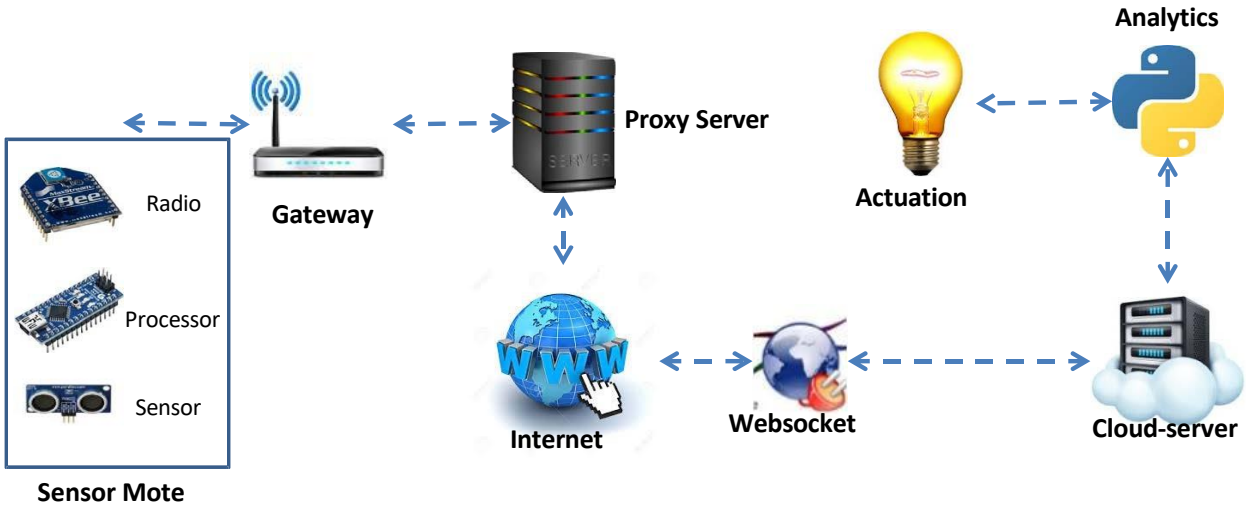

Things
Local Network
Internet
Backend Services
Communication
Processing
Analytics
Server/ Storage

# Functional Components of IoT

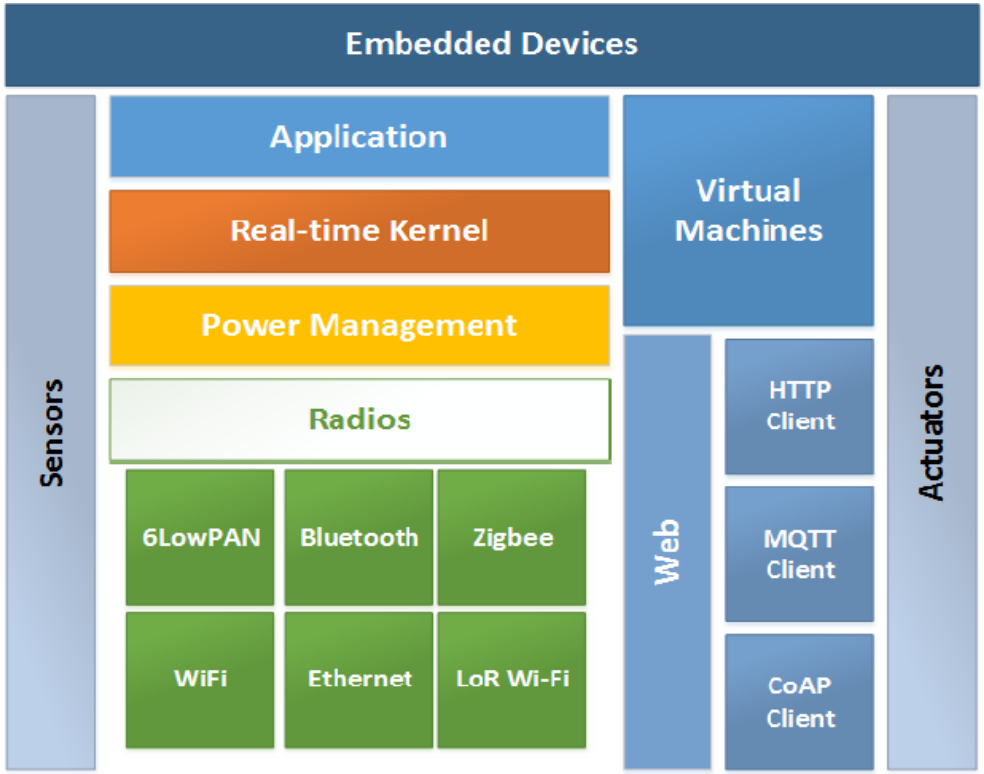
- ✓ Component for interaction and communication with other IoT devices
- ✓ Component for processing and analysis of operations
- ✓ Component for Internet interaction
- ✓ Components for handling Web services of applications
- ✓ Component to integrate application services
- ✓ User interface to access IoT

**Source:** O Vermesan, P. Friess, "Internet of Things – Converging Technologies for Smart Environments and Integrated Ecosystems", River Publishers, Series in Communications, 2013

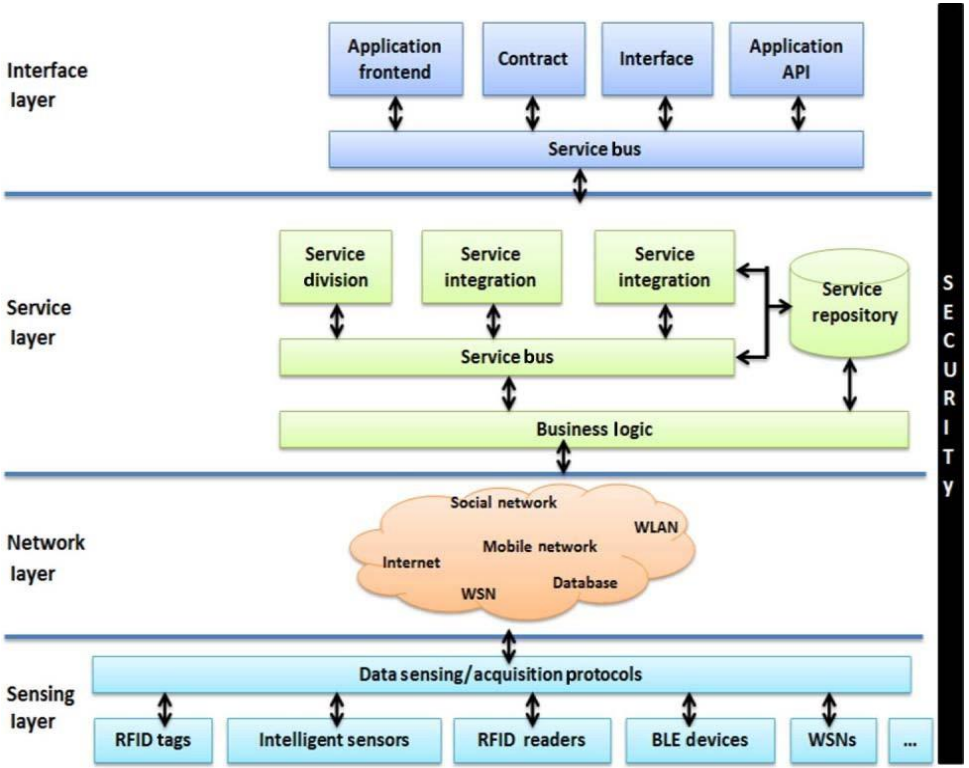
# An Example IoT Implementation



# IoT Interdependencies



# IoT Service Oriented Architecture




**Source:** Li Da Xu, Wu He, and Shancang Li, "Internet of Things in Industries: A Survey ", IEEE Transactions on Industrial Informatics, Vol. 10, No. 4, Nov. 2014.

# IoT Categories

## ✓Industrial IoT

- IoT device connects to an IP network and the global Internet.
- Communication between the nodes done using regular as well as industry specific technologies.

## ✓Consumer IoT

- IoT device communicates within the locally networked devices.
- Local communication is done mainly via Bluetooth, Zigbee or WiFi.
- Generally limited to local communication by a Gateway

# Networking

- Networking is the process of connecting multiple devices (computers, servers, etc.) to share resources such as files, internet, and communication services.
- It enables efficient communication and data exchange between devices.

**Types of Networks**

1. **LAN (Local Area Network)** – Covers a small geographic area, like a home, office, or building.
2. **MAN (Metropolitan Area Network)** – Covers a city or large campus.
3. **WAN (Wide Area Network)** – Covers large distances, like the internet.
4. **PAN (Personal Area Network)** – Used for personal devices like Bluetooth connections.
5. **SAN (Storage Area Network)** – Dedicated network for storage devices.

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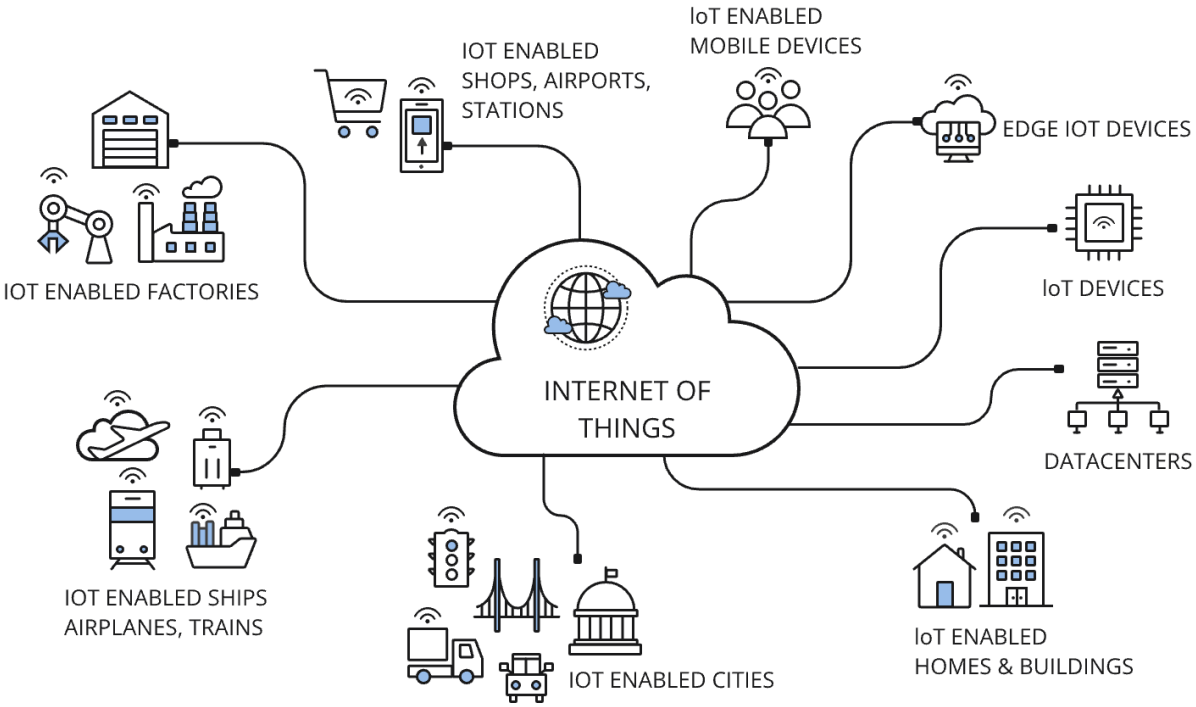
# Networking

**Networking Devices**

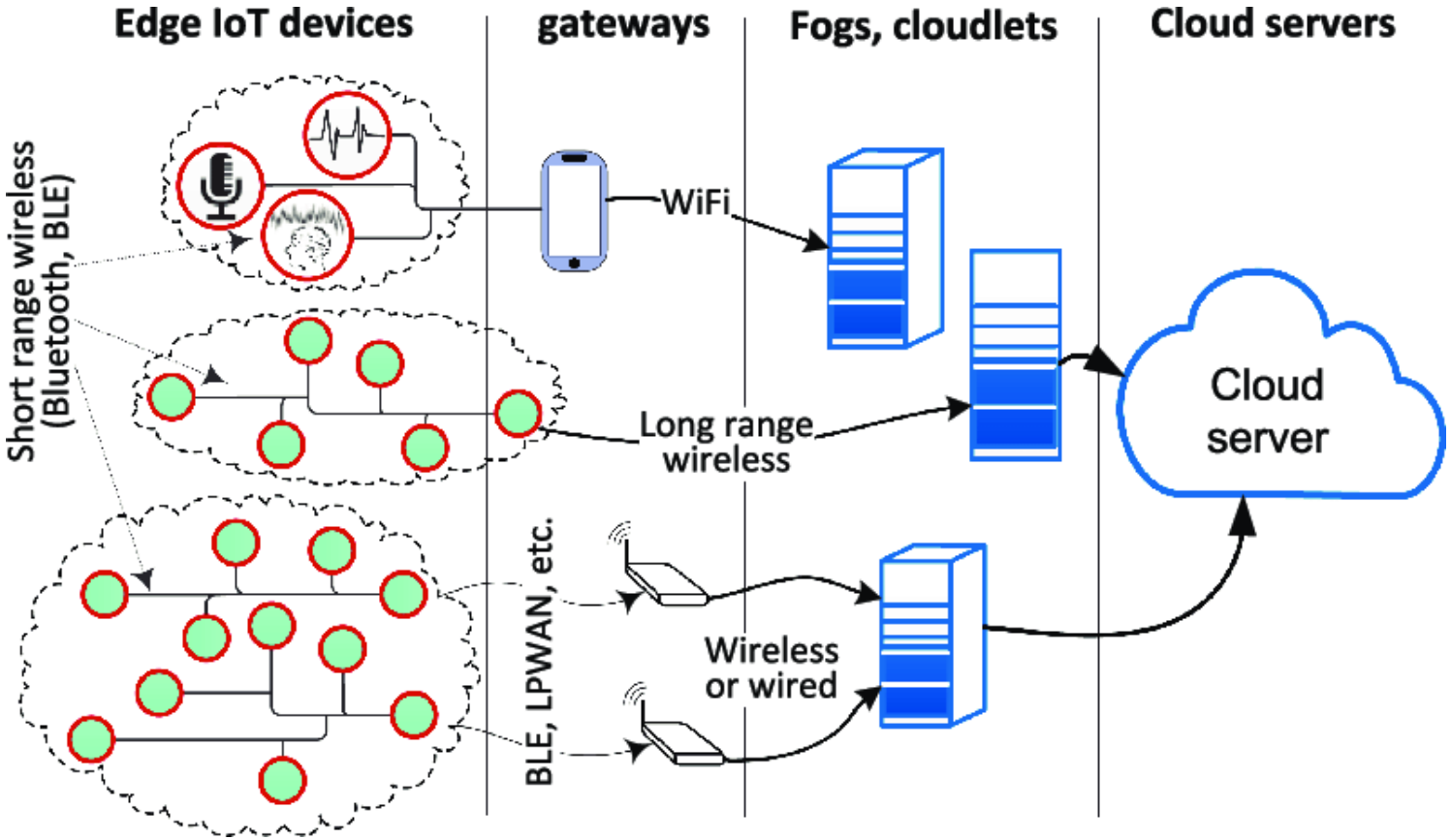
- **Router** – Directs data packets between different networks.
- **Switch** – Connects devices within a network and efficiently manages traffic.
- **Hub** – Broadcasts data to all devices in a network.
- **Modem** – Converts digital data to analog for transmission over phone lines.
- **Repeater** – Amplifies signals to extend network range.

**Access Point** – Provides wireless connectivity to devices

# Networking


IoT ENABLED
MOBILE DEVICES
IOT ENABLED
SHOPS, AIRPORTS,
STATIONS
EDGE IOT DEVICES
IOT ENABLED FACTORIES
IoT DEVICES
INTERNET OF
THINGS
DATACENTERS
IOT ENABLED SHIPS
AIRPLANES, TRAINS
IOT ENABLED CITIES
IoT ENABLED
HOMES & BUILDINGS

# Networking


Edge IoT devices
gateways
Fogs, cloudlets
Cloud servers
Short range wireless
(Bluetooth, BLE)
WiFi
Long range
wireless
Cloud
server
BLE, LPWAN, etc.
Wireless
or wired

# Network Topology

- **Network topology** defines the arrangement of nodes and connections in a network.

**1. Bus Topology**

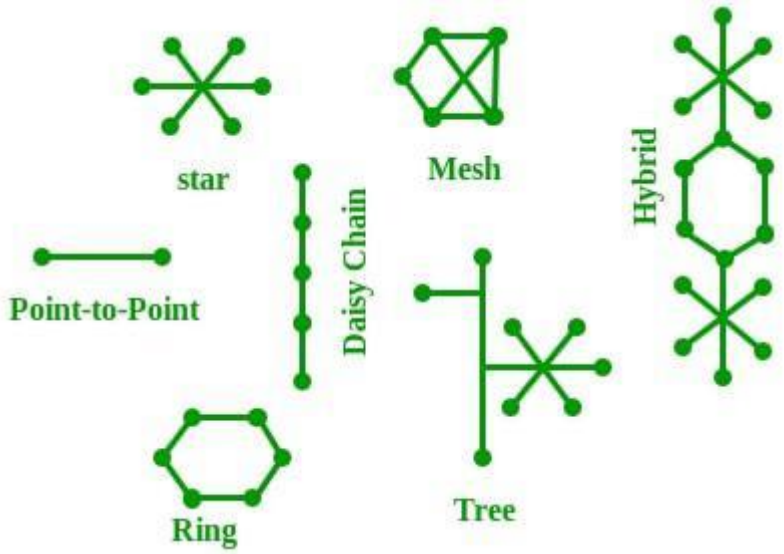
- Single central cable (backbone) connects all devices.
- **Pros**: Cheap, easy to implement.
- **Cons**: If the backbone fails, the entire network goes down.

**2. Star Topology**

- All devices are connected to a central hub/switch.
- **Pros**: Easy to manage, scalable.
- **Cons**: If the central hub fails, the network stops working.

**3. Ring Topology**

- Devices are connected in a circular loop.
- **Pros**: Predictable network performance.
- **Cons**: A single failure can disrupt the entire network.



# Network Topology

**Mesh Topology**

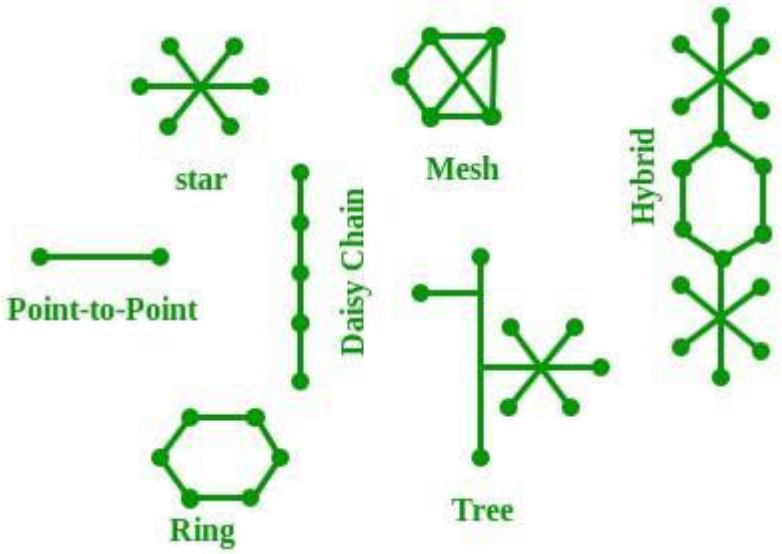
- Every node is connected to every other node.
- **Pros**: Highly reliable, multiple redundant paths.
- **Cons**: Expensive and complex.

**5. Hybrid Topology**

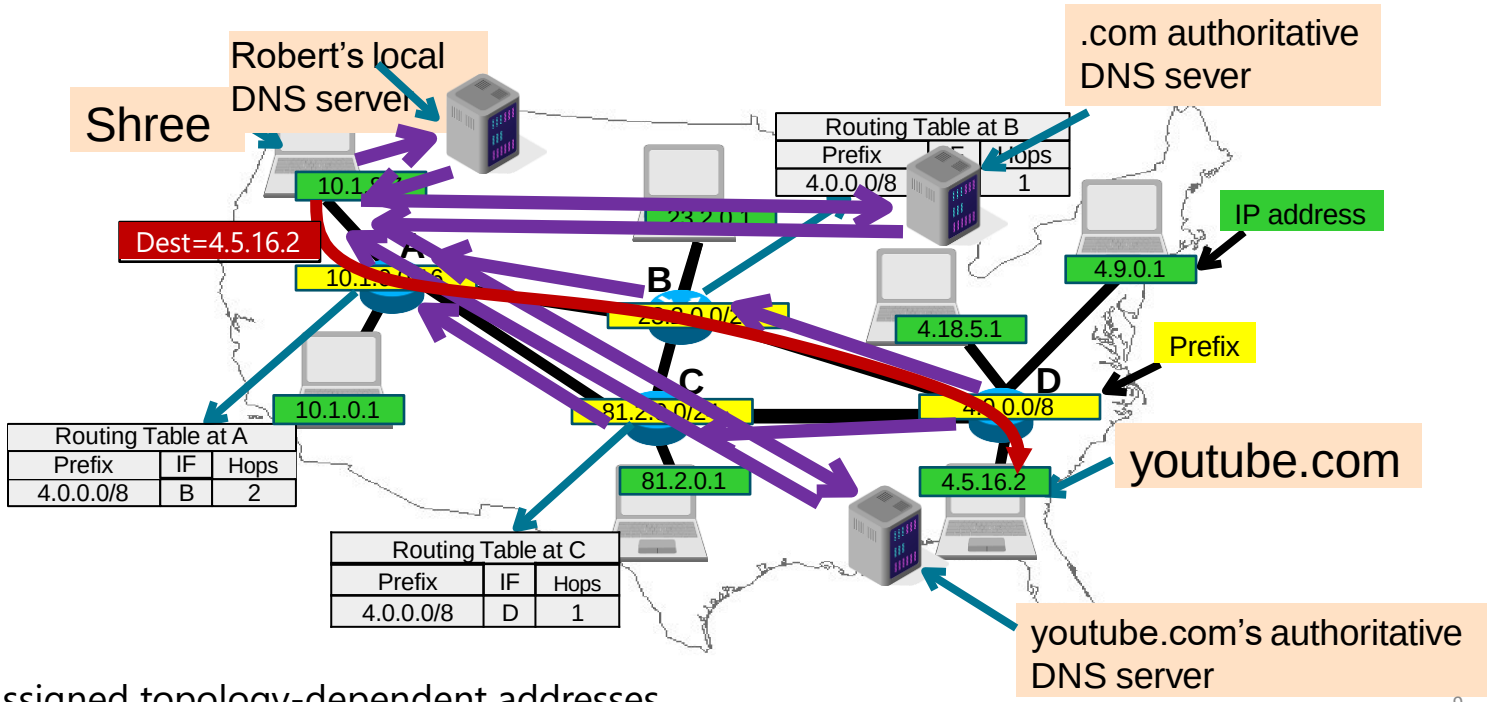
- Combination of two or more topologies (e.g., Star + Bus).
- **Pros**: Flexible and scalable.
- **Cons**: Complex to implement.

**6. Tree Topology**

- A hierarchical structure with parent-child nodes.
- **Pros**: Ideal for large networks.
- **Cons**: If a root node fails, sub-networks disconnect.



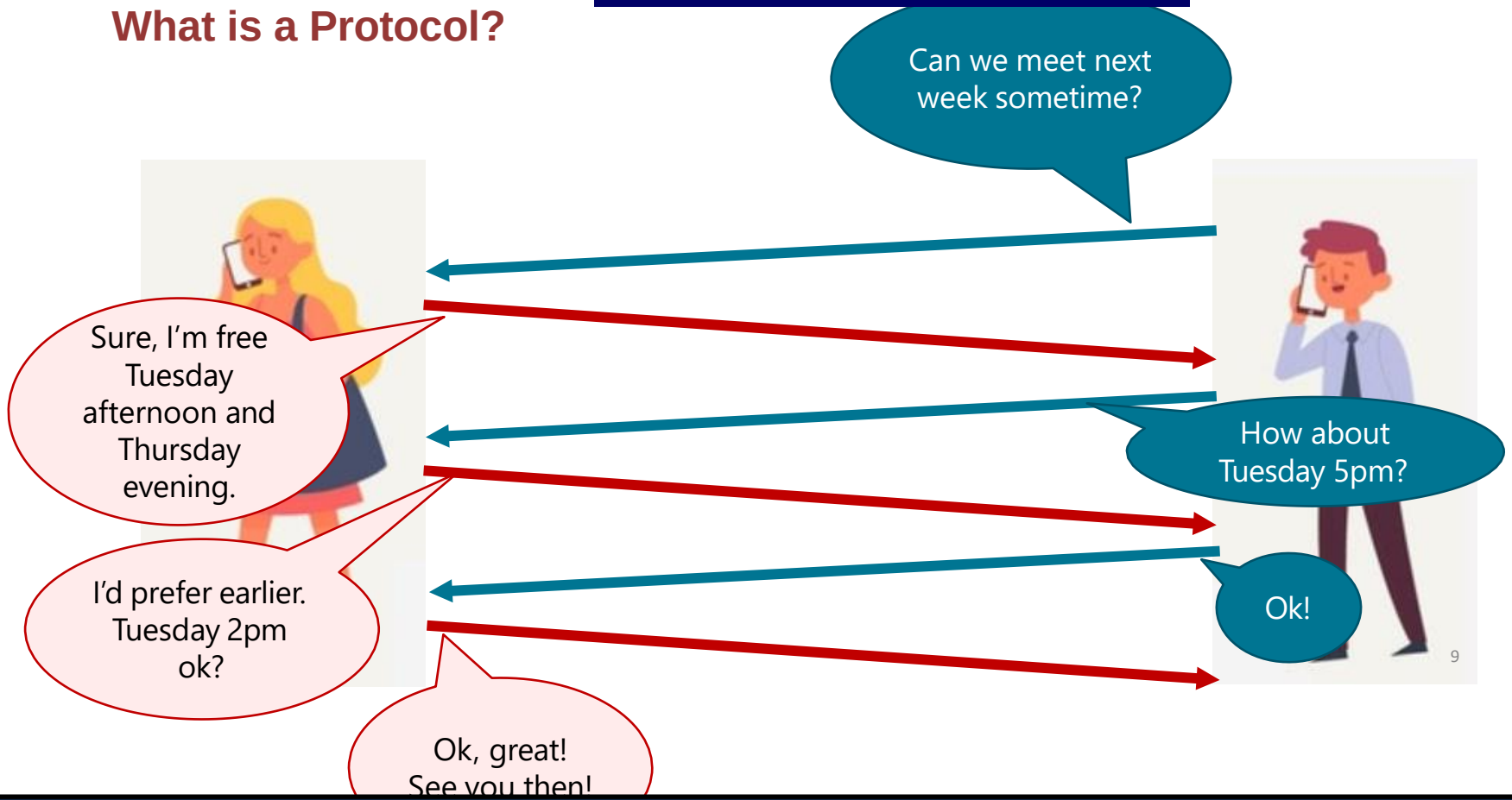
# Communication




- Hosts assigned topology-dependent addresses
- Routers advertise address blocks ("prefixes")
- Routers compute "shortest" paths to prefixes
- Map IP addresses to names with DNS

# Protocols

## What is a Protocol?



# Protocol

## What is a Protocol?

- Sequence of communications used to conduct some activity in a distributed system

- Protocols are widely used in networks
  - Figure out how fast to send data, discover paths to destinations, replicate data, encode data into transmittable patterns, etc.

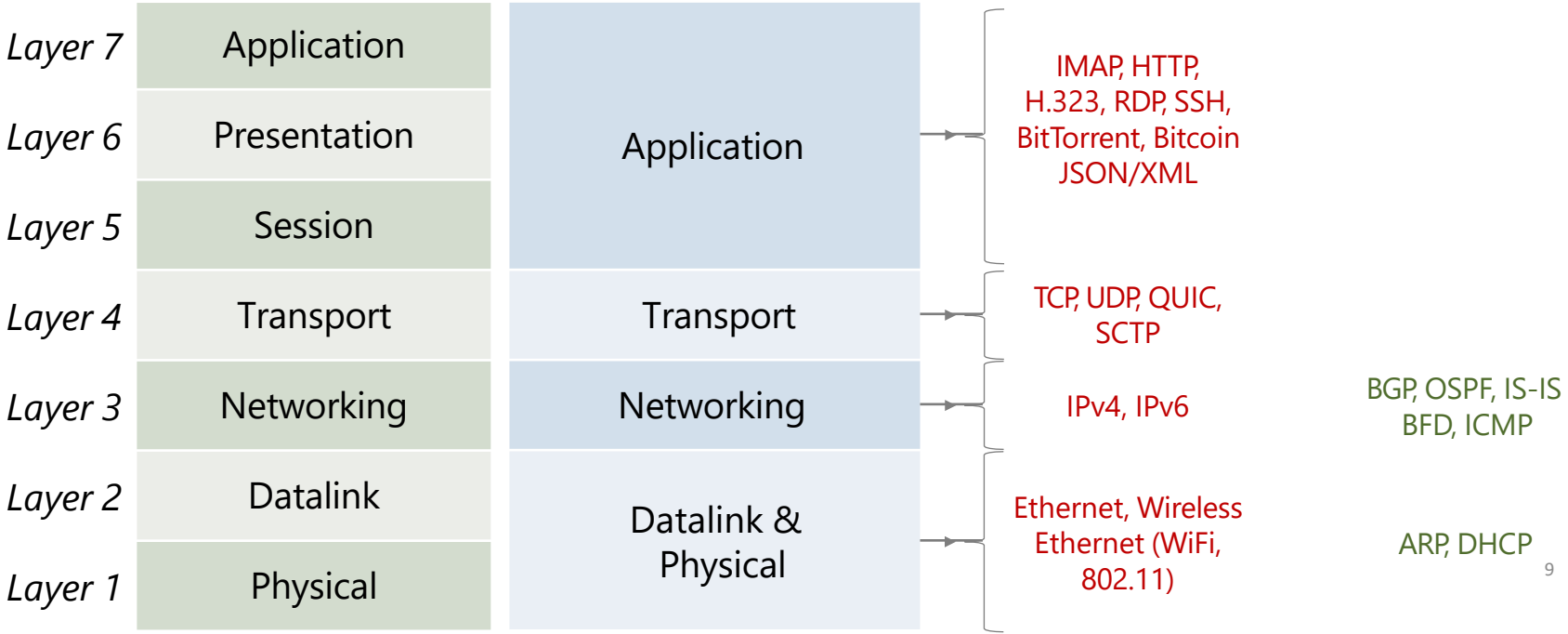
- Protocols often organized into “suites” or “stacks”
  - Handle collection of activities associated with particular environment
  - Examples: TCP/IP (Internet), Infiniband (Data Center), Bluetooth (IoT)

## Networks Have Protocols To….

| | |
|---|---|
| Compute paths through networks | Routing protocols |
| Figure out how fast to send data | Transport protocols |
| Encrypting messages so others can't read them | Encryption protocols |
| Figure out who has an address | Address resolution protocols |
| Figure out what kinds of things the network can do | Service discovery protocols [9] |

# Protocol

## The TCP/IP Protocol Stack



# Protocol

## OSI Model

- **Stack Structure:** Protocols are often arranged in a layered **stack**.
- In the 1980s, researchers developed **architectural models** to guide network design.
- One key model is the **OSI (Open Systems Interconnection) Model**, which consists of **seven layers**:

1. **Application Layer** – Implements network applications.
2. **Presentation Layer** – Handles data representation and encoding.
3. **Session Layer** – Manages sessions between endpoints.
4. **Transport Layer** – Ensures reliable data transmission.
5. **Network Layer** – Handles IP addressing and routing.
6. **Data Link Layer (MAC Layer)** – Manages local network communication.
7. **Physical Layer** – Converts data into physical signals.

# Protocol

**Data Flow in OSI Model**

**1. Application Layer (Layer 7)**

•**Purpose**: User interaction and protocols (e.g., HTTP, FTP).

•**Example**: Browser sends an HTTP request for www.example.com.

**2. Presentation Layer (Layer 6)**

•**Purpose**: Data formatting, encryption, decryption.

•**Example**: Encrypts HTTP data using SSL/TLS for secure transmission.

**3. Session Layer (Layer 5)**

•**Purpose**: Manages sessions between devices.

•**Example**: Establishes and maintains a session with the web server.

**4. Transport Layer (Layer 4)**

•**Purpose**: Ensures reliable data delivery (segmentation, error checking).

•**Example**: TCP divides data into segments, assigns sequence numbers.

# Protocol

**5. Network Layer (Layer 3)**
•**Purpose**: Logical addressing and routing.
•**Example**: Adds source and destination IP addresses to form packets.
**6. Data Link Layer (Layer 2)**
•**Purpose**: Physical addressing and error detection.
•**Example**: Frames are created with MAC addresses of devices.
**7. Physical Layer (Layer 1)**
•**Purpose**: Transmission of raw data (bits) via physical medium.
•**Example**: Converts frames into electrical, optical, or radio signals.

# Protocol

**Example of Data Flow in TCP/IP**

When you load a webpage, the following happens:

**1.Application Layer**:

1. Your browser sends an HTTP request to the server for the webpage.

**2.Transport Layer**:

1. The data (HTTP request) is segmented into packets.
2. TCP assigns port numbers (e.g., port 80 for HTTP).

**3.Internet Layer**:

1. IP assigns source and destination IP addresses.
2. Routers forward packets to the server.

**4.Network Access Layer**:

1. Data is converted into electrical or optical signals for transmission over Ethernet or Wi-Fi.

# Protocol

## Key Differences: IPv4 vs IPv6

| Feature | IPv4 | IPv6 |
|---|---|---|
| **Address Size** | 32-bit (4 octets) | 128-bit (16 octets) |
| **Address Format** | Decimal (e.g., 192.168.1.1) | Hexadecimal (e.g., 2001:db8::1) |
| **Address Space** | ~4.3 billion addresses | Virtually unlimited |
| **Security** | Limited, optional IPSec | Built-in IPSec |
| **Header Size** | 20 bytes | 40 bytes |
| **Routing** | Complex | Simplified, more efficient |
| **Compatibility** | Widely used | Gradually replacing IPv4 |
| **Configuration** | Requires manual or DHCP setup | Supports auto-configuration |

# Protocol

## Key Differences: IPv4 vs IPv6

**Why IPv6 is Important**

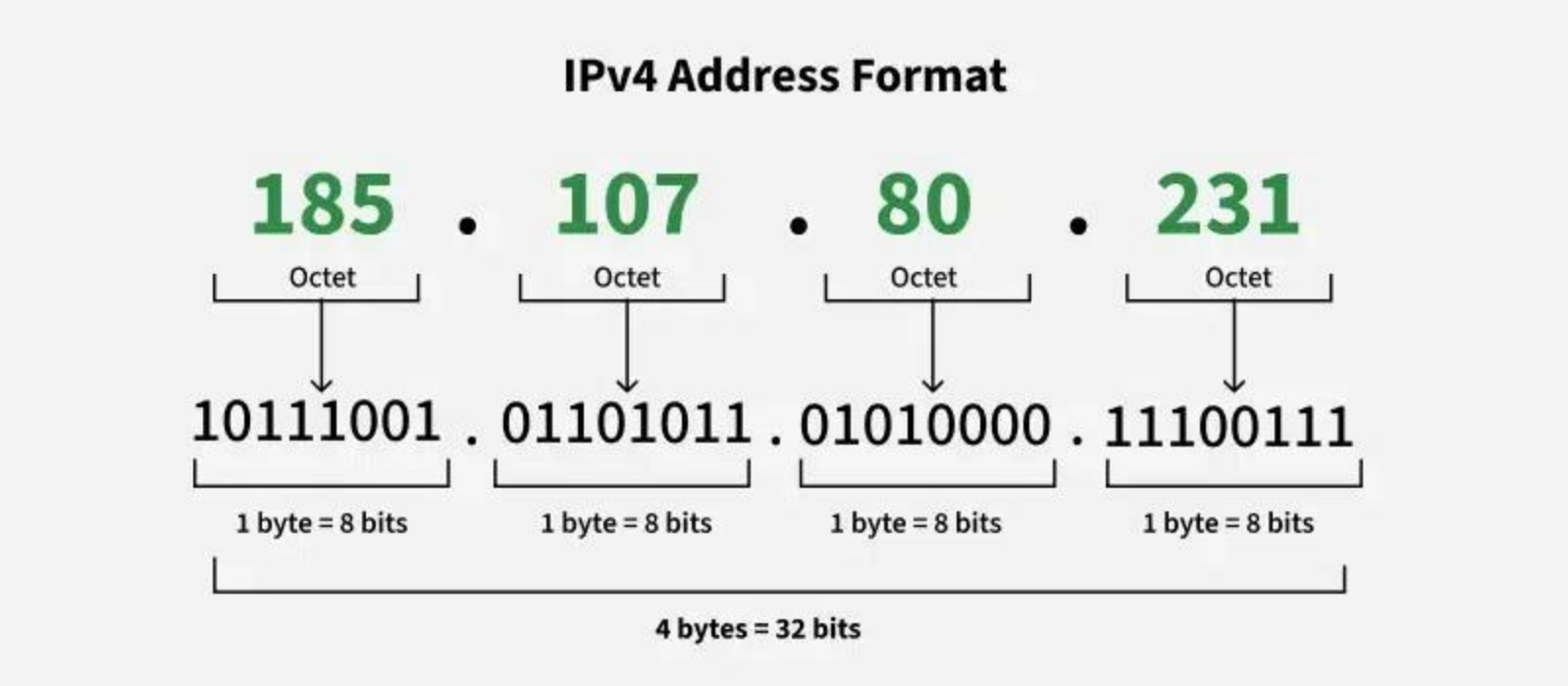
1. **Device Explosion**: With IoT and increasing devices, IPv4 cannot meet the demand.
2. **Future-Ready**: IPv6 is designed to handle future internet expansion.
3. **Better Performance**: IPv6 reduces latency with simplified routing and larger data packets.

**Example**

- **IPv4 Address**: 192.168.1.1
- **IPv6 Address**: 2001:0db8:85a3:0000:0000:8a2e:0370:7334 (or compressed: 2001:db8::8a2e:370:7334)

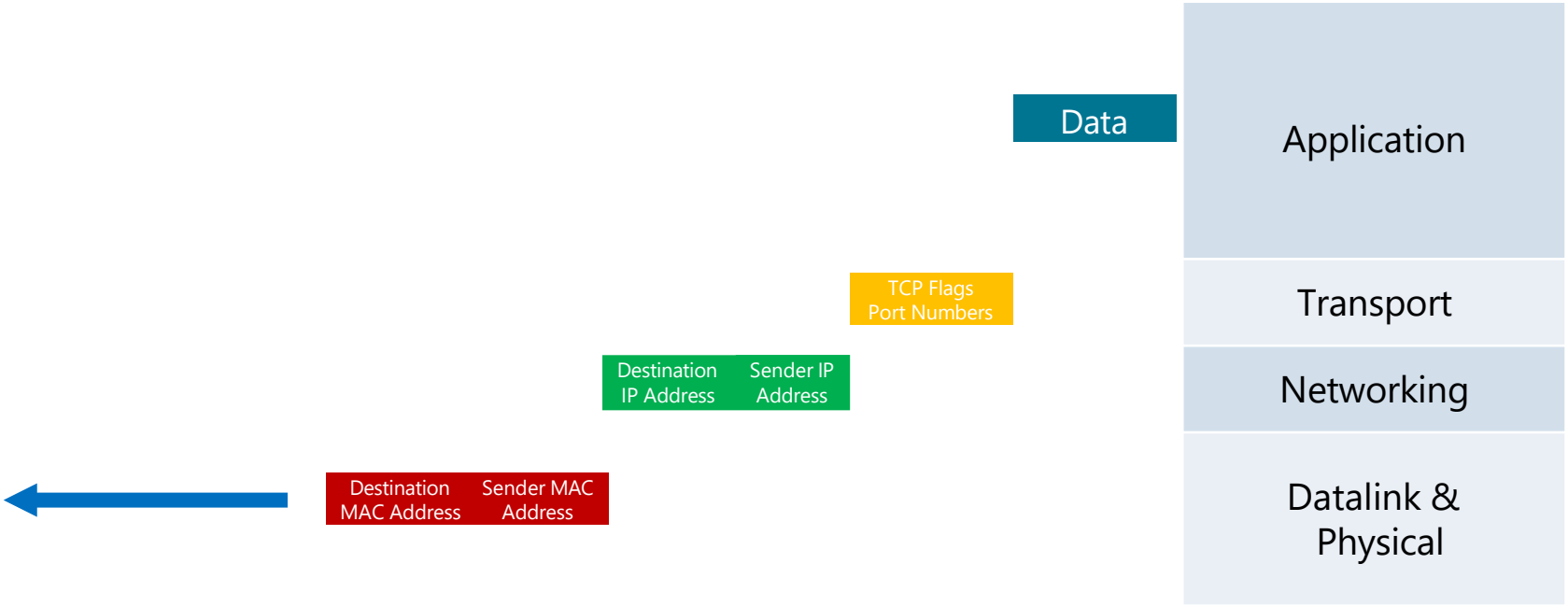
# Protocol

## IPv4



# Protocol

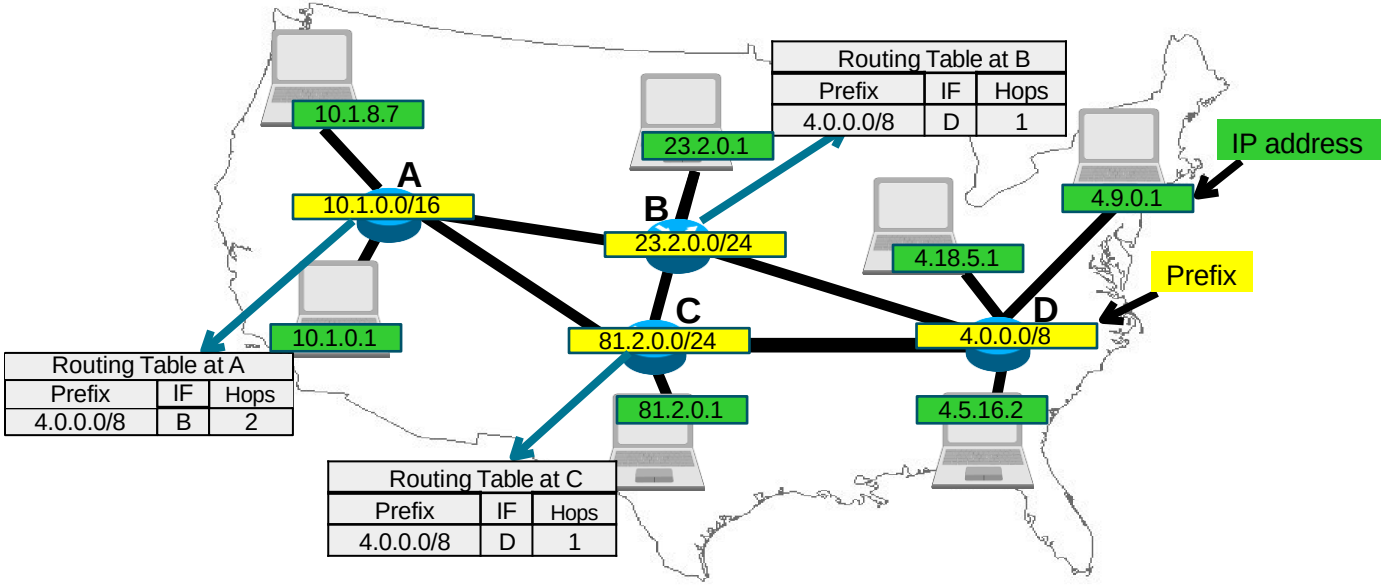
## Protocol Encapsulation




- Each layer of protocol stack encapsulates data passed to it
- Each forwarding layer inspects data only at that encapsulation layer
  - Switching only looks at Ethernet header, Routing only looks at IP header, etc.
  - Terminology: "Layer-3 switch", "Layer-4 load balancer", "Layer-7 load balancer"

9

# How Can Many Hosts Communicate?




- Hosts assigned topology-dependent addresses
- Routers advertise address blocks (“prefixes”)
- Routers compute “shortest” paths to prefixes
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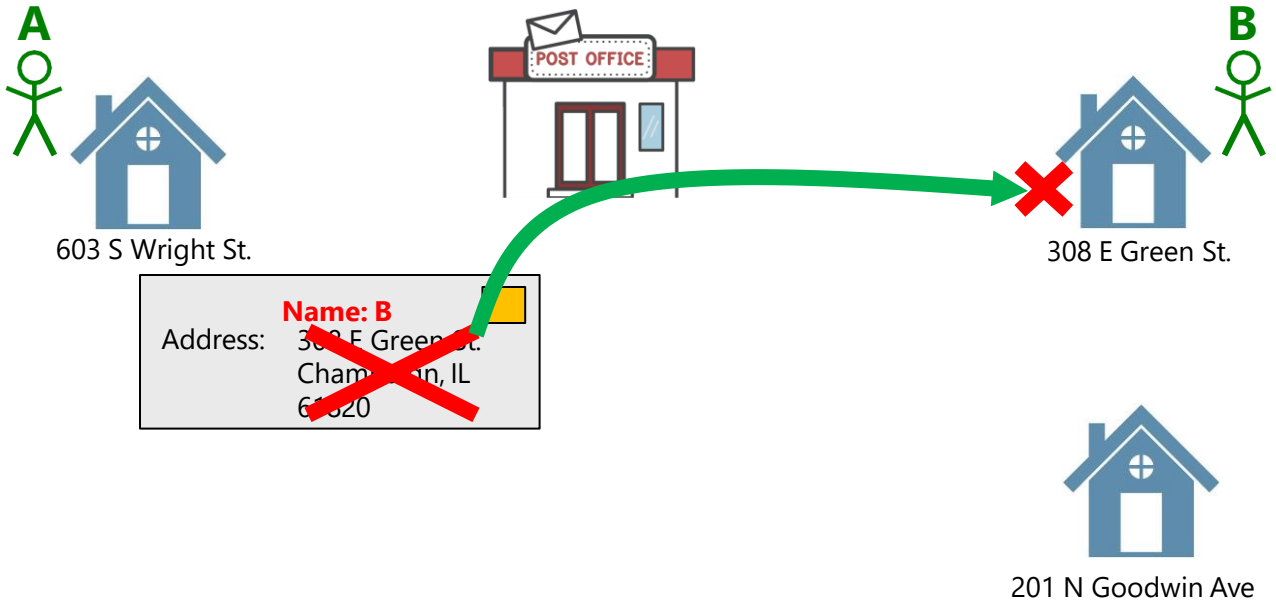
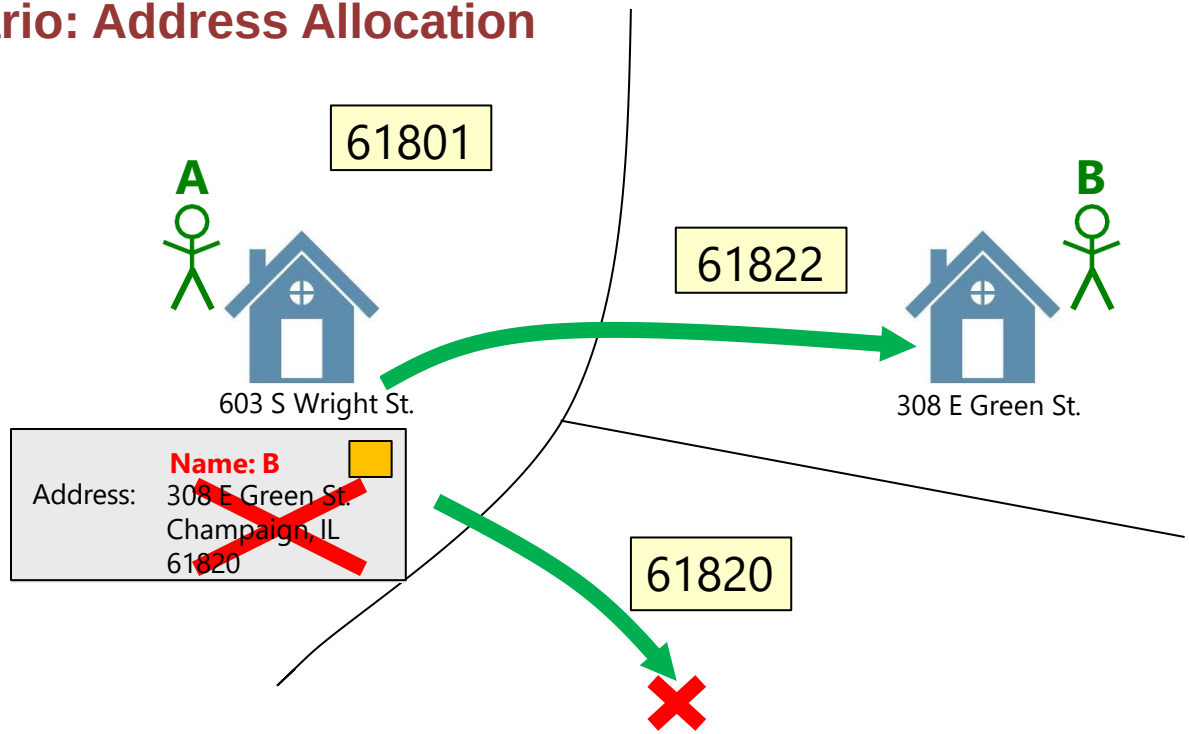
# Protocol

## Scenario: Sending a Letter



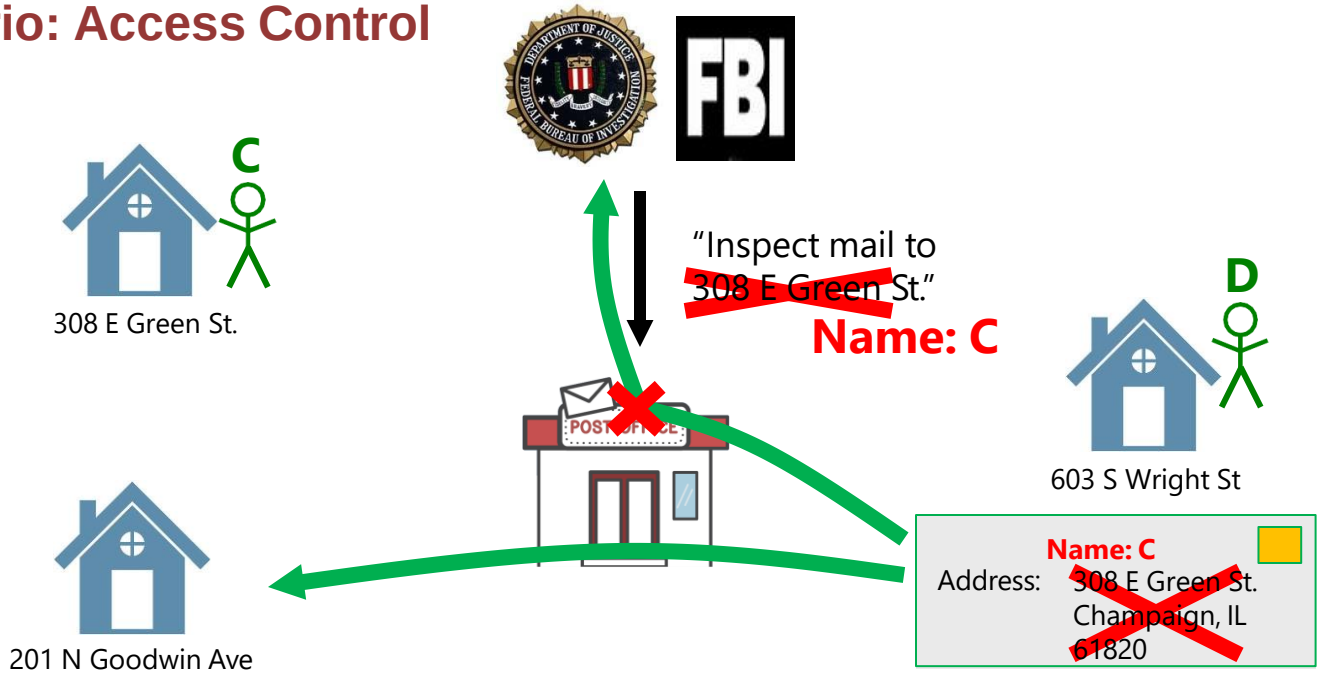
# Protocol

## Scenario: Address Allocation



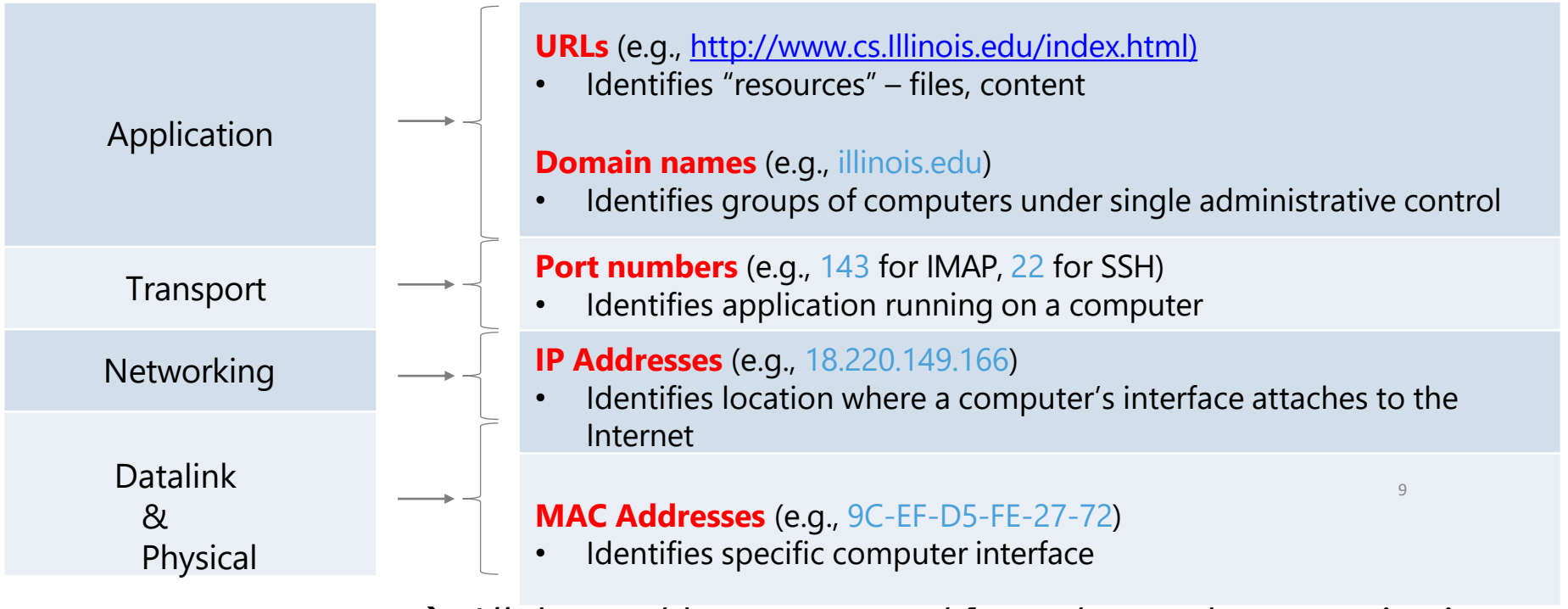
# Protocol

## Scenario: Access Control



## Internet Addressing:

# Different Layers Use Different Addresses



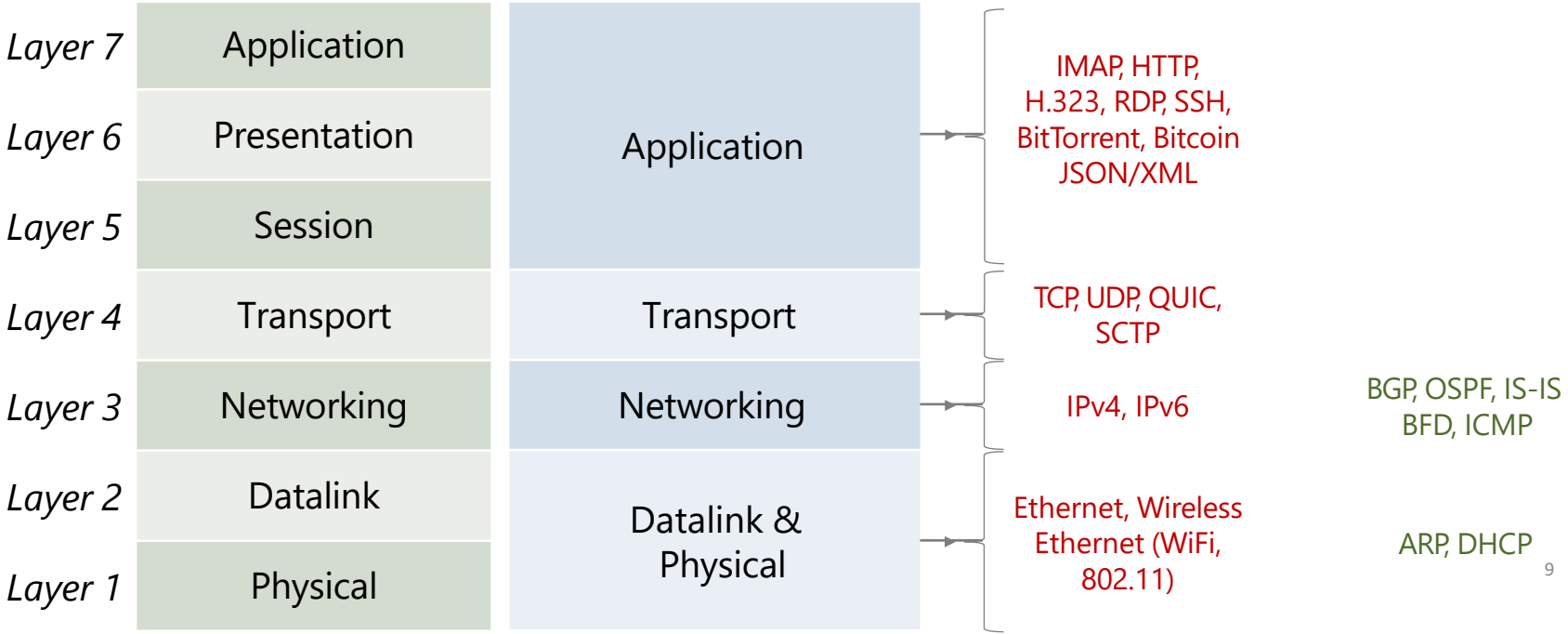

→ *All these addresses are used for end-to-end communication*

## Internet Addressing:

| MAC Address | IP Address |
|---|---|
| Datalink layer | Network layer |
| **Flat** (location-independent) identifier Like a social security number<br>Usually hard-coded,<br>**requires no configuration** | Hierarchically-assigned, **location-dependent** identifier<br>Like a postal address<br>**Needs to be manually configured**, assigned by DHCP |
| Portable; can stay the same as the host moves | Not portable; must be changed if host changes networks |
| Used to get packet to destination on same LAN | Used to get packet to destination IP subnet |
| Example: 9C-EF-D5-FE-27-72 | Example: 18.220.149.166 |

# Protocol

## The TCP/IP Protocol Stack



## Can We Use TCP/IP for IoT?

Yes

But, IoT introduces additional challenges:

- Very tight power/compute constraints
- Need to work closely with wireless
- Need to address applications, not just interfaces

Also, creating new protocols can help lock-in and market control

- Bad for innovation but good for security

## Common IoT Protocols







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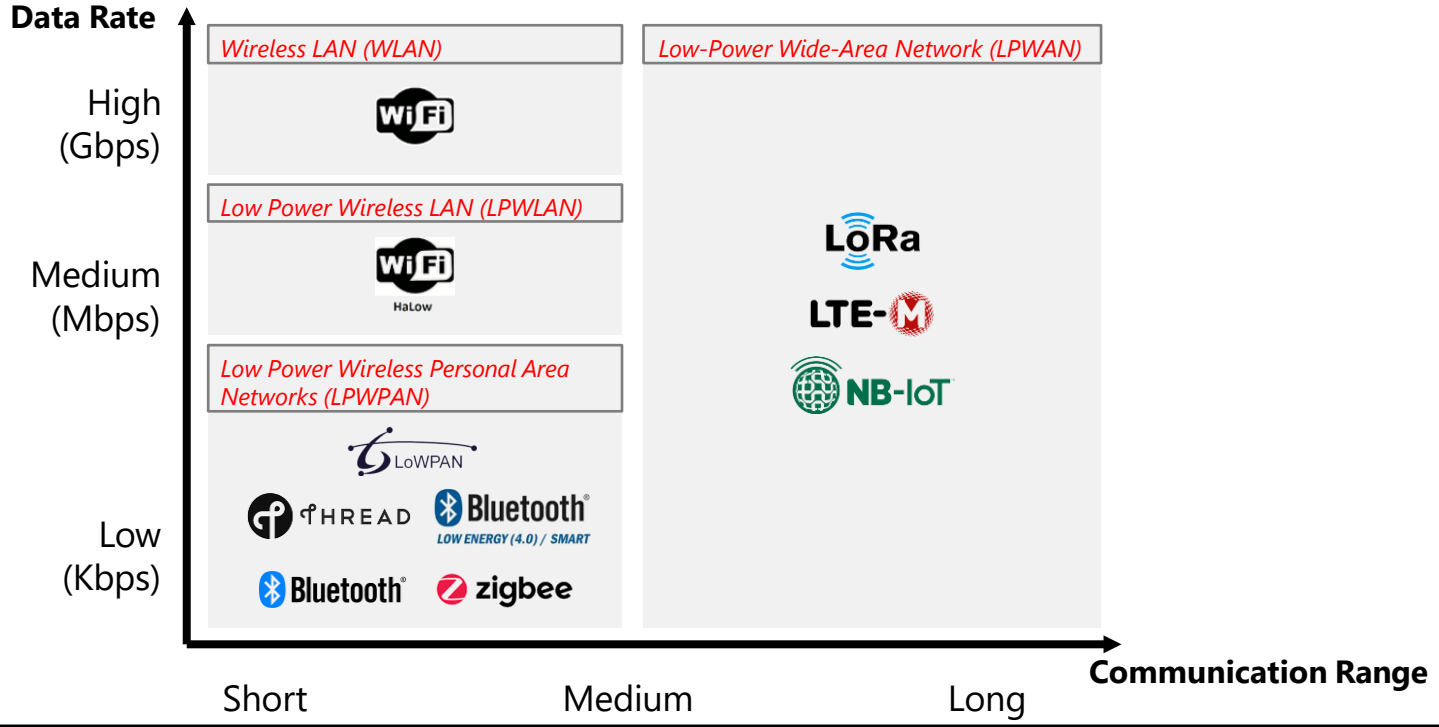
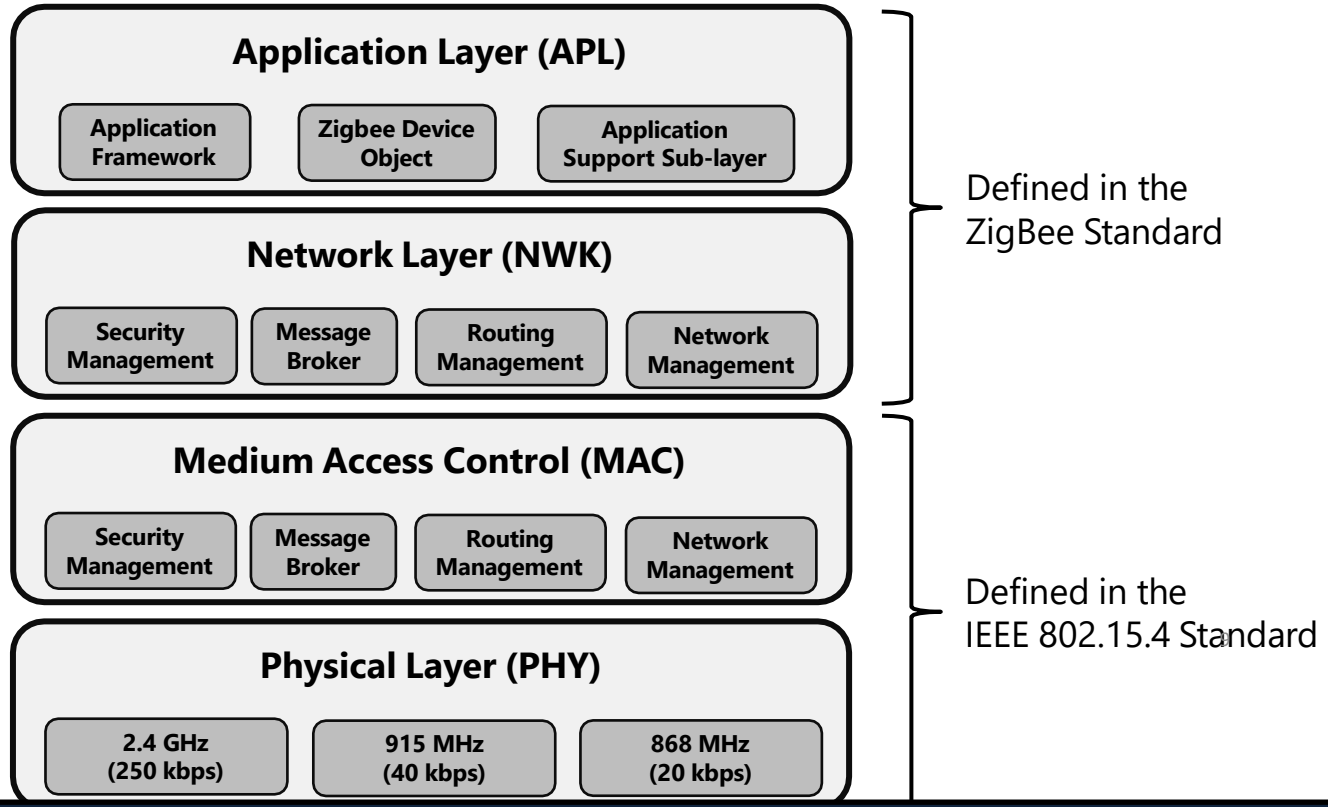
# Different IoT Protocols

# for Different Environments



# Zigbee Protocol Stack



# Zigbee Protocol Stack

**Slide 1: Introduction to Zigbee Protocol Stack**

📌 **What is Zigbee?**

- A **low-power, low-data-rate, and short-range** wireless communication protocol.
- Based on **IEEE 802.15.4** standard.
- Used in **Wireless Sensor Networks (WSN), smart homes, industrial automation, and IoT**.

📌 **Key Features of Zigbee**

✅ **Low Power Consumption** – Ideal for battery-operated devices.
✅ **Short-Range Communication** – Operates in **2.4 GHz, 915 MHz, and 868 MHz** bands.
✅ **Supports Large Networks** – Up to **65,000 devices**.
✅ **Three Network Topologies** – **Star, Tree, and Mesh**.
✅ **AES-128 Encryption** – Ensures secure communication.

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# Zigbee Protocol Stack

| Layer | Description | Functions |
|---|---|---|
| **Application (APL) Layer** | Contains **Zigbee Device Objects (ZDO)** & application profiles. | Defines device functionalities & application services. |
| **Application Support (APS) Layer** | Provides an interface between the network and application layers. | Manages **service discovery, security, and data filtering**. |
| **Network (NWK) Layer** | Manages network topology and routing. | Supports **Mesh, Tree, and Star topologies** with **AODV routing**. |
| **Medium Access Control (MAC) Layer** | Controls channel access based on **IEEE 802.15.4**. | Uses **CSMA/CA, beaconing, and addressing (16-bit or 64-bit)**. |
| **Physical (PHY) Layer** | Handles signal transmission and reception. | Uses **DSSS modulation** and operates at **2.4 GHz, 915 MHz, 868 MHz**. |

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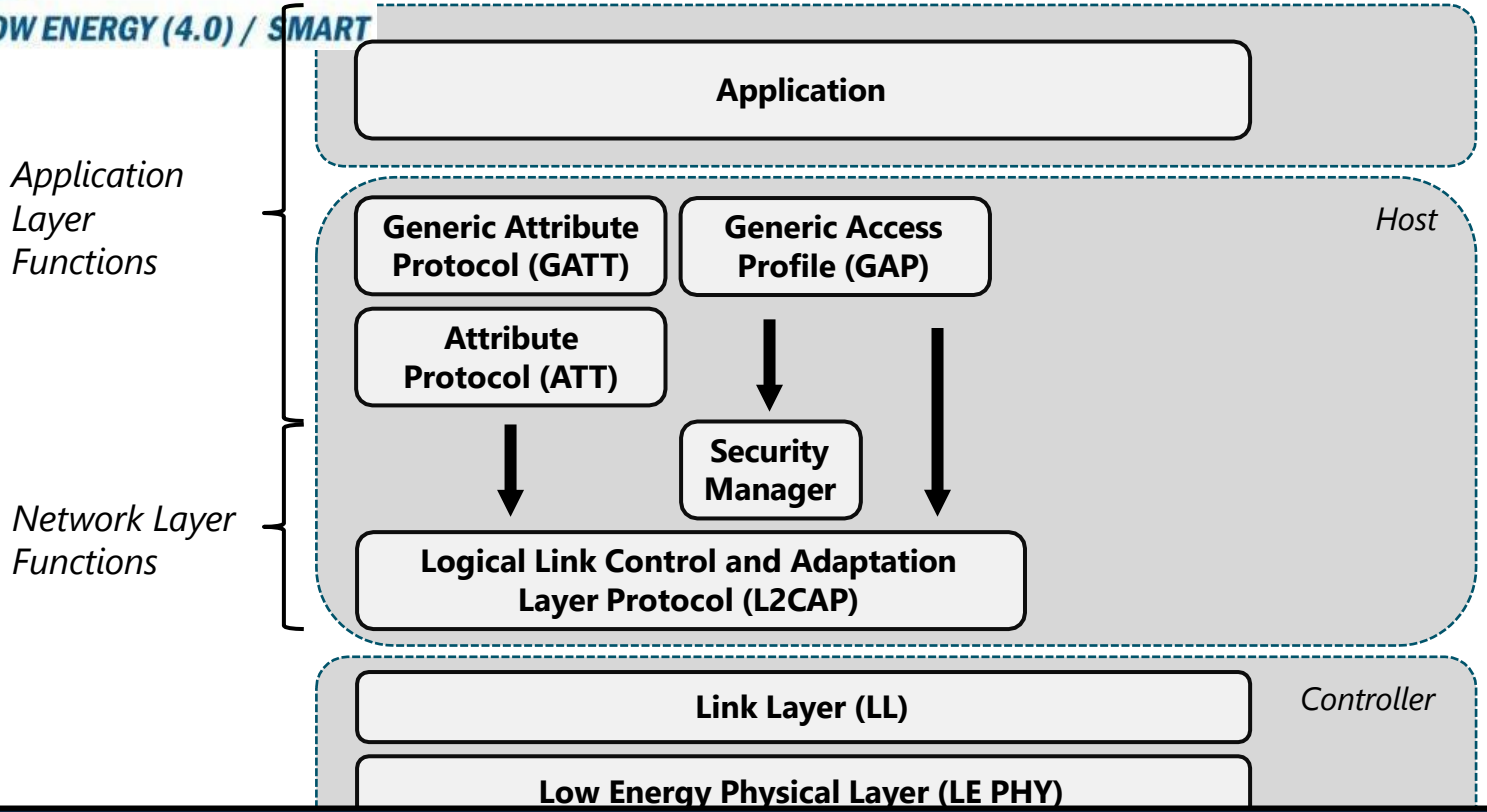
# Zigbee Protocol Stack

| Application Area | Examples | Why Zigbee? |
|---|---|---|
| Smart Home Automation | Smart lighting, security systems, smart thermostats | Low-power, secure, and supports mesh networking |
| Industrial Automation | Factory automation, wireless sensor networks, predictive maintenance | Reliable for large-scale industrial deployments |
| Healthcare Monitoring | Patient monitoring, wearable medical devices, elderly care | Supports medical-grade security and real-time monitoring |
| Smart Energy Management | Smart meters, energy-efficient appliances, demand response systems | Enables efficient energy management with low-power communication |
| Agriculture & Environment Monitoring | Soil moisture sensors, irrigation control, weather monitoring | Long battery life for outdoor monitoring applications |
| Retail & Asset Tracking | Inventory tracking, BLE beacons, automated checkout systems | Cost-effective, scalable, and supports IoT integration |

# Bluetooth Low Energy Protocol Stack

Bluetooth®
LOW ENERGY (4.0) / SMART



# Bluetooth Low Energy Protocol Stack

📌 **What is BLE?**

•A low-power wireless communication protocol designed for IoT and sensor-based applications.

•Operates in the **2.4 GHz ISM band**.

•Optimized for **low energy consumption** with intermittent data transmission.

📌 **Key Features of BLE**

✅ Low power consumption (ideal for battery-powered devices).

✅ Short-range communication (typically **10-100 meters**).

✅ Supports star topology with central and peripheral devices.

✅ Used in **wearables, healthcare devices, smart homes, and asset tracking**.

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# Bluetooth Low Energy Protocol Stack

The **BLE protocol stack** consists of five layers:

**1 Physical (PHY) Layer**

- Handles wireless transmission over the **2.4 GHz band**.
- Uses **Frequency Hopping Spread Spectrum (FHSS)** to avoid interference.

**2 Link Layer (LL)**

- Manages **device discovery, connection establishment, and encryption**.
- Supports **advertising & scanning mechanisms** for device communication.

**3 L2CAP (Logical Link Control & Adaptation Protocol)**

- Provides **data fragmentation & reassembly**.
- Multiplexes higher-layer protocols.

**4 GATT (Generic Attribute Profile) & ATT (Attribute Protocol)**

- Defines how **data is structured and exchanged** between devices.
- Uses **Services, Characteristics, and Descriptors** for communication.

**5 Application Layer**

- Implements specific **IoT applications, fitness tracking, smart lighting, etc.**.
- Uses **predefined BLE profiles** (e.g., Heart Rate Profile, HID for keyboards).

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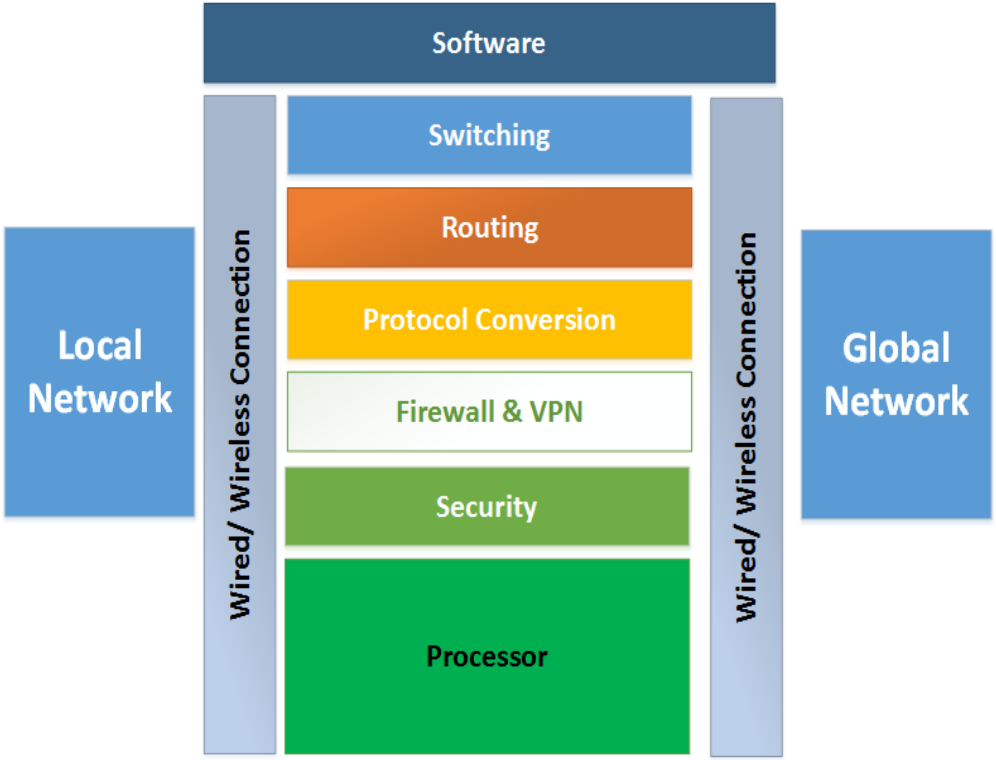
# Bluetooth Low Energy Protocol Stack

| Application Area | Examples | Why BLE? |
|---|---|---|
| Wearable Devices & Healthcare | Fitness trackers, heart rate monitors, glucose monitors | Low power for continuous health monitoring |
| Smart Home & IoT | Smart locks, lighting, voice assistants, thermostats | Seamless mobile app integration |
| Industrial & Asset Tracking | RTLS, BLE beacons, wireless sensor networks | Cost-effective tracking & monitoring |
| Automotive & Transportation | Keyless entry, infotainment, parking systems | Fast and secure vehicle communication |
| Retail & Payment Systems | Contactless payments, smart shopping carts, BLE beacons | Enhances user experience & automates transactions |
| Smart Agriculture | Soil moisture sensors, livestock monitoring, greenhouse automation | Remote monitoring with minimal power consumption |

# IoT Gateways

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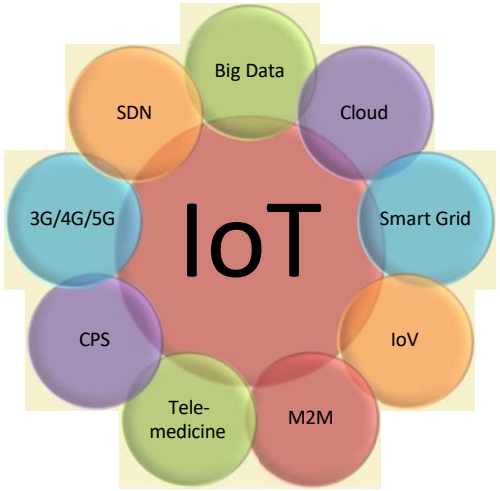
# IoT and Associated Technologies

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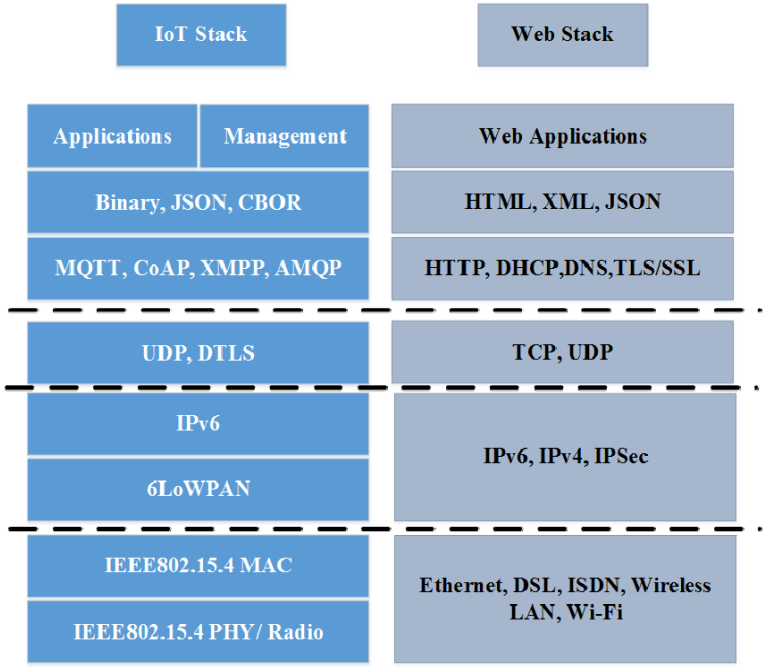
# Technical Deviations from Regular Web



# IoT Challenges

- ✓ Security
- ✓ Scalability
- ✓ Energy efficiency
- ✓ Bandwidth management
- ✓ Modeling and Analysis
- ✓ Interfacing
- ✓ Interoperability
- ✓ Data storage
- ✓ Data Analytics
- ✓ Complexity management (e.g., SDN)

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# Considerations

- ✓ Communication between the IoT device(s) and the outside world dictates the network architecture.
- ✓ Choice of communication technology dictates the IoT device hardware requirements and costs.
- ✓ Due to the presence of numerous applications of IoT enabled devices, a single networking paradigm not sufficient to address all the needs of the consumer or the IoT device.

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# Complexity of Networks

- ✓ Growth of networks
- ✓ Interference among devices
- ✓ Network management
- ✓ Heterogeneity in networks
- ✓ Protocol standardization within networks

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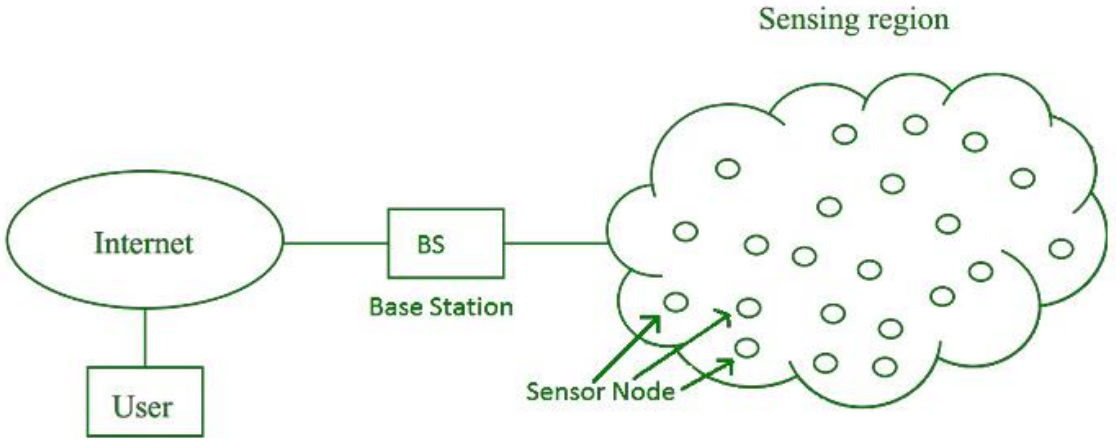
**Source:** O Vermesan, P. Friess, **"**Internet of Things – Converging Technologies for Smart Environments and Integrated Ecosystems", River Publishers, Series in Communications, 2013

# Wireless Networks

- Traffic and load management
- Variations in wireless networks – Wireless Body Area Networks and other Personal Area Networks
- Interoperability
- Network management
- Overlay networks

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**Source:** O. Vermesan, P. Friess, "Internet of Things – Converging Technologies for Smart Environments and Integrated Ecosystems", River Publishers, Series in Communications, 2013

# Wireless Sensor Network

| Layer | Function | Technologies/Protocols |
|---|---|---|
| **Physical Layer** | Ensures physical communication between sensor nodes and the base station. | Radio waves, Infrared, Bluetooth |
| **Data Link Layer** | Manages reliable data transmission and network efficiency. | IEEE 802.15.4, CSMA/CA |
| **Application Layer** | Defines data communication, formatting, and application-specific processing. | ZigBee, MQTT, CoAP |

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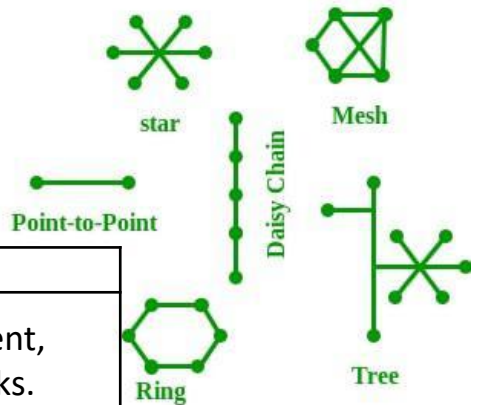
**Source:** O. Vermesan, P. Friess, "Internet of Things – Converging Technologies for Smart Environments and Integrated Ecosystems", River Publishers, Series in Communications, 2013

# Wireless Sensor Network




| Topology | Description | Key Benefits |
|---|---|---|
| Bus Topology | Nodes are connected to a single communication bus; data travels along the bus. | Simple layout, easy to implement, cost-effective for small networks. |
| Star Topology | A central master node connects to multiple nodes; data flows through the master node. | Efficient centralized control, low latency, and easy network management. |
| Tree Topology | Nodes are arranged in a hierarchical structure, resembling a tree for extended coverage. | Scalable, supports hierarchical deployments, expands network coverage. |
| Mesh Topology | Nodes are interconnected, forming a mesh; data can take multiple paths for redundancy. | Highly reliable, fault-tolerant, and supports multi-hop communication. |

**Source:** O. Vermesan, P. Friess, "Internet of Things – Converging Technologies for Smart Environments and Integrated Ecosystems", River Publishers, Series in Communications, 2013

# Wireless Sensor Network

## Applications of WSN

- Internet of Things (IoT)
- Surveillance and Monitoring for security, threat detection
- Environmental temperature, humidity, and air pressure
- Noise Level of the surrounding
- Medical applications like patient monitoring
- Agriculture
- Landslide Detection



**Source:** O. Vermesan, P. Friess, "Internet of Things – Converging Technologies for Smart Environments and Integrated Ecosystems", River Publishers, Series in Communications, 2013

# Wireless Sensor Network

## Components of WSN

- Sensors: Sensors in WSN are used to capture the environmental variables and which is used for data acquisition. Sensor signals are converted into electrical signals.
- Radio Nodes: It is used to receive the data produced by the Sensors and sends it to the WLAN access point. It consists of a microcontroller, transceiver, external memory, and power source.
- WLAN Access Point: It receives the data which is sent by the Radio nodes wirelessly, generally through the internet.
- Evaluation Software: The data received by the WLAN Access Point is processed by a software called as Evaluation Software for presenting the report to the users for further processing of the data which can be used for processing, analysis, storage, and mining of the data.

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# Wireless Sensor Network

**Challenges of WSN**

- Quality of Service
- Security Issue
- Energy Efficiency
- Network Throughput
- Performance
- Ability to cope with node failure
- Cross layer optimisation
- Scalability to large scale of deployment

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**Source:** O. Vermesan, P. Friess**, "**Internet of Things – Converging Technologies for Smart Environments and Integrated Ecosystems", River Publishers, Series in Communications, 2013

## Scalability

- Flexibility within Internet
- IoT integration
- Large scale deployment
- Real-time connectivity of billions of devices

# Thank You!!