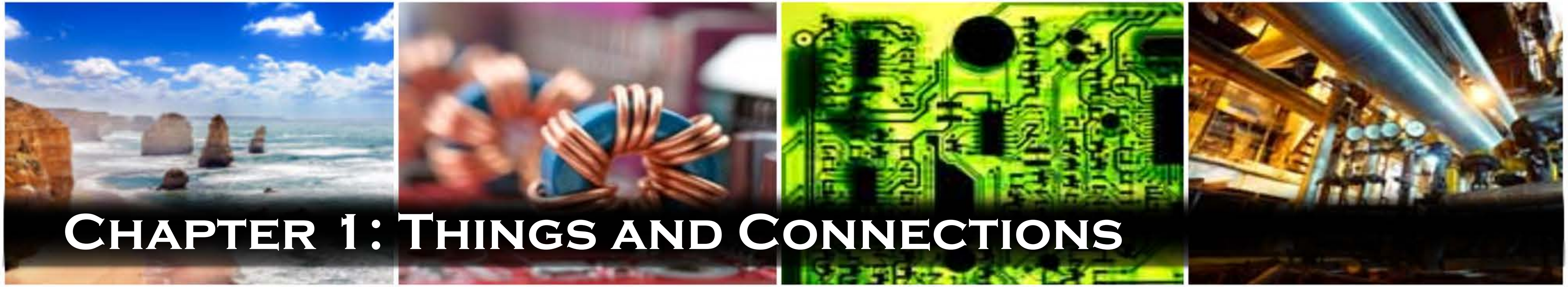

Chapter 1: Things and Connections

IoT Fundamentals
Connecting Things 2.0
Instructor Training

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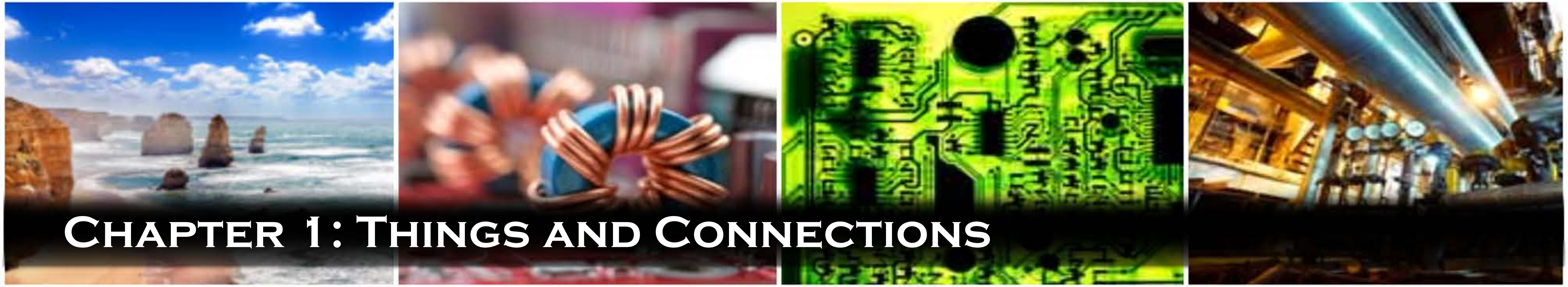

Chapter 1: Things and Connections

IoT Fundamentals
Connecting Things 2.0

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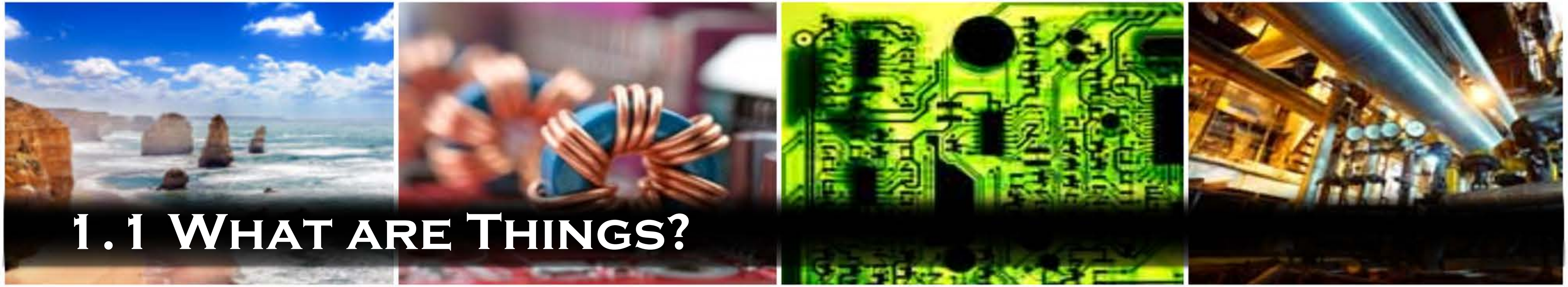
Chapter 1 - Sections & Objectives

- 1.1 What are Things?
  - Analyze the things that make up the IoT
- 1.2 What are Connections?
  - Explain how things connect to other things and to the IoT
- 1.3 Chapter Summary

1.1 What are Things?



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1.1.1 The Internet of Things

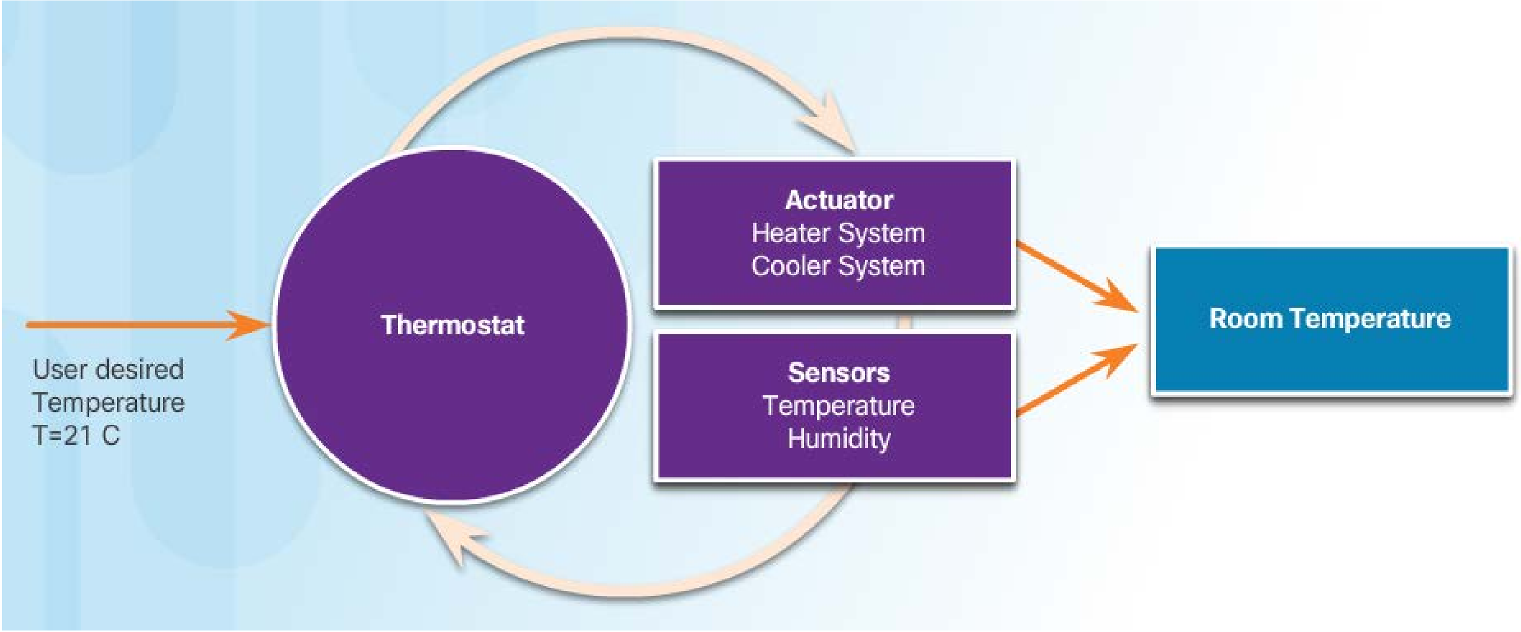
- The Presence of IoT in Today's World
  - IoT is the term for the extension of the existing Internet structure to billions of connected devices
  - The IoT is all around us
  - The IoT helps individuals to improve quality of life
  - The IoT also helps industries to become more efficient
  - An IoT system is usually made up of:
    - **Controllers** - collect, analyze, process, and send data
    - **Sensors** - monitor events
    - **Actuators** - influence the environment
    - **Hardware** - create the platform and its connections
    - **Software** - provide a framework to execute processes

1.1.1 The Internet of Things

- **Cisco IoT Solutions**
  - The rapid IoT growth has introduced new challenges.
  - Cisco IoT System reduces the complexities of digitization, implementation, and management.
  - Six Pillars of the Cisco IoT System are:
    1. **Network Connectivity** – Reliable, scalable, high-performance networking solutions available for any environment.
    2. **Fog Computing** – Software an hardware that extends IoT applications to the network edge, enabling data to be efficiently analyzed and managed where it's generated.
    3. **Cybersecurity and Physical Security** – Security solutions from the cloud to the fog that addresses the full attack continuum – before during, and after an attack.
    4. **Data Analytics** – Distributed network infrastructure components that run business-specific software analytic packages throughout the network architecture
    5. **Management and Automation** – Simplified management of large IoT networks that enables the convergence of operation technology (OT) data with the IT network.
    6. **Application Enablement Platform** – Platform that allows cloud-based app development and deployment from cloud to fog.

1.1.2 Building Blocks of an IoT System

- **IoT Process Flow**
  - A simple IoT system include sensors connecting, through a wireless or wired connection, to actuators or controllers
  - Some devices can have more than one function



1.1.2 Building Blocks of an IoT System

- **Controllers** (Raspberry Pi and Arduino)
  - Responsible for collecting data from sensors and providing network connectivity
  - Have the ability to make immediate decisions
  - adds intelligence to things
  - May also send data to remote and more powerful computer for analysis
  - Continuously analyzes and processes information, and use actuators to modify conditions

- **Actuators**
  - Performs an action
  - A basic motor that can be used to control a system
  - Can be hydraulic, electric or pneumatic
  - Responsible for transforming an electrical signal into physical output

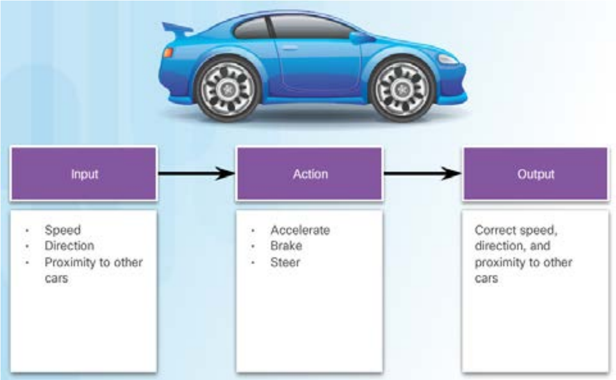
- **Sensors**
  - A device used to monitor and measure a physical property by detecting some type of information from the physical world
  - May be connected to a controller either directly or remotely

1.1.3 Processes in Controlled Systems

- **Process**
  - A series of steps or actions taken to achieve a desired result by the consumer of the process
  - Uses inputs to execute the required actions in order to achieve the desired output
- **Feedback**
  - When the output of a process affects the input
  - Referred to as a feedback loop
  - Used to provide real-time information to its controller based on current behavior
  - Can be positive or negative
  - Examples:
    - **Negative feedback** - a thermostat shuts down an air conditioning unit when the temperature reaches the set temperature
    - **Positive feedback** - a thermostat turns on an air conditioning unit when the temperature goes above the set temperature

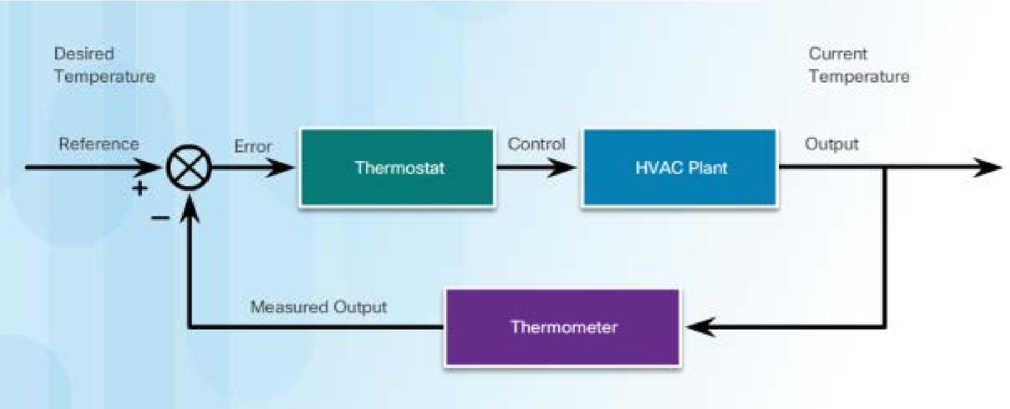
1.1.3 Processes in Controlled Systems

- **Control Systems**
  - The three components of a control system:
    - **Controller** - uses inputs and outputs to manage and regulate the behavior of the system in an attempt to achieve a desired state
    - **Plant** - the controlled portion of the system
    - **Sensor** - measure a physical property and sends it to a controller
  - **Control theory -** choosing the adjustments to apply to a plant to achieve a desired output
  - Control theory is applied to many systems
    - Driving a car
    - Home automation
    - Home security
    - Home thermostat



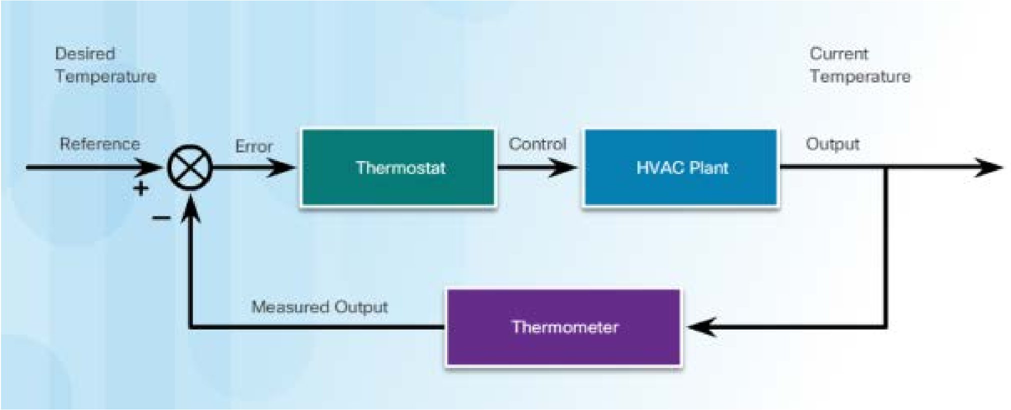
1.1.3 Processes in Controlled Systems

- **Open-Loop Control Systems**
  - Do NOT use feedback
  - The plant performs a predetermined action without any verification of the desired results
  - Often used for simple processes
  - Examples of an open-loop control system:
    - Fitness tracker
    - Light controller



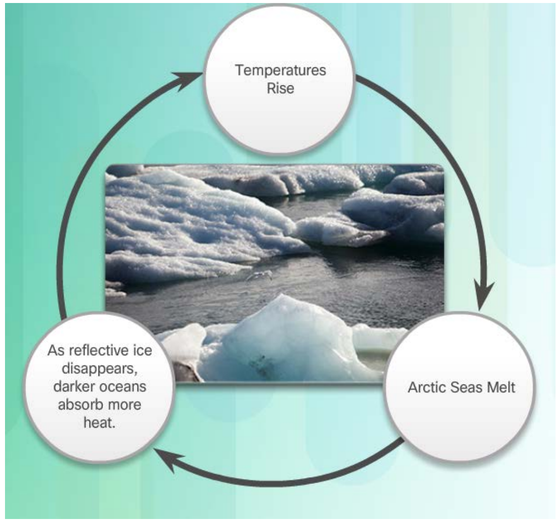
1.1.3 Processes in Controlled Systems

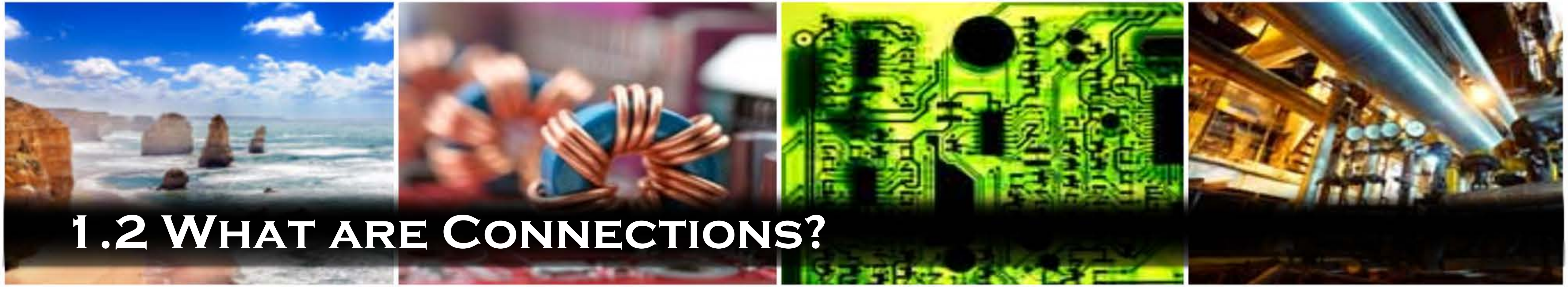
- **Closed-Loop Control Systems**
  - Uses feedback to determine whether the collected output is the desired output
  - Feedback is continuously being received by the controller from its sensors
  - The result is then fed back into a controller to adjust the plant for the next iteration of output, and the process repeats
  - Examples of a closed-loop control system:
    - Thermostat
    - Home security system
    - Cruise control
    - Active braking system



1.1.3 Processes in Controlled Systems

- **Closed-Loop Controllers**
  - Many types of closed-loop controllers:
    - **Proportional controllers (P)**: based on the difference between the measured output and the desired output
    - **Integral controllers (PI)**: use historical data to measure how long the system has deviated from the desired output
    - **Proportional, Integral and Derivative controllers (PID)**: include data about how quickly the system is approaching the desired output
      - PID controller is an efficient way to implement feedback control
      - The Arduino and Raspberry Pi devices can be used to implement PID controllers
- **Interdependent Systems**
  - Most systems have many interdependent pieces contributing to and affecting the output





1.2 What are Connections?

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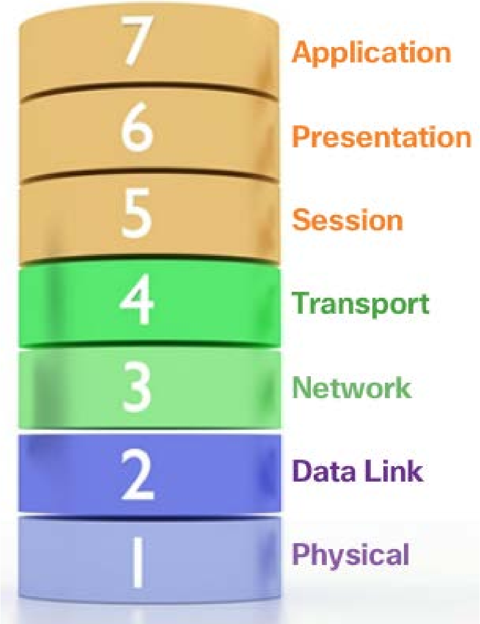
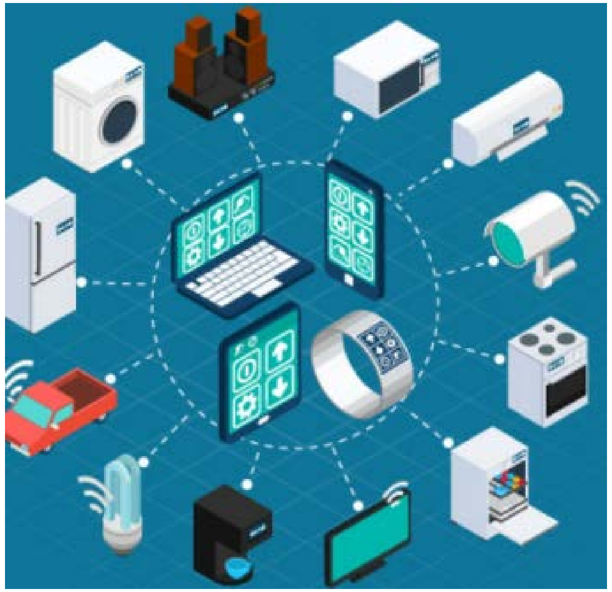
1.2.1 Models of Communication

- **Models of Communication**
  - Layered networking models are used to illustrate how a network operates and model how devices communicate.
  - Benefits include:
    - Assists in protocol design
    - Fosters competition
    - Prevent technology changes in one layer from affecting other layers
    - Provides a common language to describe network functions functions and capabilities
  - Physical, data link, and network layers are concepts that are used to illustrate how network communication operates



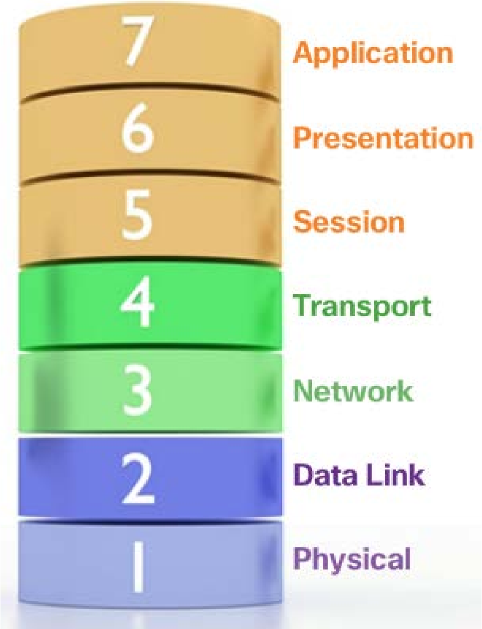
1.2.1 Models of Communication

- **Standardization**
  - The challenge for the IoT is to ensure these emerging IoT devices can connect securely and reliably to the Internet and to each other
  - Consistent, secure, and commonly recognized technologies and standards is needed
  - Organizations such as the Industrial Internet Consortium, OpenFog Consortium, and the Open Connectivity Foundation, are helping to develop standard architectures and frameworks



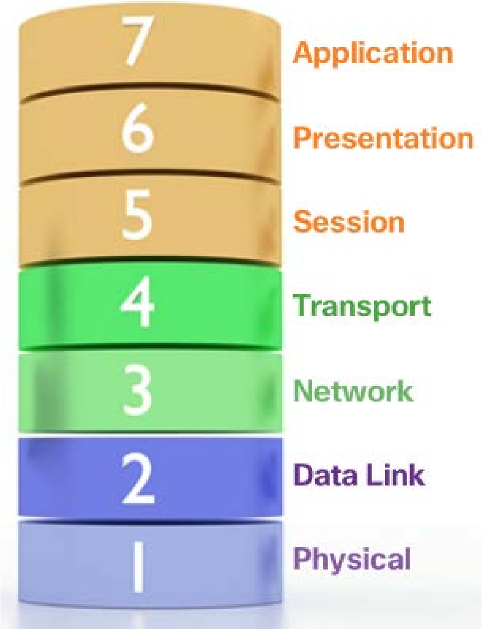
1.2.1 Models of Communication

- **OSI Model**
  - The OSI model provides an extensive list of functions and services that can occur at each layer
  - The layers of the OSI model:
    - **Layer 7: Application layer** –Provides the means for end-to-end connectivity between individuals in the human network using data networks
    - **Layer 6: Presentation layer** – Provides for common representation of the data transferred between application layer services
    - **Layer 5: Session layer** – Provides services to the presentation layer to organize its dialogue and to manage data exchange



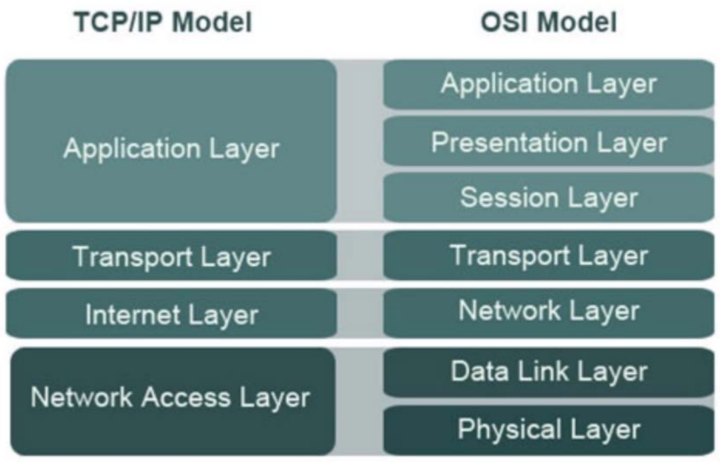
1.2.1 Models of Communication

- **OSI Model**
  - The layers of the OSI model:
    - **Layer 4: Transport layer** –Defines services to segment, transfer, and reassemble the data for individual communications between the end devices. It describes the ordered and reliable delivery of data between source and destination
    - **Layer 3: Network layer** –Provides services to exchange the individual pieces of data over the network between identified end devices (IP or Logical addressing)
    - **Layer 2: Data Link layer** –Protocols describe methods for exchanging data frames between devices over a common media (MAC or physical addressing)
    - **Layer 1: Physical layer** – Protocols describe the mechanical, electrical, functional, and procedural means to activate, maintain, physical-connections for bit transmission to and from a network device

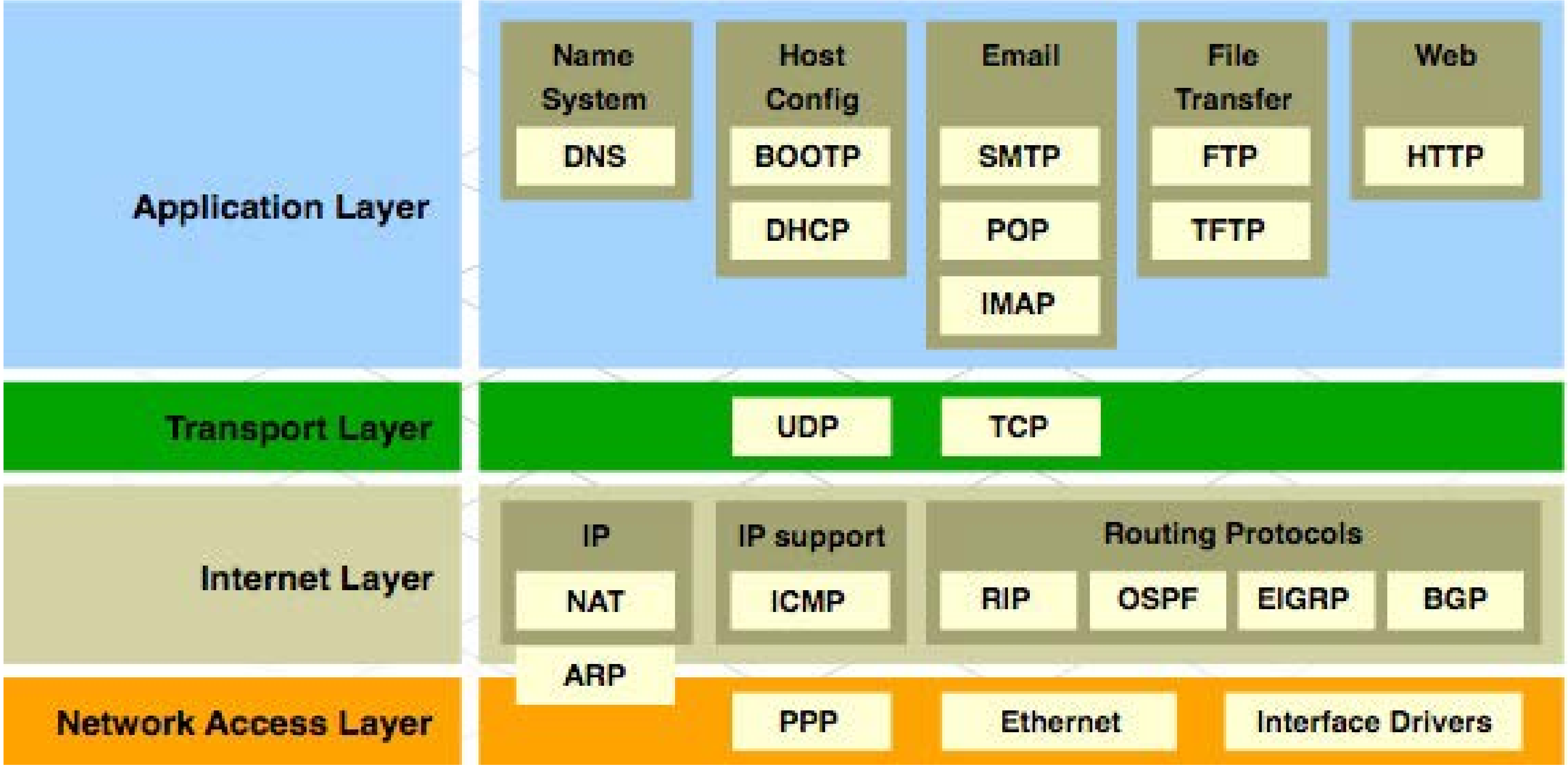


1.2.1 Models of Communication

- **TCP/IP Model**
  - Both OSI and TCP/IP models are used to describe network connections and often used interchangeably
  - The TCP/IP model is commonly referred to as the Internet model
  - The layers of the TCP/IP model:
    - **Application** - represents data to the user and provides encoding and dialog control
    - **Transport** - supports communication between various devices across diverse networks
    - **Internet** - determines the best path through the networks to send data
    - **Network access** - controls hardware devices and media that make up the network

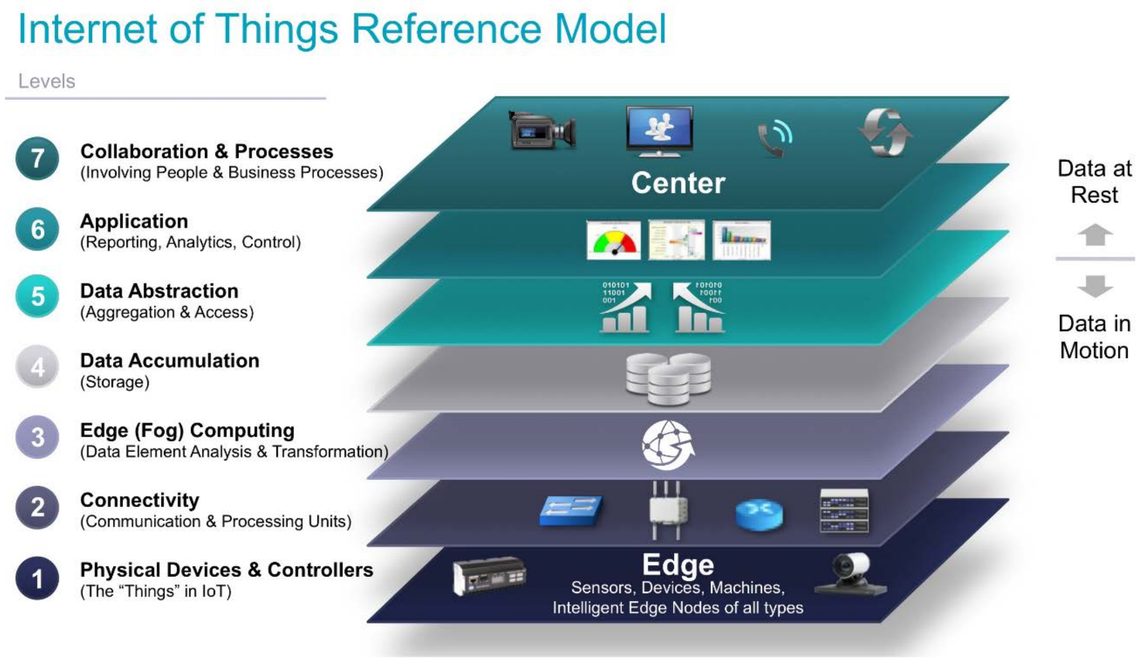


TCP/IP Protocol Suite and Communication



1.2.1 Models of Communication

- **IoT World Forum Reference Model**
  - The Internet of Everything (IoT) Reference Model is a decisive first step toward standardizing the concept and terminology surrounding the IoT.
  - Developed as a common framework to guide and to help accelerate IoT deployments
  - It’s intent is to provide common terminology and help clarify how information flows and is processed for a unified IoT industry

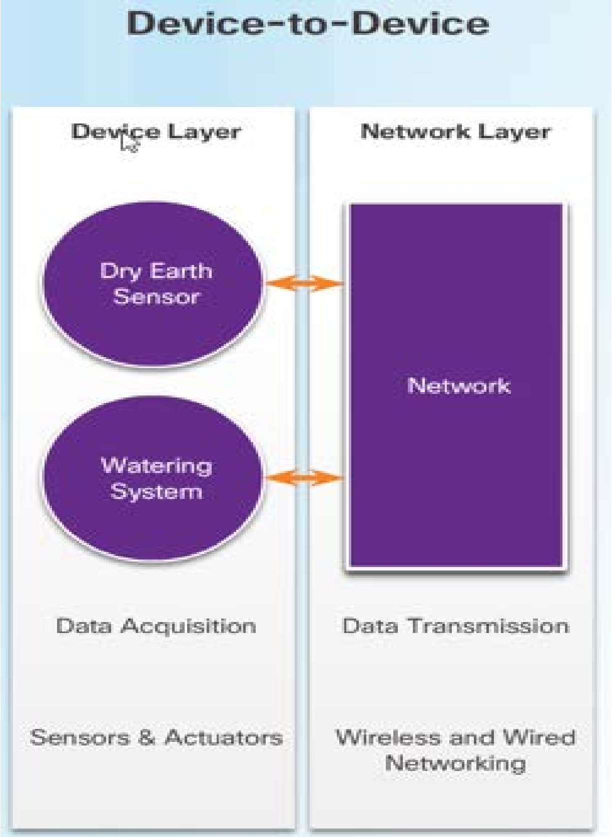


1.2.1 Models of Communication

- **7 Layers of the IoT Reference Model:**
  1. **Collaboration and Processes** – Transcends multiple applications to include the communication and collaboration required between people and business processes. Applications execute business logic to empower people to use applications and associated data for their specific needs.
  2. **Application** – Focused on Information interpretation based on the nature of the device data and business needs.
  3. **Data Abstraction** – Focused on rendering data and its storage in ways that enable developing simpler, performance-enhanced applications
  4. **Data Accumulation** – Data in motion is converted to at rest. The data is also transformed so that it can be consumed by upper layers.
  5. **Edge/Fog Computing** – Converts data into information that is suitable for storage and higher level processing. Focused on high-volume data analysis and transformation while processing information as early and as close to the edge of the network as possible
  6. **Connectivity** – Responsible for reliable and timely data transmission between devices and the network and across networks.
  7. **Physical Devices and Controllers** – Focused on physical devices and controllers that might control a wide range of endpoint devices that send and receive information.

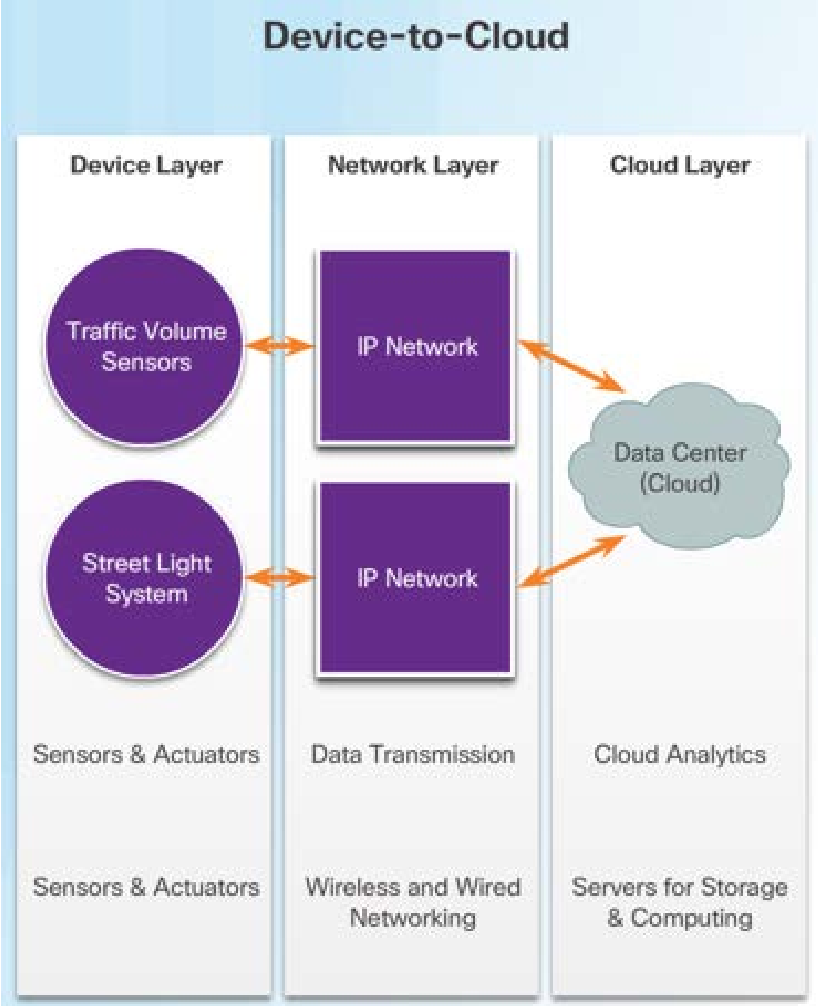
1.2.1 Models of Communication

- **Simplified IoT Architecture levels**
  - The OSI model, TCP/IP model, and the IoT model architectures exist to help facilitate the design and creation of IoT systems
  - A simpler approach is based on connection levels
  - **Device-to-Device**
    - IoT solutions often support one smart object connecting directly to another via a wireless protocol such as Bluetooth or Zigbee
    - An example of this level is a sensor that is located in a vineyard and detects dry soil. It sends a signal to an actuator that triggers the watering system



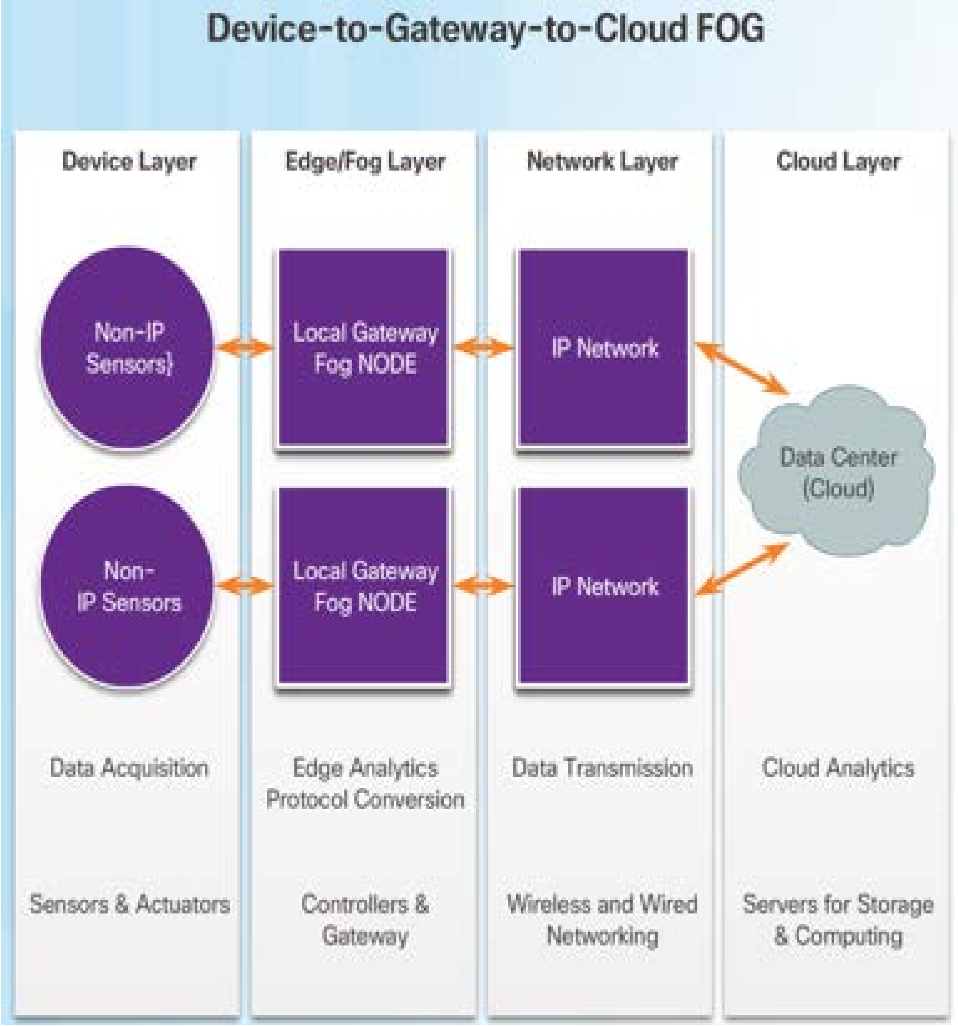
1.2.1 Models of Communication

- Simplified IoT Architecture levels:
  - **Device-to-Cloud**
    - The IoT device connects through a local network directly to an Internet cloud service using traditional wired Ethernet or Wi-Fi connections
    - Establishes a connection between the device, the IP network, and the cloud to allow the exchange of data and control messages



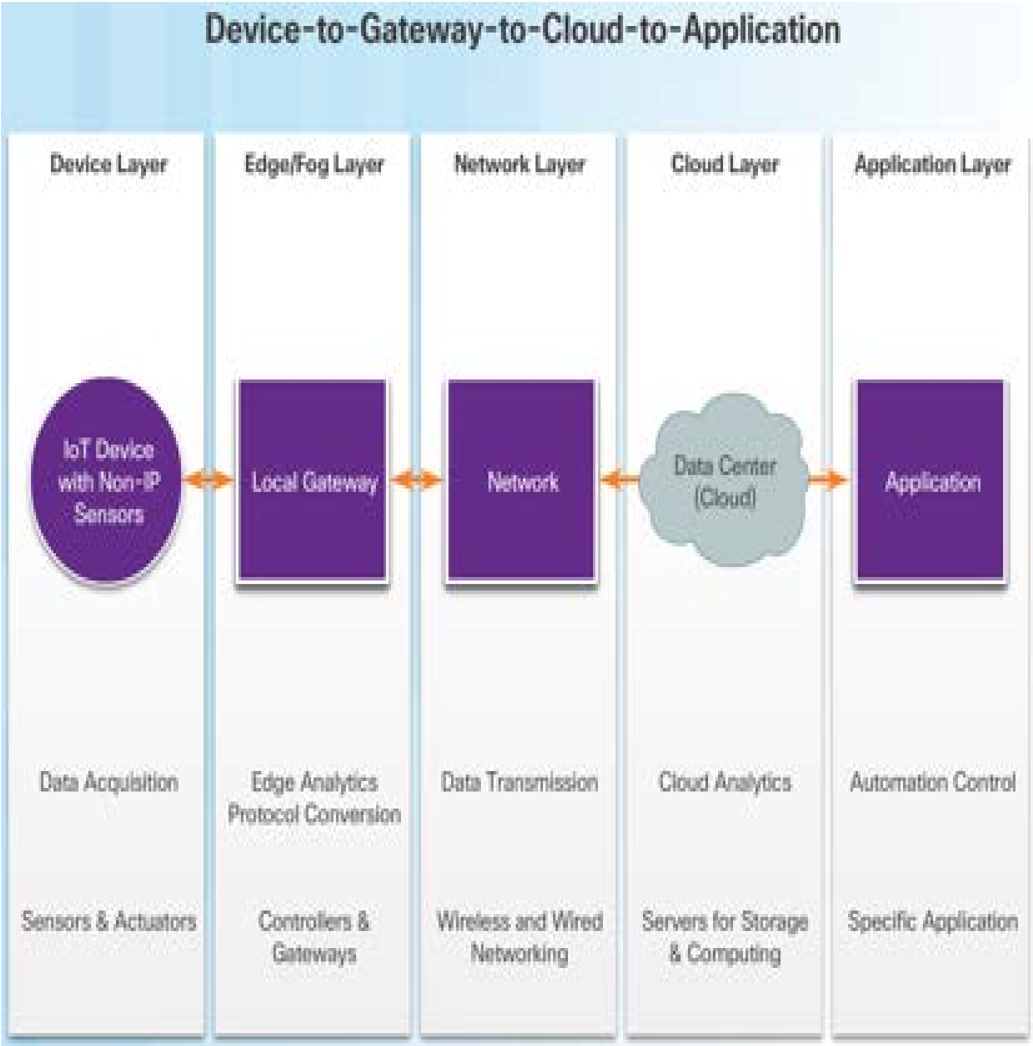
1.2.1 Models of Communication

- Simplified IoT Architecture levels:
  - **Device-to-Gateway-to-Cloud** (IP camera)
    - Many smart devices, such as fitness trackers, are not IP-enabled and do not have the native ability to connect directly to the fog or the cloud
    - Uses application software, running on a smartphone, operating on a local gateway device which acts as an intermediary between the device and the cloud service
    - The gateway may also provide security and data or protocol translation



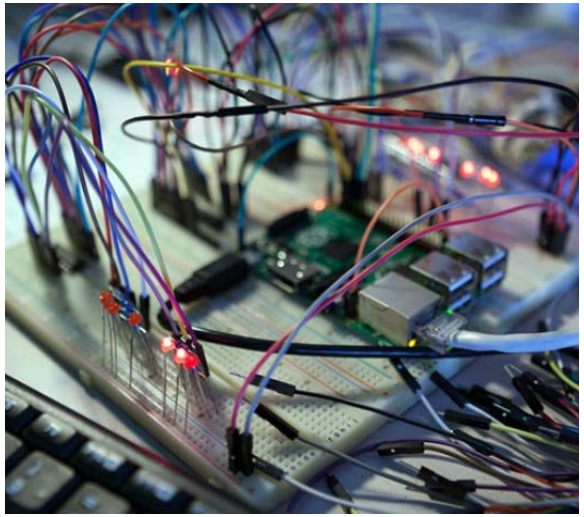
1.2.1 Models of Communication

- Simplified IoT Architecture levels:
  - **Device-to-Gateway-to-Cloud-to-Application**
    - Supports smart device data collection and transfer through a gateway to a local IP network
    - The data then flows to the fog or the cloud and is then available for users to export and analyze
    - The data is often analyzed in combination with data from other sources or other cloud services



1.2.2 Layers of Connections

- **Connections Within Networks**
  - Connections can have different contexts
  - Types of connections in an IoT system:
    - **Power connections** – DC power supply, battery, PoE
    - **Circuit connections** – Physical wires and circuitry associated with linking IoT components
    - **Network connections** – OSI Layer 2 and Layer 3 networking connections
    - **Application connections** – Connecting people and processes
  - Alternative methods of powering IoT systems deployed in remote locations:
    - Solar
    - Vibration
    - Temperature differences



1.2.2 Layers of Connections

- **Circuit Connections (Physical)**
  - Relate to the media and cable type
  - Common media types include:
    - Copper
    - Fiber optics
    - Wireless
  - Advantages of using fiber optic cables over copper cables:
    - Support higher bandwidth
    - Provide connections over longer distances
  - Wireless media uses electromagnetic signals to communicate between IoT devices

1.2.2 Layers of Connections

- **Network Connections (Transport, Network, and Data Link)**
  - Network communication requires protocols to establish the rules of communications. Data Link protocols:
    - Allow the upper layers to access the media
    - Prepare network data for the physical network
    - Control how data is placed and received on the media
    - Exchange frames between nodes over a physical network media, such as copper or fiber-optic
    - Receive and directing packets to an upper layer protocol
    - Perform error detection

1.2.2 Layers of Connections

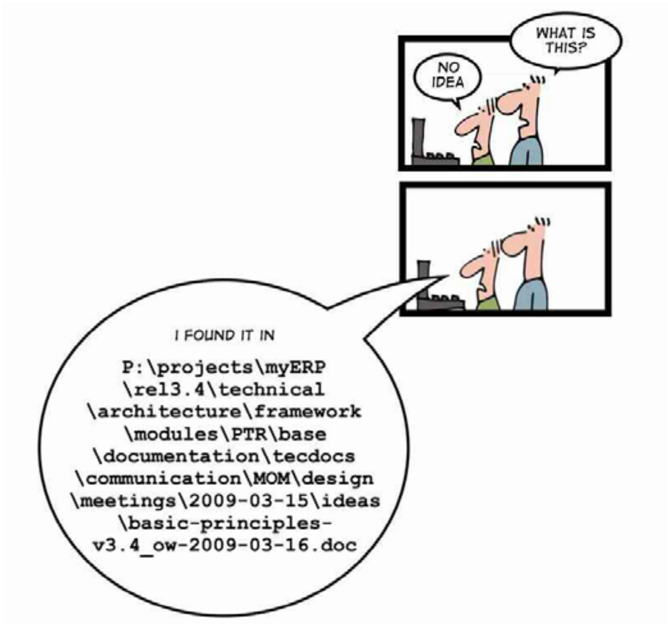
- **Network Connections (Transport, Network, and Data Link)**
  - The most popular data link layer connection used in wired networks is Ethernet
  - Other data link protocols include wireless standards such as IEEE 802.11 (Wi-Fi), IEEE 802.15 (Bluetooth), and cellular 3G or 4G networks
  - LoRaWAN and NB-IoT are examples of emerging IoT supporting technologies
  - Machine-intelligible message structures that group strings of bits for network transmission:
    - Segments
    - Packets
    - Frames

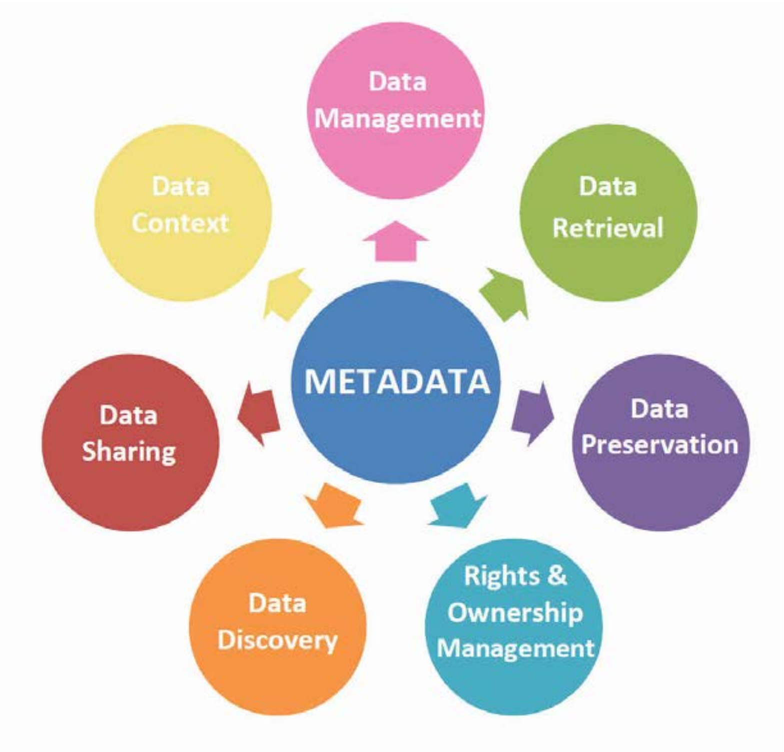
1.2.2 Layers of Connections

- **Application Connections**
  - The IoT supports many types of connections
  - Devices must use the same application layer protocols to connect
  - The application will vary depending on the devices and type of connection involved
  - Newer application protocols, created to support IoT devices that connect in the myriad of different types of remote configurations:
    - **Message Queuing Telemetry Transport (MQTT)** – A lightweight messaging protocol with minimal overhead that provides high data integrity and security for remote environments
    - **Representational State Transfer (REST)** or **RESTful** web services is a type of API designed to make it easier for programs to interact over the Internet

1.2.3 Impact of Connections on Privacy and Security

- **What is Metadata?**
  - Refers to the data about data
  - Can be embedded within a digital object or it can be stored separately
  - Embedded within a digital object, such as a photograph or email
  - Not usually seen by a user





1.2.3 Impact of Connections on Privacy and Security

- **The Impact of IoT on Privacy**
  - Suggestions and design considerations concerning privacy include:
    - **Transparency** – People should know what types of personal data are being collected, why the data is being collected, and where it is to be stored
    - **Data Collection and Use** – Smart devices should only store personal data that is adequate and relevant in relation to the purpose for which they are collected
    - **Data Access** – Before new systems are deployed, designers should determine who is able to access personal data collected by smart objects and under which conditions

1.2.3 Impact of Connections on Privacy and Security

- **Challenges for Securing IoT Devices**
  - Some IoT network security impacting factors include:
    - Increasing Number of Devices
    - Non-Traditional Location of Devices
    - Changing Type and Quantity of Gathered Data
    - Lack of Upgradeability
  - Security and privacy issues must be considered in all phases of creation of an IoT system
  - Each level of connectivity brings with it different requirements and concerns