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?

What are Things?

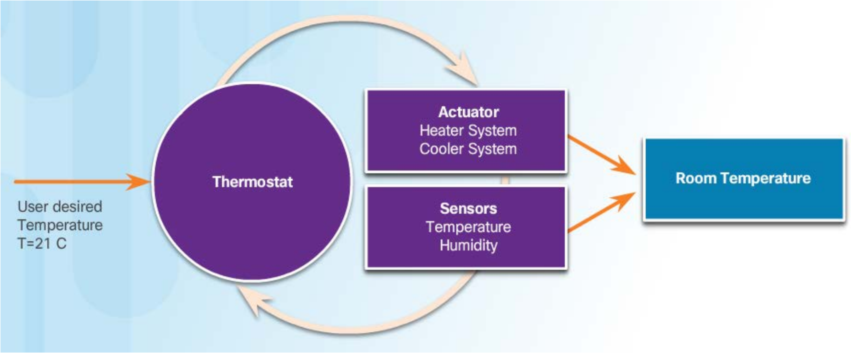
1.1.1 The Internet of Things

- The Presence of IoT in Today's World
  - The IoT is all around us.
  - The IoT helps individuals to improve quality of life.
  - The IoT also helps industries to become more efficient.
- Cisco IoT Solutions
  - The rapid IoT growth has introduced new challenges.
  - Cisco IoT System reduces the complexities of digitization.
  - Six Pillars of the Cisco IoT System are:
    - Network Connectivity
    - Fog Computing
    - Cybersecurity and Physical Security
    - Data Analytics
    - Management and Automation
    - Application Enablement Platform

What are Things?

1.1.2 Building Blocks of an IoT System

- Overview of a Controlled System
  - Feedback loops are used to provide real-time information to its controller based on current behavior.
  - In a closed loop, feedback is continuously being received by the controller from its sensors.
  - The controller continuously analyzes and processes information, and use actuators to modify conditions.
- Sensors
  - A sensor is a device that can be used to measure a physical property by detecting some type of information from the physical world.
  - A sensor may be connected to a controller either directly or remotely.



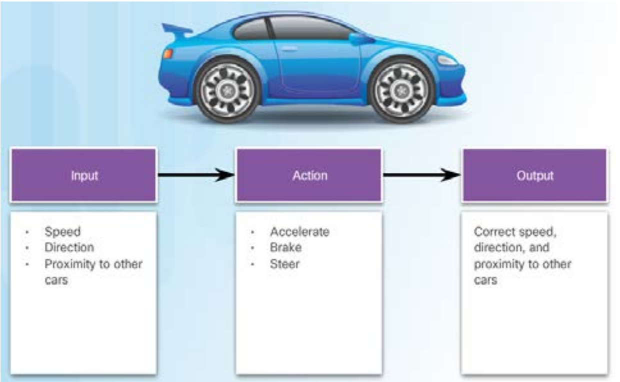
What are Things?

Building Blocks of an IoT System (Cont.)

- Actuators
  - An actuator is a basic motor that can be used to control a system.
  - Can be hydraulic, electric or pneumatic.
  - can be responsible for transforming an electrical signal into physical output.
- Controllers
  - Responsible for collecting data from sensors and providing network connectivity.
  - Controllers may have the ability to make immediate decisions.
  - May also send data to remote and more powerful computer for analysis.

- 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.

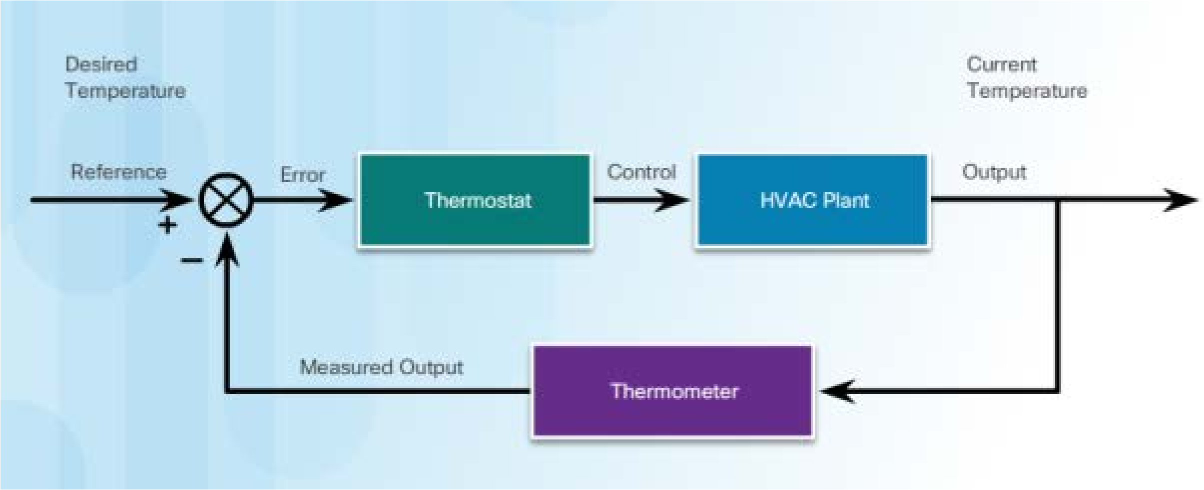
1.1.3 Processes in Controlled Systems



- Processes
  - A process is a series of steps or actions taken to achieve a desired result by the consumer of the process.
- Feedback
  - Feedback is when the output of a process affects the input.
  - Feedback is often referred to as a feedback loop.
  - Feedback loops can be positive or negative.
- Control Systems
  - Includes a controller that uses inputs and outputs to manage and regulate the behavior of the system in an attempt to achieve a desired state.
  - The controlled portion of the system is often called the plant.
  - Choosing the adjustments to apply to a plant to achieve a desired output is called control theory.
  - Control theory is applied to many systems, including driving a car.

What are Things?
Processes in Controlled Systems (Cont.)

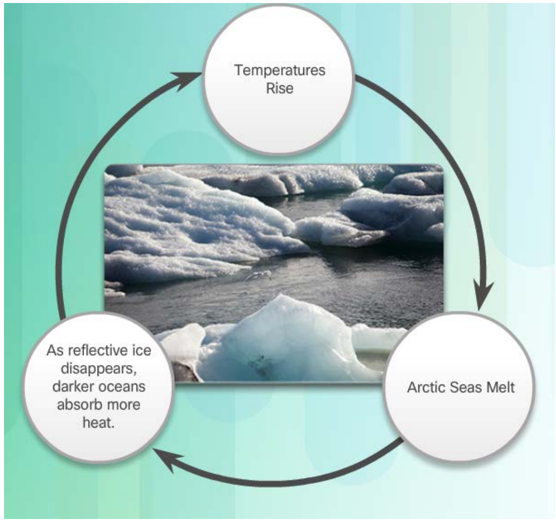
- Open-Loop Control Systems
  - Open-loop control systems do not use feedback.
  - The plant performs a predetermined action without any verification of the desired results.
  - Open-loop control systems are often used for simple processes.
- Closed-Loop Control Systems
  - A closed-loop control system uses feedback to determine whether the collected output is the desired output.
  - The result is then fed back into a controller to adjust the plant for the next iteration of output, and the process repeats.



What are Things?

Processes in Controlled Systems (Cont.)

- Closed-Loop Controllers
  - There are 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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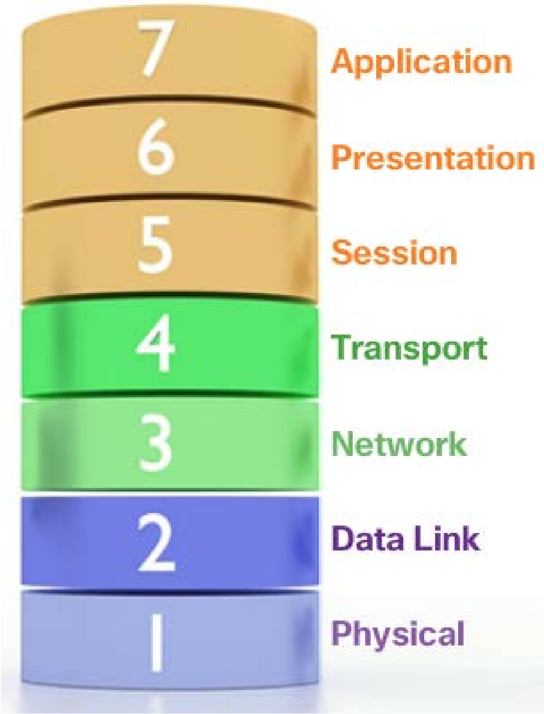
What are Connections?

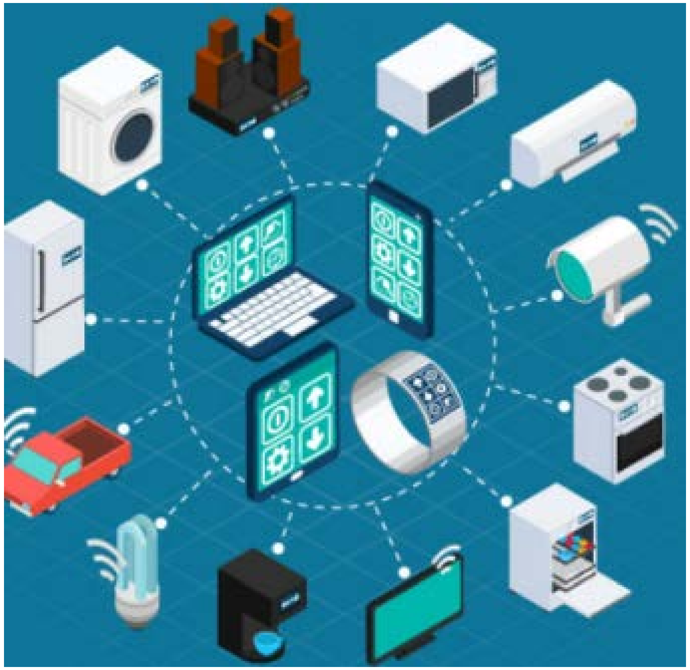
1.2.1 Models of Communication

- Models of Communication
  - Layered networking models are used to illustrate how a network operates. Benefits include:
    - Assists in protocol design.
    - Fosters competition.
    - Promotes technology or capability independence.
    - Provides a common language to describe networking functions and capabilities.



1.2.1 Models of Communication (cont'd)

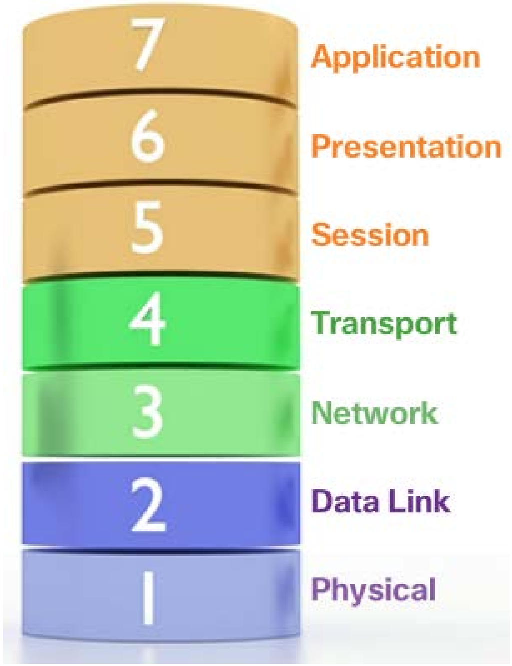
- Standardization
  - The challenge for the IoT is to ensure these emerging IoT devices can connect securely and reliably to the Internet and to each other.
  - Consistent, secure, and commonly recognized technologies and standards is needed.
  - Organizations such as the Industrial Internet Consortium,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



What are Connections?

Models of Communication (Cont.)

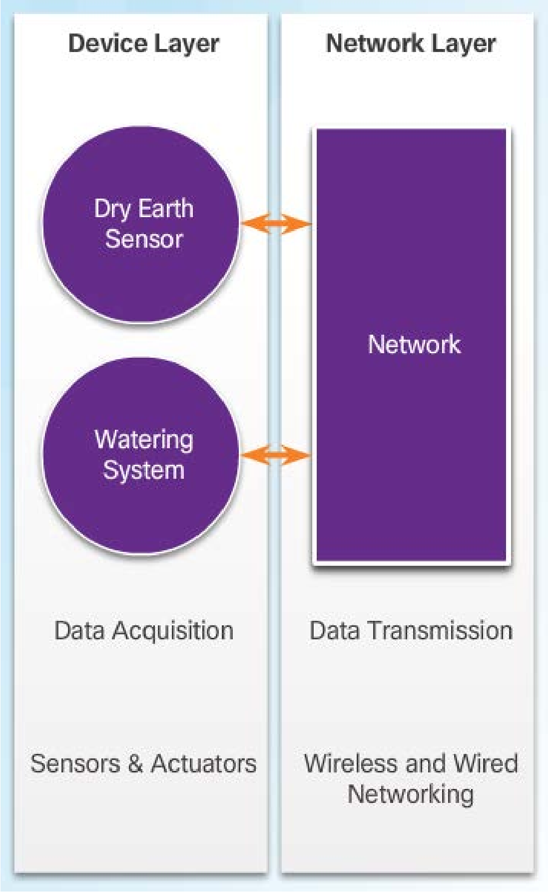
- TCP and OSI Models
  - Both OSI and TCP/IP models are used to describe network connections and often used interchangeably.
  - The TCP/IP model is commonly referred to as the Internet model.
  - The OSI model provides an extensive list of functions and services that can occur at each layer.
- IoT World Forum Reference Model
  - 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.



What are Connections?

Models of Communication (Cont.)

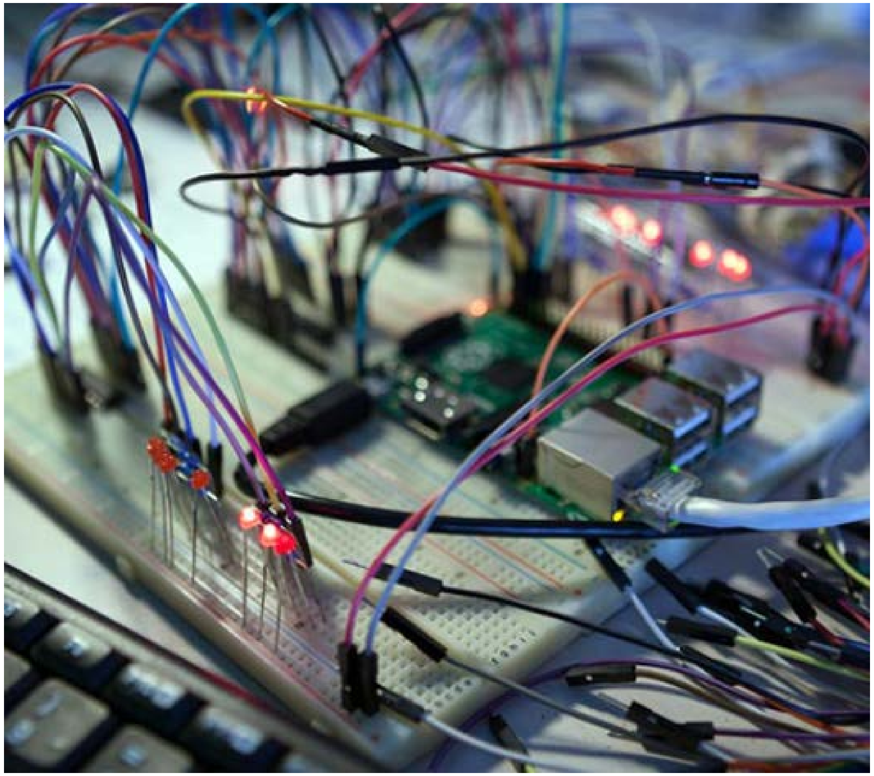
- Simplified IoT Architecture
  - Several architectures exist to help facilitate the design and creation of IoT systems.
  - The OSI model, TCP/IP model, and the IoT World Forum Reference model have been presented as examples.
  - A simpler approach is based on connection levels. The levels are:
    - Device-to-Device
    - Device-to-Cloud
    - Device-to-Gateway-to-Cloud
    - Device-to-Gateway-to-Cloud-to-Application



What are Connections?

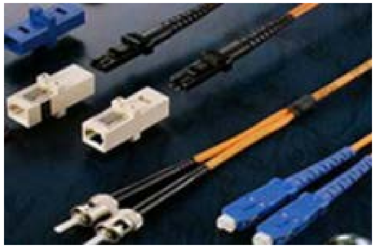
1.2.2 Layers of Connections

- Connections Within Networks
  - Connections can have different contexts.
  - Power connections, circuit connections or network connections.
- Physical Connections
  - Relate to the media and cable type.
  - Common media types include copper, fiber optics and wireless.



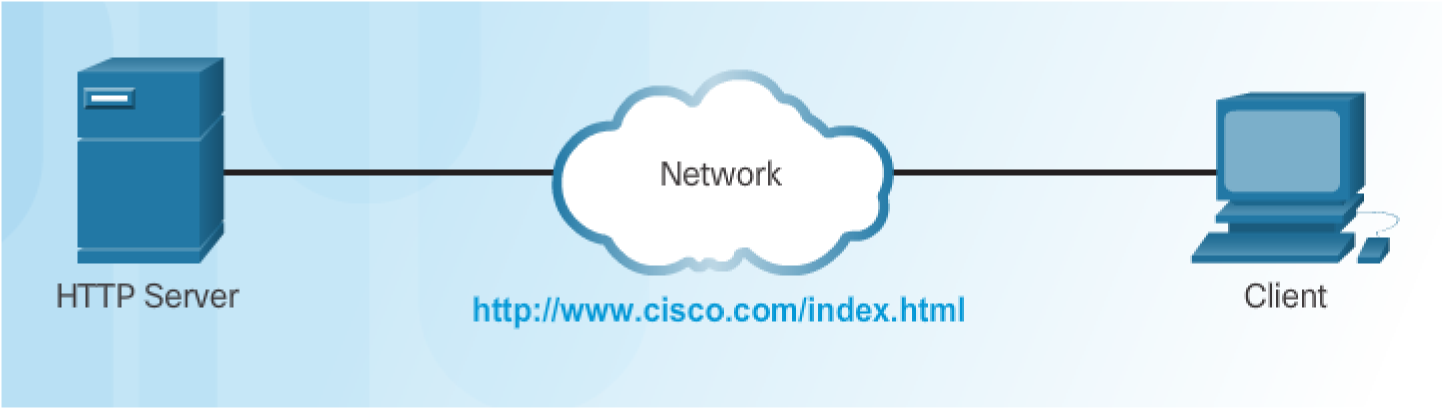
Layers of Connections (cont'd)

- Data Link and Network Connections
  - 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
  - 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.



Layers of Connections (Cont.)

- 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.
  - MQTT and REST are newer application protocols, created to support IoT devices that connect in the myriad of different types of remote configurations.
  - MQTT is a lightweight messaging protocol with minimal overhead that provides high data integrity and security for remote environments.
  - 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?
  - Metadata refers to the data about data.
  - Metadata can be embedded within a digital object or it can be stored separately.
  - Metadata is not usually seen by a user.
- The Impact of IoT on Privacy
  - Suggestions and design considerations concerning privacy include:
    - Transparency
    - Data Collection and Use
    - Data Access
- 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

1.3 Chapter Summary

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Chapter Summary
Summary

- The Internet of Things (IoT) is all around us. An IoT system is usually made up of sensors to monitor events, actuators to influence the environment, hardware to create the platform and its connections, and software to provide a framework to execute processes.
- A process is a series of steps or actions taken to achieve a desired result.
- Layered networking models are used to illustrate and model how devices communicate. Physical, data link, and network layers are concepts that are used to illustrate how network communication operates.
- 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..

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Chapter 2: Sensors, Actuators, and Microcontrollers

IoT Fundamentals

Connecting Things 2.0

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Chapter 2 - Sections & Objectives

- 2.1 Learn Electronics
  - Explain how components and devices are used to build and measure values in electronic circuits.
- 2.2 Microcontrollers: The SparkFun Inventor's Kit
  - Create circuits and microcontroller programs with the Arduino and a variety of components.
- 2.3 Packet Tracer 7.0 and the IoT
  - Explain how Packet Tracer models IoT systems.

2.1 Learn Electronics

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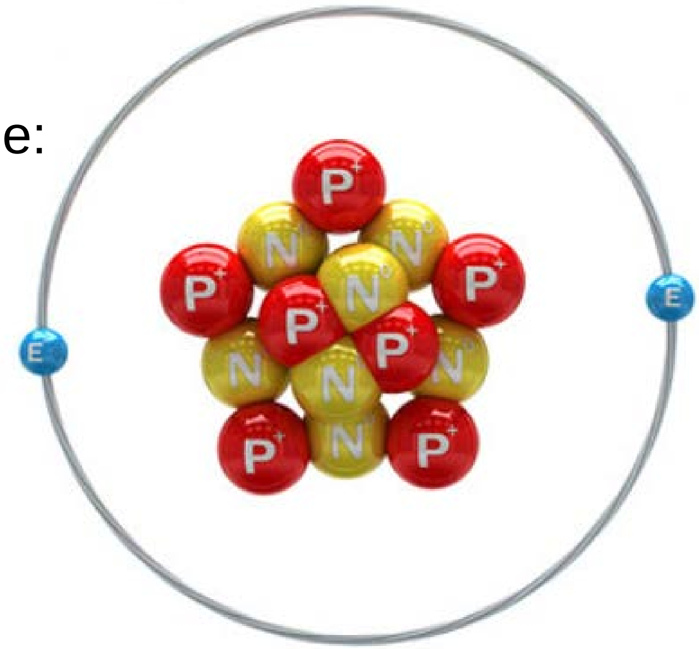
2.1.1 Basic Electronic Terminology & Concepts

- What is Electronics?
  - Electronics is the field of study focused on the control of electricity and the physical components and circuits that help direct electrical energy.
- Definitions
  - Terms commonly used in electronics include:
    - Electrons, atoms, and chemical elements
    - Electric current
    - Electrical conductors, insulators, and circuits
    - Voltage, Amperes (amps), and Power



Learn Electronics

Basic Electronic Terminology / Concepts (cont'd)

- Ohm's Law
  - Ohm's Law states that within a circuit, voltage (V) is directly proportional to the strength of current (I) multiplied by resistance (R).
  - Resistance is measured in ohms (Ω)
- Basic Circuit
  - An electrical circuit is a closed conductive path that allows electrons to flow and create an electric current.
  - A circuit also needs an electrical energy source like a battery to start the flow of electricity.

$$V = I \times R$$

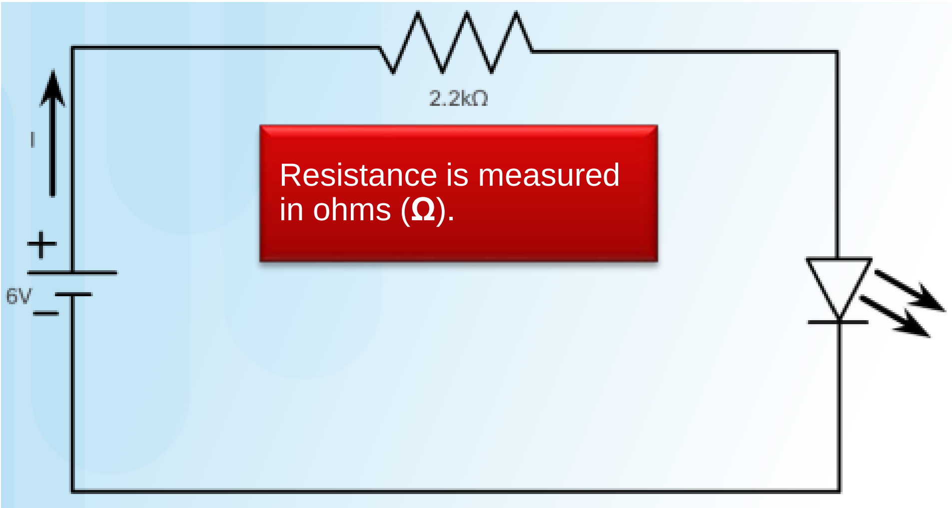
$$R = V / I$$

$$I = V / R$$

Basic Electronic Terminology / Concepts (cont'd)

- Basic Circuit (Cont.)
  - The following circuit diagram (schematic) consists of:
    - 6 volt (V) battery provides current
    - 2.2 kΩ resistor (protects the LED from receiving too much current and being destroyed)
    - A light-emitting diode (LED)

Current (I) flows from the positive terminal to the negative terminal

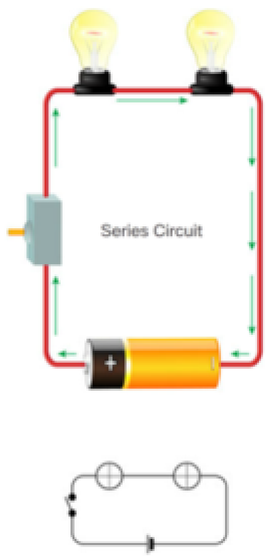
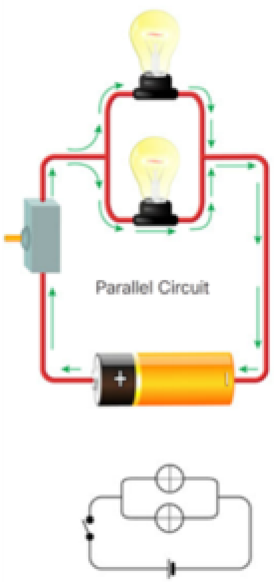


Resistance is measured in ohms (**Ω**).

The triangular part represents a diode and the two arrows facing out represent the fact that this diode emits light.

2.1.2 Advanced Electronic Terminology /Concepts

- Series and Parallel Circuits

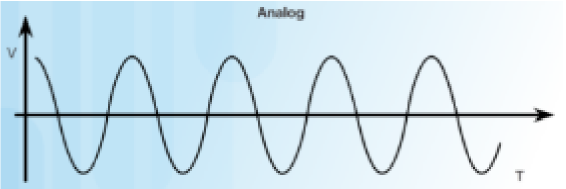
Series Circuit:	Parallel Circuit:
Series Circuit: • Components are interconnected one after another in a path between the positive and negative terminals of the power source	**Parallel Circuit:** • Current flows from the battery terminal but splits at a junction which leads to parallel pathways through the circuit. • Components connected along each pathway each get their own share of current
	

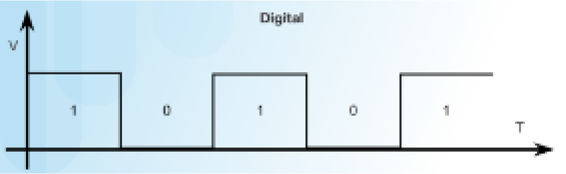
Advanced Electronic Terminology/Concepts (cont'd)

- Passive, Active, Linear, and Nonlinear Circuits
  - Active circuits contain active components; components that rely on external power source to control current flow.
  - Passive circuits contain passive components; components incapable of controlling current flow.
  - Analog circuits are circuits where the signal is contiguous.
- Direct Current vs. Alternating Current
  - In DC current, electron flow is only in one direction.
  - Batteries, power supplies, thermocouples, solar cells, or dynamos generate DC.
  - In AC current, electron flow periodically reverses direction.
  - Hydroelectric plants generate AC.

Advanced Electronic Terminology/Concepts (cont'd)

- Analog Circuits vs. Digital Circuits
  - Analog Circuits**:** Circuits in which signals vary continuously with time.
  - Digital circuits: Circuits in which signals that take one of two discrete values.
- Components
  - Electronic components are specialized devices used in a circuit to control current.
  - Components have two or more electrical terminals (leads) that enable them to connect to an electronic circuit.
- Larger Electronic Building Blocks
  - Solenoids can be used to electrically open door latches, open or shut valves, move robotic limbs, and even actuate electric switch mechanisms.
  - Relays allow for controlling a large amount of current and/or voltage with a small electrical signal.

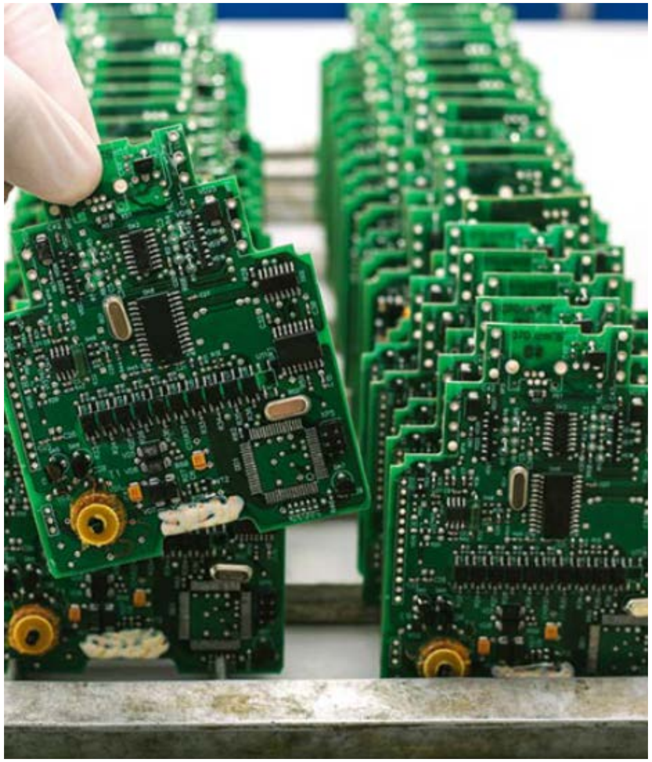




Learn Electronics

2.1.3 From Schematic Diagram to Breadboard to Soldered PCB

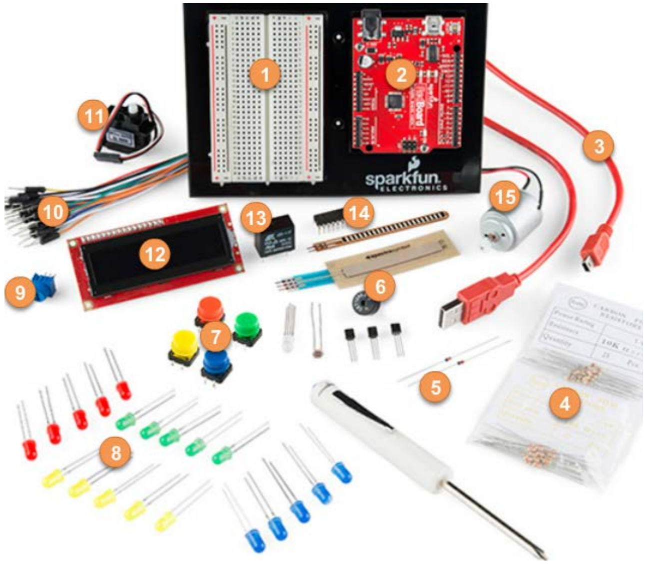
- Design Phase:
  - Consists of three steps: Concept, Research, Circuit Design.
  - A circuit diagram shows the components and interconnections of the circuit using standardized symbolic representations.
- Prototype Phase:
  - Consists of four steps: Hardware, Mechanical, and Software Development, PCB layout, Build prototypes, Product Testing
  - A solderless breadboard is a tool commonly used in electronic prototyping.
- Production Phase:
  - Consists of three steps: Production Readiness Review, Production, On-going Maintenance.
  - Often employ on printed circuit boards (PCBs).



2.2 Microcontrollers: The SparkFun Inventors Kit

2.2.1 Introducing the Kit

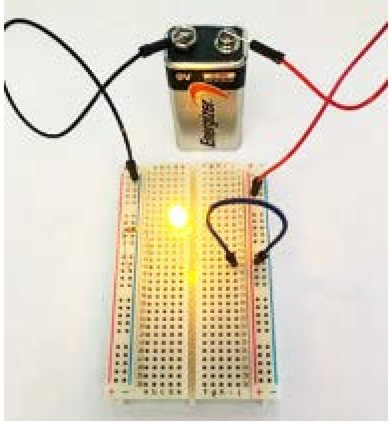
- Introduction to the SparkFun Inventor’s Kit (SIK)
  - This is a starter kit for building circuits and includes:
    - Solderless breadboard
    - SparkFun RedBoard (Arduino-like board)
    - Various resistors, diodes, LEDs, sensors and actuators
    - Connecting wires (jumper wires, mini-B cable, …)
- Arduino Microcontroller
  - The Arduino is a popular microcontroller for prototyping.
  - Instructions for the Arduino are programmed using the Arduino integrated development environment (IDE).
  - The SparkFun RedBoard is an Arduino-like board that can be programmed using Arduino IDE.



Microcontrollers: The SparkFun Inventors Kit

2.2.2 Simple Circuits

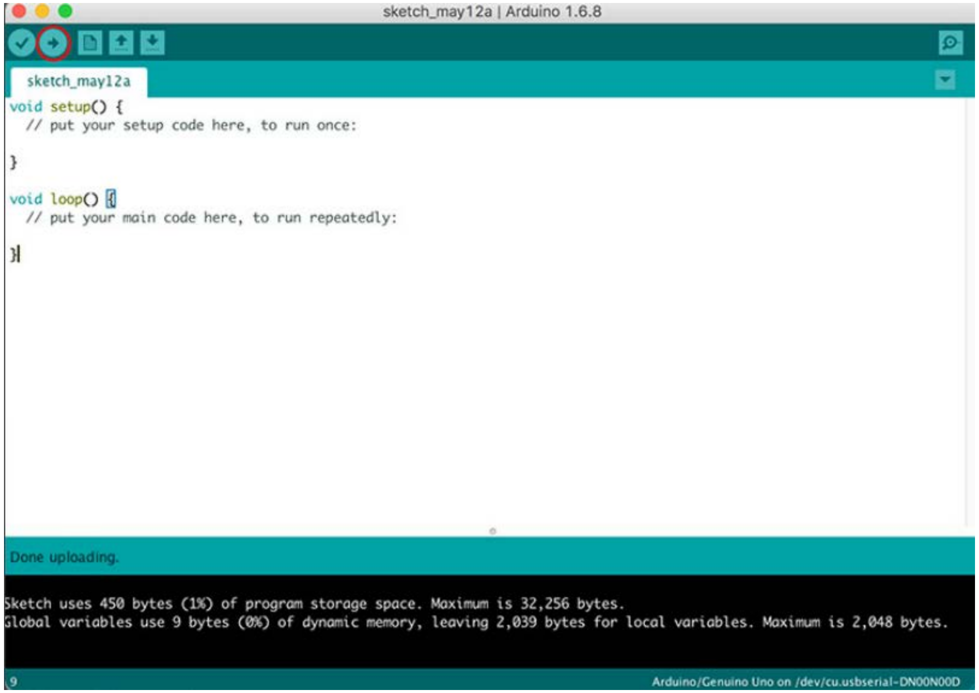
- Building a Circuit
  - A simple circuit can be created by:
    - Connecting electronic components (LED, resistor, and jumper wires) in series along a row on the breadboard.
    - Connecting the power source to the lower red and black jumper wires.
    - This should complete the circuit and light the LED.
- The Arduino IDE
  - Free, downloadable software used to interact with the Arduino board.
- Writing code
  - Programs written using the Arduino IDE are called sketches and are saved with the file extension of .ino.
  - Arduino sketch keywords can be divided in three main category types: structures, values (variables and constants), and functions.
  - Keywords used include void, setup(), loop() function, and more.



Microcontrollers: The SparkFun Inventors Kit

Simple Circuits (cont'd)

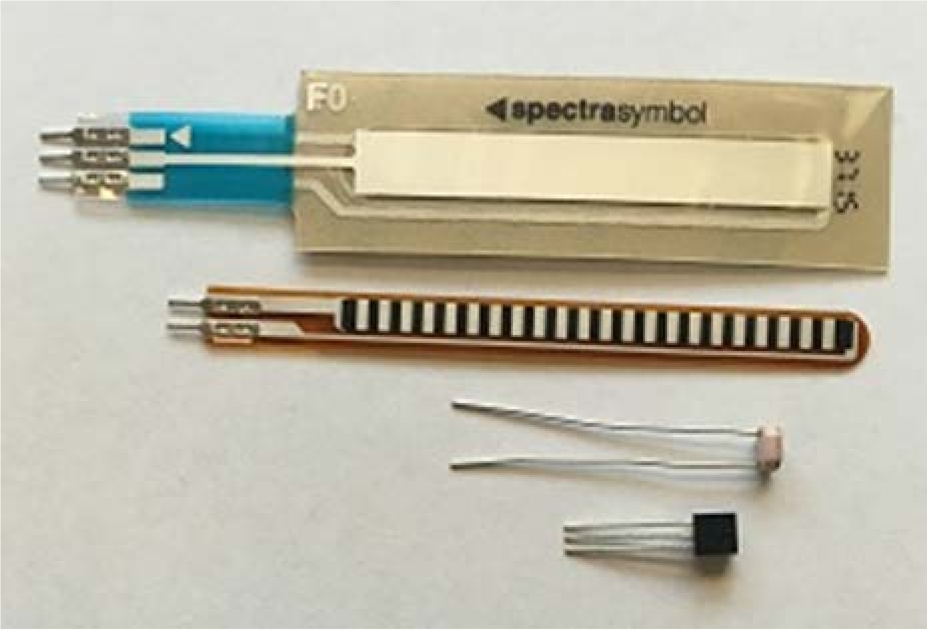
- Testing
  - To test and verify the sketch code, click on the checkmark toolbar icon.
  - The IDE compiles the code and checks for syntax errors.
  - To upload the sketch to the Arduino and test the code, click on the second toolbar icon (⇨)



Microcontrollers: The SparkFun Inventors Kit

2.2.3 Sensing the Environment

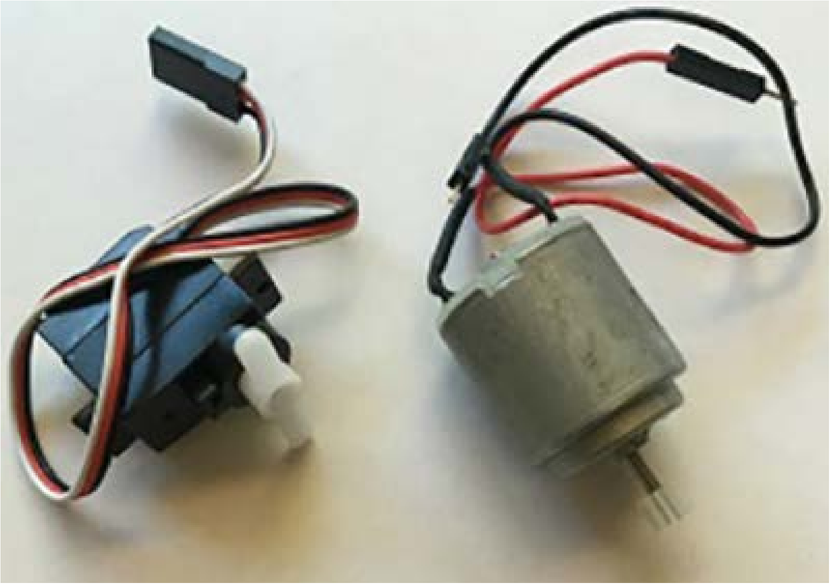
- Sensors
  - Devices that detect an event from the physical environment and respond with electrical or optical signals as output.
  - The SIK contains various sensors including Soft potentiometer, Flex sensor, Photo resistor and Temperature sensor.



Microcontrollers: The SparkFun Inventors Kit

2.2.4 Making it Happen

- Actuators and Relays
  - An actuator is a type of motor that is responsible for creating movement.
  - The SIK includes two types of electric actuators that convert electrical energy into mechanical torque.
  - A relay is an electrically controlled mechanical switch.
  - The SIK includes a plastic box that contains an electromagnet that causes a switch to trip when it receives a current.



2.3 Packet Tracer 7.0 and the IoT

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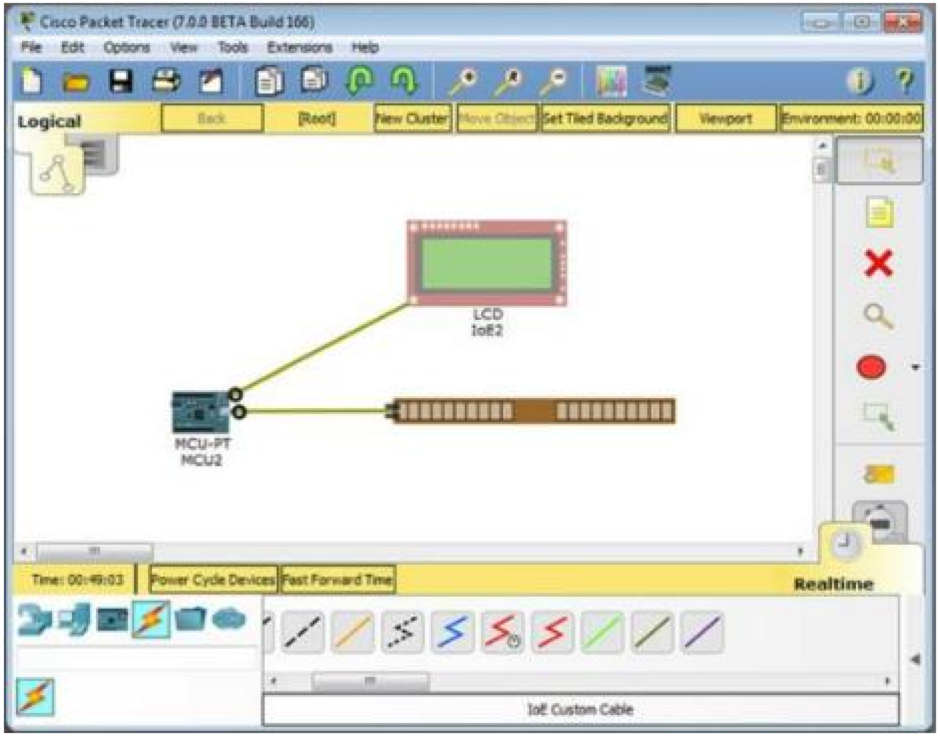
PT 7.0 – End-to-End IoT System Model

- How Everything Connects in PT
  - Packet Tracer 7.x can be used as a prototyping tool.
  - There is a new group icon contained in Packet Tracer version 7.0 that is labeled Components.
  - The PT IoT boards contains an MCU and a SBC.
  - The MCU and SBC are similar to an Arduino and a Raspberry Pi, respectively.
  - There are also actuators and sensors that can be used in prototypes.
  - The IoE Custom Cable found in the Connections group can be used to connect IoT things to an MCU board.



2.4 Chapter Summary

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Chapter Summary
Summary

- Electronics is an important part of the IoT.
- IoT devices are often built from scratch; therefore, understanding electronics concepts, components and terminology is critical. It is also important for an IoT professional to be able to read and create electronics schematics.
- The SparkFun kit contains a number of devices and parts to help a beginner to get started with electronics and microcontrollers. It also introduces important concepts such as electronic circuits and how to program Arduino microcontrollers. Working with the kit, a beginner can also learn how to program sensors to monitor the environment. Actuators and relays are often used to influence the environment or create action.
- Students can use Cisco Packet Tracer 7.x as a tool for modeling and prototyping IoT systems.

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Chapter 3: Software is Everywhere

Connecting Things

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Chapter 3 - Sections & Objectives

- 3.1 Programming
  - Explain the value of computer programs.
- 3.2 The Raspberry Pi Single Board Computer (SBC)
  - Use the Raspberry Pi for simple applications.
- 3.3 Building Models of IoT Systems in Packet Tracer
  - Use Packet Tracer to model IoT systems.

3.1 Programming

Programming

3.1.1 What is Code?

- What is a Program
  - Code is a set of ordered instructions created to accomplish a specific task.
  - A bread recipe can be seen as a program.
  - Computer programs can be written in different programming languages.
- Programs are Everywhere
  - All computers need programs.
  - Operating Systems, firmware, and applications are examples of programs.
- Why Learn Code?
  - Programmers are valued in the job market.
  - Today, programmers may work on firmware, device drivers, mobile applications, web interfaces, data analysis, and more.
  - Programmers can create their own tools.

Programming

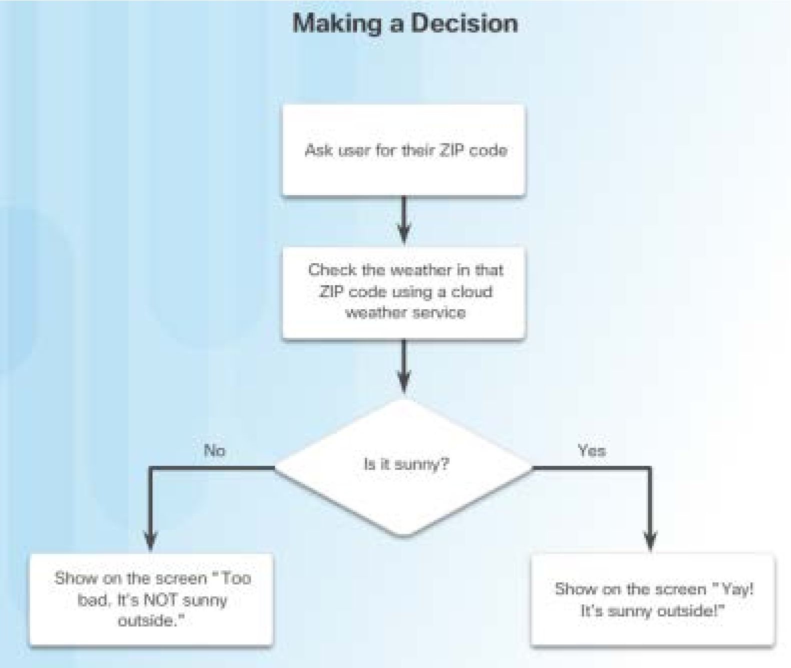
3.1.2 Code Does the Job!

- What Makes Up a Program?
  - Programs allow people impart logic to computers and are made out of logic structures.
  - IF-THEN, FOR Loops, and WHILE Loops are a few logical structures commonly found in programs.
- Interpreted Vs. Compiled
  - Interpreted languages rely on another program to read, parse, and execute the code.
  - Compiled languages rely on a compiler, another program, to turn the human-readable code into a binary executable code.
- Computer Languages
  - There are several different computer languages.
  - Some computer languages are better than others at certain types of tasks.
  - JavaScript, Python, Blockly, C, and Java are examples of computer languages.

```
#include <stdio.h>
int main()
{
  int year;

  printf("Enter a year to check if it is a leap year\n");
  scanf("%d", &year);

  if ( year%400 == 0)
    printf("%d is a leap year.\n", year);
  else if ( year%100 == 0)
    printf("%d is not a leap year.\n", year);
  else if ( year%4 == 0 )
    printf("%d is a leap year.\n", year);
  else
    printf("%d is not a leap year.\n", year);

  return 0;
}
```

3.1.3 Lending Intelligence

- IOT Devices and Data Processing
  - A common IoT application uses sensors to collect data.
  - Data is often not useful until it has been processed. Collected data is often transported and stored in the cloud for processing at a later date.
- IoT Devices Make Decisions
  - Software must be written and uploaded onto IoT devices to allow them to make decisions.
  - Decisions can be as simple as triggering an alarm or as complex as facial recognition.
- Software APIs
  - Application Program Interface (API) is a set of routines and software tools that facilitate one application communicating with another.
  - Different types of APIs exist: operating system APIs, application APIs, website APIs.
  - APIs allow applications to communicate, share data, or ask for specific services from another application.



Programming

Lending Intelligence – cont'd

- REST API

```
GET https://www.googleapis.com/calendar/v3/calendars/calendarID
```

  - REST APIs use HTTP based calls between applications to access and manipulate information stored on powerful databases.
  - Web resources used to be identified using a URL. Now resources can be any entity or thing that can be addressed: today's step goal, house temperature setting, glucose setting.
  - A unique Uniform Resource Identifier (URI) can identify an entity. A URI typically begins with a slash (/steps)
  - REST API requests trigger responses in well-defined formats such as XML or JSON

Programming

Lending Intelligence – cont'd

- Securing the Code
  - Devices should protect themselves from attacks that impair its function or allow it to be used for unintended purposes without authorization.
  - Devices should protect the private authentication credentials and key material from disclosure to unauthorized parties.
  - Devices should protect the information received, transmitted, or stored locally on the device, from inappropriate disclosure to unauthorized parties.
  - Devices should protect themselves from being used as a vector to attack other devices or hosts on the Internet.

3.2 The Raspberry Pi Single Board Computer (SBC)

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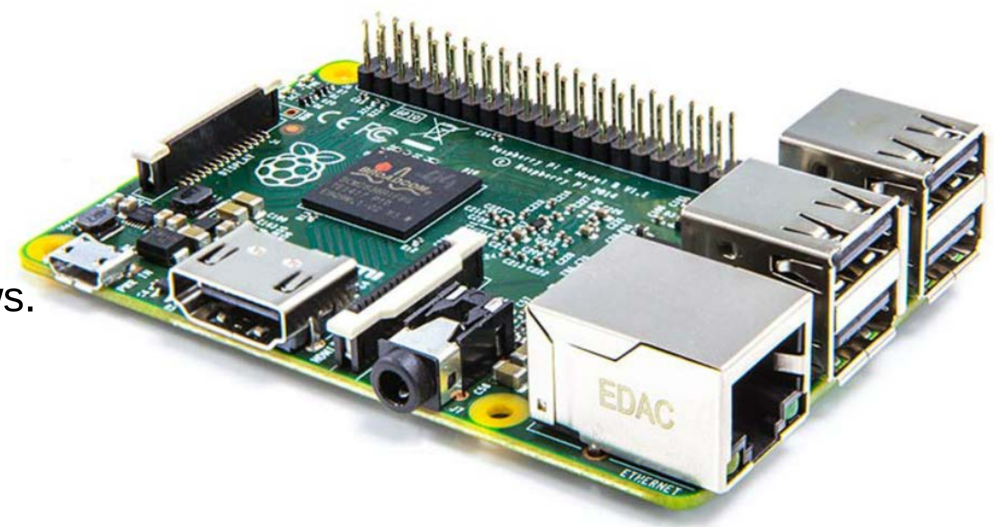
The Raspberry Pi Single Board Computer (SBC)

3.2.1 Raspberry Pi Hardware

- The Raspberry Pi and its Ports
  - The Pi is a small and inexpensive computer.
  - It has a number of USB ports that can be used to connect various devices including keyboards, mice, external drives and cameras.
  - The Pi includes an 10/100Mbps Ethernet port and 40 GPIO pins, operating at 3.3V.
  - Other Pi ports include an audio out, a micro SD card slot, and a micro USB (used for power) connector.

- The Pi3 also adds:
  - 1.2 Ghz 64-bit quad-core ARMv8 CPU
  - 802.11n Wireless LAN
  - Bluetooth 4.1
  - Bluetooth Low Energy (BLF)

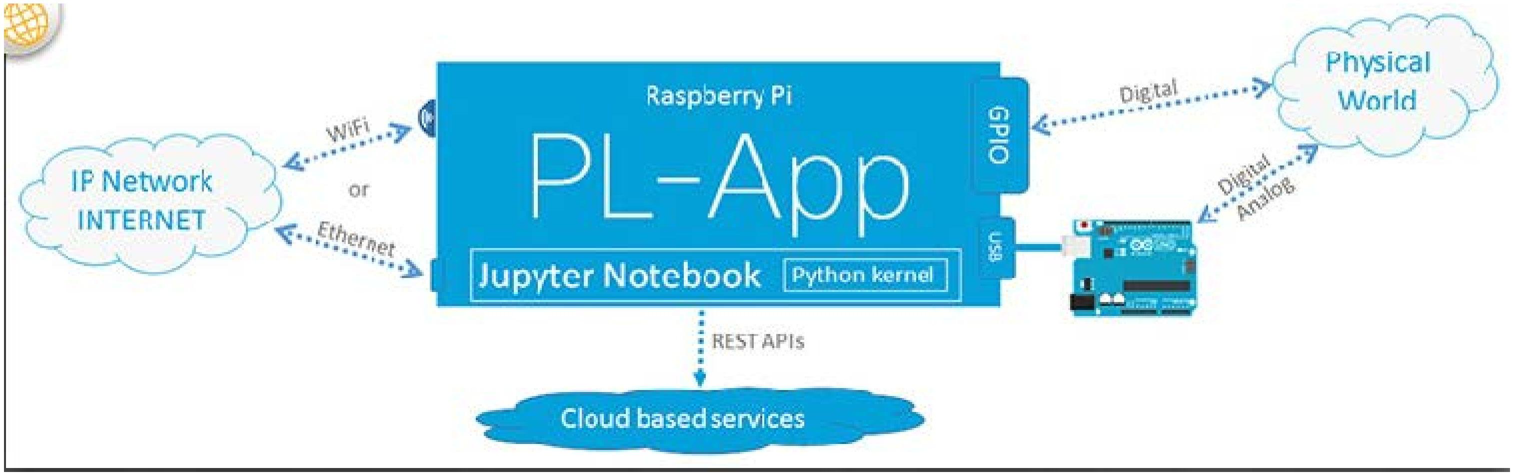
- The Pi can run a number of operating systems, including Linux and Windows.



The Raspberry Pi Single Board Computer (SBC)

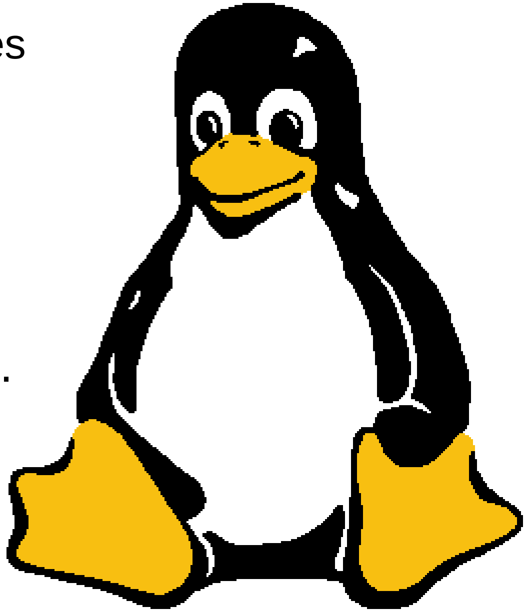
3.2.2 PL-App

- The Raspberry Pi can be accessed locally:
  - 1. Install an operating system image on the micro SD card.
  - 2. Place the card in the micro SD card slot of the RaPi.
  - 3. Connect a USB keyboard.
  - 4. Connect a monitor or TV using the HDMI port.
  - 5. Power the device with a power adapter.
- The Raspberry Pi can be accessed remotely using the PL-App



3.2.3 Using the Linux Operating System

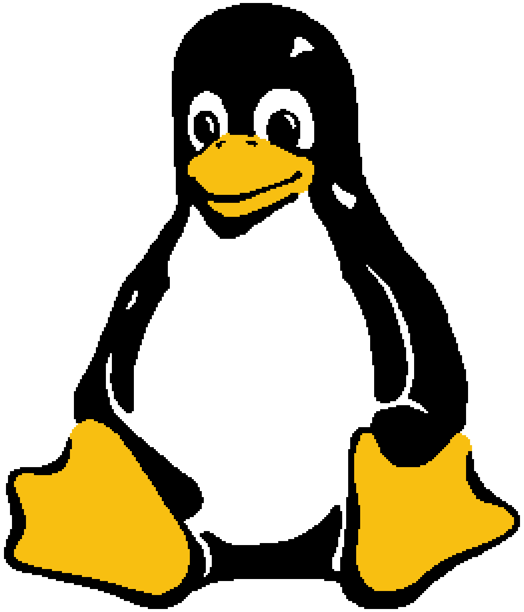
- Understanding Linux
  - Linux is open source, fast, reliable and small and requires very little hardware resources to run.
  - Linux is part of several platforms; from wristwatches to supercomputers.
  - Linux distributions include the Linux kernel, plus a number of customized tools and software packages.
  - Debian, Red Hat, Ubuntu and Slackware are just a few examples of Linux distributions.
  - Raspbian is a Linux distribution based on Debian and created specifically for the Raspberry Pi.
- Accessing the Linux Shell
  - The Linux operating system can be divided into kernel and shell.
  - The shell is a command interpreter.
  - The shell is text based and also called CLI (command line interface



The Raspberry Pi Single Board Computer (SBC)

Using the Linux Operating System (Cont.)

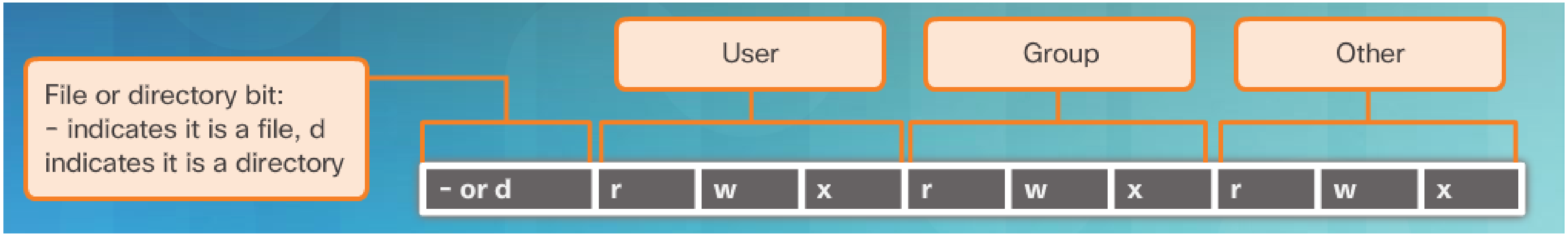
- Accessing the CLI
  - The CLI can be accessed directly through a shell in non-graphical systems.
  - Bourne Shell (**sh**), Bash (**bash**), C Shell (**csh**), improved C Shell (**tcsh**), and Z Shell (**zsh**) are popular shells.
  - A terminal emulator application can be used to access the CLI in graphical environments.
  - Popular terminal emulators on Linux are **Terminator**, **eterm**, **xterm**, **console**, and **gnome-terminal**.
- Basic Linux Commands
  - Linux commands are programs created to perform a specific task.
  - To invoke a command via shell, simply type its name.
  - **grep**, **ifconfig**, **iwconfig**, **passwd** and **pwd** are a few basic Linux commands.
  - Commands can be piped together, using the output of one as the input of the other.



The Raspberry Pi Single Board Computer (SBC)

Using the Linux Operating System (Cont.)

- Process Managing Commands
  - In Linux, a process is any task or command being executed by the system.
  - PIDs are unique numbers assigned to processes for identification.
  - **ps**, **top** and **kill** are commands used to manage processes.
- File Permissions
  - In Linux, most everything is treated as a file.
  - File Permissions provide a mechanism to define permissions to files.
  - Possible permissions rights are **Read**, **Write**, and **Execute** and can be defined for the user who owns the file, the group, and other system users.
  - The root user can override file permissions.



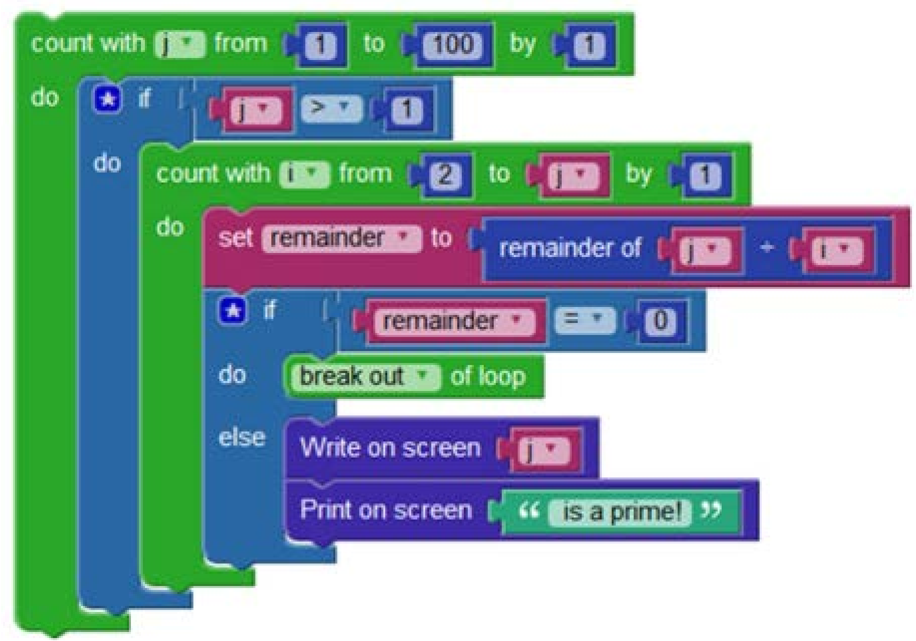
Using the Linux Operating System (Cont.)

- Package Managers
  - Maintaining computer programs and their library dependencies manually is not scalable
  - Package managers facilitate the installation, removal, and upgrade of computer programs.
  - Package managers usually include user tools and a remote package repository.
  - The repository hosts software packages and their dependencies.
  - **dpkg** and **rpm** are popular package managers for Debian Linux and Red Hat Linux, respectively.
  - Raspbian includes **dpkg** and **apt** by default.

3.2.4 Blockly

- Variables and Basic Statements
  - Blockly allows the creation of a program without entering any lines of code; it uses colored blocks.
  - Blocks can be connected together by dragging and attaching the appropriate blocks.
  - Creating a new variable in Blockly is a simple matter of dragging the variable block and filling in the value slot.

- IF-THEN
  - Used to allow the code to make decisions.
- FOR Loops
  - Used to repeat the execution of a block of code for a specific number of times.
- WHILE Loops
  - Used to execute a block of code while a condition is true.

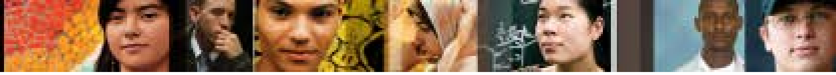


The Raspberry Pi Single Board Computer (SBC)

3.2.5 Python on the Raspberry Pi

- Using Blocky to Learn Python
  - Blockly can be used to enhance Python understanding.
  - Beginners can create Blockly programs, convert them to Python and study the result.
- The Python Interpreter
  - The Python interpreter understands and executes Python code.
  - Python code can be created in any text editor and Python interpreters are available for many operating systems.
  - Python developers can create and deploy Python programs in practically any operating system.
  - When called with no arguments, the Python interpreter displays the “>>>” prompt and waits for commands; this is called interactive mode.

```
Python 2.7 (#1, Feb 19 2010, 12:06:02)
Type "help", "copyright", "credits" or "license" for
more information.
>>>
```



The Raspberry Pi Single Board Computer (SBC)

Python on the Raspberry Pi (cont'd)

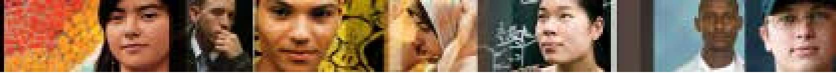
- Variables and Basic Statements in Python
  - Variables are labeled memory areas used to store runtime program data.
  - To assign values to variables in Python, use the = (equal to) sign.
  - Python's interactive mode implements the special variable "_".

```
>>>
>>> tax = 12.5 / 100
>>> price = 100.50
>>> price * tax
12.5625
>>> price + _
113.0625
>>> round(_, 2)
113.06
```

- Useful Functions and Data Types in Python
  - Python supports many useful functions and data types such as range(), tuples, lists, sets, and dictionary

```
list1 = ['car', 'train', 47, 2016];
list2 = [1, 2, 3, 4, 5, 6, 7 ];
print "list1[0]: ", list1[0]
print "list2[1:5]: ", list2[1:5]

When the above code is executed, it produces the following result -
 list1[0]: car
 list2[1:5]: [2, 3, 4, 5]
```



Python on the Raspberry Pi (cont'd)

- Importing Modules Into Your Code
  - Use the **import <module>** keyword to import pre-written code into your programs.
- IF THEN In Python
  - Allows the execution a block of code based on the result of an expression.
- FOR Loops in Python
  - Iterates through the items of any sequence
- WHILE Loops in Python
  - Executes a block of code while the expression is true
- Indentation is important in Python!

```
>>>
>>> x = int(raw_input("Please enter an integer: "))
Please enter an integer: 42
>>> if x < 0:
...     x = 0
...     print 'Negative changed to zero'
... elif x == 0:
...     print 'Zero'
... elif x == 1:
...     print 'Single'
... else:
...     print 'More'
...
More
```

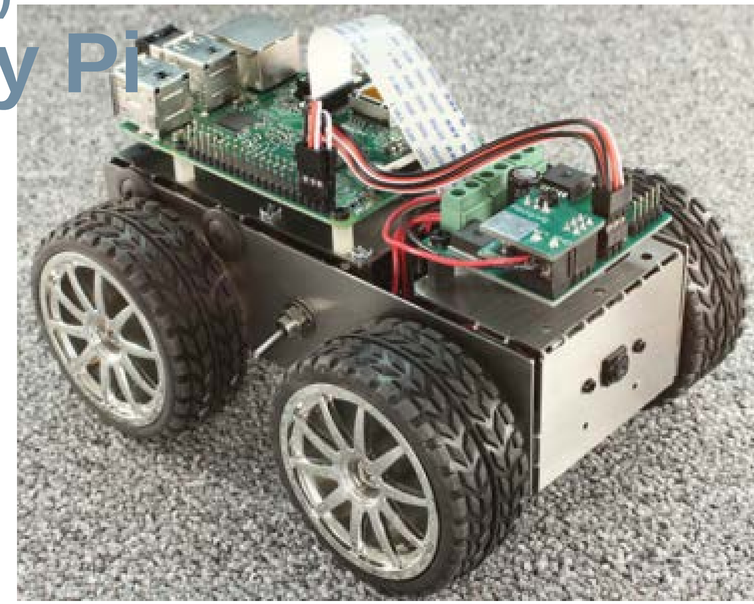
The Raspberry Pi Single Board Computer (SBC)

Python on the Raspberry Pi (cont'd)

- Cisco Support for Cybersecurity Professionals
  - DevNet
    - Cisco provides a beneficial community named DevNet.
    - DevNet is available to assist you in learning to code, use software and programs, and partner with others.
  - Cisco Spark
    - Cisco Spark is a cloud service that provides persistent chat, room-based collaboration, WebRTC video conferencing, and more.
    - Developers can create code that can be used to integrate specific solutions with Spark via the Spark REST API.
    - Spark REST API can include automated Spark messages based on real-world events that occur in a popular application/program

The Raspberry Pi Single Board Computer (SBC)

3.2.6 Uses of the Raspberry Pi



- Artificial Raspberry Pi Pancreas
  - Dana Lewis and her husband used a Raspberry Pi to build an artificial pancreas.
  - It was possible due to the Pi's small size and low power requirements.
- 4Borg Pi Robot
  - PiBorg is an affordable robot kit built around a Raspberry Pi.
  - It is both fun and educational.
- Controlling the Arduino Through the Pi
  - While the Pi is powerful, it may not be the best option for all projects.
  - The Pi doesn't include analog GPIO pins.
  - The Pi is **not** real-time.
  - The Pi's power requirements and size may be too large, depending on the application.
  - To adjust to these limitations, an Arduino may be used.

3.3 Building Models of IoT Systems in Packet Tracer

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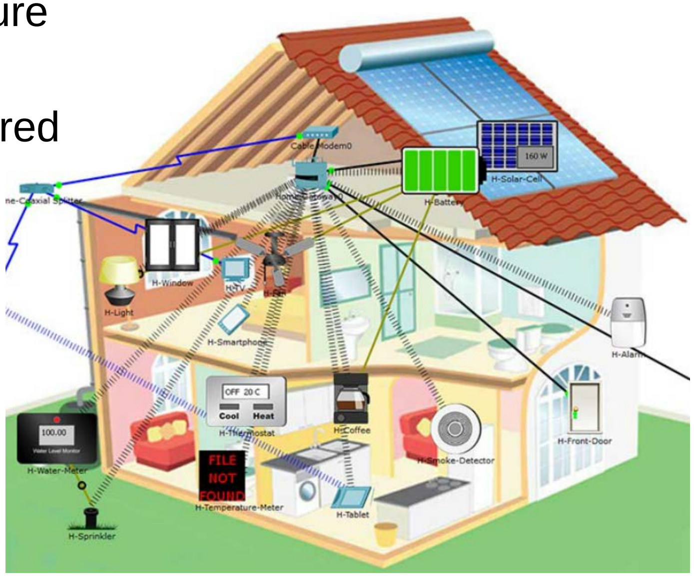
Building Models of IoT Systems in Packet Tracer

3.3.1 A Model of an IoT System

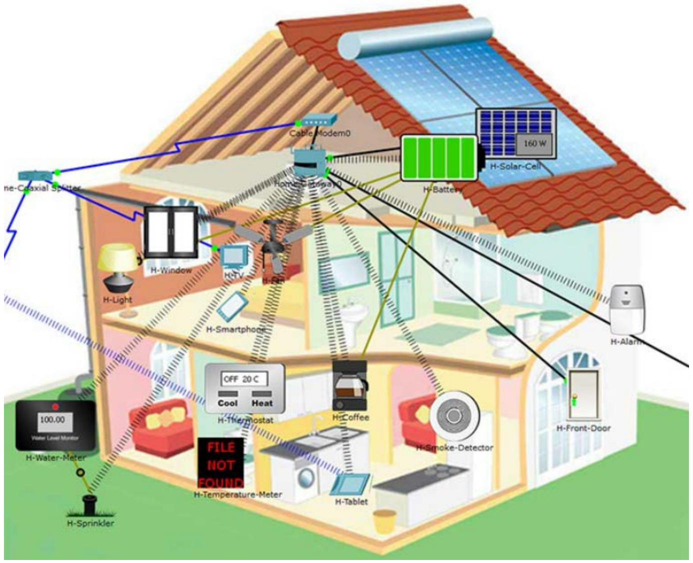
- Introducing The Home Automation Model
  - PT7.0 supports a wide range of IoT devices, such as sensors, actuators, microcontrollers, single board computers, and fog computing devices.
  - PT7.0 allows the design, configuration, programming, and troubleshooting of sophisticated models of IoT systems.
- The Components of the Systems
  - In the Smart Home example, all devices connect to the Home Gateway, which acts as a concentrator for all devices.
  - Sensors monitor the environment while code makes sure values stay within a pre-defined threshold.
  - The code also takes appropriated actions if the monitored values fall out of the pre-defined threshold.
  - The cable modem and splitter pair is what provides Internet connectivity to the Home Gateway and consequently, to the entire home.



Building Models of IoT Systems in Packet Tracer

A Model of an IoT System (Cont.)

- The SBC Code in Packet Tracer
  - PT 7.0 also introduces a single board computer (SBC) and a microcontroller unit (MCU).
  - PT SBC simulates an SBC such as a Raspberry Pi.
  - PT SBC provides 2 USB ports and 10 digital I/O ports which can be used to connect IoT sensors and devices.
  - PT SBC has a Python interpreter built in, accessible via PT SBC’s Programming tab.
  - PT 7.0 also supports an MCU emulator.
  - PT MCU can be programmed similarly to real-word MCUs.
  - PT MCU has one USB port, six digital I/O ports, and four analog I/O ports.
  - PT MCU can also be programmed with Python.



3.4 Chapter Summary

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Summary

- Programs (also called code) are used in IoT to provide logic and intelligence to the devices. A programmer can create code to allow an IoT device to perform tasks such as monitoring, communicating to others, data processing and more.
- The Raspberry Pi, single board computer, is designed to be small and consume very little power.
- The Cisco PL-App allows access to the Raspberry Pi directly from the network without the need for a monitor, keyboard or mouse to be directly connected to the Pi.
- The Raspberry Pi runs Raspbian, a modified version of the open source and wide-spread Linux operating system.
- The Raspberry Pi supports many different programming languages including Blockly, a visual programming language, designed to help beginners learn how to program. This course focuses on Python, a popular, simple and powerful programming language.
- With added support to Python, Cisco Packet Tracer is a great tool to model, prototype and test entire IoT systems.

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Chapter 4: Networks, Fog and Cloud Computing

IoT Fundamentals

Connecting Things 2.0

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Chapter 4 - Sections & Objectives

- 4.1 Connecting Things to the Network
  - Explain how the network supports the IoT.
- 4.2 Fog and Cloud Computing
  - Explain why fog and cloud computing are used in IoT systems.

4.1 Connecting Things to the Network

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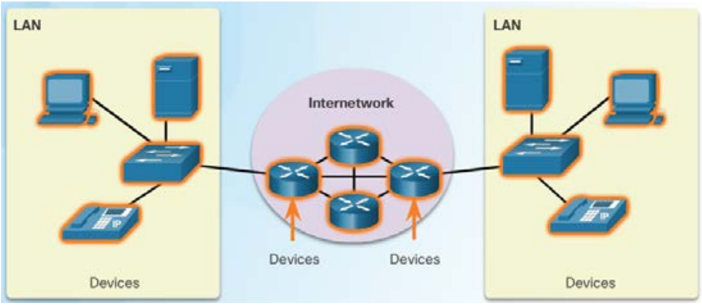
Connecting Things to the Network

4.1.1 The Role of the Network

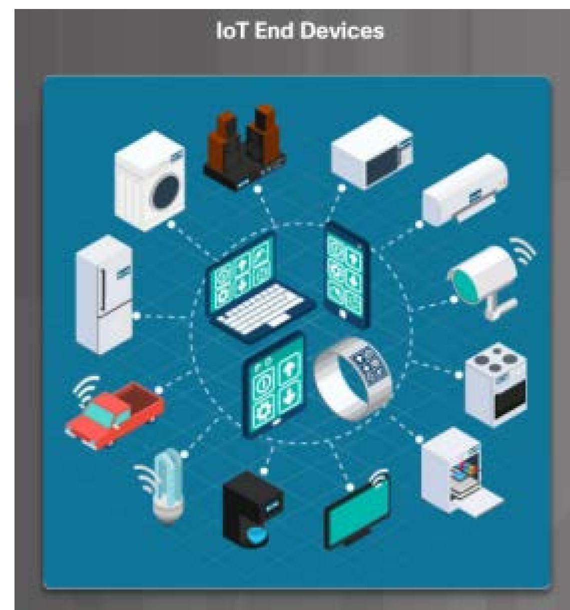
- LAN and WAN
  - The path from source to destination can be a single cable or a collection of networks.
  - A Personal Area Network (PAN) is a type of network that usually spans a few meters around an individual and is often used in IoT.
  - A Local Area Network (LAN) is a type of network infrastructure that spans a small geographical area and is used to connect end devices..
  - A LAN is normally a high-speed network under the control of a single administrative entity.
  - A Wide Area Network (WAN) is a type of network infrastructure that spans a wide geographical area and is used to connect WANs.
  - A WAN is normally a low-speed network and may include portions from different Internet Service Providers (ISPs)
  - LANs often connect machines in the factory plant.
  - WAN devices have evolved to create Low PowerWide Area Networks (LPWAN) for use in the IOT

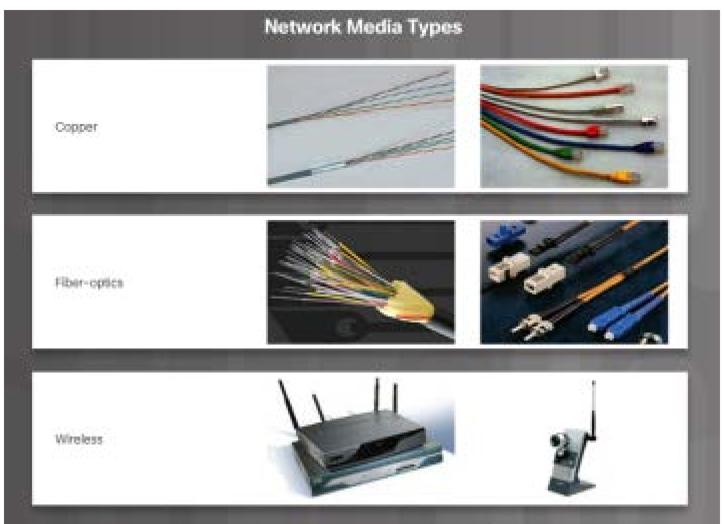


Connecting Things to the Network
The Role of the Network (Cont.)

- Network Devices and Communication Media
  - Network devices are devices that connect to each other through a network.
  - An end device is either the source or destination of a message transmitted over the network.
  - Intermediary devices connect the individual end devices to the network and can connect multiple individual networks to form an internetwork.
  - Network addresses are used to uniquely identify devices on a network.
  - Network media provide the physical channel over

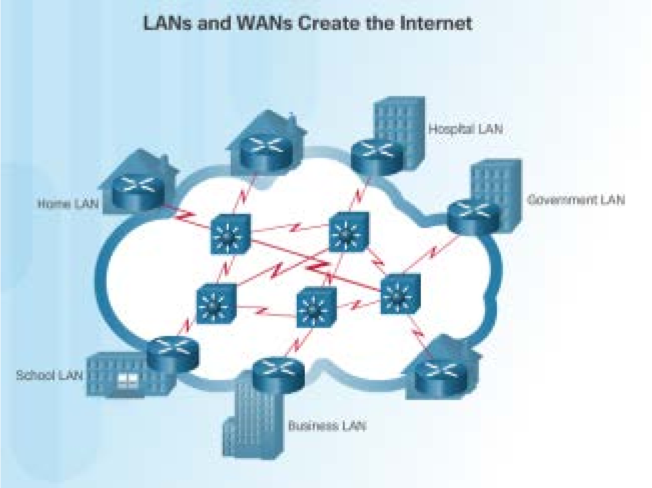
which the message travels from source to destination.





The Role of the Network (Cont.)

- Network Protocols
  - Devices must conform to common protocols before they can communicate.
  - Two very important network protocols are Ethernet and IP.
  - Ethernet rules enable communication between local devices.
  - IP enable communication between remote devices.
- Basic Routing
  - Network packets must often transverse several networks to get to the destination.
  - Routing is the process of directing a network packet to its destination.
  - Routers are intermediary network devices that perform routing.
- LANs, WANs and the Internet
  - Single router designs are common in SOHO.
  - The single router connects SOHO devices to the Internet.
  - The single router is the default gateway for all SOHO devices.

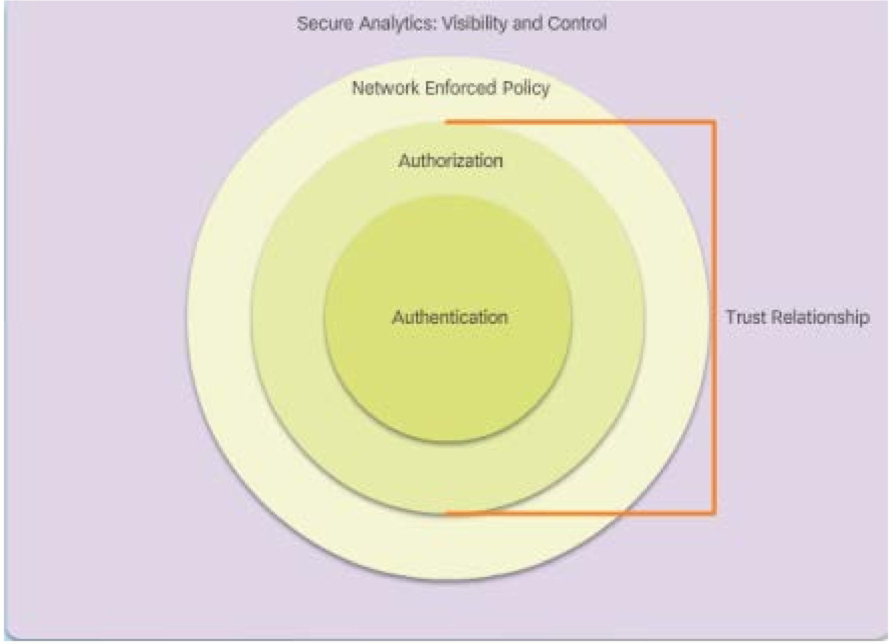


Connecting Things to the Network

The Role of the Network (Cont.)

- IoT Protocols
  - IoT Devices are often embedded devices designed to work in sub-optimal conditions.
  - These devices require specialized protocols to function with low power and limited connectivity.
  - IoT devices use CoAP (Constrained Application Protocol) and MQTT (Message Queuing Telemetry Transport).

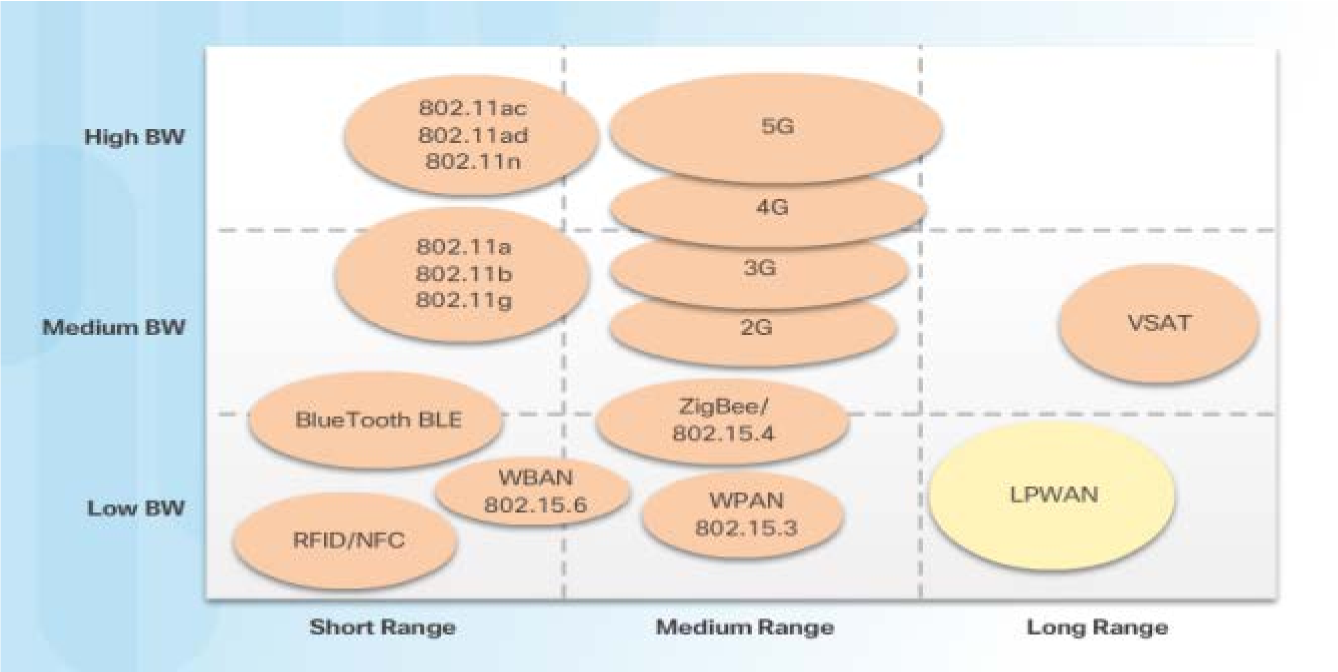
- Securing the Network
  - IoT devices are integrated into all aspects of daily life.
  - IoT applications carry traceable signatures and carry confidential data.
  - IoT devices must adhere to a secure framework (Authentication, Authorization, Network Enforced Policy, Secure Analytics)



Connecting Things to the Network

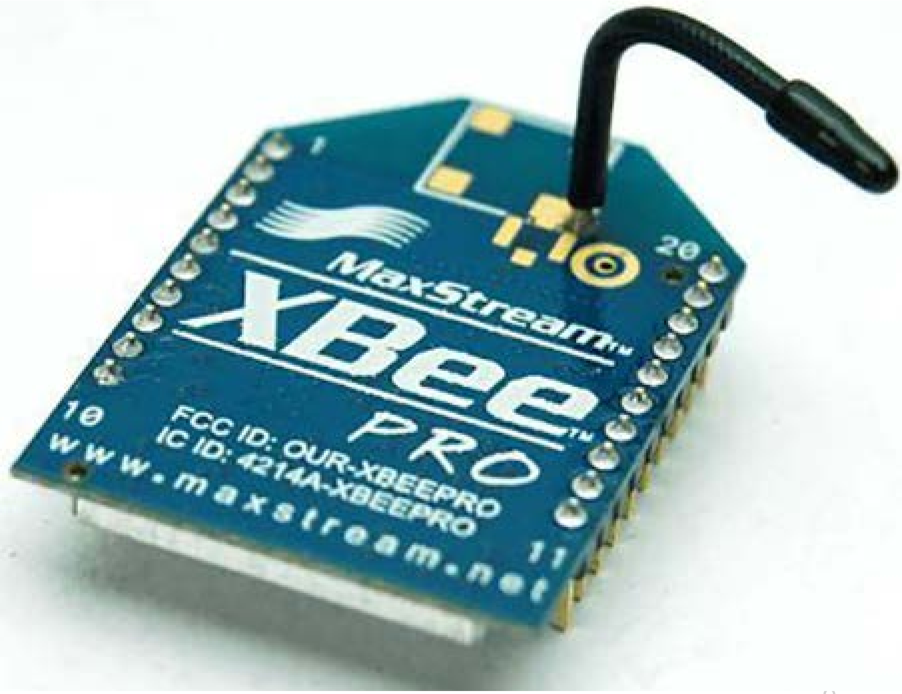
4.1.2 Wireless Technologies

- WiFi
  - Wireless connectivity is the biggest growth area.
  - New protocols created/updated to support diverse IoT devices: ZigBee, Bluetooth, 4G/5G, LoRaWAN
  - Protocols created for short, medium, and wide ranges
  - Low-Power Wide-Area Networks (LPWAN) is designed to support long range communications for low bit rate devices such as sensors, actuators, and controllers



Connecting Things to the Network
Wireless Technologies (cont'd)

- ZibBee
  - A low-energy, low-power, low-data rate wireless protocol specification used to create personal area networks
  - Areas of utilization: home automation, medical device data collection, and other low-power low-bandwidth needs
  - 250 kbps transfer rate best suited for intermittent data transmissions
  - Every ZigBee data request uses an Application Profile Identification Number.
  - Application profile ID numbers - 16-bit numbers that relate to public profiles, manufacturing profiles, or private profiles.
  - ZigBee version 1.2 has a number of serious and exploitable security vulnerabilities. Most of these protocol design flaws relate to attempts to make it easier for the end-user to add a ZigBee device to the ZigBee network.



Wireless Technologies (cont'd)

- Bluetooth
  - Wireless protocol used for data communication over short distances (PAN)
  - Supported by almost all mobile devices and accessories - the defacto standard for audio between mobile devices.
  - Bluetooth Low Energy (BLE) - very popular because of the smartphone industry and new applications in healthcare, fitness, and beacons.
    - operates in the 2.4 GHz ISM band
    - Has a very fast connection rate (milliseconds) and a very high data rate (1 Mbps).
    - The BLE device then goes into "sleep mode" until a connection is reestablished - lengthens the battery life for several years.
  - Beacons use BLE technology - positioned on buildings, in coffee shops, and on light posts to provide location services.

Wireless Technologies (cont'd)

- 4G/5G
  - Cellular-based data networks designed to take advantage of communications over large geographic areas
  - High mobility bandwidth (trains and cars) of 4G system is 100 Mbps
  - Low mobility (pedestrians and stationary users) of 4G systems is 1 Gbps
  - 4G provides support for voice, IP telephony, mobile Internet access, video calling, gaming services, cloud computing, high-definition mobile TV, and mobile 3D TV.
  - Long Term Evolution (LTE) and WiMAX (IEEE 802.16e) are two popular 4G systems.
  - LTE 4G technology release 13e includes the standardization of NarrowBand IoT (NB-IoT) - an LPWAN technology.
  - Next Generation Mobile Networks Alliance defining the standards and requirements for 5G

Wireless Technologies (cont'd)

- LoRaWAN
  - Wireless technology designed to provide wireless WAN connections to power constricted devices.
  - targets key requirements of the Internet of Things such as secure bi-directional communication, mobility and localization services.
  - Architecture is often an extended star topology in which gateways relay messages between end-devices and a central network server is located in the backend.
  - Data rates range from 0.3 kbps to 50 kbps
  - Security is built into the LoRaWAN standard, implemented in a multi-layer encryption scheme.
    - Unique keys are used in the Application, Network, and Device layers.

4.2 Fog and Cloud Computing

Connecting Things to the Network

4.2.1 Fog and Cloud Services

- Cloud Computing Model
  - On-demand access to a shared pool of configurable computing resources.
  - Resources can be made available quickly with minimal management effort.
  - Cloud service providers use data centers for their cloud services and cloud-based resources.
  - “Pay-as-you-go” model treats computing and storage expenses as a utility.
  - Enables access to organizational data and applications anywhere and at any time
  - Reduces cost for equipment, energy, physical plant requirements, and personnel training needs
  - Cloud services offered: Infrastructure as a Service (IaaS), Platform and mobile Platform as a Service (PaaS) (mPaaS), Software as a Service (SaaS)

Connecting Things to the Network

Fog and Cloud Services (cont'd)

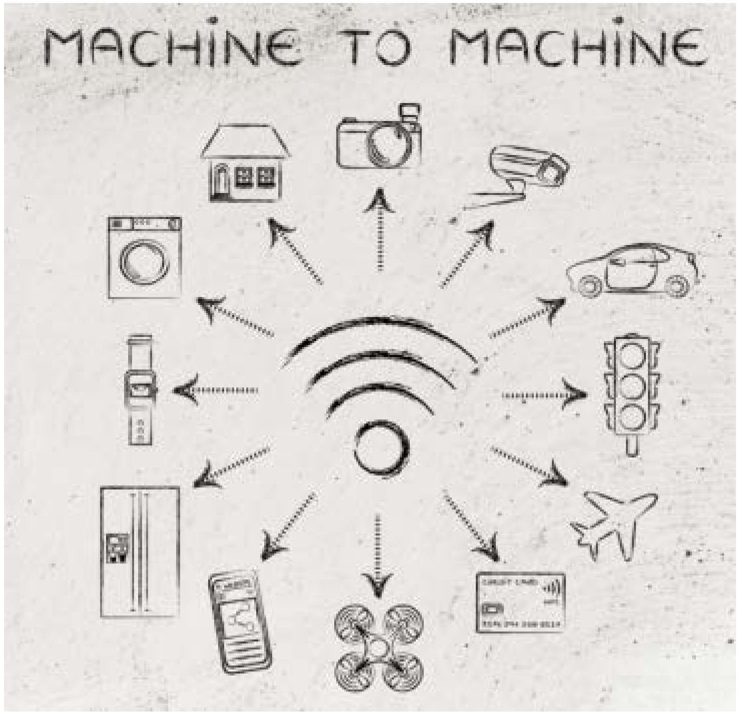
- Cloud Services
  - Cloud customers have access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort.
  - Extends functionality of an IoT system: data processing and storage done in the cloud instead of in the IoT devices.
  - Data and resources - always available to any device in the system as long as the device has Internet connectivity
  - Cloud service providers are also very serious about security, ensuring customer data is kept safe and secure..
  - Examples of cloud services: Amazon AWS, IFTTT, Zapier, Built.io, Cisco Spark

Connecting Things to the Network

Fog and Cloud Services (cont'd)

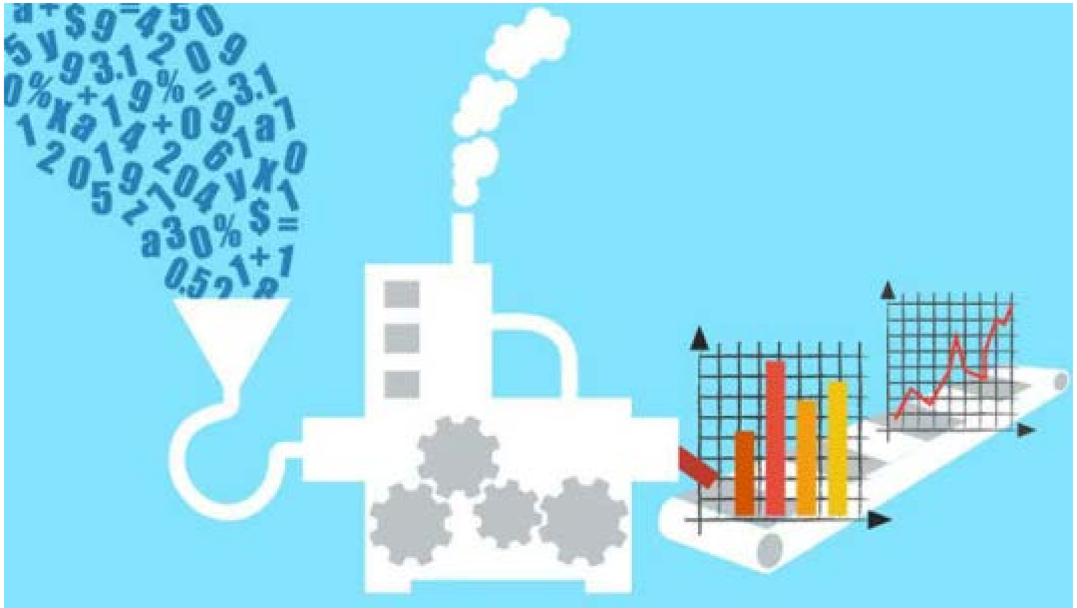
Fog and Cloud Services (cont'd)

- Fog Computing Model
  - Distributed computing infrastructure closer to the network edge.
  - Edge devices run applications locally and make immediate decisions
  - Reduces the data burden on networks as raw data not sent over network connections.
  - Enhances security - keeping sensitive data from being transported beyond the edge where it is needed.
  - Fog applications monitor or analyze real-time data from network-connected things and then take action such as locking a door, changing equipment settings, applying the brakes on a train, zooming in with a video camera,
  - The action can involve machine-to-machine (M2M) communications and machine-to-people (M2P) interaction
  - Cisco predicts that 40% of IoT-created data will be processed in the fog by 2018



4.2.2 Big Data (cont'd)

- Data Growth
  - Number of sensors and other IoT end devices growing exponentially and collecting a constant stream of data.
  - Consumer behavior is changing requires anytime, anywhere, on-demand access.- fitness monitors, smartphones, medical devices
  - Smart cities and smart grids, connected trains, cars – growing in frequency
  - Problems arise in terms of the requirements for storage, analysis, and security



Connecting Things to the Network

4.2.2 Big Data (cont'd)

- It is All About the Data
  - Big data is data that is so vast and complex it is difficult to store, process, and analyze using traditional data storage and analytics applications.
  - Typically characterized in three dimensions: volume, velocity, and variety
    - Volume - the amount of data being transported and stored
    - Velocity - the rate at which this data is generated
    - Variety - the type of data, which is rarely in a state that is perfectly ready for processing and analysis
  - Apache Hadoop, Spark, Cassandra, and Kafka – examples of open source projects dealing with Big Data

Connecting Things to the Network

4.2.3 Security Concerns in the IoT

- Data Storage
  - IoT devices may store data for a period of time before sending it out for processing. – especially for devices that do not maintain constant connections to their gateways or controllers.
  - Critical that all IoT storage devices encrypt data for storage to avoid data tampering or theft
  - Self-encrypting drives have encryption capability built into the drive controller - encryption and decryption done by the drive itself, independent of the operating system.
  - Self-encrypting flash memory – manufacturers beginning to release new devices with self-encrypting flash memory

4.2.3 Security Concerns in the IoT (cont'd)

- Data Transmission
  - If data is not properly secured through encryption, it can be intercepted, captured or manipulated while in transit.
  - Modern encryption algorithms may require more processing power than what is available in the IoT device.
  - As well as physical security, IoT devices must be able to protect its own firmware and the data it transmits.
  - Ensure that IoT devices are running the latest version of their firmware and protocols.
  - Common attack: trick devices into using sub-optimal security parameters under which the connection can be exploited
  - Servers, cloud endpoints, intermediary devices should also be secured and use strong encryption algorithms before communicating with IoT devices.

4.3 Chapter Summary

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Chapter Summary

Summary

- Personal information related to health, location, wealth, personal preferences and behaviors is passing through the IoT devices in increasing volumes. This increase in volume elevates the relevance of increasing the attention on data privacy and data protection.
- New wireless technologies and protocols, such as ZigBee, Bluetooth, 4G/4G, and LoRaWAN, have been developed to accommodate the diversity of IoT devices. Wireless technology is selected based on the range of coverage, bandwidth requirements, power consumption, and deployment location.
- Wireless security considerations include: selecting a secure protocol, protection for management frames, identification of frequency jamming, detecting rogue access points, and using security at the application layer.
- Cloud computing is a service that offers off-premise, on-demand access to a shared pool of configurable computing resources. Cloud computing offers services such as IaaS, PaaS, mPaaS and SaaS.
- A fog computing model identifies a distributed computing infrastructure closer to the network edge. It enables edge devices to run applications locally and make immediate decisions.
- The proliferation of devices in the IoT is one of the primary reasons for the exponential growth in data generation. Data can be deemed at rest or in motion. Big Data is typically characterized in three dimensions: volume, velocity, and variety.
- Data stored in servers must be encrypted to avoid data tampering or theft. Regular backups are mandatory to minimize losses in case of a disaster
- IoT devices should run the latest version of firmware and protocols and any communication between devices should be done using protocols that provide secure encryption by default.

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Chapter 5: Connecting and Digitizing Business

IoT Fundamentals

Connecting Things v2.0

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Chapter 5 - Sections & Objectives

- 5.1 The Cisco IoT System
  - Explain how Cisco equipment, software, and services enable IoT systems.
- 5.2 Industrial IoT Applications
  - Explain the value of Industrial IoT Applications.
- 5.3 IoT Systems in the Real World
  - Explain how IoT systems solve real world problems.

5.1 The Cisco IoT System

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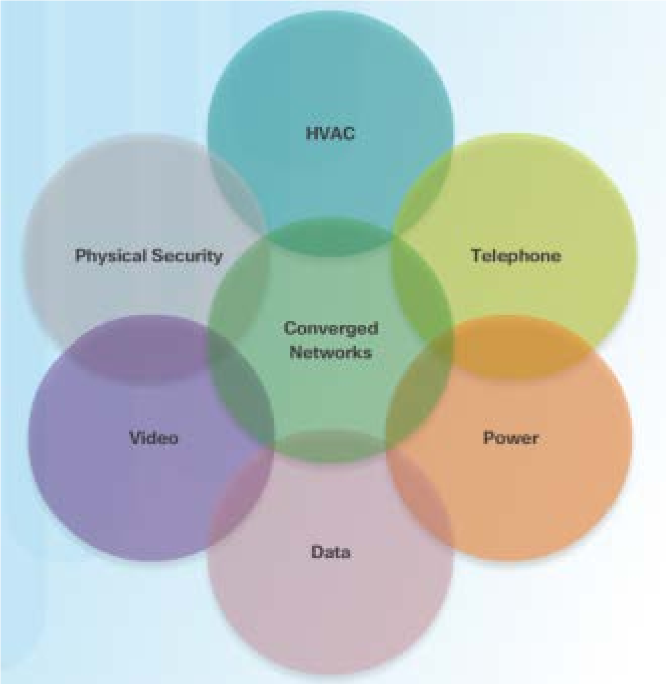
Cisco IoT System Overview

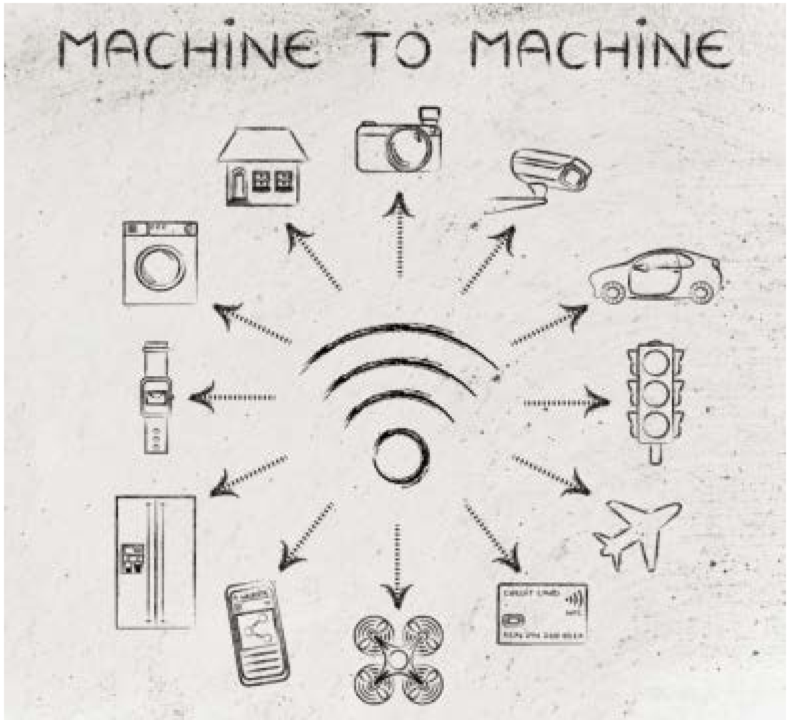
- Connecting Things
  - Allows for things to be accessible over the Internet that historically have not been.
  - Home appliances, cars, sensors, and more.
  - Industrial applications require a higher degree of reliability
- The Converged Network and Things
  - Many things are currently connected using a loose collection of independent networks.
  - Independent networks are harder to incorporate into the IoT.
  - Networks that would benefit from convergence: cars and residential and office buildings (heating, ventilation, air conditioning (HVAC), telephone service, security, and lighting).
  - A converged network is a powerful network that includes comprehensive security, analytics, and management capabilities.



The Cisco IoT System

Cisco IoT System Overview (cont'd)

- Connecting and Digitizing Industry
  - M2M enables communication between machines.
  - M2M occurs in cars with temperature and oil sensors communicating with an onboard computer.



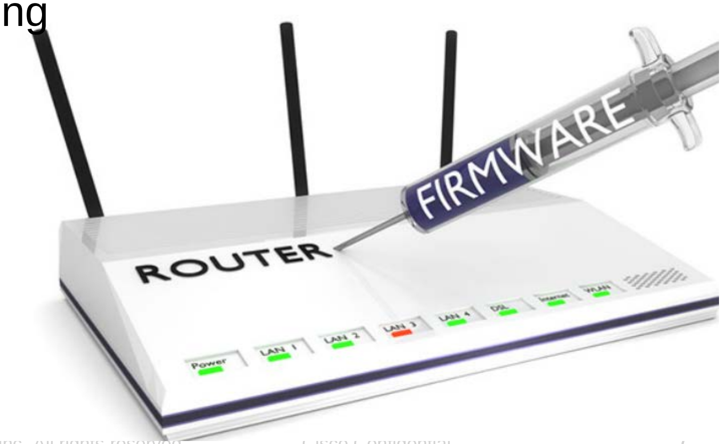
- Challenges to Connecting Things
  - How to integrate millions of things from different vendors?
  - How to integrate new things into the existing network infrastructure?
  - How to secure these new devices, each configured with varying levels of security?

Cisco IoT System Overview (Cont.)

- The Six Pillars of the Cisco IoT System
  - Uses a set of new and existing products and technologies to reduce the complexity of digitization.
  - Network Connectivity, Fog Computing, Security, Data Analytics, Management and Automation, Application Enablement Platform.
- Supporting the IoT in Industry
  - Network connectivity equipment varies depending on the type of network.
  - Cisco IoT network connectivity pillar identifies devices that can be used to provide IoT connectivity to home networks and various industries.
- Industrial IoT Devices
  - Industrial routers, Industrial switches, Industrial wireless, embedded networks.
  - These devices can support a variety of communication interfaces such as Ethernet, serial, cellular, WiFi, RF mesh, and LoRoWAN.

IoT Security

- Control Plane, Data Plane, Management Plane
  - Control plane is the brains of the device, used to make forwarding decisions.
  - Data plane is activities done to receive data from other devices and to forward them to the next device
  - Management Plane allows connection to modify a configuration or update software running on a device.
- Securing the Control, Data, and Management Planes in IoT
  - Securing the data plane relates to secure data as it crosses network devices.
  - Securing the control plane relates to securing the network device itself with tools such as passwords and data encryption.
  - Securing the management plane is secured by updating software and firmware with the latest patches.



IoT Security (Cont.)

- Securing the Control, Data, and Management Planes in IoT (cont'd)
  - A few recommendations:
    - Make sure the new IoT device can be easily updated.
    - Buy from a reputable manufacturer.
    - Segment IoT devices to a different network or VLAN.
    - Check for updates regularly.
    - Default usernames/passwords must be changed
    - Limit management access od devices to trusted sources
    - Turn off all unnecessary services

- Securing Things Using the Cisco IoT System
  - The IoT introduces new attack vectors.
  - Cisco IoT System security pillar offers scalable cybersecurity solutions.
- These cybersecurity solutions include:
  - Operational Technology (OT) Security, IoT Network Security, IoT Physical Security

5.2 Industrial IoT Applications

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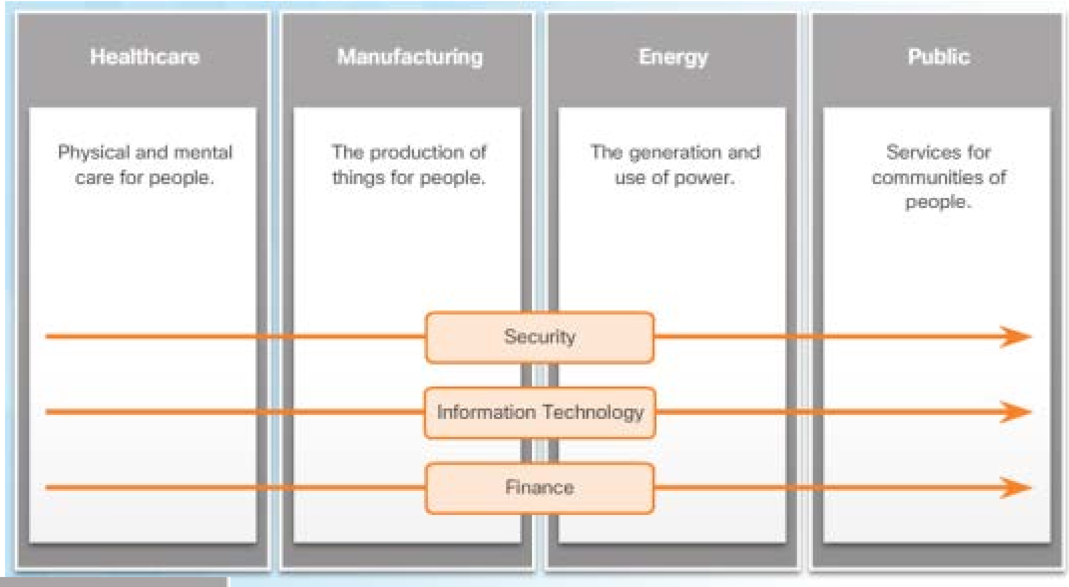
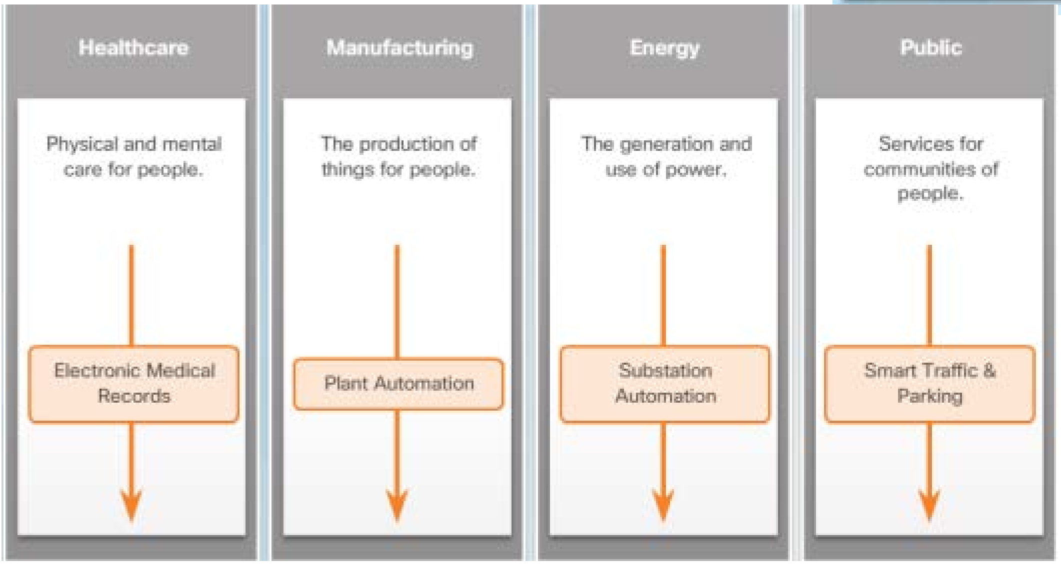
IoT Industries and Markets

- Horizontal Markets
  - Meet common or similar needs for a wide range of industries.
  - Security, information technology, and finance companies are examples of industries that operate in horizontal markets..





- Vertical Markets
  - Offer goods and services to a set of customers with specialized needs.
  - Automotive, banking, education, healthcare, retail, and technology are considered vertical markets.

Industrial IoT Applications

IoT Industries and Markets

- Integrated Solutions
  - The IoT creates new opportunities for the interaction and relationship between a variety of connected devices.
  - The IoT is about the integration of devices as a whole system, a holistic approach.
  - The integration of devices and systems creates new business opportunities and customer experiences.
- The Industrial Internet
  - Integration of complex machinery, sensors and software.
  - Example: driverless car uses data from different systems to be driven safely
  - Most common application is predictive maintenance.
  - Sensors is trains, planes, and large equipment keep track of hours of operation, machine output, environmental factors and determine when it needs maintenance.

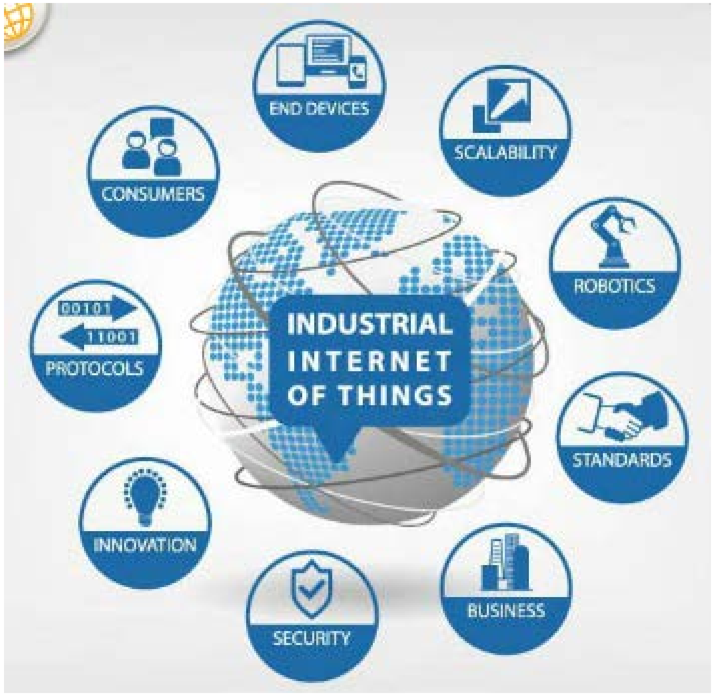


Diagram a Business Model

Business Model Canvas

- Business Model Canvas Overview
  - Helps organizations and entrepreneurs map, discuss, design, and invent new business models.
  - A business model consists of nine building blocks:
    - Customer Segments, Value Proposition, Channels, Customer Relationships, Revenue Stream, Key Resources, Key Activities, Key Partnerships and Cost Structure.
- Customer Interface
  - Customer Interface is comprised by Customer Segments, Value Proposition, Channels, Customer Relationship.
- Infrastructure Management
  - Defines how to build the value proposition.
  - Key Resources, Key Activities, and Key Partnerships make up ~~the~~ Infrastructure Management.

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5.3 IoT Systems in the Real World

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IoT Systems in the Real World

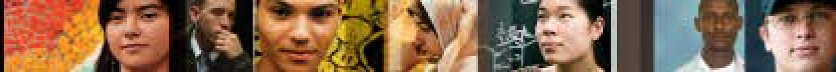
Connected Healthcare

- Challenges in Healthcare
  - Increasingly aging population.
  - High-demand services.
  - Shortages in key medical specialties.
  - Rising healthcare costs.
- Cisco Care-At-A-Distance Solutions
  - Care-at-a-distance value propositions:
    - Cisco Extended Care
    - Cisco TelePresence for Healthcare
    - Cisco WebEx for Healthcare

IoT Systems in the Real World

Connected Healthcare (Cont.)

- Cisco Clinical Workflow Solutions
  - Cisco Virtual Patient Observation
  - Cisco Patient Connect
  - Cisco Healthcare Intelligent Contact Center
  - Cisco Context-Aware (Location-Aware) Healthcare
  - Digital Media Suite for Healthcare
- Cisco Healthcare Management Solutions
  - Cisco also provides healthcare provider management solutions:
    - Cisco Services for Connected Health
    - Cisco Medical-Grade Network



IoT Systems in the Real World

Smart Cities

- Challenges Faced By Modern Cities
  - Overcrowding
  - Increasing pollution
  - Increasing traffic congestion
  - Inadequate parking
  - Inefficient use of street lighting, water, and waste management
  - Need for continued growth
  - Pressure to provide safer and more secure cities
  - Budget and resource constraints

- Cisco Smart+Connected Solutions
  - Customer segments of a city include its citizens, visitors, industry partners, businesses, and municipal operations.
  - Smart cities must address the needs of these segments.
  - Smart City Value Propositions:
    - Lighting, Operations Centers, Parking, Safety and Security, Traffic, Wi-Fi.

IoT Systems in the Real World

Smart Cities (Cont.)

- Smart City - Hamburg, Germany
  - The city of Hamburg, Germany has transformed itself into a smart city. [VIDEO]
- Cisco Smart+Connected Wi-Fi
  - Connects people, data, devices, processes, and city services.
  - Value propositions provided by the Cisco Smart+Connected Wi-Fi to customer segments include:
    - Citizen Services, City Services, Business Services, City commerce, Infrastructure Management Services.

Smart Cities (Cont.)

- Cisco Smart+Connected Lighting
  - A standards-based system for gathering a wide variety of data from the environment.
  - Collects levels for humidity, CO_2 and O_2, UVA and UVB light, particulate matter, motion and seismic activity, video, sound, and more.
  - Drastically reduce city energy consumption.
  - Improve citizen vehicle compliance.
  - Enhance situational awareness, real-time collaboration, and decision making across city agencies
  - Add intelligent, sensor-based IoT innovations to transportation, utilities, public safety, and environmental monitoring.
- Cisco Smart+Connected Parking and Traffic
  - Smart cities can simplify parking and improve traffic flow.
  - The Cisco Smart+Connected Parking solution provides citizens with real-time information about available parking.
  - Also allows them to book spaces in advance using mobile applications.

IoT Systems in the Real World

Smart Cities (Cont.)

- Cisco Smart+Connected Operations Center
  - Cities are increasingly looking for a customized, integrated, single-interface view of this data.
  - The Cisco Smart+Connected Operations Center solution displays sensor, map, and video data across a single layout.
  - It allows operators to control dynamic activities involving image processing, video feeds, data integration, and alerts.

IoT Systems in the Real World

Smart Grids

- Challenges in Energy
  - Rapid increase in consumption is putting a strain on energy providers in many countries.
  - There is also an increasing pressure to use low-carbon energy sources instead of fossil fuels.
  - Different ways of thinking about power and the way that it is consumed are needed.
- IoT Solutions for the Power Grid
  - Utilities need a more modern and agile electric grid.
  - Smart grid provides more complex interconnections between the producers, storage facilities, and consumers of electricity.
  - Smart grid brings the notion of the consumers generating power for themselves and to the grid.

Smart Grids (Cont.)

- Cisco Smart Grid Solutions
  - Cisco provides many smart grid solutions including:
    - GridBlocks Architecture
    - Connected Grid Services
    - Field Area Network
    - Transmission and Substation
    - Grid Security
    - Grid Operations

IoT Systems in the Real World

Connected Manufacturing

- Challenges in Manufacturing
  - Manufacturing must continually integrate new innovative technology into the existing plant infrastructure.
  - Multiple siloed operational technology networks become a problem.
  - Diversity in networks increases cost and complexity.
  - That lack of integration leads to a broad range of issues, including:
    - Inefficient operations
    - Slow response times both in the factory and in the market
    - Poor quality control
    - High overhead
    - Compromised security

IoT Systems in the Real World

Connected Manufacturing (Cont.)

- IoT Solutions for Manufacturing
  - IoT solutions connect the right people to the right information.
  - Connected sensors provide a unique level of visibility into the factory operations and supply chain flow.
  - Collected data contributes to identifying trends and relationships, revealing opportunities for improvement.
  - For example, car companies now use sensor data to decide if conditions are favorable to paint a car.
- Cisco Manufacturing Solutions
  - Cisco provides the following IoT manufacturing value propositions:
    - Cisco Connected Factory
    - Cisco Connected Machines
    - Cisco Secure Ops
    - Cisco Connected Supply Chain
    - Cisco Communications and Collaboration Tools

5.4 Chapter Summary

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Chapter Summary

Summary

- The Cisco IoT System relies on six pillars: Network Connectivity, Fog Computing, Security, Data Analysis, Management and Automation, and Application Enablement Platform. Security is very important for IoT, because it ensures that the data, control, and management planes are secure.
- The IoT spreads across both vertical and horizontal markets. Connected Healthcare, Smart Cities, Smart Grids and Connected Manufacturing are a few examples of real world IoT Systems.
- Connected Healthcare uses the IoT to help healthcare providers reduce costs, improve productivity, and deliver better care to people in rural communities as well as in urban centers.
- Smart Cities value propositions encompass lighting, operations centers, parking, safety and security, traffic, and Wi-Fi.
- Smart grid brings the notion of the consumers generating power for themselves and the grid. Connected
- Manufacturing relies on sensors to provide visibility into factory operations and supply chain flow.

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Instructor Materials
Chapter 6 Create an IoT Solution

IoT Fundamentals

Connecting Things v2.0

Chapter 6 - Sections & Objectives

- 6.1 Become a Global Problem Solver
  - Investigate real-world social or environmental problems.
- 6.2 Design a Solution
  - Design an IoT solution that addresses a real-world social or environmental problem.
- 6.3 Build, Test & Document a simple IoT System
  - Create an IoT system.
- 6.4 The Business Aspects
  - Design a plan to market an IoT solution.
- 6.5 What is Next?
  - Explain how to continue your learning about the IoT.

6.1 Become a Global Problem Solver

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6.1.1 Solving Global Problems

- Organizations Doing Global Good
  - Global problems include the burning of fossil fuels, air pollution, oceans becoming more acidic, climate change, poverty, hunger, disease, gender inequality, and access to water and sanitation.
  - Some companies and organizations provide funds to help these global problems such as the Bill & Melinda Gates Foundation and The Musk Foundation.
- The Millennium development Goals
  - In 2000, leaders from 189 countries made a list of 8 goals to be achieved in 15 years.
  - These eight goals were called the Millennium Development Goals (MDGs).
  - United Nations Development Programme (UNDP) is working on fulfilling these goals.
- Progress on MDGs so far:
  - People who live on less than $1.25 per day has dropped by more than half.
  - Young children going to school is up by almost half.
  - People receiving HIV treatment increased by over 15 times.
  - Lowered child mortality rate by almost half.
    - .

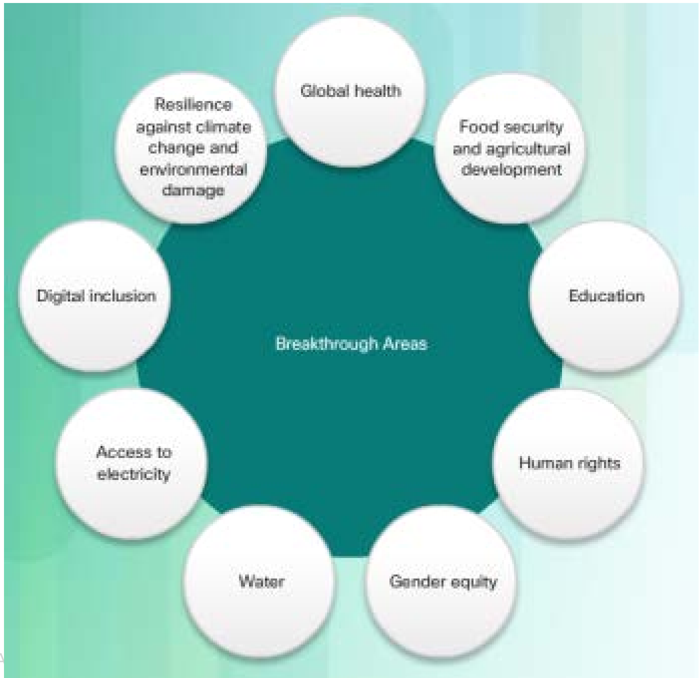
Solving Global Problems (Cont.)

- The Sustainable Development Goals
  - In 2015, 189 world leaders at the United Nations Sustainable Development Summit unanimously adopted the 2030 Agenda for Sustainable Development.
  - The result was a set of 17 Sustainable Development Goals (SDGs).
  - These new SDGs go much further than the MDGs.
  - They are addressing the root causes of poverty and the universal need for development that works for all people.

Become a Global Problem Solver

6.1.2 Globally Transformative Breakthrough Technologies

- Lawrence Berkeley National Lab
  - The Lawrence Berkeley National Lab (LBNL).
  - The Institute of Globally Transformative Technologies (LIGTT) (pronounced 'light') is part of LBNL and was created in 2012.
  - The goal of LIGTT is to leverage LBNL's resources to develop and deploy breakthrough technologies for sustainable global development.
- Institute of Globally Transformative Technologies
  - The LIGTT released a top "50 Breakthroughs" study in 2014.
  - Identified some of the most important breakthrough technologies that are required for sustainable global development.
  - LIGTT aims to develop many of these breakthroughs. Achieving this will make substantial impacts on poverty.
  - Breakthrough #42 is directly related to using the IoT to enable new services.



6.2 Designing a Solution

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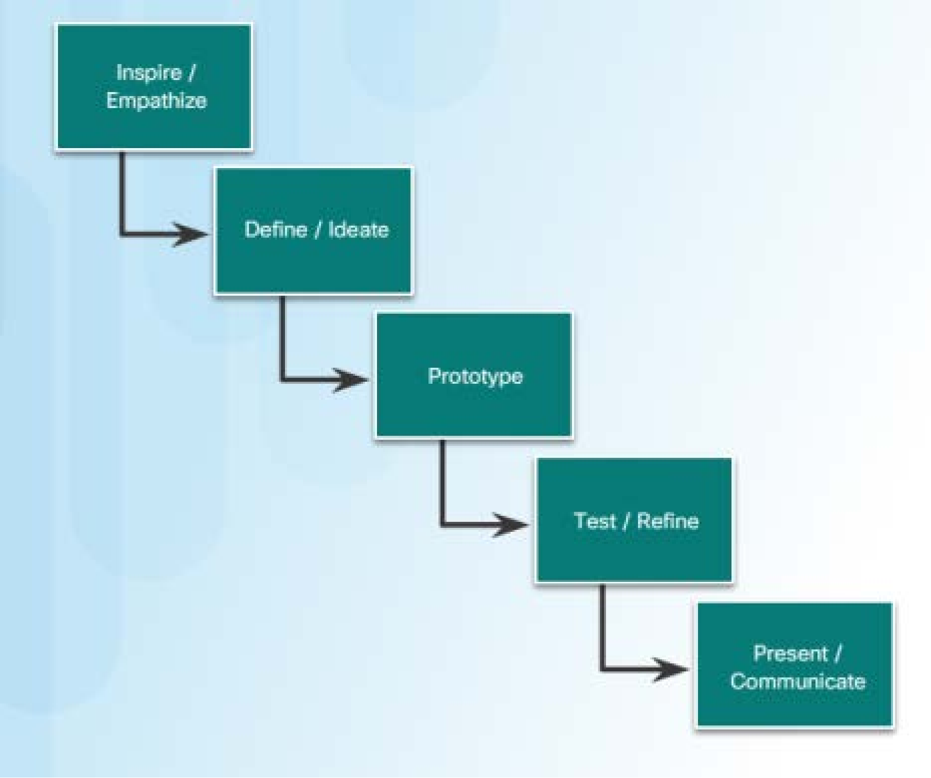
6.2.1 Designing Solutions

- The Engineering Design Process
  - How can we help solve global challenges?
  - The engineering design process is a proven method.
  - The five steps are cyclical which means that they can be repeated as many times as needed to make improvements in the design process.
    - Inspire/Empathize
    - Define/Ideate
    - Prototype
    - Test/Refine
    - Present/Communicate.



Become a Global Problem Solver

6.2.1 Designing Solutions (Cont.)

- Security Design
  - Security should be included from the beginning, in the design phase.
  - Ensure new devices facilitate software updates and all hidden backdoors are removed
  - On pre-manufactured devices used in projects ensure the following:
    - Default passwords/usernames are changed.
    - UPnP is disabled on IoT devices if possible.
    - Remote device management is protected with strong passwords and access limited to trusted personnel.
    - Ensure all devices are updated with the latest software updates and patches.
    - Ensure all devices support and use encryption and certificates.
    - Secure the physical location of IoT devices as much as possible.

6.3 Create an IoT System

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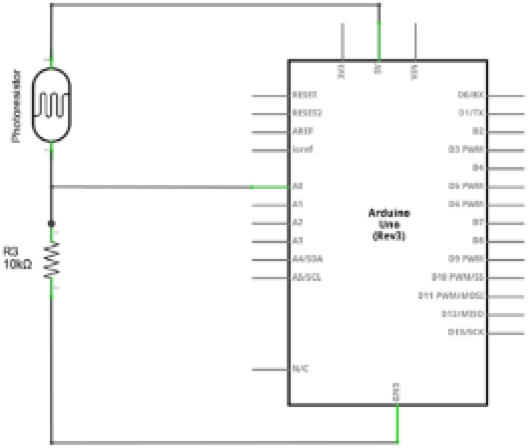
Create an IoT System

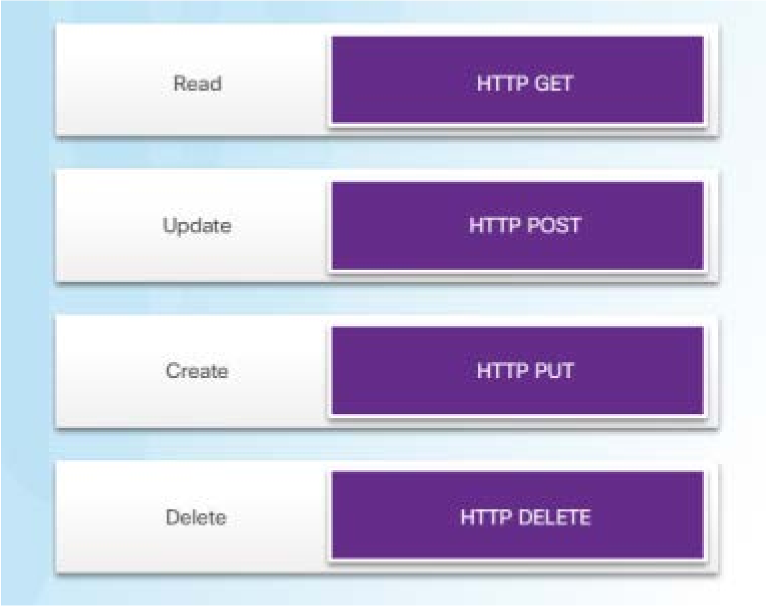
6.3.1 THE IoT System Project

- Project Overview
  - Identify a problem that can be solved by an IoT device.
  - Example used: building a device that senses the amount of and determines sunrise and sunset.
- The Circuit Layout
  - Electronic components have specific power, polarity, and connection requirements.
  - The circuit layout identifies/describes these requirements.
  - Sunrise/sunset example requires a voltage divider - produces an output voltage that is a fraction of its input voltage by distributing the input voltage among the components of the divider.



6.3.1 THE IoT System Project (cont'd)

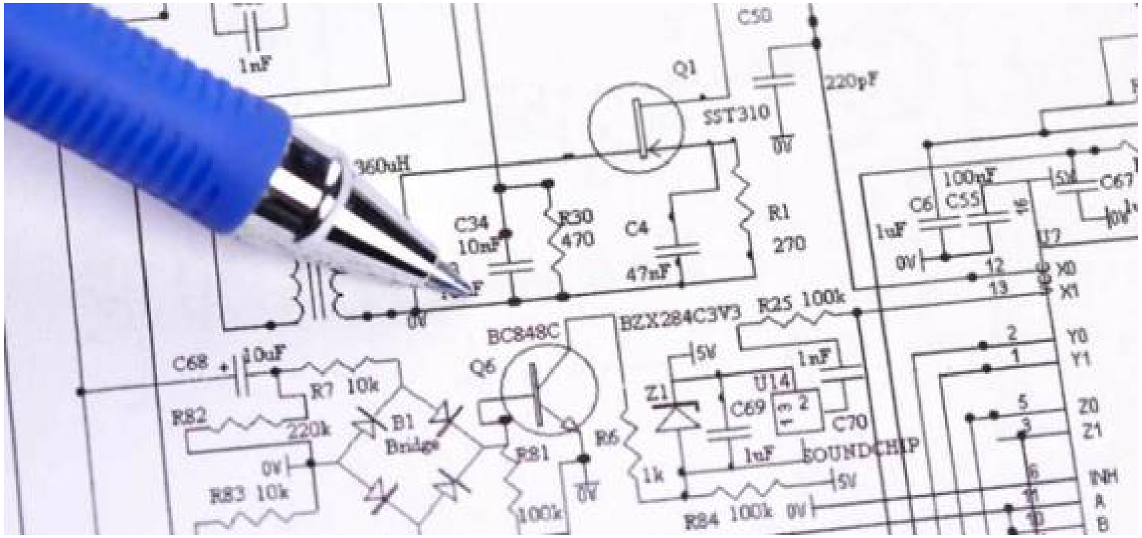
- REST API in an IoT System
  - REST APIs use HTTP methods to exchange data between systems or applications
  - RESTful systems use Uniform Resource Identifiers (URIs) to represent their services to external systems.
  - Sample URIs:
    - GET /people/michael to receive Michael's user profile dataset
    - POST /people/michael to update Michael's profile with new data.

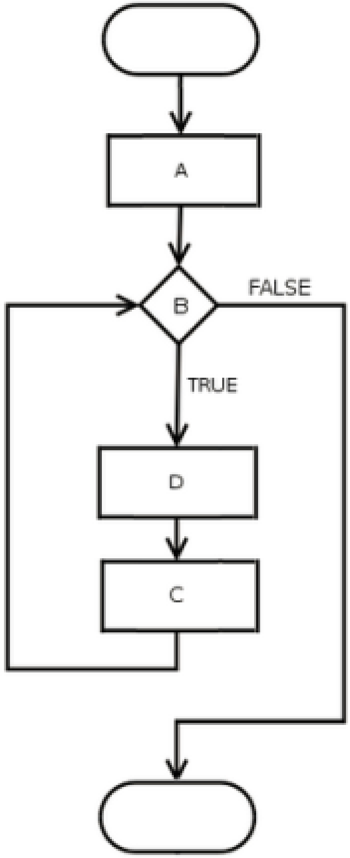


  - The IFTTT web service allows for special resource URIs to be created and mapped to specific IFTTT actions.
  - Example IFTTT URI - **https://maker.ifttt.com/trigger/SunRise/with/key/**
  - The sunrise/sunset example uses both IFTTT and Google Calendar services

6.3.1 THE IoT System Project (cont'd)

- Flowcharts, Electronic Schematics, and Sequence Diagrams
  - Documenting project is very important for building the devices, testing, troubleshooting, and creating a business model.
  - Flowcharts use standardized symbols to represent the processes and workflows.
  - Electronic schematics is a graphical representation of a circuit diagram using internationally standardized components.
  - Sequence diagrams represent interactions between entities along a timeline.

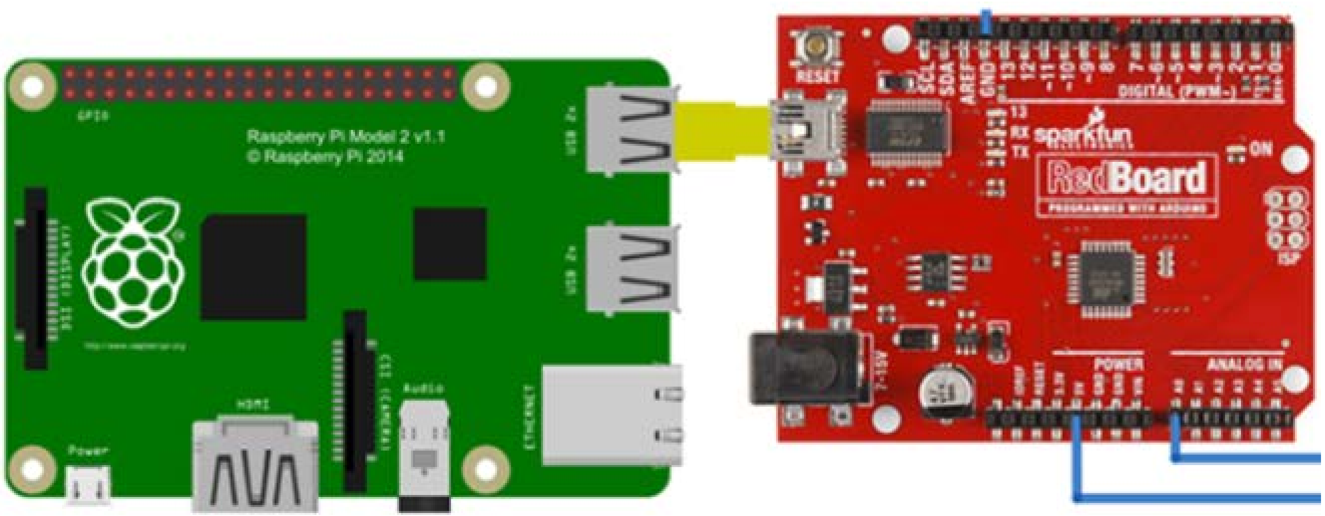




Create an IoT System

6.3.1 THE IoT System Project (cont'd)

- The Code
  - The sunrise/sunset example is written in Python using a Raspberry Pi
  - The Arduino is connected to the Raspberry Pi.
  - The programming is done on the Raspberry Pi to send the level of voltage drop from the Arduino to the RaPi.
  - Firmata, a generic protocol for communicating with microcontrollers, is used to communicate between the Arduino firmware and the RaPi.
  - The Python code used for the sunrise/sunset example is explained line by line.



Create an IoT System

6.3.2 THE IoT System Prototype

- Overview of the Problem
  - Simple problem identified that can be solved by an IoT system: remote access to determine if garage door is open or closed
    - Switch can determine if a door is open or closed
    - Switch attaches to a controller – which keeps track of switch status
    - Controller connected to Internet to provide remote access
- Prototyping and testing System
  - Create electronic schematic, flowchart, and sequence diagram for prototype
  - Packet Tracer 7 used to create and test the prototype.
  - Update documentation once prototype works successfully.
  - Documenting is important not only for future reference but also for situations where marketing material or patent applications are to be created.

6.4 Business Model Canvas

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6.4.1 Business Model Canvas

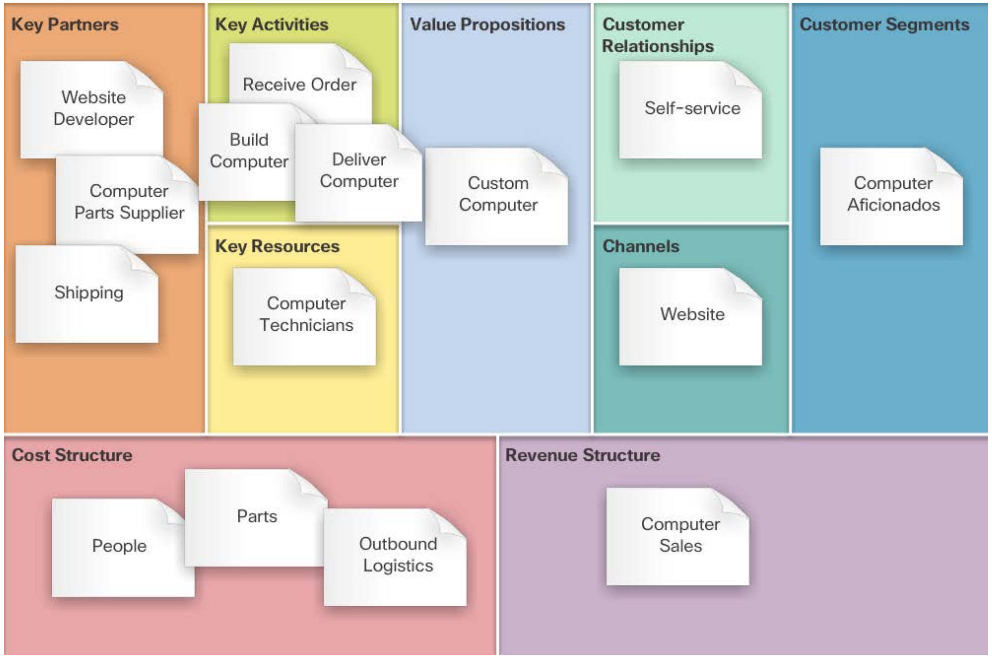
- Business Model Canvas Overview
  - Helps organizations and entrepreneurs map, discuss, design, and invent new business models.
  - A business model consists of nine building blocks:
    - Customer Segments, Value Proposition, Channels, Customer Relationships, Revenue Stream, Key Resources, Key Activities, Key Partnerships and Cost Structure.
- Customer Interface
  - Customer Interface is comprised by Customer Segments, Value Proposition, Channels, Customer Relationship.
- Infrastructure Management
  - Defines how to build the value proposition.
  - Key Resources, Key Activities, and Key Partnerships make up the Infrastructure Management.

Business Model Canvas

6.4.1 Business Model Canvas (Cont.)

- Business Finances
  - Include the cost structure and revenue streams created by the value proposition.

- Business Model Canvas Example
  - Example of a completed business model canvas for a custom computer manufacturer.



6.5 What is Next?

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What is Next?
6.5.1 Lifelong Learning

- 21st Century Skills
  - 21st century job market is now looking for employees who can accomplish one or more job roles such as: design a project, prototype a device, create and maintain documentation, and create a business plan.
- IoT employees also need learning and innovation skills
  - Creativity and innovation
  - Critical thinking and problem solving
  - Communication
  - Collaboration

What is Next?
6.5.1 Lifelong Learning (cont'd)

- Resources for Continued Learning
  - There are many resources available to enable you to continue learning about the IoT including:
    - Cisco Networking Academy
    - Cisco Learning Network
    - Cisco DevNet
    - IEEE Computer Society (IEEE-CS) and the Association for Computing Machinery (ACM)
    - Many other online resources including forums, wikis, blogs, and more
    - There are also IoT communities of practice consisting of other like-minded individuals who want to share ideas with others.

6.6 Chapter Summary

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Chapter Summary
Summary

- There are many global social and environmental problems that can be solved by IoT systems. The Institute for Globally Transformative Technologies (LIGTT) has compiled a list of 50 breakthrough technologies that will drastically improve the work on these global problems.
- The Engineering Design Process is a proven method to develop a product.
- The first step to design an IoT solution is to identify a problem that can be solved with an IoT device. To test the idea, a prototype could be built simply by using a Raspberry Pi with an attached Arduino. To provide an example, a sunrise/sunset tracker was built.
- Another prototype was designed on Packet Tracer to remotely check to see if the garage door was open or closed..
- Documentation is very important component of any project. Flowcharts, Electronic Schematics and sequence diagrams are often used to provide documentation.
- The **Business Model Canvas** helps organizations and entrepreneurs map, discuss, design, and invent new business models based on a value proposition, customer interface, infrastructure management, and finances
- IoT professionals should be individuals who espouse life-long learning. They need to be flexible, take the initiative, lead when necessary, and be able to produce something new and useful

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Chapter 1: What is the Internet of Things?

Introduction to the Internet of Things

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Chapter 1 - Sections & Objectives

- 1.1 Internet of Things
  - Explain the positive effects of the Internet of Everything on our everyday lives
- 1.2 The Value of the IoE
  - Identify the elements of the IoE
- 1.3 Globally Connected
  - Explain how multiple networks are used in everyday life.

1.1 Internet of Things

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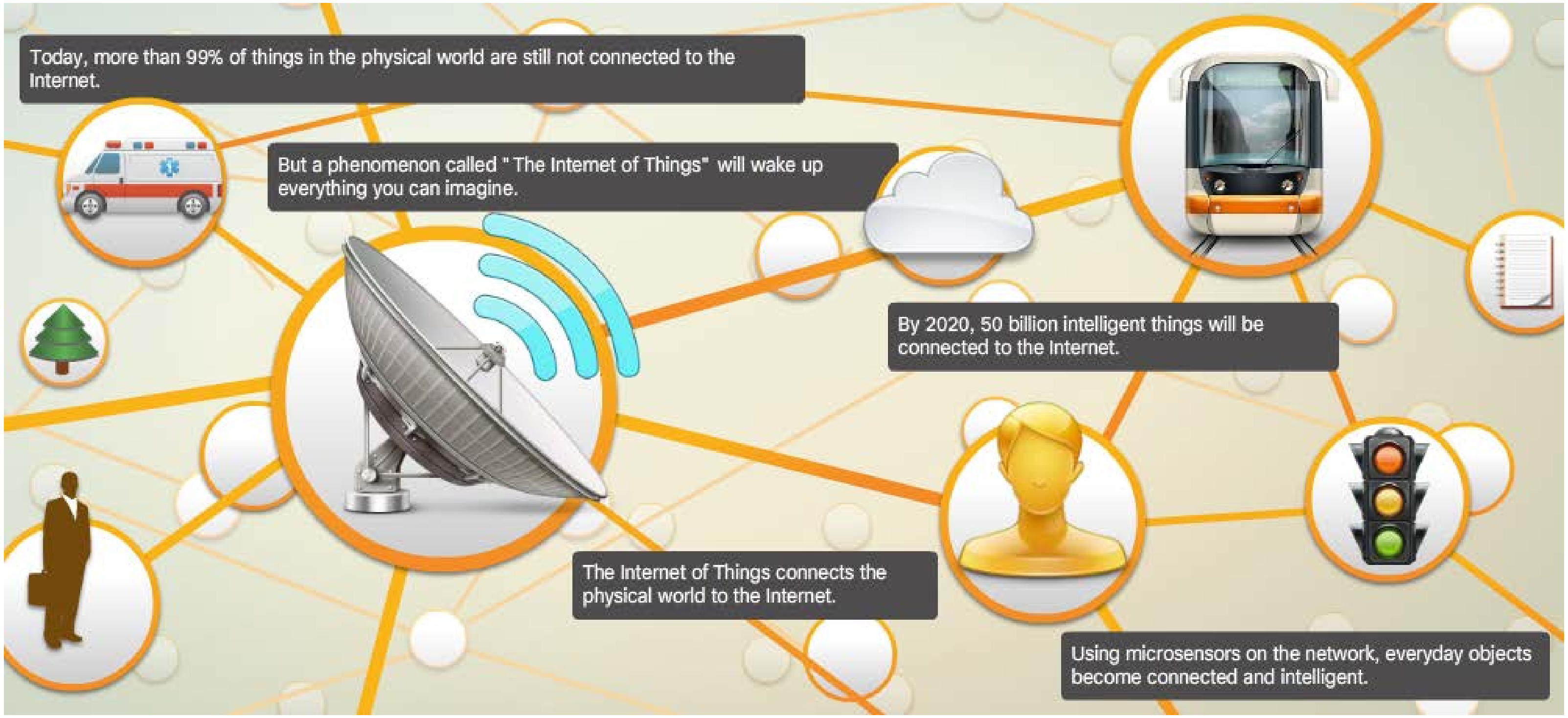
The Internet

- The Internet
  - A network of networks
  - Using a physical cable or wireless media for connection
- Transitioning to the IoT



The Value of the IoE

The Changing Environment

- Adapt or Lose Competitive Edge
  - Streamline through the use collaboration and automation
  - Provide more relevant offerings
  - React to feedback by customers or employees
- Governments and Technology
  - Government must change with technology
  - Government must respond to emergencies
  - Citizens can connect through social media
  - Citizens can gather support for change
  - Barcelona, Spain – This project uses technical innovations to foster economic growth and the welfare of its citizens.

Transforming Businesses with IoE

Hyper-Aware, Predictive, Agile

Hyper-Aware

- Sense the location, status, and context of company assets and customers.
- Monitor customer sentiment and behaviors in real time.
- Identify market and competitive changes.

Predictive

- Anticipate market transitions.
- Optimize performance of assets and operations.
- Foresee and proactively address emerging security threats.

Agile

- Achieve competitive differentiation by responding faster than rivals.
- Foster innovation by building “platforms” for sustainable advantage.
- Respond to rapidly evolving threats.

Accelerating Innovation

The Value of the IoE

Transforming Businesses with IoE (Cont.)

Core Priorities

The IoE affects five core priorities of an organization:

Customer Experience
Improving customer relationships to garner more of the market.

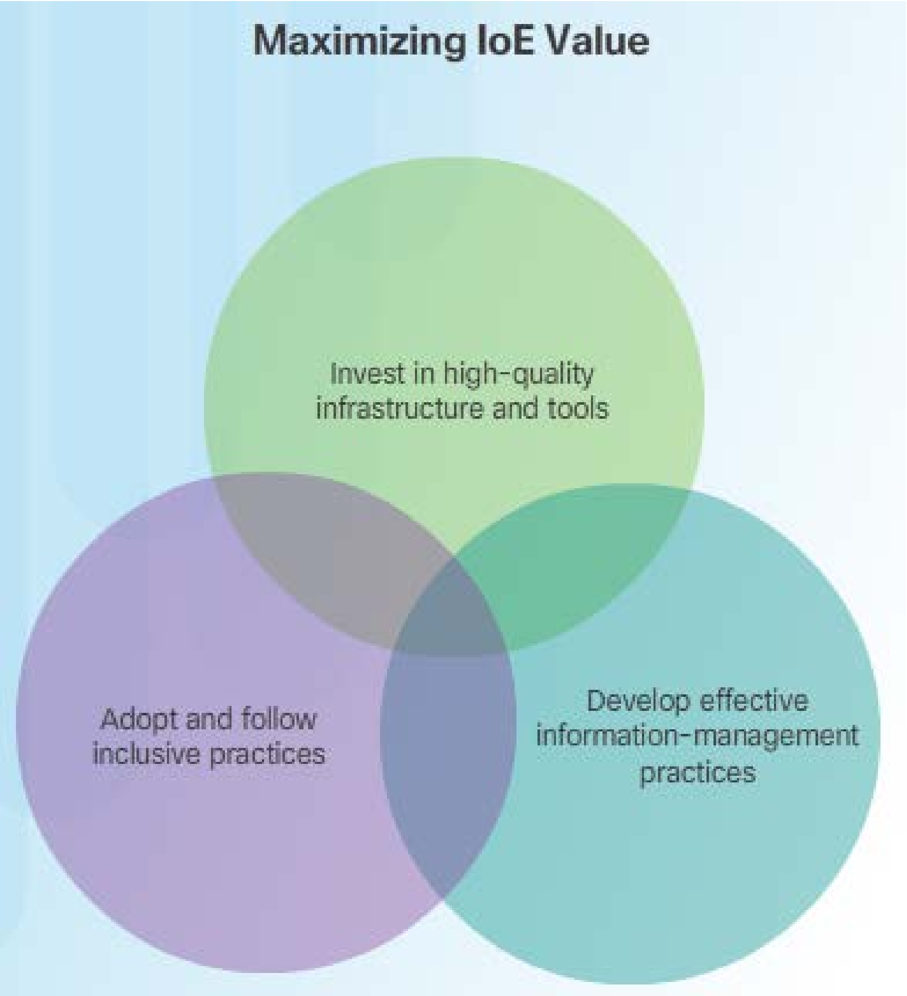
Innovation
Reducing time to market products and improving product development to meet customer needs.

Employee Productivity
Providing the ability to be more productive and scalable.

Asset Utilization
Lowering costs.

Supply
Identifying areas of waste and delay, while increasing logistical efficiency.

Transforming Businesses with IoE (Cont.)



Globally Connected

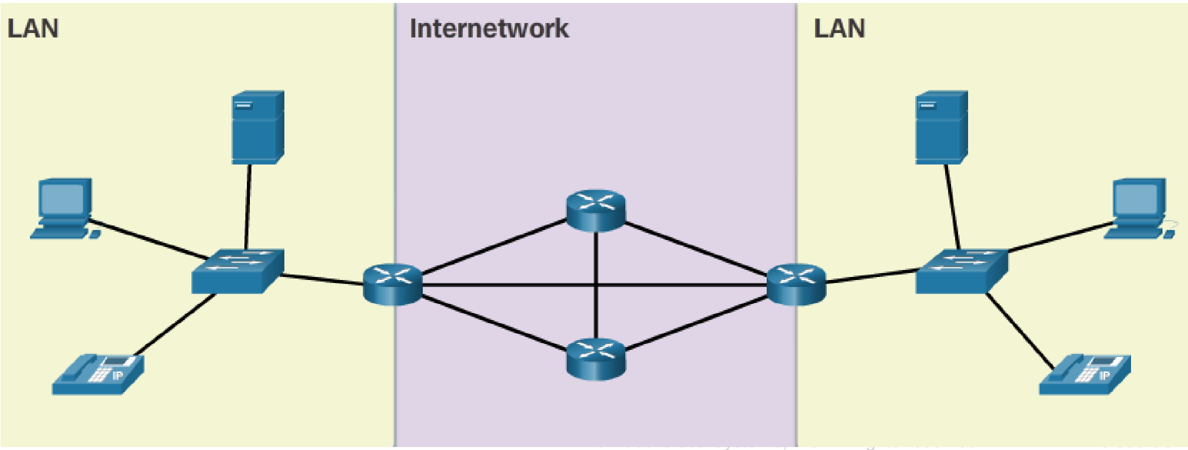
Networking Today

- Networks of Many Sizes
  - Simple networks
    - Home networks or small office / home office (SOHO)
    - Few devices and shared resources
  - Business and large organization networks
    - Provide products and services to their customers
    - Provide consolidation, storage, and access to information on network servers
    - Allow for email, instant messaging, and collaboration among employees
    - Enable connectivity to new places, giving machines more value in industrial environments.
  - Internet
    - Network of a collection of interconnected private and public networks

Globally Connected

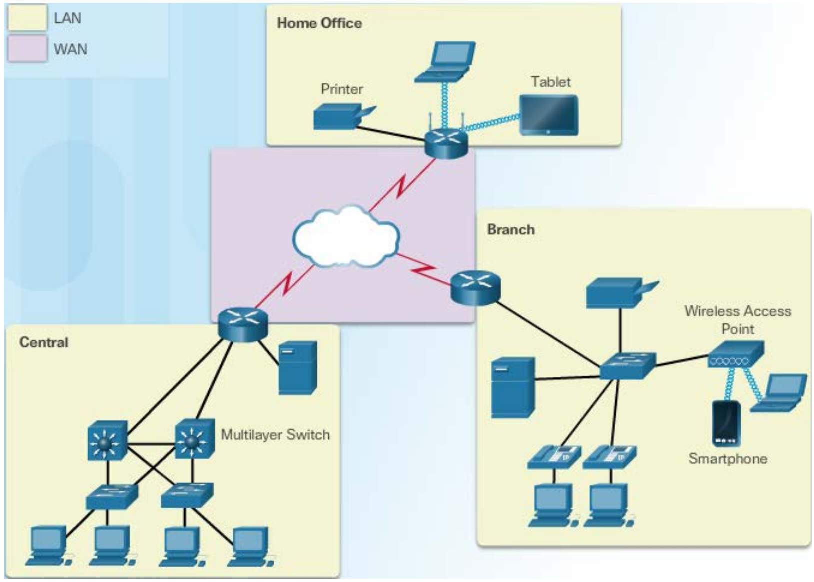
Components of a Network

- End Devices
  - Form the interface between users and the communication network
  - Source or destination of data transmission over the network
  - Servers vs. clients
- Intermediate Network Devices
  - Interconnect end devices
  - Connect end devices to the network
  - Connect multiple networks to from an internetwork
- Network Media
  - Cable or through the air
- Can you identify each component?



LANs, WANs, and the Internet

- LAN (Local Area Network)
  - Provides access in a limited area
  - Provides high speed bandwidth
- WAN (Wide Area Network)
  - Interconnects LANs over wide geographical areas
  - Owned by an autonomous organization



- Internet
  - Not owned by any individual or group
  - a worldwide collection of interconnected networks
  - exchange information using common standards.
  - Use telephone wires, fiber optic cables, wireless transmissions, and satellite links to exchange information

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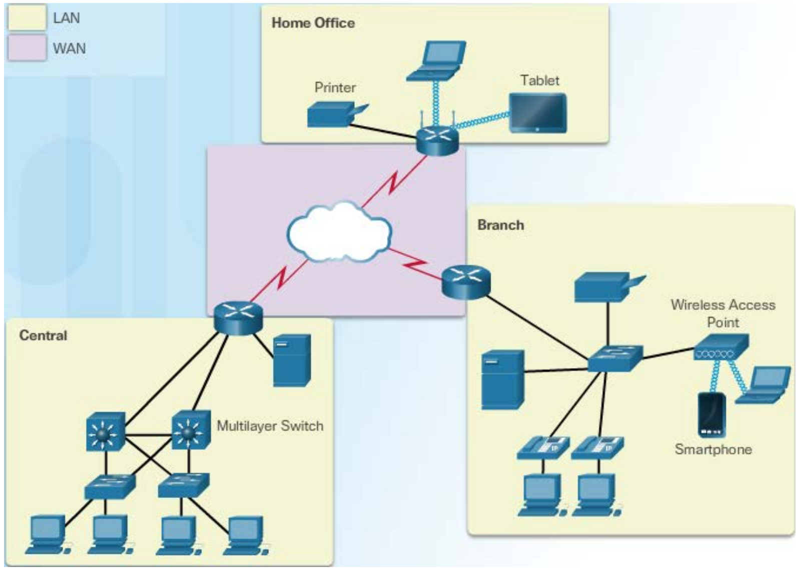
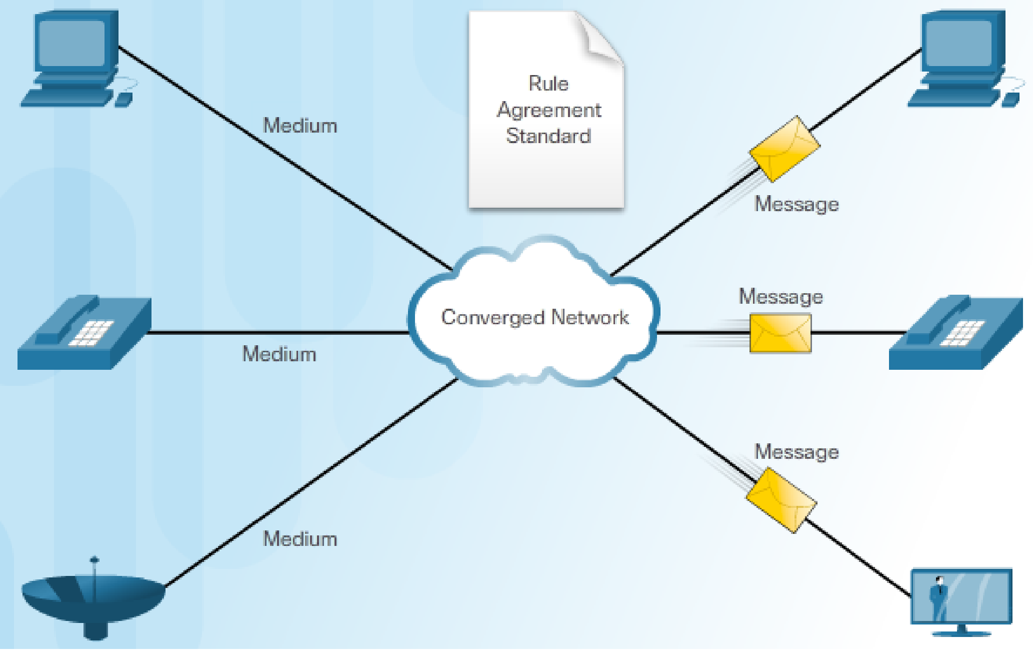


Globally Connected

LANs, WANs, and the Internet (Cont.)

- Converged Networks
  - Consolidate these different kinds of networks onto one platform
  - Capable of delivering voice, video, text, and graphics
  - One common network infrastructure
  - Uses a common set of rules, agreements, and implementation standards



Globally Connected

Communication Across Networks

- Need for Standards
  - Rules of communication that devices use and are specific to the characteristics of the conversation.
  - Protocols define the details of how messages are transmitted and received.
  - Protocols contain rules for how devices communicate.
- Protocol Suite - TCP/IP
  - Application
  - Transport
  - Internet
  - Network Access
- Network Connectivity (Network Access Layer)
  - Transfer data across the network
  - Wired examples - Category 5 cable, coaxial cable, Ethernet over powerline
  - Wireless examples – Wi-Fi, Cellular, NFC, ZigBee, Bluetooth
- Network Access for Currently Unconnected Things
  - Bluetooth, ZigBee, NFC, 6LoWPAN

1.4 Chapter Summary

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Summary

- The Internet is a network of networks that brings people, process, data, and things together.
- The IoE brings value to organizations in these five areas: customer experience, innovation, employee productivity, asset utilization, and supply.
- Networks provide the foundation for the Internet and, ultimately, the IoE. The components of a network fall into one of three categories: devices, media, and services.
- The two most common types of networks are LAN and WAN.
- Consolidating different types of networks onto one platform creates a “converged network.” Protocols define the details of how messages are transmitted and received. A group of inter-related protocols that are necessary to perform a communication function is called a protocol suite. Protocol suites help ensure interoperability between network devices.
- One of the most common networking protocol suites is known as Transmission Control Protocol/Internet Protocol (TCP/IP). The bottom layer of the TCP/IP protocol suite, network access covers the protocols that devices must use when transferring data across the network. The devices can be connected to the network in one of two ways: wired and wireless.

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Chapter 2: Elements of the IoE

Introduction to the Internet of Things

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Chapter 2 - Sections & Objectives

- 2.1 Things as an Element
  - Explain things as an element of the IoE
- 2.2 Data as an Element
  - Explain data as an element of the IoE
- 2.3 People as an Element
  - Explain people as an element of the IoE
- 2.4 Process as an Element
  - Explain process as an element of the IoE that manages the way things, data, and people work together.

2.1 Things as an Element

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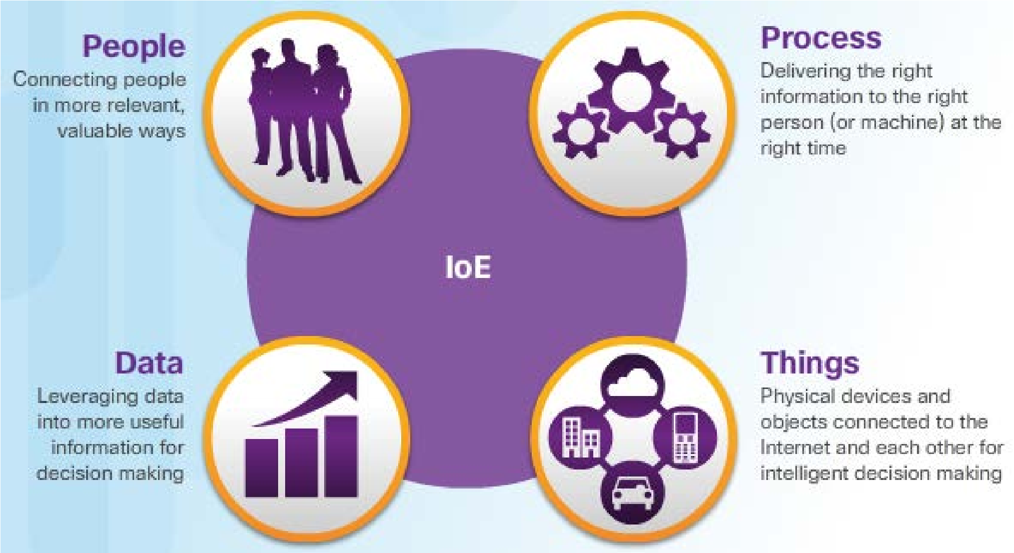
Connecting to Traditional Computer Things

- The Four Elements
  - People, Process, Data, and Things
- What are Things
  - contain embedded technology to interact with internal servers and the external environment
  - network-capable
  - can communicate across a secure, reliable and available network platform
  - Can create vast amounts of data.



Things as an Element

Connecting to Traditional Computers

- Can you name a few common devices and different ways to connect them wirelessly?
- Here are some examples:
  - Common devices: laptop and desktop computers
  - Ways to connect: Wi-Fi

Things as an Element

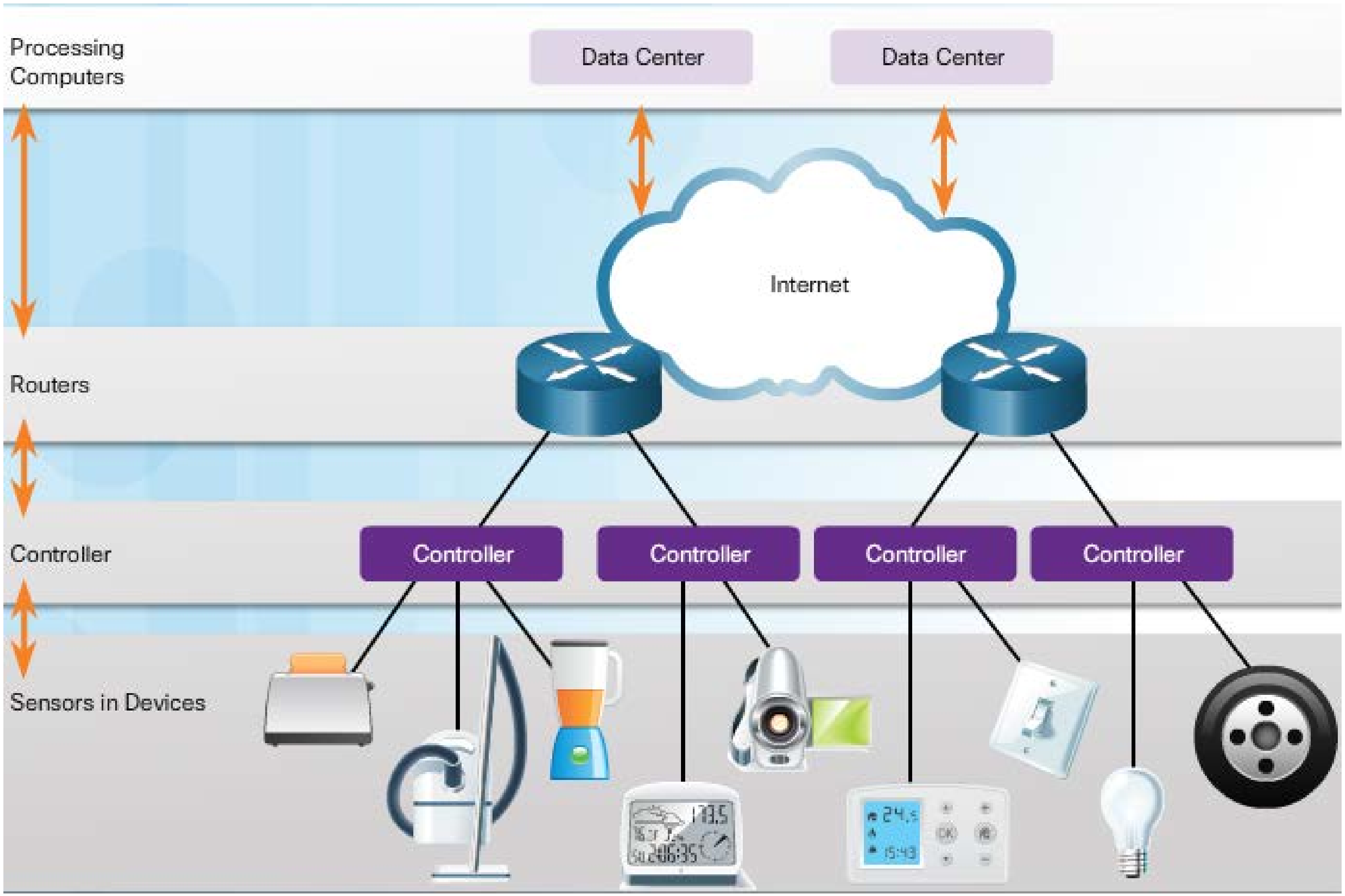
Connecting to Non-Traditional Computer Things

- Sensors
  - Collect data from non-computers
  - convert physical aspects of our environment into electrical signals that can be processed by computers
  - Some examples: soil moisture sensors, air temperature sensors, radiation sensors, and motion sensors

- RFID – Radio frequency identification
  - Communicate information between small coded tags (RFID tags) and an RFID reader. Usually, RFID tags are
  - Use to identify and track what they are embedded into

- Controller
  - collects data from sensors and providing an Internet connection
  - May have the ability to make immediate decisions or send data to a more powerful computer for analysis.

Connecting to Non-Traditional Computer Things (Cont.)



Data as an Element

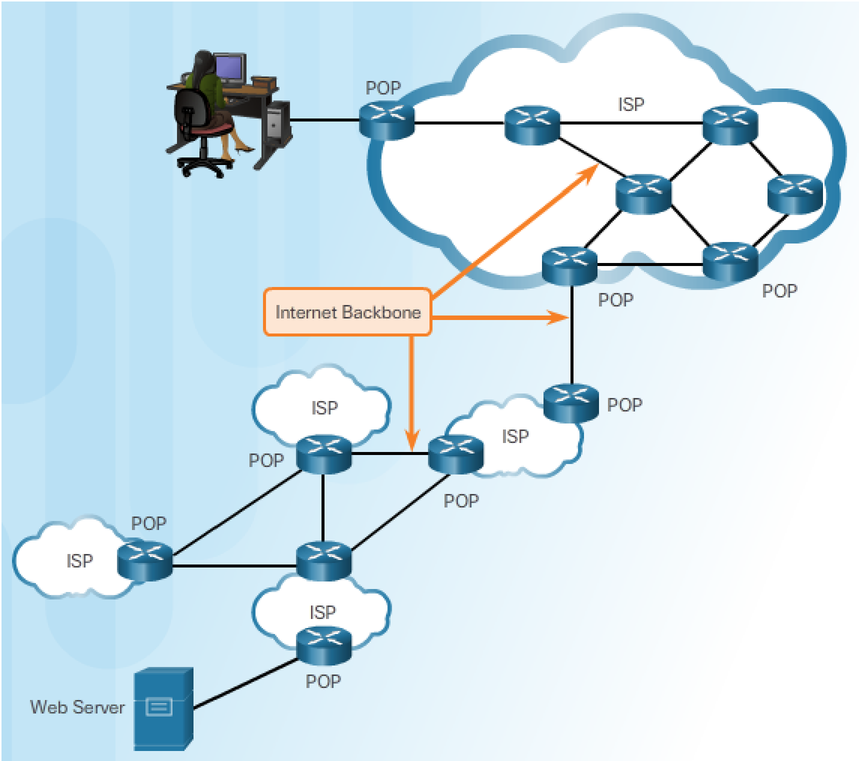
Data

- What is Data?
  - Data is a value assigned to anything that is around us.
  - In electronic communication, data is represented as 1s and 0s, known as bits (or binary digits).
  - The advantage of using digital coding is that data can be stored more efficiently and can be transmitted over long distances without the quality becoming degraded.
- Management of Data
  - Structured Data – data entered and maintained in fixed fields within a file or record
  - Unstructured Data – raw data
- Data Storage – local data, centralized data, and distributed data

Data as an Element

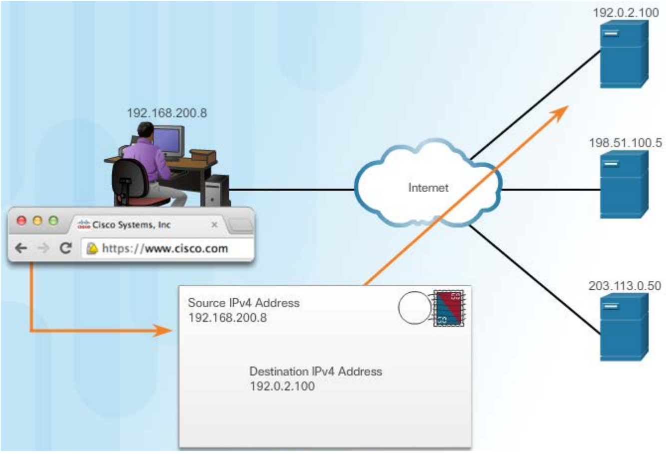
Transportation of Data

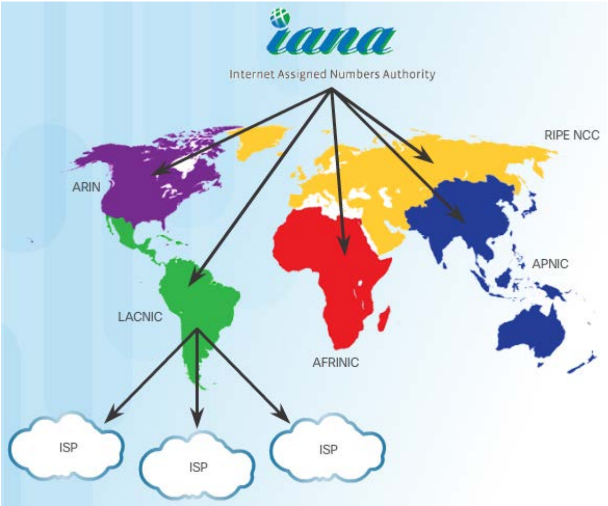
- Internet Service Providers
  - Forward the data across the Internet
  - Supply the connections to allow Internet access to individuals and businesses
  - Interconnect with other ISPs
  - Connect networks at Point of Presence (POP)
  - Form the Internet Backbone when multiple ISPs are interconnected



Transportation of Data (Cont.)

- IP Addressing
  - IP packet must contain a valid source and destination IP address
  - IP protocol specifies how these addresses are used in routing of packets
- IP Address Management
  - Internet Assigned Numbers Authority (IANA)
    - Distributes IP addresses so that there is no duplication.
    - Allocates blocks of IP addresses to one of five regional Internet registries (RIR).
  - ISPs
    - Obtain blocks of IP addresses from the RIR in their geographic region.
    - Manage and assign IP addresses to customer networks
    - Determine where to forward the traffic





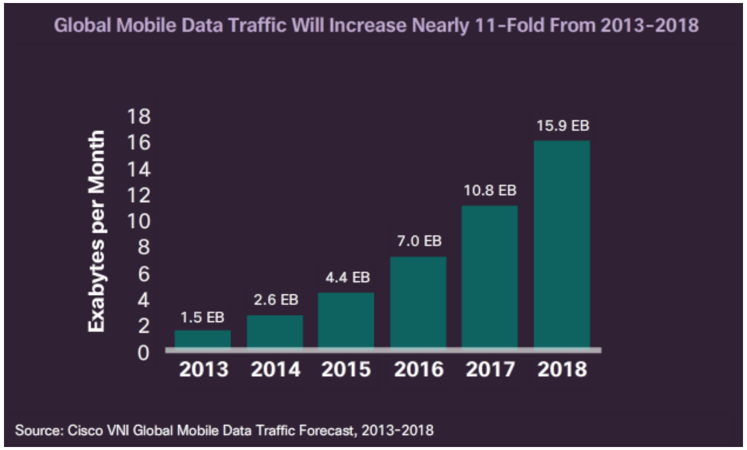
Data as an Element

Big Data

- Data in Motion
  - Data at rest - Collected, static data
  - Data in motion - Devices, sensors, and video on the IoT are a growing source of new data on a constant basis. This data provides maximum value while it is interacting in real-time.
- Managing Big Data
  - Volume – amount of data being transported and stored
  - Variety – type of data
  - Velocity – rate of data movement

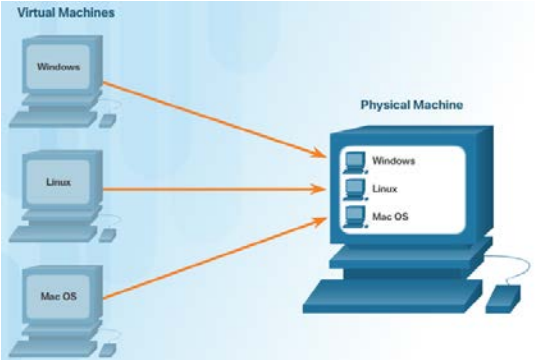
Big Data (Cont.)

- Big Data Analytics
  - Collection and analysis of vast stores of data for insights
    - How much data is generated
    - How this data is identified and managed as an asset to the organization
    - How this data is turned into usable information
    - How organizations use this data to make decisions
  - Data sources and trends
    - Mobility - Mobile devices, events, sharing, and sensor integration
    - Data access and consumption – Internet, interconnected systems, social networking, and access models
    - Ecosystem capabilities – Major changes in the information processing model and the availability of an open source framework



Data as an Element

Virtualization and Cloud Computing



- Virtualization
  - Software emulation
  - Virtual computer operates independently
  - Virtual computer has its own operating system, applications, and dedicated hardware components.
- Cloud Computing
  - Is another way to mange, store, and access data
  - Involves large numbers of computers connected through a network
  - Allows the users to access their data anywhere and at any time
  - Uses a shared pool of computing resources
  - Types of cloud services: SaaS, PaaS, IaaS, ITaaS
  - enables organizations to streamline their IT operations by subscribing only to needed services
- Data Centers
  - Are a critical enabler to cloud computing
  - Provide business continuity by keeping computing services available at all times

Data as an Element

Virtualization and Cloud Computing (Cont.)

The IoE Requires a Variety of Cloud Models

Organizations need maximum flexibility to efficiently and reliably connect people and things:

- Private
- Public
- Community
- Hybrid

Organizations need a flexible infrastructure that:

- Adapts
- Speeds service introduction
- Ensures governance and financial reporting for each model

All Cloud Models Must Work Together Seamlessly

When selecting Cloud solution providers, integration and consistency across all models is a critical factor. Cloud solution providers must offer:

- Security
- Compliance
- Performance

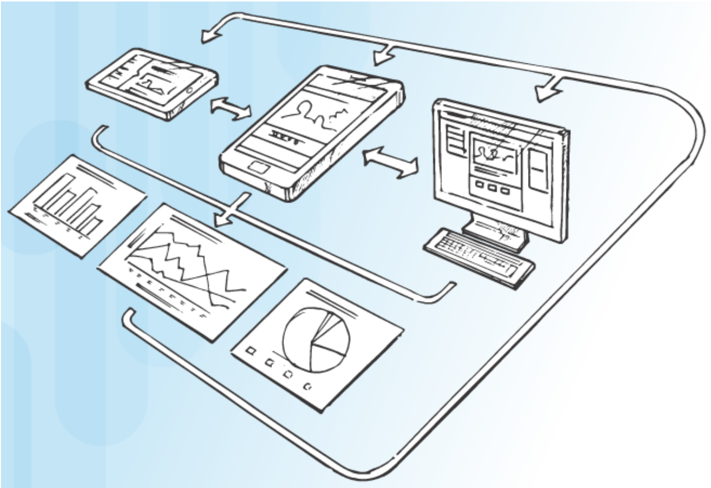
Enterprises Must Keep Their Options Open

- The IoE is an evolving marketplace and organizations must evolve with it.
- Choice is critical.
- Avoid getting locked in to one provider or one methodology.
- Need expert advice to capitalize on the evolution of the Cloud.

People as an Element

Behavior Adapts to Information

- People Must be Connected
  - Data transform into usable information leads to:
    - better-informed decisions
    - appropriate actions
- Information Transforms Behavior
  - Allows people to make informed decisions that bridge the differences between actual outputs and desired output
  - Feedback loop
    - real-time information based on current behavior
    - deliver actionable information to modify that behavior



People as an Element

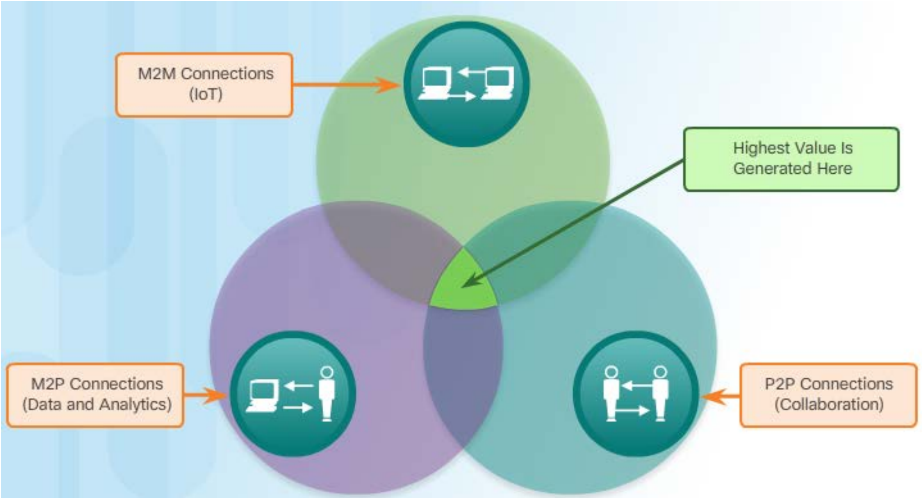
Organization Adapts to Information

- How Businesses Use Data
  - creates differentiated offerings based on customer needs
  - Target marketing
    - aimed at a specific group of people, separate from the market as a whole
    - based upon people who live in the same region, or have the same job title, or make a certain amount of money
  - Micromarketing – more precise version of marketing by businesses
    - loyalty cards
    - E-commerce
- Collaboration
  - Facilitate innovative new offerings that realize the potential of the IoE
  - Make organizations more aware of customer needs and opportunities
  - Allows organizations to identify potential problems and resolve them, foster better relationships

Process as an Element

The Role of Process

- M2M Connections
  - Data is transferred from one machine or “thing” to another over a network.
  - M2M is the most critical part of the Internet of Things.
  - Critical components include sensors, actuators, and controllers with network connections for communications and instructions
  - The most well-known type of M2M communication is telemetry.
- M2P Connections
  - Information is transferred between a machine and a person
  - Facilitate the movement, manipulation, and reporting of data from machines to help people make informed judgments
- P2P Connections
  - Information is transferred from one person to another, often called Collaboration.
- Timely and Relevant Information
  - Leverages the connections between data, things, and people to deliver the right information, to the right thing or person, at the right time



2.5 Chapter Summary

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Chapter Summary

Summary

- The four elements of the IoE are: People, Process, Data, and Things.
- Things
  - Devices are connected via wires or wirelessly so that they can communicate.
  - Devices that are not traditionally connected to the network require sensors, RFIDs, and controllers.
- Data
  - Big Data requires new products and techniques to manage, store, and analyze the data generated by the connected devices: virtualization and cloud computing.
  - Organizations collect and analyze vast stores of data for insights that can help identify trends, predict behavior, and empower decision makers.
- People
  - Connected people make behavioral transformations based on their access to information, and their changed behavior affects the information that is generated. This is known as a feedback loop.
  - Organizations use data generated by connected people to refine and target their marketing strategies.
- Process
  - Processes occur between people, things, and data.
  - The IoE brings them all together by combining M2M, M2P, and P2P connections.

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Chapter 3 Connecting the Unconnected

Introduction to the Internet of Things

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Chapter 3 - Sections & Objectives

- 3.1 Introduction to the Cisco IoT System
  - Explain the features and functions of the Cisco IoT System.
- 3.2 Introduction to Configuring Things
  - Configure devices to communicate in the IoT.
- 3.3 Programming
  - Apply basic programming codes.
- 3.4 Prototyping Your Ideas
  - Explain prototyping and its purpose.

3.1 Introduction to the Cisco IoT System

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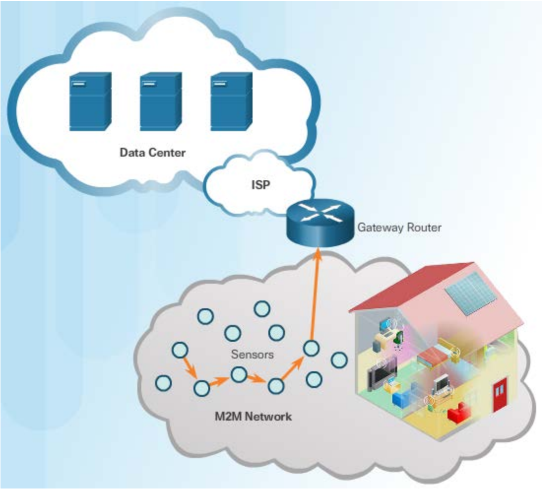
Things to Connect

- Connecting Things for Consumers
  - The home network probably has a router with both wired and wireless capabilities.
  - The home network connects to the Internet through a local Internet Service Provider (ISP).
  - Sensors can be part of the home network.
  - These sensors are part of the M2M networks that are unique to the IoT. The sensors can communicate with each other and send data through the gateway router (home router), through the ISP network, to a server environment in the Cloud. Here data can be accumulated and analyzed.
- Connecting Things for Industries
  - Requires reliability and autonomy
  - May require operations and calculations that happen too quickly to depend on human intervention.



The Cisco IoT System

- Challenges to Connecting Things
  - Integration of millions of things consisting of devices from different vendors each using custom applications
  - Integration new things to the existing network infrastructure
  - Security of these new devices, each configured with varying levels of security
- The Six Pillars of the Cisco IoT System
  - Help organizations and industries adopt IoT solutions by reducing the complexities of digitization
  - Provide an infrastructure designed to manage large scale systems of very different endpoints and platforms, and the huge amount of data that they create
  - Use the concept of pillars to identify foundational elements

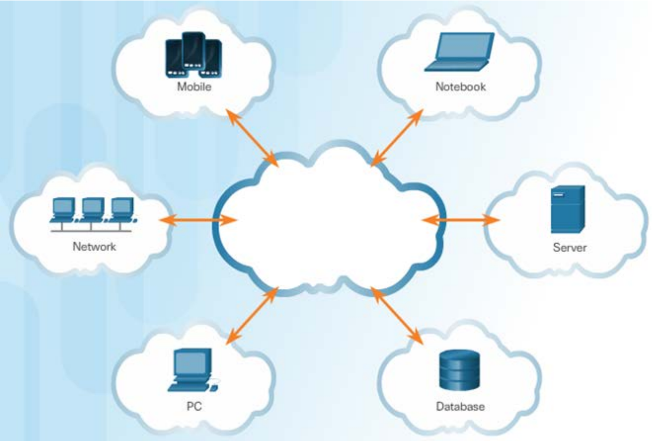
Introduction to the Cisco IoT System

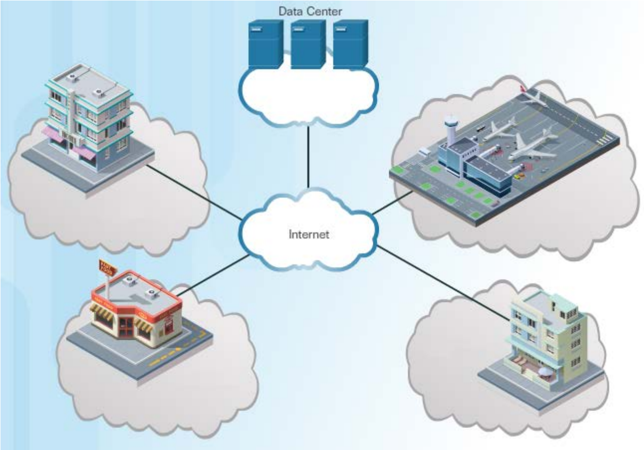
The Network Connectivity Pillar

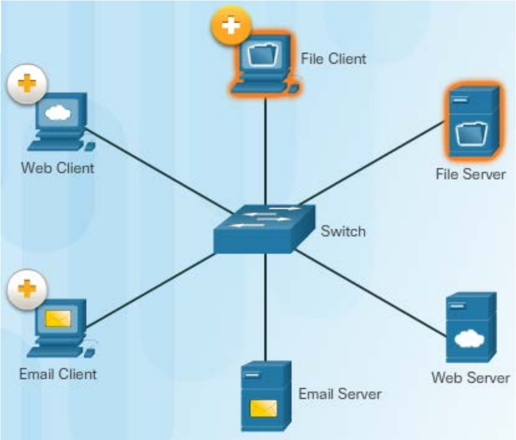
- Support the IoT in Industry
  - create a safe and more comfortable environment
  - provide network connectivity
- Industrial IoT Devices
  - Industrial routers – compact, ruggedized modular platforms on which industrial organizations can build a highly secure, reliable, and scalable communications infrastructure.
  - Industrial switches – compact, ruggedized switches that handle security, voice, and video traffic across industrial networks.
  - Industrial wireless – can be deployed in outdoor, harsh, and hazardous environments
  - Embedded networks – compact form factor switch and router cards

The Fog Computing Pillar

- Network Models - describe how data flows within a network.
- Can you describe the models? Can you match the figures to the models?







The Fog Computing Pillar (Cont.)

- Fog Applications
  - All Fog applications monitor or analyze real-time data from network-connected things and then take action
  - The action can involve machine-to-machine (M2M) communications and machine-to-people (M2P) interaction.
  - The Fog computing pillar provides a combination of hardware and software solutions.
  - Some Fog computing platforms support a special operating system called Cisco IOx. IOx enables an IoT router to run IOS and a Linux-based Fog application without interaction with the cloud.

Introduction to the Cisco IoT System

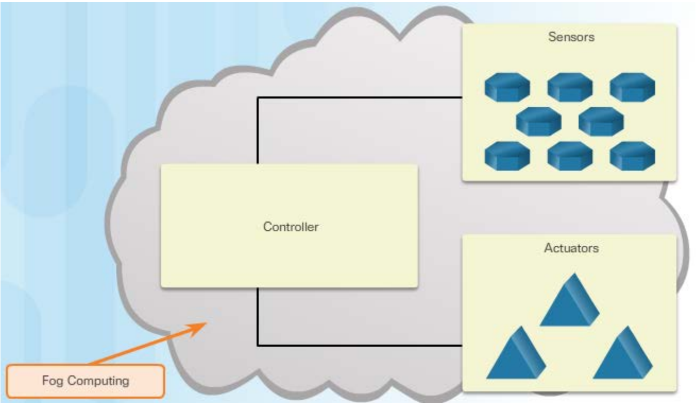
Other Cisco IoT System Pillars

- Security (Cyber and Physical) Pillar
  - offers scalable cybersecurity solutions, enabling an organization to quickly and effectively discover, contain, and remediate an attack to minimize damage.
  - Cybersecurity solutions include:
    - Operational Technology (OT) specific security
    - IoT Network security
    - IoT Physical Security
- Data Analytics Pillar
  - Process data rapidly and transformed into actionable intelligence
- Management and Automation Pillar
  - Deliver a broad range of IoT management and automation capabilities throughout the extended network.
  - Can be customized for specific industries to provide enhanced security and control and support.
- Application Enablement Platform Pillar
  - Provides the infrastructure for application hosting and application mobility between Cloud and Fog computing

Introduction to Configuring Things

Non-IP-Enabled Devices Communicate Across a Network

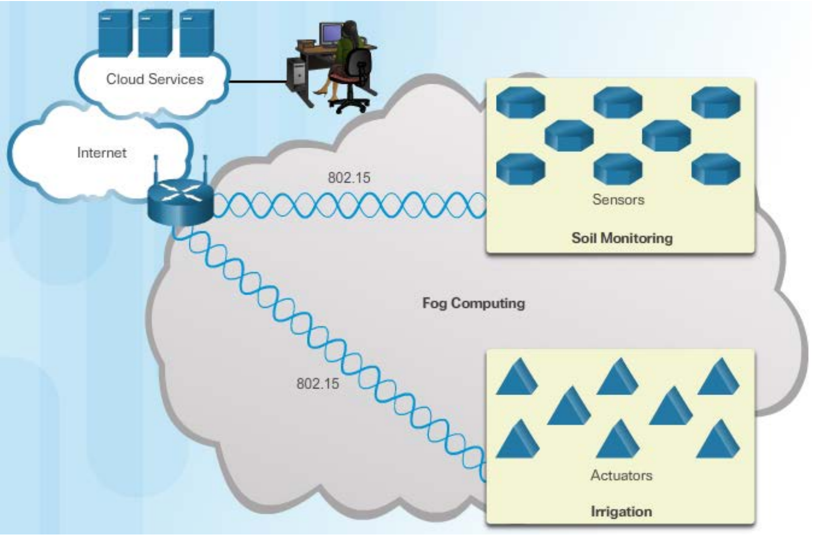
- Sensors
  - Purchased with pre-programmed specific instructions
  - Maybe configured to change their degree of sensitivity or the frequency of feedback.
- Actuators
  - Basic motors that can be used to move or control a mechanism or system, based on a specific set of instructions. Three types of actuators used in the IoT:
    - Hydraulic - Uses fluid pressure to perform mechanical movement.
    - Pneumatic - Uses compressed air at high pressure to enable mechanical operation.
    - Electrical - Powered by a motor that converts electrical energy to mechanical operation.
  - Do not process data, only perform actions signaled by the controller
- Controllers in the Fog
  - Can forward any information gathered from the sensors to other devices in the Fog



Introduction to Configuring Things

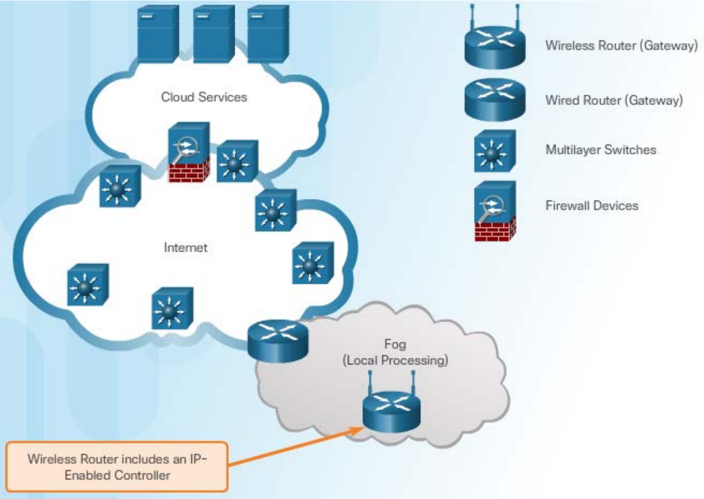
Configuring IP-Enabled Devices

- IP-Enabled Controllers
  - Forward information across an IP network
  - Allows individuals to access the controller remotely
  - May perform more complex operations in an M2M configuration
  - May consolidate information from multiple sensors or perform basic analysis of data received.
- IP-Enabled Sensors
  - Some sensors and actuators support TCP/IP.
  - The data these devices generate can be transported remotely for further processing
- IP Addressing
  - To communicate over an IP network, the IP-enabled devices must be configured with correct IP address information.
    - Static IP Addressing – configured manually
    - Automatic IP Addressing – assigned automatically by Dynamic Host Configuration Protocol (DHCP) server for IPv4 or IPv6 and Stateless Address Autoconfiguration (SLAAC) .



Configuring Infrastructure Devices

- Role of IoT Infrastructure Devices
  - Wireless and wired connectivity
  - Quality of service queuing
  - High availability
  - Secure transfer



- Routers
  - Route traffic from the local network to devices on remote networks
  - Collect information about the location of different networks and determine the best path

Introduction to Configuring Things

Configuring Small Business Routers

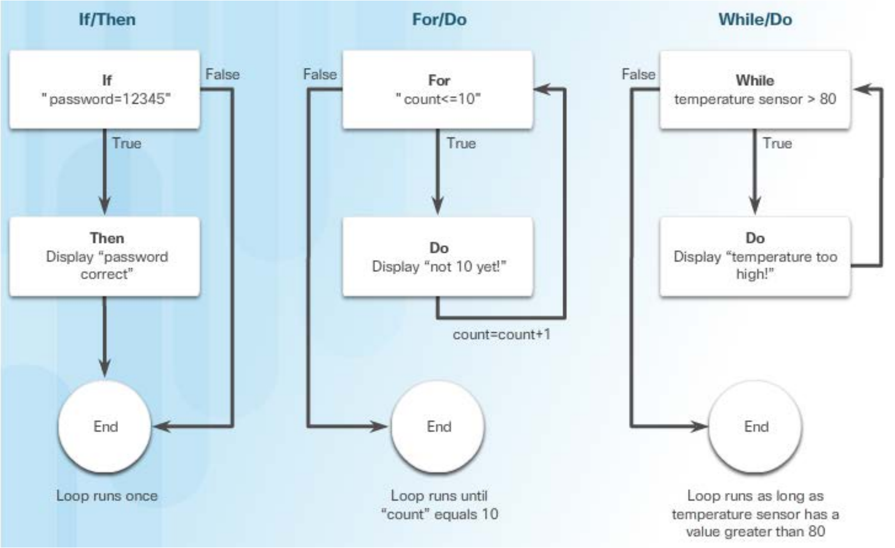
- Types of Ports
  - Small business and home routers typically have two primary ports:
  - **Ethernet Ports** - These ports connect to the internal switch portion of the router. All devices connected to the switch ports are on the same local network.
  - **Internet Port** - This port is used to connect the device to another network, such as the Internet.

- Settings
  - Wireless Network Name (SSID) - Name of the WLAN network
  - Wireless Password - Password clients use to connect to the wireless network
  - Router Password - Password used to manage the router
  - Wireless router provides DHCP services to connected local network clients when connected to the wireless router.
  - What can you do secure the router?
- Gateway
  - To reach a device on a different IP network, the devices must first forward the packet to the default gateway.
  - In a small business environment the default gateway is the router used to connect the LAN to the Internet.

Programming

What are Programs?

- Programming Facilitates the IoT
  - Sensors must be told what to capture and where to send that data.
  - A controller must be programmed with a set of instructions to receive that data and decide if it should process and relay that data to another device.
- What is a program?
  - A computer program is a set of instructions given to a computer, to be executed in a specific order.
  - Most common logical structures found in programming languages:
    - IF *condition* THEN *instructions* (If/Then)
    - FOR *expression* DO *instructions* (For/Do)
    - WHILE *condition* DO *instructions* (While/Do)
- Types of Programs
  - Firmware contains the instructions that the device performs as it boots up.
  - Operating Systems allow humans to interact with a computer.
  - Applications are designed and written to perform a specific task or service.
- Programming Languages
  - Can you name a few?

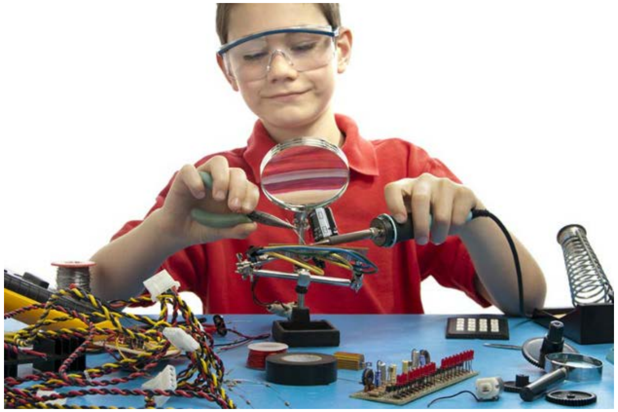


What is Prototyping?

- Defining Prototyping
  - Prototyping is the process of creating a rudimentary working model of a product or system.
  - Prototyping requires some design skills, electrical skills, physical/mechanical skills, programming skills, and to understand how TCP/IP works.
- How to Prototype
  - One method is “Rapid Prototyping Method”. Can you explain the process?
  - Some crowd funding programs - Kickstarter, Indiegogo, and Crowdfunder

Prototyping Your Ideas
Prototyping Resources

- Physical Materials
  - What materials would you use to prototype your ideas?
- Electronic Toolkits
  - Arduino - an open-source physical computing platform based on a simple microcontroller board and a development environment for writing software for the board to interact with a variety of switches or sensors to control lights, motors, and other physical objects.
  - Raspberry Pi is a low cost, credit-card-sized computer that plugs into a computer monitor or TV and can be operated with a standard keyboard and mouse.
  - The Beaglebone - very similar to the Raspberry Pi in size, power requirements, and application, but it has more processing power.
- Programming Resources
  - Khan Academy is a non-profit educational website that provides "a free, world-class education for anyone, anywhere".
  - Code Academy relies on interactivity to teach computer programming.



- What workshops are available in your community?

3.5 Chapter Summary

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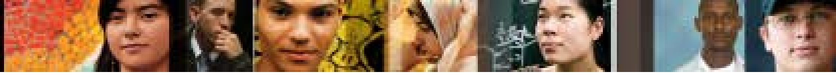

Summary

- The IoT is made up of a loose collection of disparate, use-specific networks. The M2M connection is a network type that is unique to the IoT.
- Cisco introduced an approach to the IoT which is named the Cisco IoT System. The six pillars of Cisco's IoT System are:
  - Network Connectivity
  - Fog Computing
  - Security (Cyber and Physical)
  - Data Analytics
  - Management and Automation
  - Application Enablement
- Protocols refer to the rules of communication that devices use and are specific to the characteristics of the conversation.
- A group of interrelated protocols is called a protocol suite, which helps ensure interoperability between network devices.

Chapter Summary

Summary (Cont.)

- Cloud computing is a type of client-server model in which servers and services are dispersed all over the globe in distributed data centers. Fog computing extends Cloud computing and services to the edge of the network.
- End devices, sensors, RFID tags, and actuators can use controllers that are in the Fog. These IP-enabled controllers are able to forward information across an IP network, and allow individuals to access the controller remotely.
- Infrastructure devices are primarily responsible for moving data between the controller devices and other end devices across the network.
- Sensors must be told what data to capture and where to send that data. A controller must be programmed to receive that data and decide if it should relay a message to another device.
- A computer program is a set of instructions given to a computer, to be executed in a specific order. These languages allow humans to write instructions in a way that computers can understand.
- Programming is critical to the IoE. There are many other free resources that can help you get started with programming. Three of the most popular platforms are Arduino, Raspberry PI, and Beaglebone.

Chapter 4: Transitioning to the IoE

Introduction to the Internet of Things

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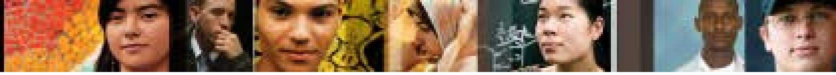

Chapter 4 - Sections & Objectives

- 4.1 The IoE Connections
  - Explain the characteristics of given IoE solutions.
- 4.2 Implementing an IoE Solution
  - Explain an IoE solution to address real-world opportunities.
- 4.3 IoE Security
  - Explain how the IoE increases the need for additional security measures.

4.1 The IoE Connections

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The IoE Connections

IT and OT in IoE

- IT and OT
  - IT - The network infrastructure, telecommunications, and software applications that allows the exchange of information between humans.
  - OT - Industrial control and automation infrastructure that allows communications between machines.

- Converging IT and OT
  - Simplify the Infrastructure (Simple)
  - Create Intelligence and Agility (Smart)
  - Deliver End-to-End Security (Secure)

M2M, M2P, and P2P Interactions in an IoE Solution

- M2M Connections
  - sensors, actuators, and controllers
  - a network communications link
  - programming that instructs a device how to interpret data, and based on predefined parameters, forward that data.
- M2P Connections
  - People can send information to technical systems and receive information from these systems.
  - The gathered intelligence from M2M connections allows people to make optimal decisions.
- P2P Connections
  - Collaboration via voice, video, and data
- P2P Interactions in IoE Solutions
- M2M, M2P, P2P Interacting to Form Solutions
  - Provides organizations and individuals with actionable insights and seamless automation.

Implementing an IoE Solution
Preparing for the Transition to the IoE

- Understanding Existing Business Processes
  - Who their suppliers and customers are
  - What their customers need
  - What the schedule and process steps are for creating and delivering an offering
- Understanding Existing IT and OT Networks
  - Understand how IT network users interact with the network resources and services
  - Gather information about all internal and external access to the existing network infrastructure.
  - Understand how current networks of OT systems operate.
- Business Goals and Opportunities
  - Profitability
  - Business growth and market share
  - Customer satisfaction

Implementing an IoE Solution
Preparing for the Transition to the IoE (Cont.)

- Technical Requirements and Potential Constraints

Implementing an IoE Solution

Planning an IoE Solution

- The IoE Architectural Approach
  - Application Layer
  - Platform Layer
  - Infrastructure Layer
- Adjusting Technologies
  - Standard Infrastructure
  - Responsive Software
  - Holistic Security
- Connecting Processes
  - Interaction between people, data, and things
  - Visibility into new processes

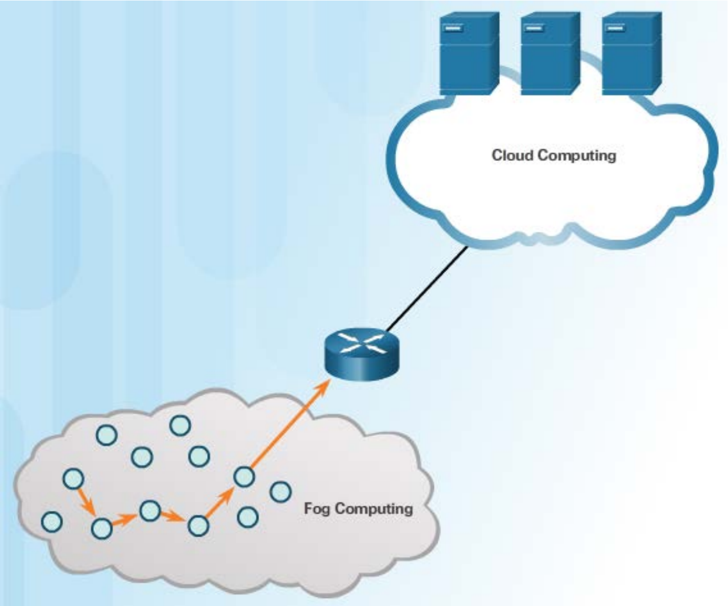
Implementing an IoE Solution

IoE Examples Across Industries

- The IoE in Retail
  - Retailers have the opportunity to create new and better connections in their stores, corporate offices, distribution centers, and other environments.
- The IoE in Manufacturing
  - Products and services can include embedded sensors that provide manufacturers with constant data and feedback.
- The IoE in the Public Sector
  - Create new and better connections with the public
- The IoE for Service Providers
  - Deliver rich, new services to the customers
- The Cisco IoT System in IoE Solutions
  - Critical part to the IoE solutions

Challenges to Implementing IoE Solutions

- Proprietary Ecosystems = Proprietary Protocols
  - convert proprietary networks to IP-based networks
  - proprietary protocols can communicate through a translator
- Accelerated Technological Growth
- Growth Relevancy to IoE
  - Moore's and Metcalfe's Laws allows the prediction of:
    - Computing powers
    - Availability of new technology
    - Advances of competitors
- Big Data Challenges
  - Bandwidth capacity
  - User data privacy
  - Data Management
  - Selection and analysis of appropriate data
- More connected things = Bandwidth Requirements
- Cloud vs Fog Computing
  - Where should the data be processed? – away (cloud computing) or close to the source (fog computing)
- The Learning Society – Training is necessary to take advantage of the opportunities in IoE



Security and the IoE

IoE Security

- Need for Additional Security
  - Increased amount of connected devices and data = increased demand for security of data
  - Hacking attacks are a daily occurrence
  - No organization is immune
- Security Strategy
  - Adaptable & Real-Time Security
  - Secure & Dynamic Connections
  - Protecting Customer & Brand Trust

Security and the IoE

IoE Security (Cont.)

- Pervasive security solution avoids disjointed security implementations.
  - Consistent, automated, and extend to secured boundaries across organizations
  - Dynamic, to better recognize security threats through real-time predictive analytics
  - Intelligent, providing visibility across all connections, and elements of the infrastructure
  - Scalable, to meet the needs of a growing organization
  - Agile, able to react in real-time
  - Comprehensive, end-to-end solution

Security and the IoE

Security Measures

- Security Architecture
  - Access Control
  - Context-Aware Policies
  - Context-Aware Inspection and Enforcement
  - Network and Global Intelligence
- Security Devices
  - Firewalls
  - Intrusion Prevention System (IPS)
- Application-Centric Security
  - protect environments by fully integrating customized security technologies for the needs of a specific application
- Wireless Security – What security would you implement at the access point?
- Redundancy and High Availability
  - Redundant equipment and network connections
  - Load sharing
  - Secured backups of data in an encrypted format

People and the IoE

- People are the Weakest Link
  - Malicious intent
  - Mistakes or follow unsecure practices
- Security Policy – rules, regulations, and procedure
  - Remote Access Policy
  - Information Privacy Policy
  - Computer Security Policy
  - Physical Security Policy
  - Password Policy
- Personal Data and the IoE
  - Volunteered
  - Observed
  - Inferred

4.4 Chapter Summary

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Chapter Summary
Summary

- The IoE requires a convergence of the OT and IT systems that an organization has in place.
- M2M refers to any technology that enables networked devices to exchange information and perform actions without the manual assistance of humans. In M2P connections, technical systems interact with individuals and organizations to provide or receive information. P2P connections are collaborative solutions that leverage the existing network infrastructure, devices, and applications, to allow seamless communication and collaboration between people. Each of these types of connections is transactional.
- Steps in implementing an IoE solution are to understand current processes and procedures and consider the existing IT network infrastructure, network operations, and network management tools.
- Security must be able to react in real-time, so it must be high-performance and scalable. A security policy defines all of the rules, regulations, and procedures that must be followed to keep an organization, people, and systems secure.
- The definition of personal data is evolving.

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Chapter 5: Bringing it all Together

Introduction to the Internet of Things

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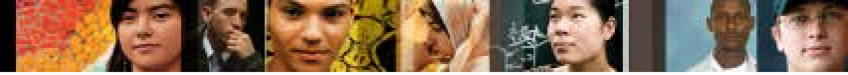

Chapter 5 - Sections & Objectives

- 5.1 Modeling an IoE Solution
  - Explain a given IoE solution.
- 5.2 Digitally Transforming Everything
  - Explain the advantages of digitization.
- 5.3 Want to Go Further?
  - Explain IoE educational and employment opportunities.

5.1 Modeling an IoE Solution

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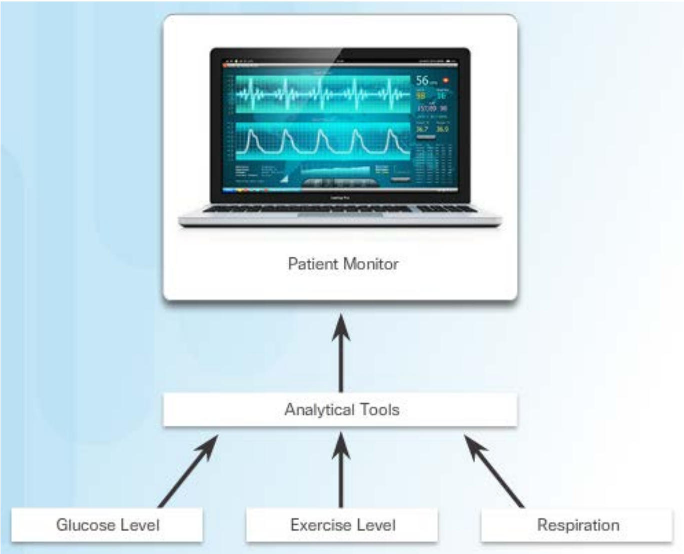
Modeling an IoE Solution

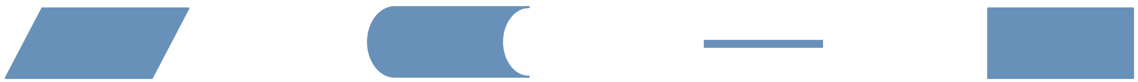
IoE Interactions in a Healthcare Model

- A Diabetic Patient Healthcare Solution Model
  - M2M Interactions – The traffic signal changes as mobile treatment center is approaching.
  - M2P Interactions – The health monitor company collects the data to allow for better treatment
  - P2P Interactions – Doctor to patient interaction
- Analytical Tools
  - Descriptive - Uses historical data to create reports designed to facilitate understanding
  - Predictive - Uses data mining and modeling techniques to determine what could happen next
  - Prescriptive - Uses simulation, business rules, and machine learning to recommend a course of action and predict the possible outcome
- Analytics in Healthcare
  - Monitor patient's health by analyzing the stream of data gathered from sensors
  - Other uses: faster response time in an emergency

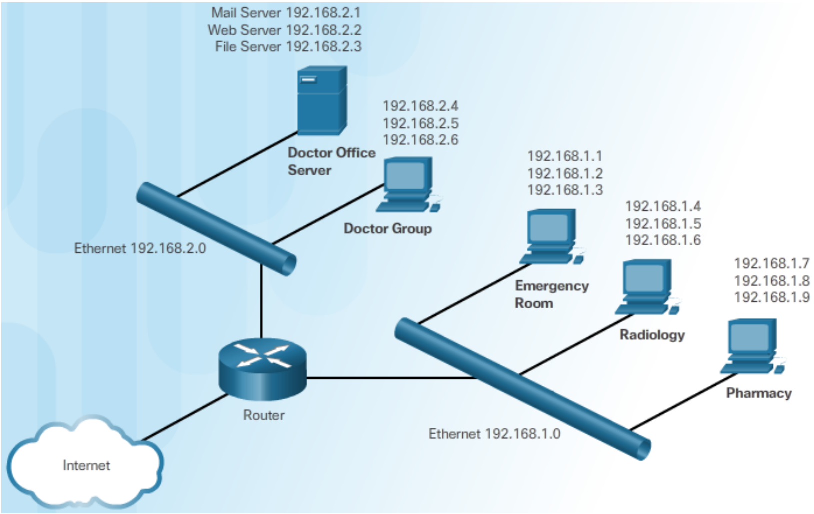


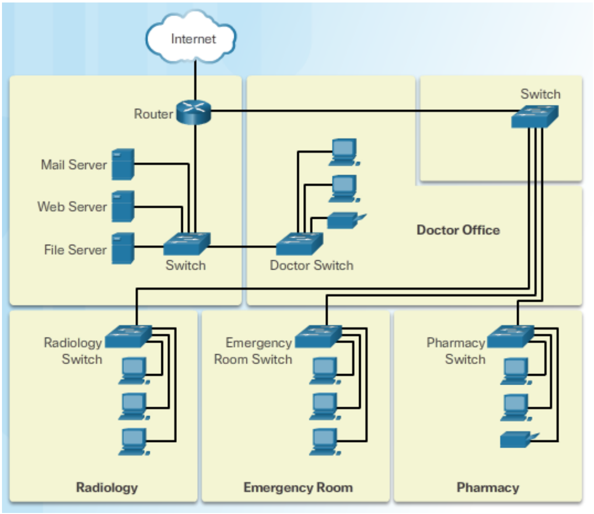
Modeling an IoE Solution
Modeling

- What are the benefits of good modeling?
- Can you name and describe these symbols in a flowchart?



- Network Topology – Map that identifies various elements of a computer network
  - Physical Topology - Displays the layout and location of all of the devices and how they are connected
  - Logical Topology – Represents how the data flows through the network
  - Can you the type of network topology represented below?





Digitally Transforming Everything
The Path is Clear

- Let’s get Digital
  - IoE – When people, process, data, and things are all intelligently connected.
  - Digitization – The process by which an organization becomes digital.
  - Digital – An ideal end-state whereby an enterprise is fully technology-enabled and optimized
- What are some of the benefits of Digital Transformation?

Want to Go Further?

Learning Opportunities

- The Cisco Networking Academy Program
  - Prepares individuals for information and communication technology (ICT) careers
  - Addresses the growing demand for ICT professionals
- IT Industrial Certifications
  - Vendor neutral
  - Vendor specific
- Name a few other learning opportunities.

Want to Go Further?
IoE Occupations

- IT Industry Jobs for the IoE
  - Process development
  - Specialization
  - Computer science, computer engineering
  - Software engineering
- Create Your Own IoE Job
  - New kind of IT specialist
  - Skillsets to create new products and process the data

5.4 Chapter Summary

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Chapter Summary

Summary

- The Healthcare model that is used in this chapter details M2M, M2P, and P2P interactions. It models every aspect of patient monitoring from basic vital signs to dispatching healthcare professionals to treat patients.
- Descriptive, predictive, and prescriptive analytics help shape how a business functions.
- Modeling the potential IoE solution identifies the changes in the organization’s processes. A flowchart uses symbols to represent workflows and decisions.
- A network topology is a kind of map. There are two types of network topologies, physical and logical. The physical topology displays the layout and location of all of the devices that comprise the network. The logical topology represents the way data flows through the network.
- To prototype ideas for the IoE, it helps to have design skills, electrical skills, physical/mechanical skills, programming skills, and an understanding of how TCP/IP works.
- The Cisco Networking Academy helps individuals prepare for industry-recognized certifications and entry-level information and communication technology (ICT) careers in virtually every type of industry. The Internet of Everything is creating demand for a broad spectrum of IT jobs, and creating opportunities for exciting new jobs in emerging fields.

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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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What are Things?

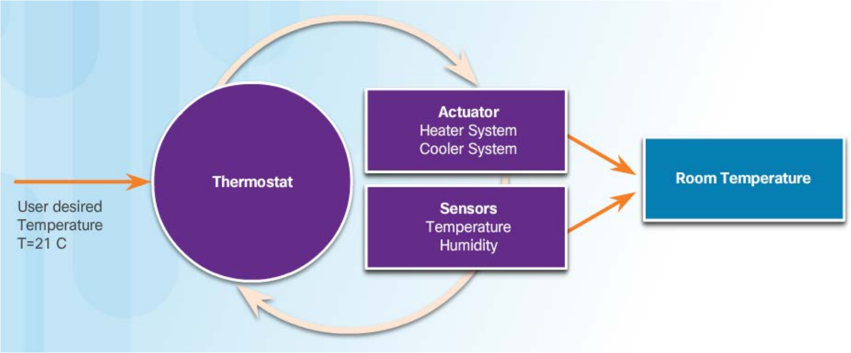
1.1.1 The Internet of Things

- The Presence of IoT in Today's World
  - The IoT is all around us.
  - The IoT helps individuals to improve quality of life.
  - The IoT also helps industries to become more efficient.
- Cisco IoT Solutions
  - The rapid IoT growth has introduced new challenges.
  - Cisco IoT System reduces the complexities of digitization.
  - Six Pillars of the Cisco IoT System are:
    - Network Connectivity
    - Fog Computing
    - Cybersecurity and Physical Security
    - Data Analytics
    - Management and Automation
    - Application Enablement Platform

What are Things?

1.1.2 Building Blocks of an IoT System

- Overview of a Controlled System
  - Feedback loops are used to provide real-time information to its controller based on current behavior.
  - In a closed loop, feedback is continuously being received by the controller from its sensors.
  - The controller continuously analyzes and processes information, and use actuators to modify conditions.
- Sensors
  - A sensor is a device that can be used to measure a physical property by detecting some type of information from the physical world.
  - A sensor may be connected to a controller either directly or remotely.



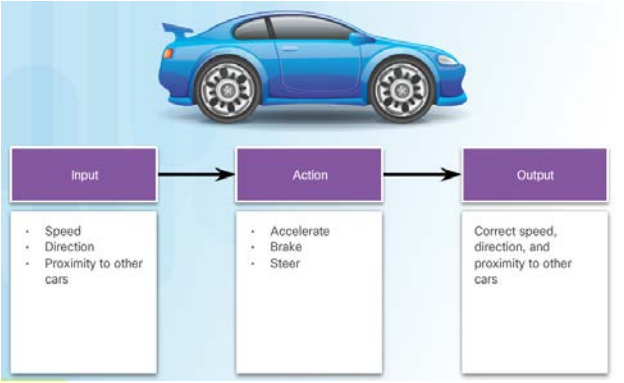
What are Things?

Building Blocks of an IoT System (Cont.)

- Actuators
  - An actuator is a basic motor that can be used to control a system.
  - Can be hydraulic, electric or pneumatic.
  - can be responsible for transforming an electrical signal into physical output.
- Controllers
  - Responsible for collecting data from sensors and providing network connectivity.
  - Controllers may have the ability to make immediate decisions.
  - May also send data to remote and more powerful computer for analysis.

- 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.

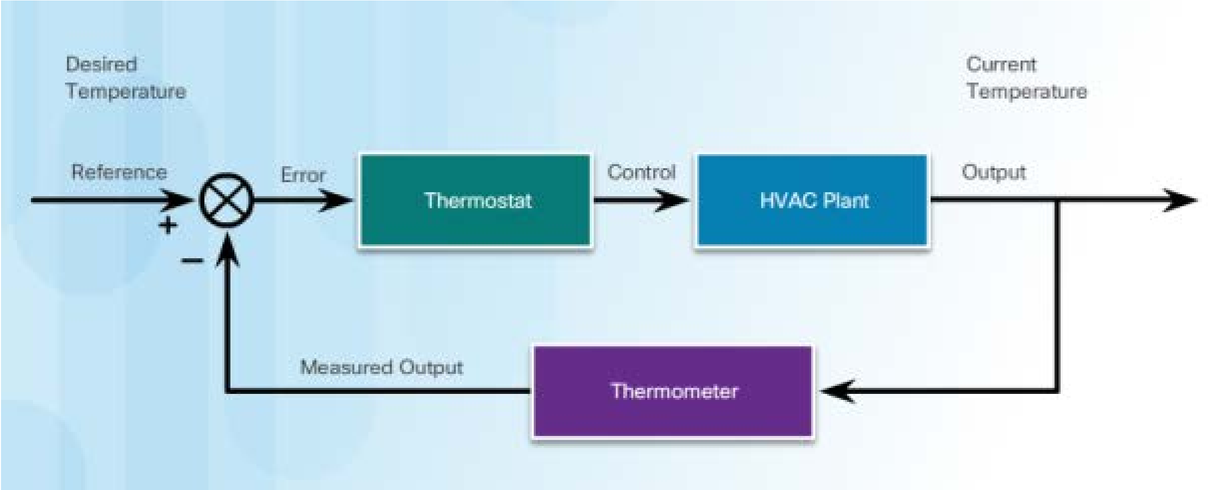
1.1.3 Processes in Controlled Systems



- Processes
  - A process is a series of steps or actions taken to achieve a desired result by the consumer of the process.
- Feedback
  - Feedback is when the output of a process affects the input.
  - Feedback is often referred to as a feedback loop.
  - Feedback loops can be positive or negative.
- Control Systems
  - Includes a controller that uses inputs and outputs to manage and regulate the behavior of the system in an attempt to achieve a desired state.
  - The controlled portion of the system is often called the plant.
  - Choosing the adjustments to apply to a plant to achieve a desired output is called control theory.
  - Control theory is applied to many systems, including driving a car.

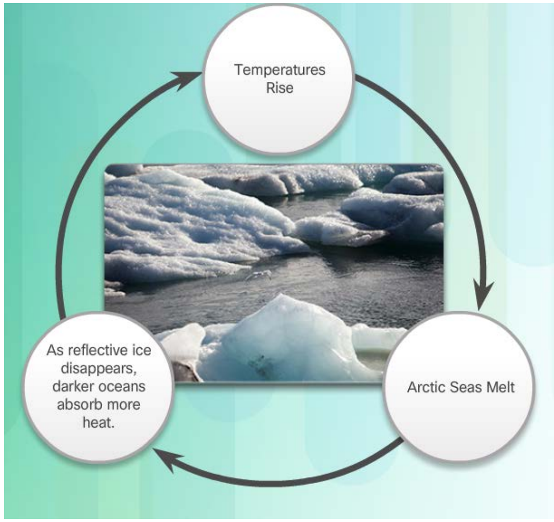
Processes in Controlled Systems (Cont.)

- Open-Loop Control Systems
  - Open-loop control systems do not use feedback.
  - The plant performs a predetermined action without any verification of the desired results.
  - Open-loop control systems are often used for simple processes.
- Closed-Loop Control Systems
  - A closed-loop control system uses feedback to determine whether the collected output is the desired output.
  - The result is then fed back into a controller to adjust the plant for the next iteration of output, and the process repeats.



Processes in Controlled Systems (Cont.)

- Closed-Loop Controllers
  - There are 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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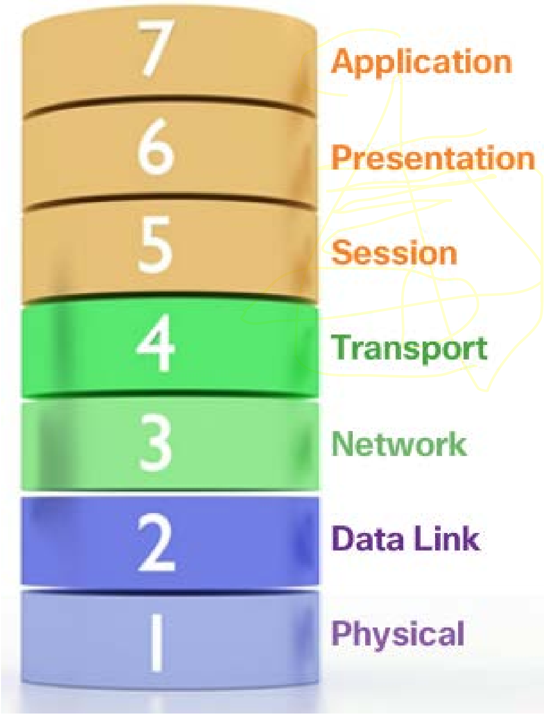
1.2.1 Models of Communication

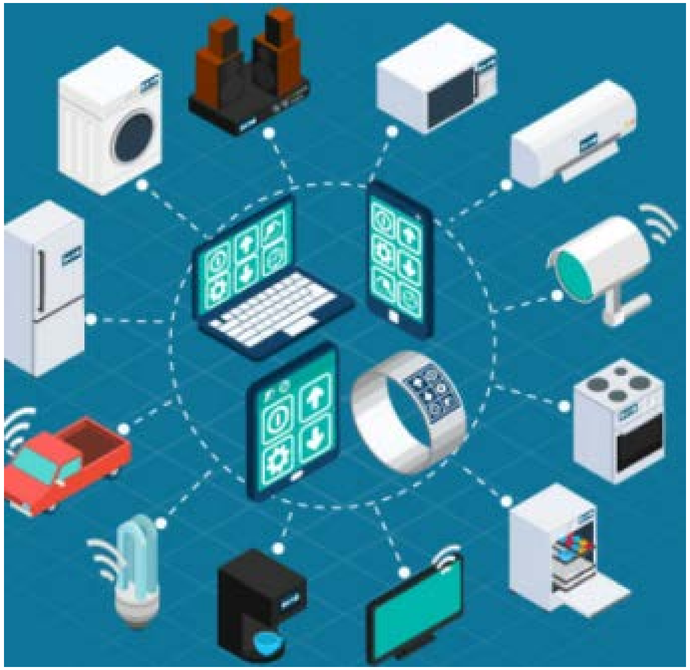
- Models of Communication
  - Layered networking models are used to illustrate how a network operates. Benefits include:
    - Assists in protocol design.
    - Fosters competition.
    - Promotes technology or capability independence.
    - Provides a common language to describe networking functions and capabilities.



What are Connections?

1.2.1 Models of Communication (cont'd)

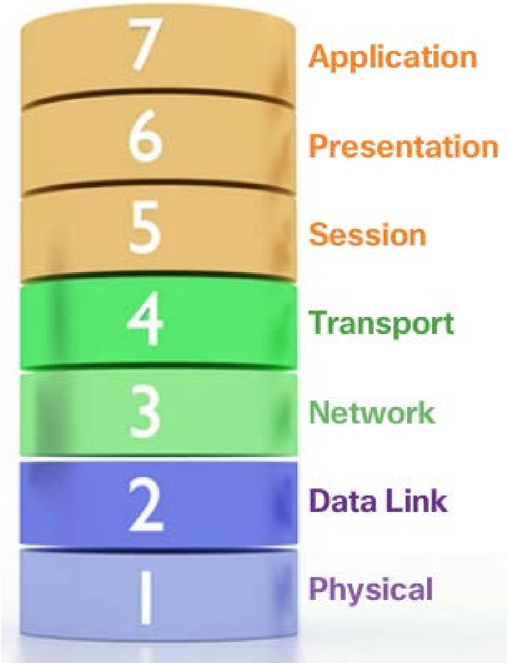
- Standardization
  - The challenge for the IoT is to ensure these emerging IoT devices can connect securely and reliably to the Internet and to each other.
  - Consistent, secure, and commonly recognized technologies and standards is needed.
  - Organizations such as the Industrial Internet Consortium,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



What are Connections?

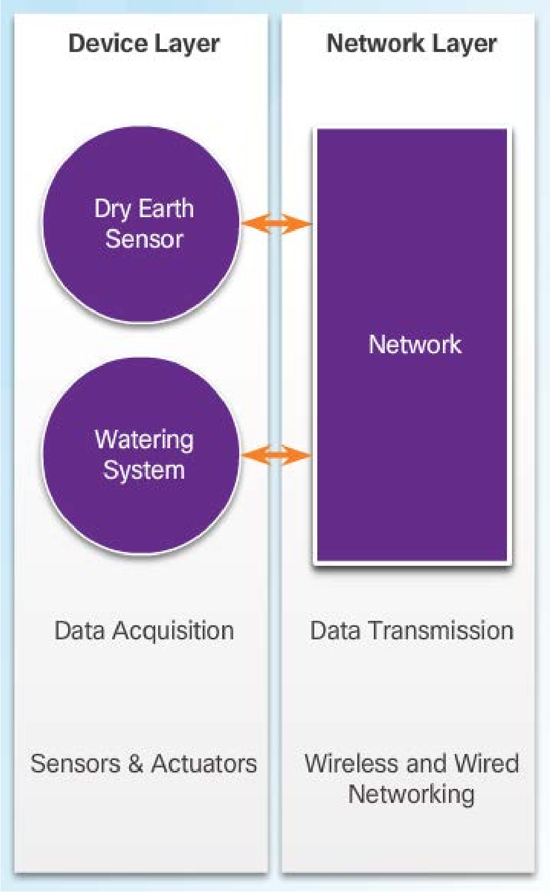
Models of Communication (Cont.)

- TCP and OSI Models
  - 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 OSI model provides an extensive list of functions and services that can occur at each layer.
- IoT World Forum Reference Model
  - 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.



What are Connections?
Models of Communication (Cont.)

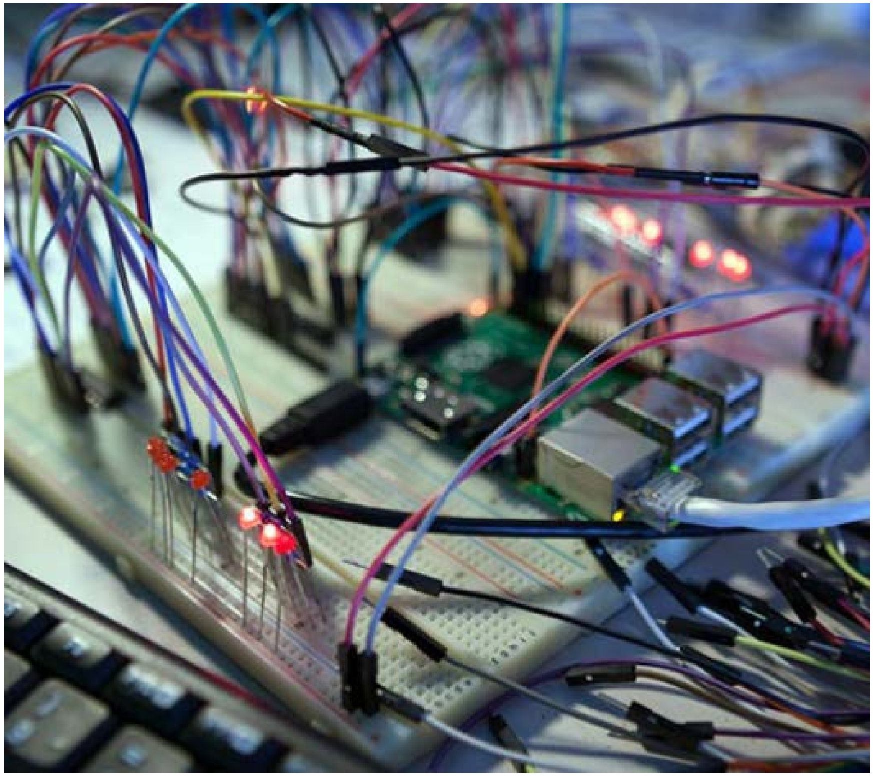
- Simplified IoT Architecture
  - Several architectures exist to help facilitate the design and creation of IoT systems.
  - The OSI model, TCP/IP model, and the IoT World Forum Reference model have been presented as examples.
  - A simpler approach is based on connection levels. The levels are:
    - Device-to-Device
    - Device-to-Cloud
    - Device-to-Gateway-to-Cloud
    - Device-to-Gateway-to-Cloud-to-Application



What are Connections?

1.2.2 Layers of Connections

- Connections Within Networks
  - Connections can have different contexts.
  - Power connections, circuit connections or network connections.
- Physical Connections
  - Relate to the media and cable type.
  - Common media types include copper, fiber optics and wireless.



What are Connections?

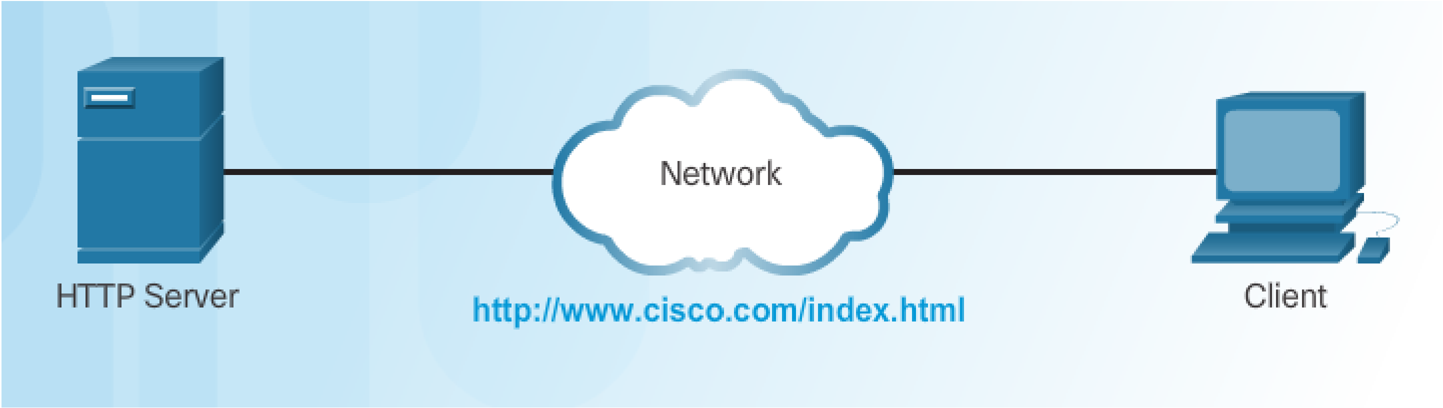
Layers of Connections (cont'd)

- Data Link and Network Connections
  - 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
  - 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.

What are Connections?

Layers of Connections (Cont.)

- 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.
  - MQTT and REST are newer application protocols, created to support IoT devices that connect in the myriad of different types of remote configurations.
  - MQTT is a lightweight messaging protocol with minimal overhead that provides high data integrity and security for remote environments.
  - 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?
  - Metadata refers to the data about data.
  - Metadata can be embedded within a digital object or it can be stored separately.
  - Metadata is not usually seen by a user.
- The Impact of IoT on Privacy
  - Suggestions and design considerations concerning privacy include:
    - Transparency
    - Data Collection and Use
    - Data Access
- 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

1.3 Chapter Summary

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Chapter Summary
Summary

- The Internet of Things (IoT) is all around us. An IoT system is usually made up of sensors to monitor events, actuators to influence the environment, hardware to create the platform and its connections, and software to provide a framework to execute processes.
- A process is a series of steps or actions taken to achieve a desired result.
- Layered networking models are used to illustrate and model how devices communicate. Physical, data link, and network layers are concepts that are used to illustrate how network communication operates.
- 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..

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Chapter 2: Sensors, Actuators, and Microcontrollers

IoT Fundamentals

Connecting Things 2.0

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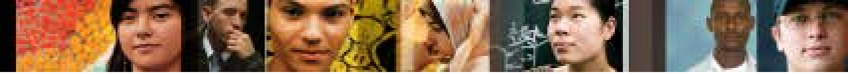

Chapter 2 - Sections & Objectives

- 2.1 Learn Electronics
  - Explain how components and devices are used to build and measure values in electronic circuits.
- 2.2 Microcontrollers: The SparkFun Inventor’s Kit
  - Create circuits and microcontroller programs with the Arduino and a variety of components.
- 2.3 Packet Tracer 7.0 and the IoT
  - Explain how Packet Tracer models IoT systems.

2.1 Learn Electronics

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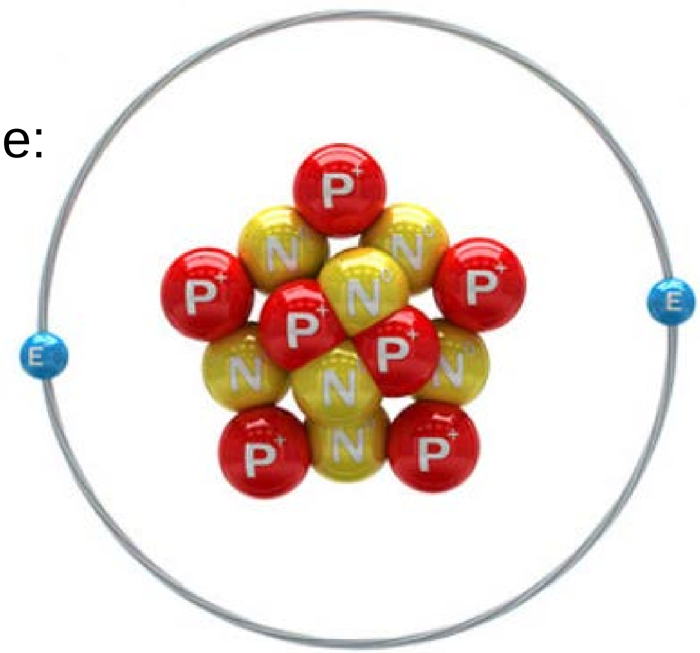
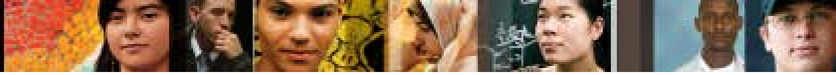
2.1.1 Basic Electronic Terminology & Concepts

- What is Electronics?
  - Electronics is the field of study focused on the control of electricity and the physical components and circuits that help direct electrical energy.
- Definitions
  - Terms commonly used in electronics include:
    - Electrons, atoms, and chemical elements
    - Electric current
    - Electrical conductors, insulators, and circuits
    - Voltage, Amperes (amps), and Power





Learn Electronics
Basic Electronic Terminology / Concepts (cont'd)

- Ohm's Law
  - Ohm's Law states that within a circuit, voltage (V) is directly proportional to the strength of current (I) multiplied by resistance (R).
  - Resistance is measured in ohms (Ω)
- Basic Circuit
  - An electrical circuit is a closed conductive path that allows electrons to flow and create an electric current.
  - A circuit also needs an electrical energy source like a battery to start the flow of electricity.

$$V = I \times R$$

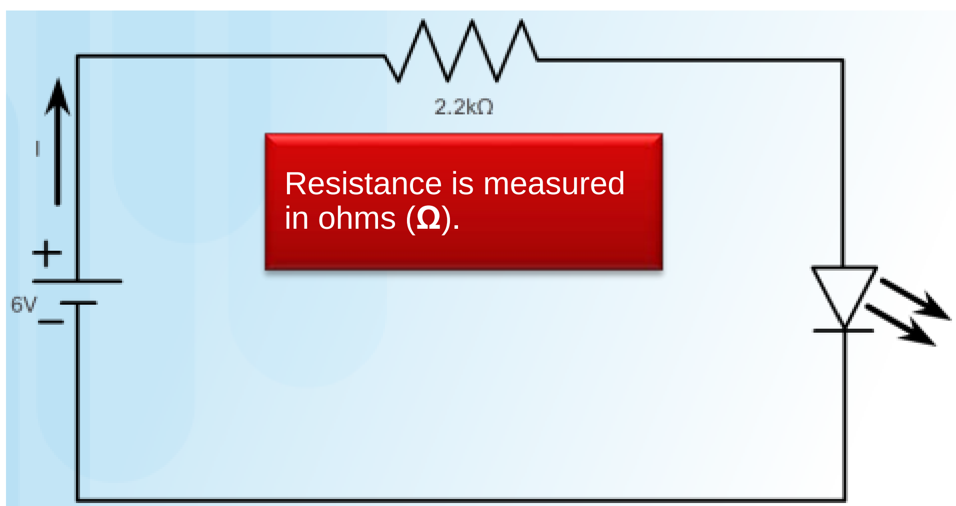
$$R = V / I$$

$$I = V / R$$

Learn Electronics
Basic Electronic Terminology / Concepts (cont'd)

- Basic Circuit (Cont.)
  - The following circuit diagram (schematic) consists of:
    - 6 volt (V) battery provides current
    - 2.2 kΩ resistor (protects the LED from receiving too much current and being destroyed)
    - A light-emitting diode (LED)

Current (I) flows from the positive terminal to the negative terminal

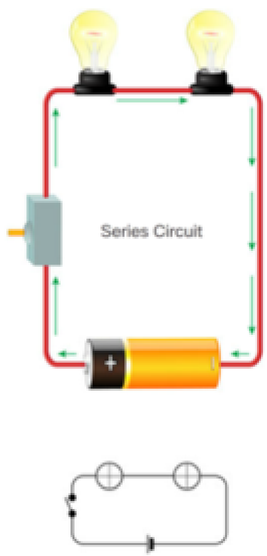
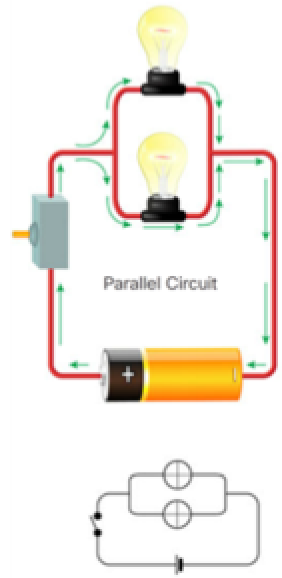


Resistance is measured in ohms (**Ω**).

The triangular part represents a diode and the two arrows facing out represent the fact that this diode emits light.

2.1.2 Advanced Electronic Terminology /Concepts

- Series and Parallel Circuits

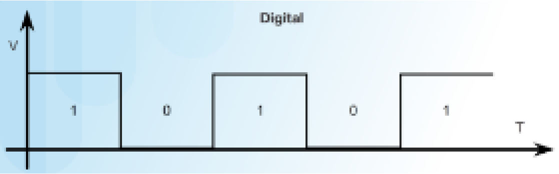
Series Circuit:	Parallel Circuit:
• Components are interconnected one after another in a path between the positive and negative terminals of the power source	• Current flows from the battery terminal but splits at a junction which leads to parallel pathways through the circuit. • Components connected along each pathway each get their own share of current
	

Advanced Electronic Terminology/Concepts (cont’d)

- Passive, Active, Linear, and Nonlinear Circuits
  - Active circuits contain active components; components that rely on external power source to control current flow.
  - Passive circuits contain passive components; components incapable of controlling current flow.
  - Analog circuits are circuits where the signal is contiguous.
- Direct Current vs. Alternating Current
  - In DC current, electron flow is only in one direction.
  - Batteries, power supplies, thermocouples, solar cells, or dynamos generate DC.
  - In AC current, electron flow periodically reverses direction.
  - Hydroelectric plants generate AC.

Advanced Electronic Terminology/Concepts (cont'd)

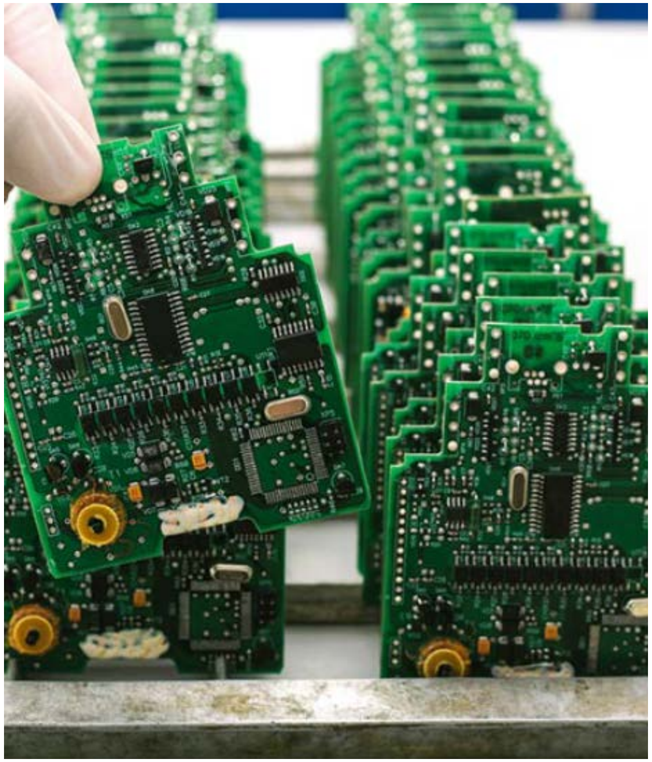
- Analog Circuits vs. Digital Circuits
  - Analog Circuits**:** Circuits in which signals vary continuously with time.
  - Digital circuits: Circuits in which signals that take one of two discrete values.
- Components
  - Electronic components are specialized devices used in a circuit to control current.
  - Components have two or more electrical terminals (leads) that enable them to connect to an electronic circuit.
- Larger Electronic Building Blocks
  - Solenoids can be used to electrically open door latches, open or shut valves, move robotic limbs, and even actuate electric switch mechanisms.
  - Relays allow for controlling a large amount of current and/or voltage with a small electrical signal.



Learn Electronics

2.1.3 From Schematic Diagram to Breadboard to Soldered PCB

- Design Phase:
  - Consists of three steps: Concept, Research, Circuit Design.
  - A circuit diagram shows the components and interconnections of the circuit using standardized symbolic representations.
- Prototype Phase:
  - Consists of four steps: Hardware, Mechanical, and Software Development, PCB layout, Build prototypes, Product Testing
  - A solderless breadboard is a tool commonly used in electronic prototyping.
- Production Phase:
  - Consists of three steps: Production Readiness Review, Production, On-going Maintenance.
  - Often employ on printed circuit boards (PCBs).



2.2 Microcontrollers: The SparkFun Inventors Kit

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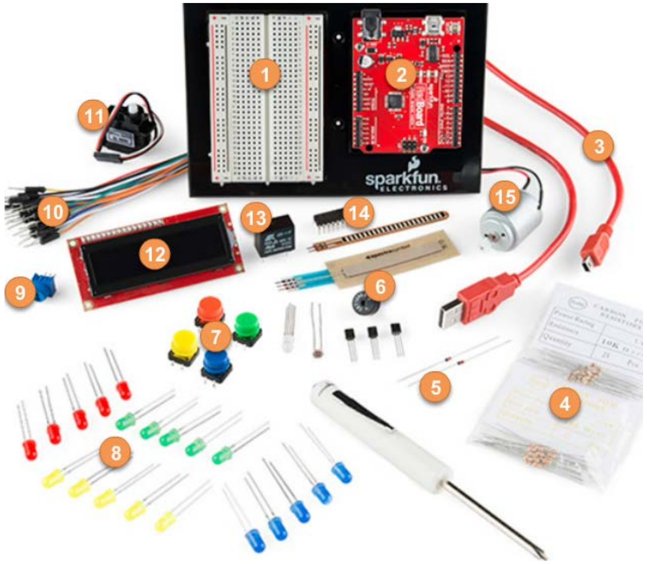
Microcontrollers: The SparkFun Inventors Kit

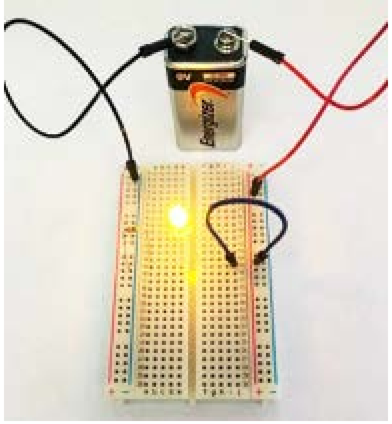
2.2.1 Introducing the Kit

- Introduction to the SparkFun Inventor’s Kit (SIK)
  - This is a starter kit for building circuits and includes:
    - Solderless breadboard
    - SparkFun RedBoard (Arduino-like board)
    - Various resistors, diodes, LEDs, sensors and actuators
    - Connecting wires (jumper wires, mini-B cable, …)
- Arduino Microcontroller
  - The Arduino is a popular microcontroller for prototyping.
  - Instructions for the Arduino are programmed using the Arduino integrated development environment (IDE).
  - The SparkFun RedBoard is an Arduino-like board that can be programmed using Arduino IDE.



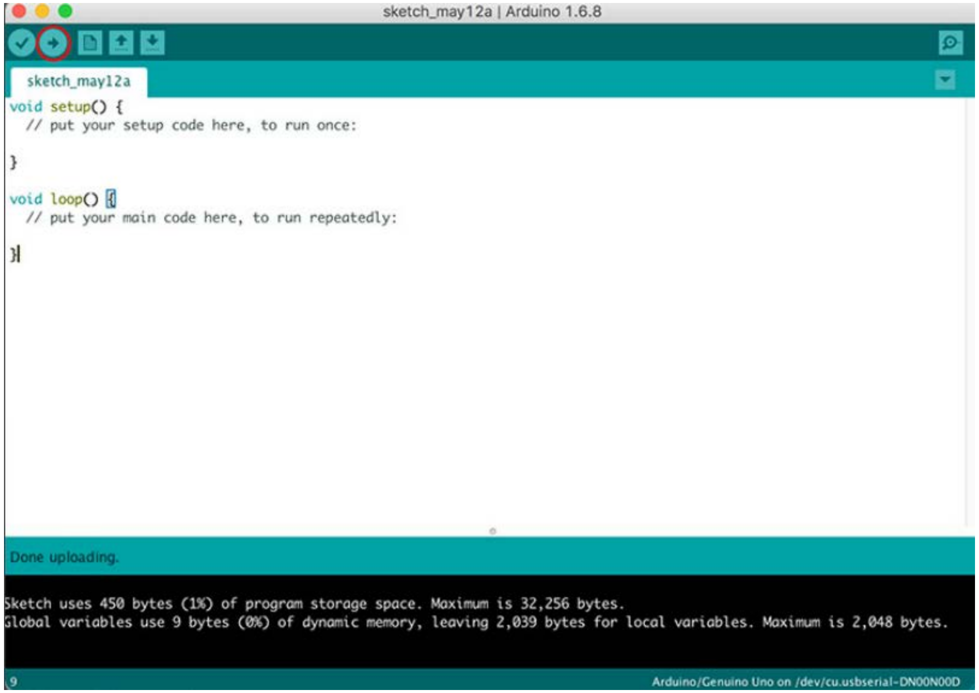
2.2.2 Simple Circuits

- Building a Circuit
  - A simple circuit can be created by:
    - Connecting electronic components (LED, resistor, and jumper wires) in series along a row on the breadboard.
    - Connecting the power source to the lower red and black jumper wires.
    - This should complete the circuit and light the LED.
- The Arduino IDE
  - Free, downloadable software used to interact with the Arduino board.
- Writing code
  - Programs written using the Arduino IDE are called sketches and are saved with the file extension of .ino.
  - Arduino sketch keywords can be divided in three main category types: structures, values (variables and constants), and functions.
  - Keywords used include void, setup(), loop() function, and more.



Simple Circuits (cont'd)

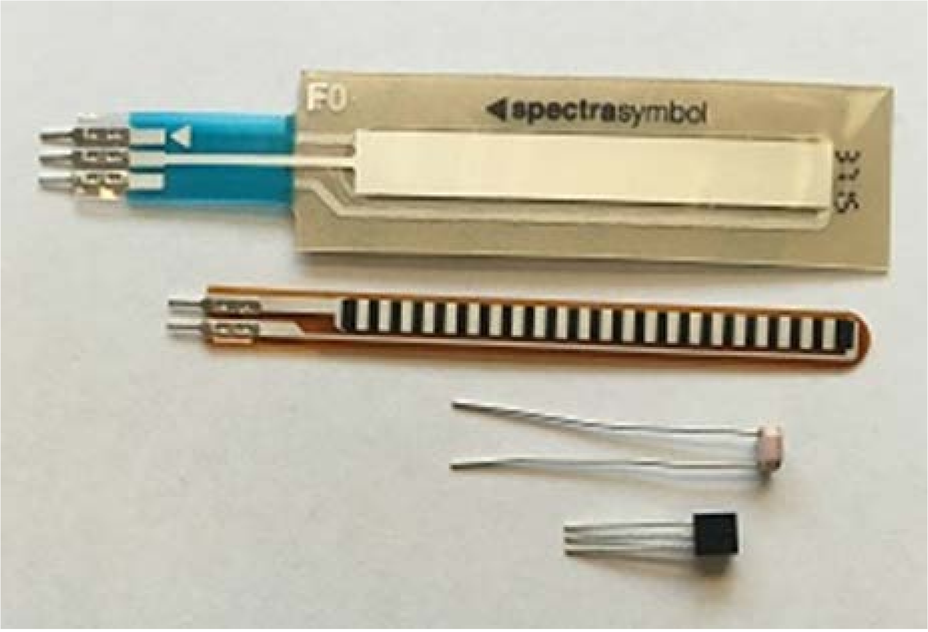
- Testing
  - To test and verify the sketch code, click on the checkmark toolbar icon.
  - The IDE compiles the code and checks for syntax errors.
  - To upload the sketch to the Arduino and test the code, click on the second toolbar icon (⇨)



Microcontrollers: The SparkFun Inventors Kit

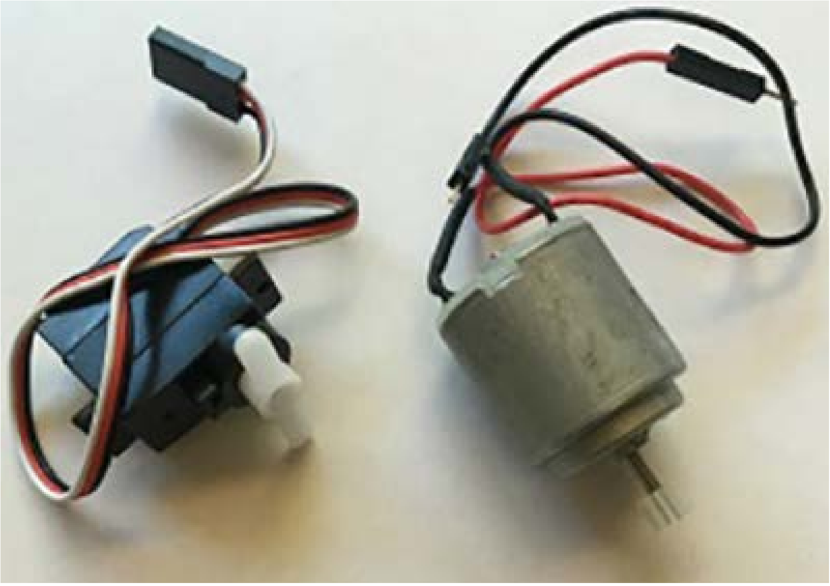
2.2.3 Sensing the Environment

- Sensors
  - Devices that detect an event from the physical environment and respond with electrical or optical signals as output.
  - The SIK contains various sensors including Soft potentiometer, Flex sensor, Photo resistor and Temperature sensor.



2.2.4 Making it Happen

- Actuators and Relays
  - An actuator is a type of motor that is responsible for creating movement.
  - The SIK includes two types of electric actuators that convert electrical energy into mechanical torque.
  - A relay is an electrically controlled mechanical switch.
  - The SIK includes a plastic box that contains an electromagnet that causes a switch to trip when it receives a current.



2.3 Packet Tracer 7.0 and the IoT

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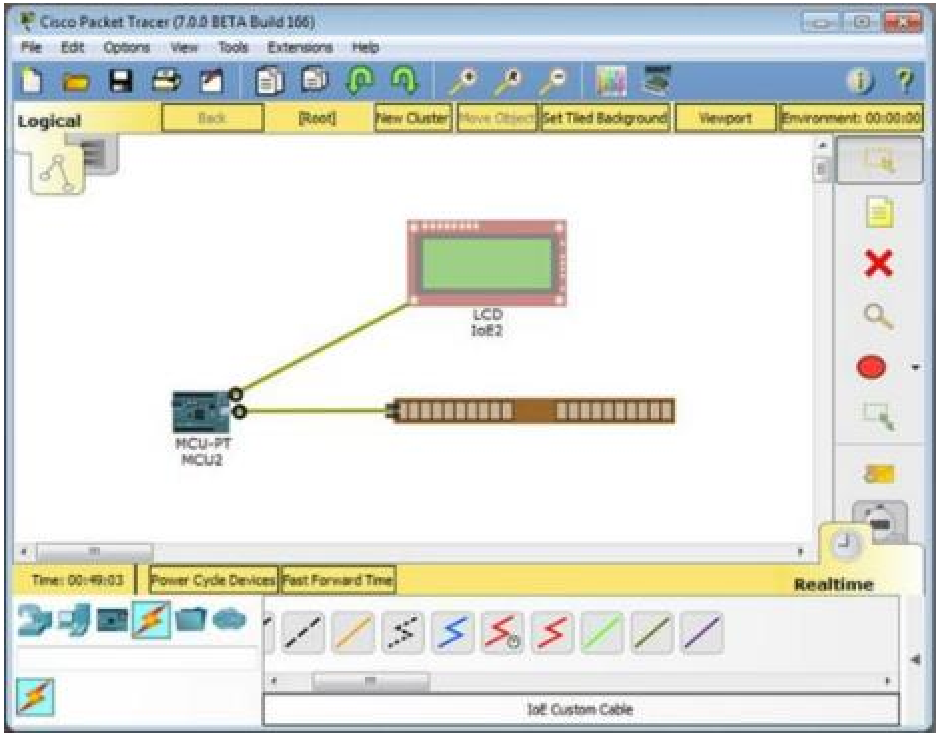
Packet Tracer 7.0 and the IoT

PT 7.0 – End-to-End IoT System Model

- How Everything Connects in PT
  - Packet Tracer 7.x can be used as a prototyping tool.
  - There is a new group icon contained in Packet Tracer version 7.0 that is labeled Components.
  - The PT IoT boards contains an MCU and a SBC.
  - The MCU and SBC are similar to an Arduino and a Raspberry Pi, respectively.
  - There are also actuators and sensors that can be used in prototypes.
  - The IoE Custom Cable found in the Connections group can be used to connect IoT things to an MCU board.



2.4 Chapter Summary

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Chapter Summary

Summary

- Electronics is an important part of the IoT.
- IoT devices are often built from scratch; therefore, understanding electronics concepts, components and terminology is critical. It is also important for an IoT professional to be able to read and create electronics schematics.
- The SparkFun kit contains a number of devices and parts to help a beginner to get started with electronics and microcontrollers. It also introduces important concepts such as electronic circuits and how to program Arduino microcontrollers. Working with the kit, a beginner can also learn how to program sensors to monitor the environment. Actuators and relays are often used to influence the environment or create action.
- Students can use Cisco Packet Tracer 7.x as a tool for modeling and prototyping IoT systems.

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Chapter 3: Software is Everywhere

Connecting Things

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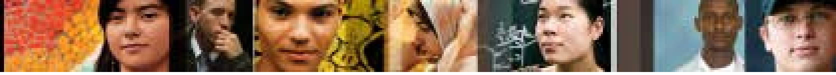

Chapter 3 - Sections & Objectives

- 3.1 Programming
  - Explain the value of computer programs.
- 3.2 The Raspberry Pi Single Board Computer (SBC)
  - Use the Raspberry Pi for simple applications.
- 3.3 Building Models of IoT Systems in Packet Tracer
  - Use Packet Tracer to model IoT systems.

3.1 Programming

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3.1.1 What is Code?

- What is a Program
  - Code is a set of ordered instructions created to accomplish a specific task.
  - A bread recipe can be seen as a program.
  - Computer programs can be written in different programming languages.
- Programs are Everywhere
  - All computers need programs.
  - Operating Systems, firmware, and applications are examples of programs.
- Why Learn Code?
  - Programmers are valued in the job market.
  - Today, programmers may work on firmware, device drivers, mobile applications, web interfaces, data analysis, and more.
  - Programmers can create their own tools.

Programming

3.1.2 Code Does the Job!

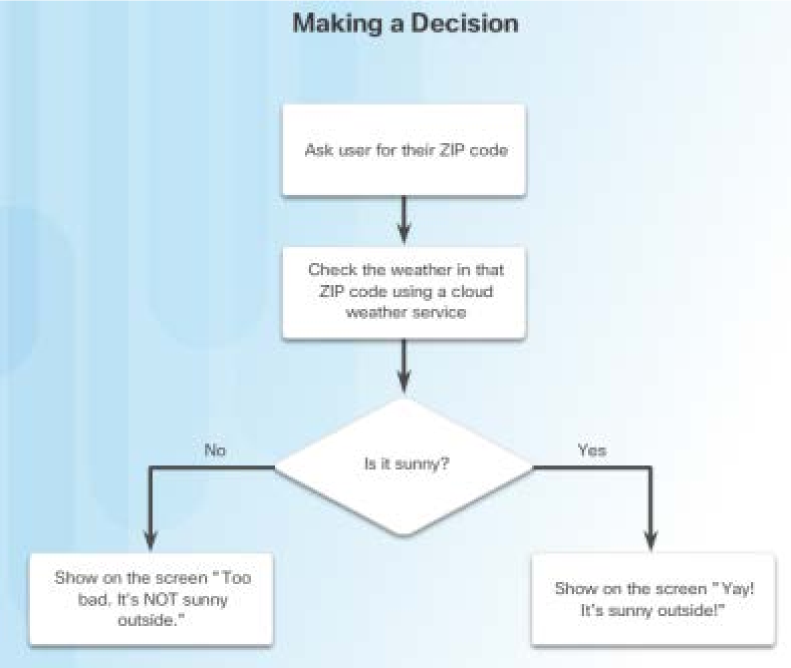
- What Makes Up a Program?
  - Programs allow people impart logic to computers and are made out of logic structures.
  - IF-THEN, FOR Loops, and WHILE Loops are a few logical structures commonly found in programs.
- Interpreted Vs. Compiled
  - Interpreted languages rely on another program to read, parse, and execute the code.
  - Compiled languages rely on a compiler, another program, to turn the human-readable code into a binary executable code.
- Computer Languages
  - There are several different computer languages.
  - Some computer languages are better than others at certain types of tasks.
  - JavaScript, Python, Blockly, C, and Java are examples of computer languages.

```
#include <stdio.h>
int main()
{
  int year;

  printf("Enter a year to check if it is a leap year\n");
  scanf("%d", &year);

  if ( year%400 == 0)
    printf("%d is a leap year.\n", year);
  else if ( year%100 == 0)
    printf("%d is not a leap year.\n", year);
  else if ( year%4 == 0 )
    printf("%d is a leap year.\n", year);
  else
    printf("%d is not a leap year.\n", year);

  return 0;
}
```

Programming

3.1.3 Lending Intelligence

- IOT Devices and Data Processing
  - A common IoT application uses sensors to collect data.
  - Data is often not useful until it has been processed. Collected data is often transported and stored in the cloud for processing at a later date.
- IoT Devices Make Decisions
  - Software must be written and uploaded onto IoT devices to allow them to make decisions.
  - Decisions can be as simple as triggering an alarm or as complex as facial recognition.
- Software APIs
  - Application Program Interface (API) is a set of routines and software tools that facilitate one application communicating with another.
  - Different types of APIs exist: operating system APIs, application APIs, website APIs.
  - APIs allow applications to communicate, share data, or ask for specific services from another application.



Programming

Lending Intelligence – cont'd

- REST API

```
GET https://www.googleapis.com/calendar/v3/calendars/calendarID
```

- REST APIs use HTTP based calls between applications to access and manipulate information stored on powerful databases.
- Web resources used to be identified using a URL. Now resources can be any entity or thing that can be addressed: today's step goal, house temperature setting, glucose setting.
- A unique Uniform Resource Identifier (URI) can identify an entity. A URI typically begins with a slash (/steps)
- REST API requests trigger responses in well-defined formats such as XML or JSON

Programming

Lending Intelligence – cont'd

- Securing the Code
  - Devices should protect themselves from attacks that impair its function or allow it to be used for unintended purposes without authorization.
  - Devices should protect the private authentication credentials and key material from disclosure to unauthorized parties.
  - Devices should protect the information received, transmitted, or stored locally on the device, from inappropriate disclosure to unauthorized parties.
  - Devices should protect themselves from being used as a vector to attack other devices or hosts on the Internet.

3.2 The Raspberry Pi Single Board Computer (SBC)

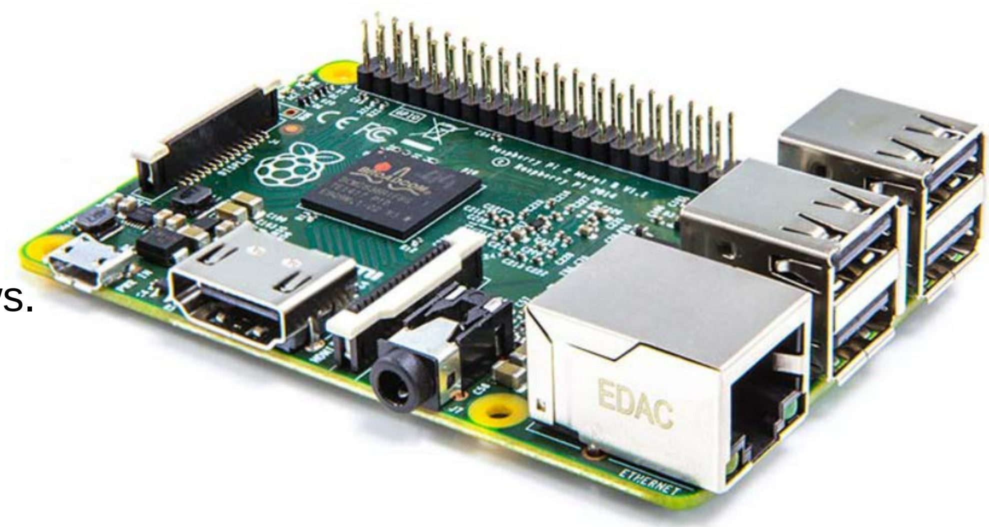
The Raspberry Pi Single Board Computer (SBC)

3.2.1 Raspberry Pi Hardware

- The Raspberry Pi and its Ports
  - The Pi is a small and inexpensive computer.
  - It has a number of USB ports that can be used to connect various devices including keyboards, mice, external drives and cameras.
  - The Pi includes an 10/100Mbps Ethernet port and 40 GPIO pins, operating at 3.3V.
  - Other Pi ports include an audio out, a micro SD card slot, and a micro USB (used for power) connector.

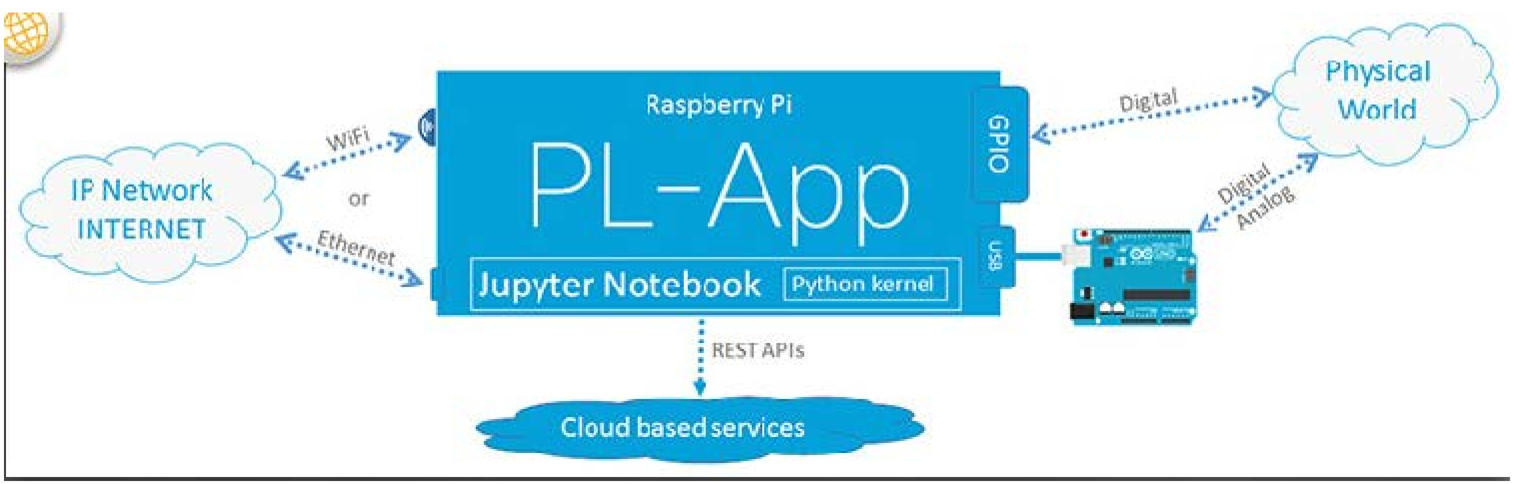
- The Pi3 also adds:
  - 1.2 Ghz 64-bit quad-core ARMv8 CPU
  - 802.11n Wireless LAN
  - Bluetooth 4.1
  - Bluetooth Low Energy (BLF)

- The Pi can run a number of operating systems, including Linux and Windows.



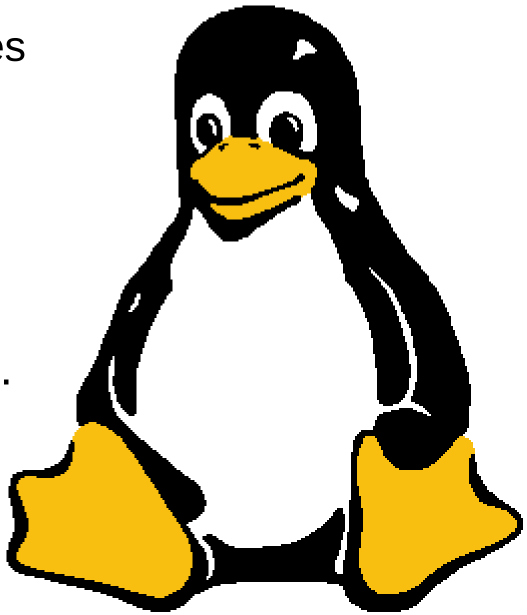
3.2.2 PL-App

- The Raspberry Pi can be accessed locally:
  - 1. Install an operating system image on the micro SD card.
  - 2. Place the card in the micro SD card slot of the RaPi.
  - 3. Connect a USB keyboard.
  - 4. Connect a monitor or TV using the HDMI port.
  - 5. Power the device with a power adapter.
- The Raspberry Pi can be accessed remotely using the PL-App



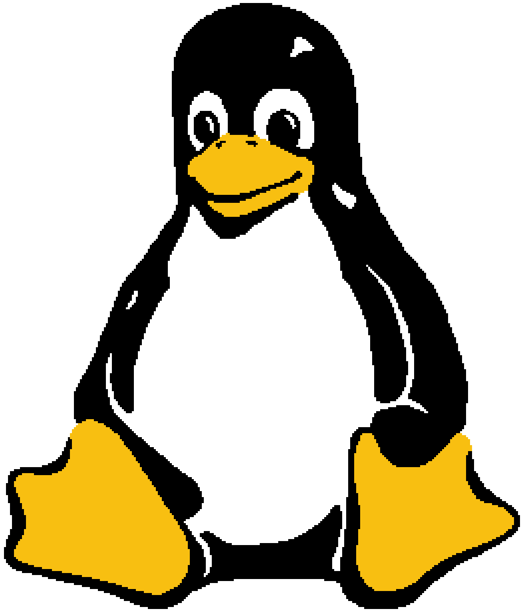
3.2.3 Using the Linux Operating System

- Understanding Linux
  - Linux is open source, fast, reliable and small and requires very little hardware resources to run.
  - Linux is part of several platforms; from wristwatches to supercomputers.
  - Linux distributions include the Linux kernel, plus a number of customized tools and software packages.
  - Debian, Red Hat, Ubuntu and Slackware are just a few examples of Linux distributions.
  - Raspbian is a Linux distribution based on Debian and created specifically for the Raspberry Pi.
- Accessing the Linux Shell
  - The Linux operating system can be divided into kernel and shell.
  - The shell is a command interpreter.
  - The shell is text based and also called CLI (command line interface



Using the Linux Operating System (Cont.)

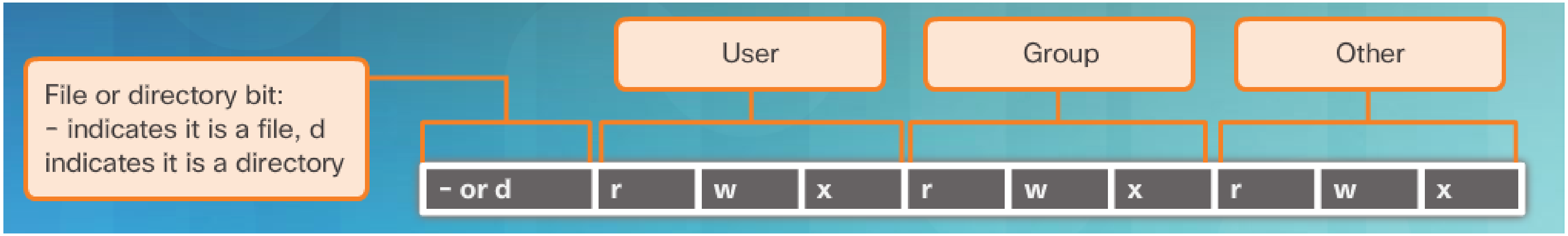
- Accessing the CLI
  - The CLI can be accessed directly through a shell in non-graphical systems.
  - Bourne Shell (**sh**), Bash (**bash**), C Shell (**csh**), improved C Shell (**tcsh**), and Z Shell (**zsh**) are popular shells.
  - A terminal emulator application can be used to access the CLI in graphical environments.
  - Popular terminal emulators on Linux are **Terminator**, **eterm**, **xterm**, **console**, and **gnome-terminal**.
- Basic Linux Commands
  - Linux commands are programs created to perform a specific task.
  - To invoke a command via shell, simply type its name.
  - **grep**, **ifconfig**, **iwconfig**, **passwd** and **pwd** are a few basic Linux commands.
  - Commands can be piped together, using the output of one as the input of the other.



The Raspberry Pi Single Board Computer (SBC)

Using the Linux Operating System (Cont.)

- Process Managing Commands
  - In Linux, a process is any task or command being executed by the system.
  - PIDs are unique numbers assigned to processes for identification.
  - **ps**, **top** and **kill** are commands used to manage processes.
- File Permissions
  - In Linux, most everything is treated as a file.
  - File Permissions provide a mechanism to define permissions to files.
  - Possible permissions rights are **Read**, **Write**, and **Execute** and can be defined for the user who owns the file, the group, and other system users.
  - The root user can override file permissions.



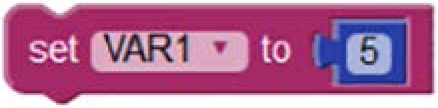
The Raspberry Pi Single Board Computer (SBC)

Using the Linux Operating System (Cont.)

- Package Managers
  - Maintaining computer programs and their library dependencies manually is not scalable
  - Package managers facilitate the installation, removal, and upgrade of computer programs.
  - Package managers usually include user tools and a remote package repository.
  - The repository hosts software packages and their dependencies.
  - **dpkg** and **rpm** are popular package managers for Debian Linux and Red Hat Linux, respectively.
  - Raspbian includes **dpkg** and **apt** by default.

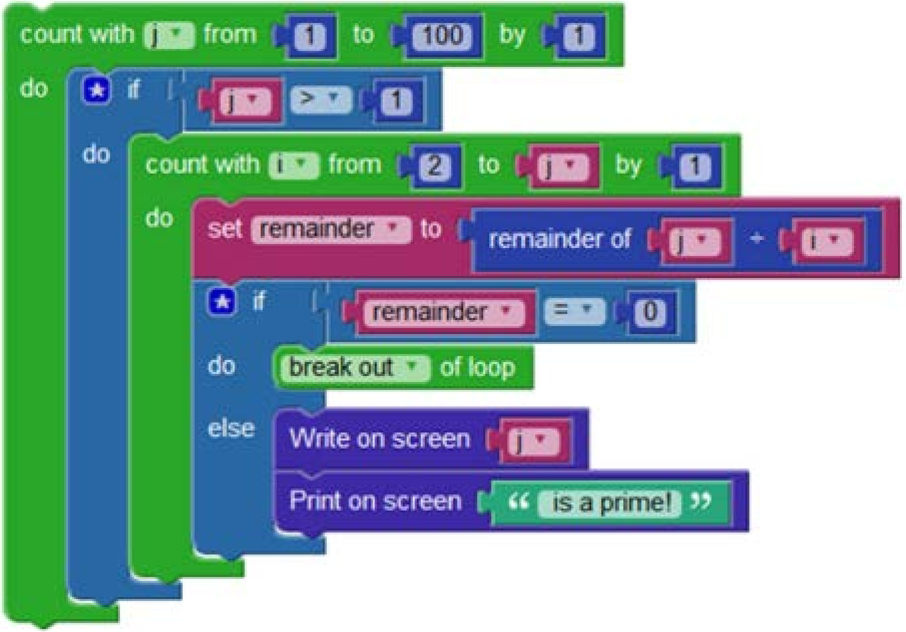
The Raspberry Pi Single Board Computer (SBC)

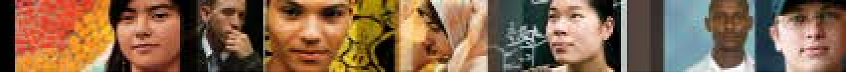
3.2.4 Blockly



- Variables and Basic Statements
  - Blockly allows the creation of a program without entering any lines of code; it uses colored blocks.
  - Blocks can be connected together by dragging and attaching the appropriate blocks.
  - Creating a new variable in Blockly is a simple matter of dragging the variable block and filling in the value slot.

- IF-THEN
  - Used to allow the code to make decisions.
- FOR Loops
  - Used to repeat the execution of a block of code for a specific number of times.
- WHILE Loops
  - Used to execute a block of code while a condition is true.





The Raspberry Pi Single Board Computer (SBC)

3.2.5 Python on the Raspberry Pi

- Using Blocky to Learn Python
  - Blockly can be used to enhance Python understanding.
  - Beginners can create Blockly programs, convert them to Python and study the result.
- The Python Interpreter
  - The Python interpreter understands and executes Python code.
  - Python code can be created in any text editor and Python interpreters are available for many operating systems.
  - Python developers can create and deploy Python programs in practically any operating system.
  - When called with no arguments, the Python interpreter displays the “>>>” prompt and waits for commands; this is called interactive mode.

```
Python 2.7 (#1, Feb 19 2010, 12:06:02)
Type "help", "copyright", "credits" or "license" for
more information.
>>>
```

The Raspberry Pi Single Board Computer (SBC)

Python on the Raspberry Pi (cont'd)

- Variables and Basic Statements in Python
  - Variables are labeled memory areas used to store runtime program data.
  - To assign values to variables in Python, use the = (equal to) sign.
  - Python's interactive mode implements the special variable "_".

```
>>>
>>> tax = 12.5 / 100
>>> price = 100.50
>>> price * tax
12.5625
>>> price + _
113.0625
>>> round(_, 2)
113.06
```

- Useful Functions and Data Types in Python
  - Python supports many useful functions and data types such as range(), tuples, lists, sets, and dictionary

```
list1 = ['car', 'train', 47, 2016];
list2 = [1, 2, 3, 4, 5, 6, 7 ];
print "list1[0]: ", list1[0]
print "list2[1:5]: ", list2[1:5]

When the above code is executed, it produces the following result -
 list1[0]: car
 list2[1:5]: [2, 3, 4, 5]
```

The Raspberry Pi Single Board Computer (SBC)

Python on the Raspberry Pi (cont'd)

- Importing Modules Into Your Code
  - Use the **import <module>** keyword to import pre-written code into your programs.
- IF THEN In Python
  - Allows the execution a block of code based on the result of an expression.
- FOR Loops in Python
  - Iterates through the items of any sequence
- WHILE Loops in Python
  - Executes a block of code while the expression is true
- Indentation is important in Python!

```
>>>
>>> x = int(raw_input("Please enter an integer: "))
Please enter an integer: 42
>>> if x < 0:
...     x = 0
...     print 'Negative changed to zero'
... elif x == 0:
...     print 'Zero'
... elif x == 1:
...     print 'Single'
... else:
...     print 'More'
...
More
```

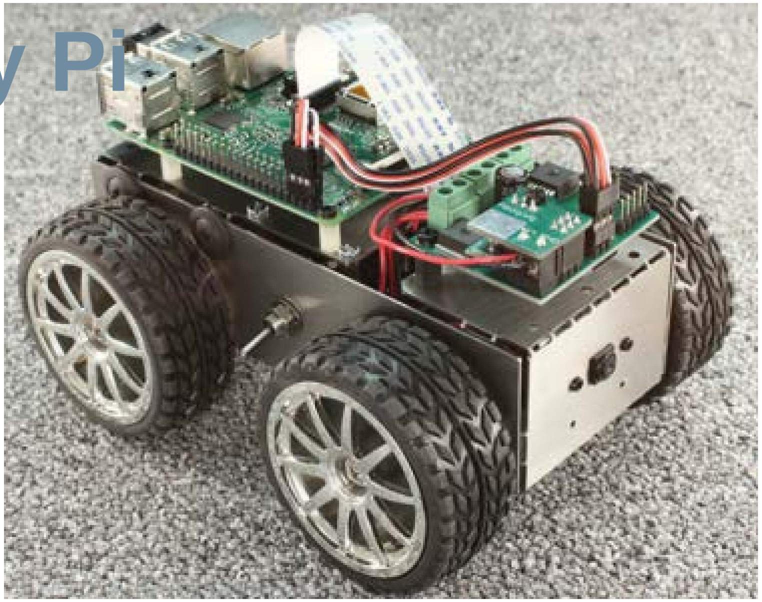
The Raspberry Pi Single Board Computer (SBC)

Python on the Raspberry Pi (cont'd)

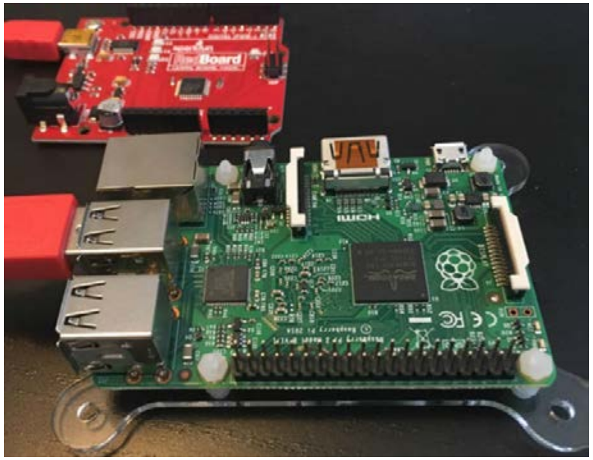
- Cisco Support for Cybersecurity Professionals
  - DevNet
    - Cisco provides a beneficial community named DevNet.
    - DevNet is available to assist you in learning to code, use software and programs, and partner with others.
  - Cisco Spark
    - Cisco Spark is a cloud service that provides persistent chat, room-based collaboration, WebRTC video conferencing, and more.
    - Developers can create code that can be used to integrate specific solutions with Spark via the Spark REST API.
    - Spark REST API can include automated Spark messages based on real-world events that occur in a popular application/program

The Raspberry Pi Single Board Computer (SBC)

3.2.6 Uses of the Raspberry Pi



- Artificial Raspberry Pi Pancreas
  - Dana Lewis and her husband used a Raspberry Pi to build an artificial pancreas.
  - It was possible due to the Pi’s small size and low power requirements.
- 4Borg Pi Robot
  - PiBorg is an affordable robot kit built around a Raspberry Pi.
  - It is both fun and educational.
- Controlling the Arduino Through the Pi
  - While the Pi is powerful, it may not be the best option for all projects.
  - The Pi doesn’t include analog GPIO pins.
  - The Pi is **not** real-time.
  - The Pi’s power requirements and size may be too large, depending on the application.
  - To adjust to these limitations, an Arduino may be used.



3.3 Building Models of IoT Systems in Packet Tracer

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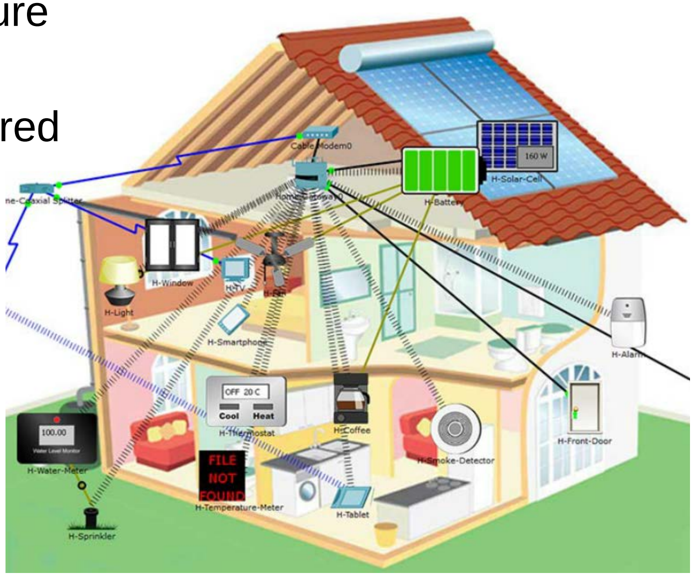
Building Models of IoT Systems in Packet Tracer

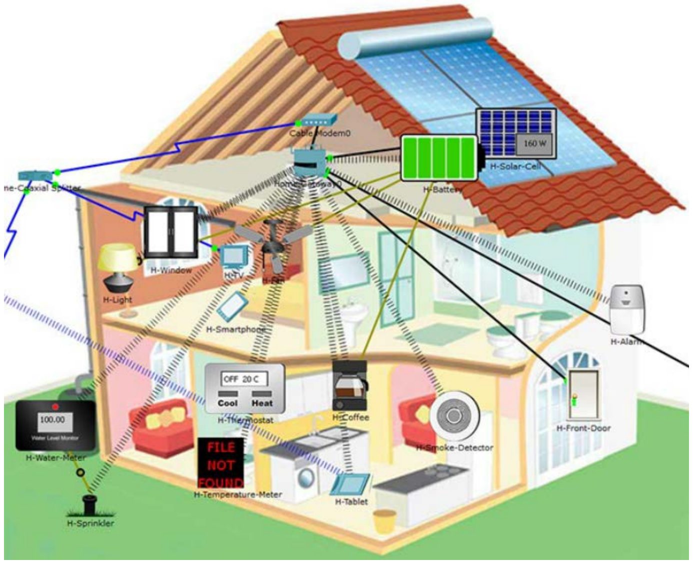
3.3.1 A Model of an IoT System

- Introducing The Home Automation Model
  - PT7.0 supports a wide range of IoT devices, such as sensors, actuators, microcontrollers, single board computers, and fog computing devices.
  - PT7.0 allows the design, configuration, programming, and troubleshooting of sophisticated models of IoT systems.
- The Components of the Systems
  - In the Smart Home example, all devices connect to the Home Gateway, which acts as a concentrator for all devices.
  - Sensors monitor the environment while code makes sure values stay within a pre-defined threshold.
  - The code also takes appropriated actions if the monitored values fall out of the pre-defined threshold.
  - The cable modem and splitter pair is what provides Internet connectivity to the Home Gateway and consequently, to the entire home.



A Model of an IoT System (Cont.)

- The SBC Code in Packet Tracer
  - PT 7.0 also introduces a single board computer (SBC) and a microcontroller unit (MCU).
  - PT SBC simulates an SBC such as a Raspberry Pi.
  - PT SBC provides 2 USB ports and 10 digital I/O ports which can be used to connect IoT sensors and devices.
  - PT SBC has a Python interpreter built in, accessible via PT SBC’s Programming tab.
  - PT 7.0 also supports an MCU emulator.
  - PT MCU can be programmed similarly to real-word MCUs.
  - PT MCU has one USB port, six digital I/O ports, and four analog I/O ports.
  - PT MCU can also be programmed with Python.



3.4 Chapter Summary

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Summary

- Programs (also called code) are used in IoT to provide logic and intelligence to the devices. A programmer can create code to allow an IoT device to perform tasks such as monitoring, communicating to others, data processing and more.
- The Raspberry Pi, single board computer, is designed to be small and consume very little power.
- The Cisco PL-App allows access to the Raspberry Pi directly from the network without the need for a monitor, keyboard or mouse to be directly connected to the Pi.
- The Raspberry Pi runs Raspbian, a modified version of the open source and wide-spread Linux operating system.
- The Raspberry Pi supports many different programming languages including Blockly, a visual programming language, designed to help beginners learn how to program. This course focuses on Python, a popular, simple and powerful programming language.
- With added support to Python, Cisco Packet Tracer is a great tool to model, prototype and test entire IoT systems.

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Chapter 4: Networks, Fog and Cloud Computing

IoT Fundamentals

Connecting Things 2.0

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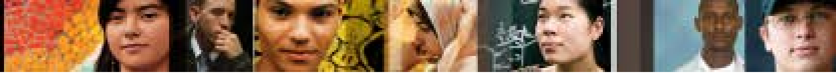

Chapter 4 - Sections & Objectives

- 4.1 Connecting Things to the Network
  - Explain how the network supports the IoT.
- 4.2 Fog and Cloud Computing
  - Explain why fog and cloud computing are used in IoT systems.

4.1 Connecting Things to the Network

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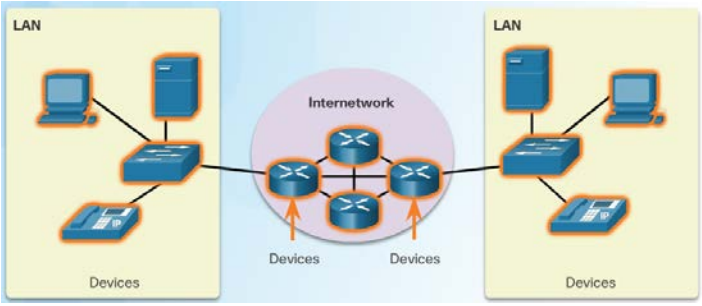
Connecting Things to the Network

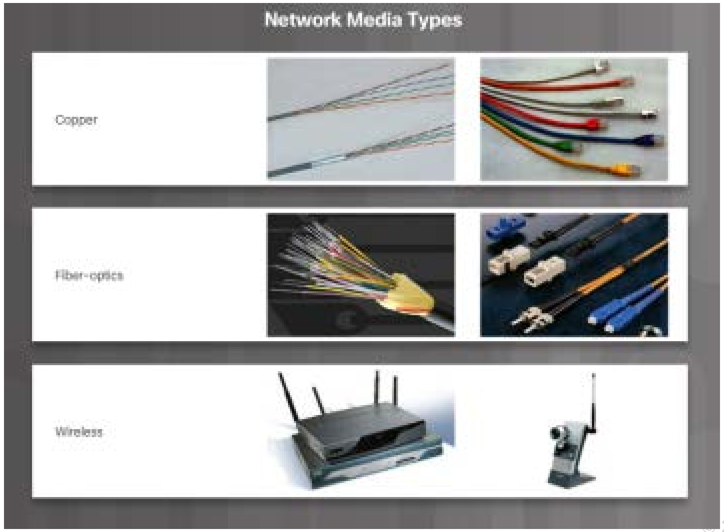
4.1.1 The Role of the Network

- LAN and WAN
  - The path from source to destination can be a single cable or a collection of networks.
  - A Personal Area Network (PAN) is a type of network that usually spans a few meters around an individual and is often used in IoT.
  - A Local Area Network (LAN) is a type of network infrastructure that spans a small geographical area and is used to connect end devices..
  - A LAN is normally a high-speed network under the control of a single administrative entity.
  - A Wide Area Network (WAN) is a type of network infrastructure that spans a wide geographical area and is used to connect WANs.
  - A WAN is normally a low-speed network and may include portions from different Internet Service Providers (ISPs)
  - LANs often connect machines in the factory plant.
  - WAN devices have evolved to create Low PowerWide Area Networks (LPWAN) for use in the IOT



The Role of the Network (Cont.)

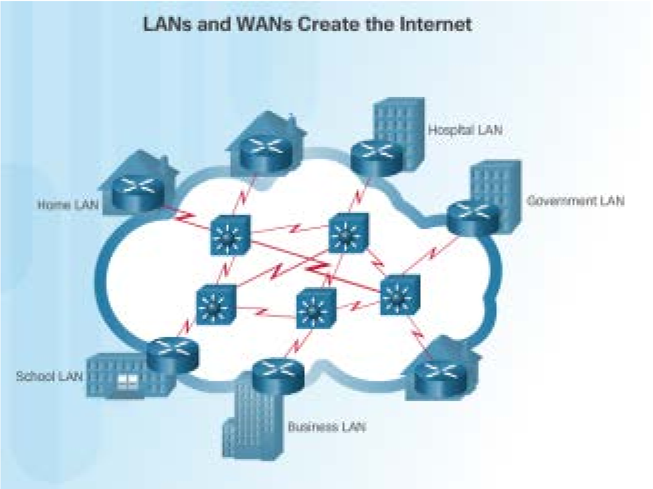
- Network Devices and Communication Media
  - Network devices are devices that connect to each other through a network.
  - An end device is either the source or destination of a message transmitted over the network.
  - Intermediary devices connect the individual end devices to the network and can connect multiple individual networks to form an internetwork.
  - Network addresses are used to uniquely identify devices on a network.
  - Network media provide the physical channel over which the message travels from source to destination.



Connecting Things to the Network

The Role of the Network (Cont.)

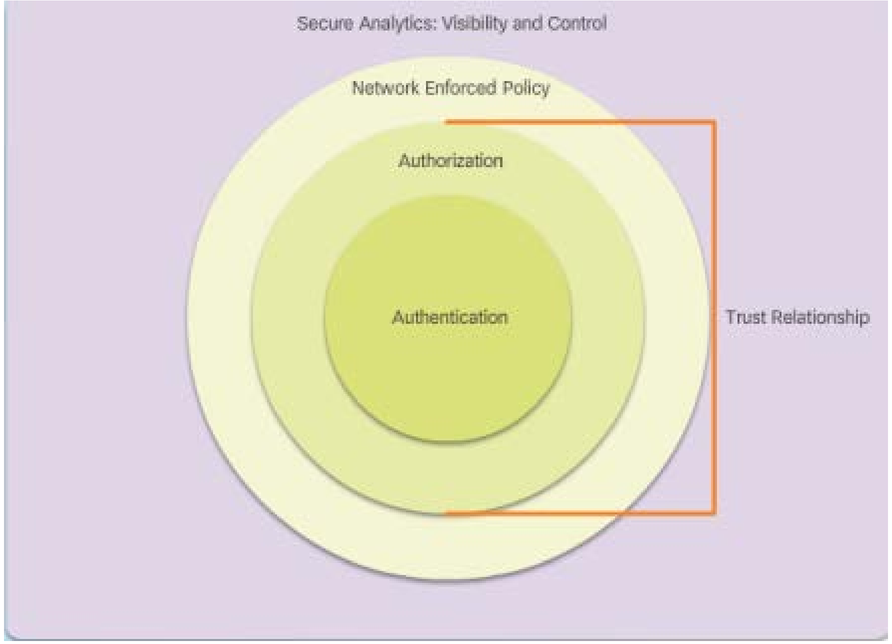
- Network Protocols
  - Devices must conform to common protocols before they can communicate.
  - Two very important network protocols are Ethernet and IP.
  - Ethernet rules enable communication between local devices.
  - IP enable communication between remote devices.
- Basic Routing
  - Network packets must often transverse several networks to get to the destination.
  - Routing is the process of directing a network packet to its destination.
  - Routers are intermediary network devices that perform routing.
- LANs, WANs and the Internet
  - Single router designs are common in SOHO.
  - The single router connects SOHO devices to the Internet.
  - The single router is the default gateway for all SOHO devices.



The Role of the Network (Cont.)

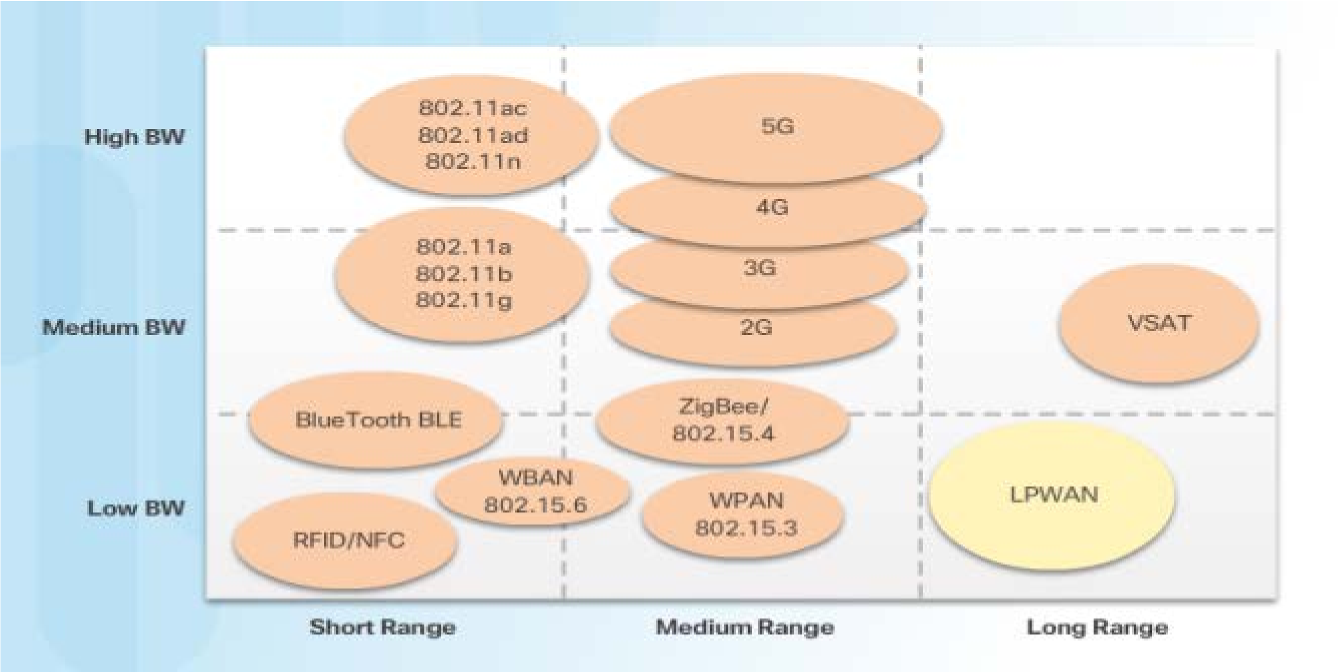
- IoT Protocols
  - IoT Devices are often embedded devices designed to work in sub-optimal conditions.
  - These devices require specialized protocols to function with low power and limited connectivity.
  - IoT devices use CoAP (Constrained Application Protocol) and MQTT (Message Queuing Telemetry Transport).

- Securing the Network
  - IoT devices are integrated into all aspects of daily life.
  - IoT applications carry traceable signatures and carry confidential data.
  - IoT devices must adhere to a secure framework (Authentication, Authorization, Network Enforced Policy, Secure Analytics)



4.1.2 Wireless Technologies

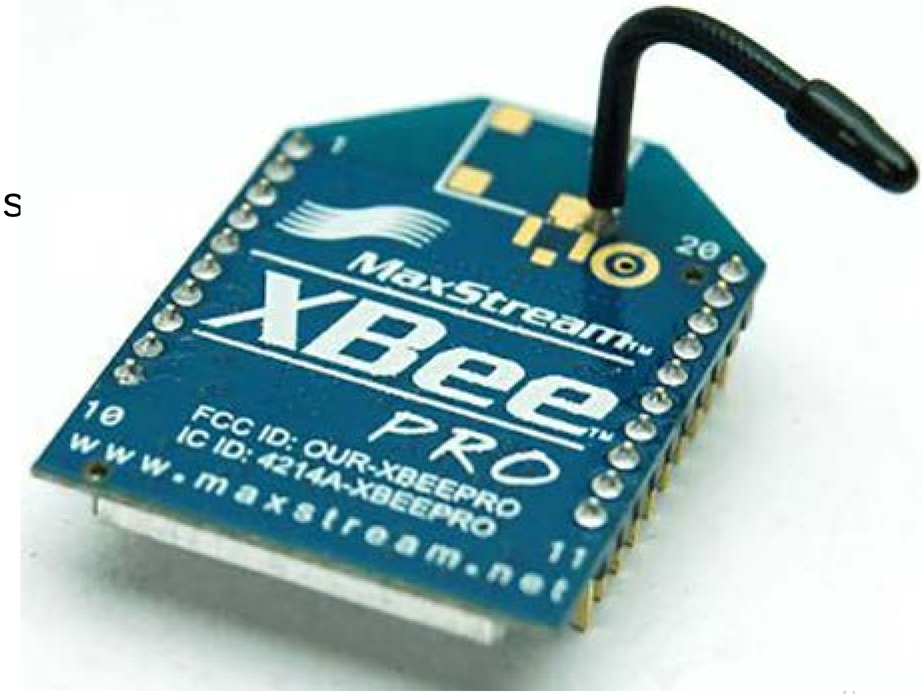
- WiFi
  - Wireless connectivity is the biggest growth area.
  - New protocols created/updated to support diverse IoT devices: ZigBee, Bluetooth, 4G/5G, LoRaWAN
  - Protocols created for short, medium, and wide ranges
  - Low-Power Wide-Area Networks (LPWAN) is designed to support long range communications for low bit rate devices such as sensors, actuators, and controllers



Connecting Things to the Network

Wireless Technologies (cont'd)

- ZibBee
  - A low-energy, low-power, low-data rate wireless protocol specification used to create personal area networks
  - Areas of utilization: home automation, medical device data collection, and other low-power low-bandwidth needs
  - 250 kbps transfer rate best suited for intermittent data transmissions
  - Every ZigBee data request uses an Application Profile Identification Number.
  - Application profile ID numbers - 16-bit numbers that relate to public profiles, manufacturing profiles, or private profiles.
  - ZigBee version 1.2 has a number of serious and exploitable security vulnerabilities. Most of these protocol design flaws relate to attempts to make it easier for the end-user to add a ZigBee device to the ZigBee network.



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Wireless Technologies (cont’d)

- Bluetooth
  - Wireless protocol used for data communication over short distances (PAN)
  - Supported by almost all mobile devices and accessories - the defacto standard for audio between mobile devices.
  - Bluetooth Low Energy (BLE) - very popular because of the smartphone industry and new applications in healthcare, fitness, and beacons.
    - operates in the 2.4 GHz ISM band
    - Has a very fast connection rate (milliseconds) and a very high data rate (1 Mbps).
    - The BLE device then goes into “sleep mode” until a connection is reestablished - lengthens the battery life for several years.
  - Beacons use BLE technology - positioned on buildings, in coffee shops, and on light posts to provide location services.

Connecting Things to the Network
Wireless Technologies (cont'd)

- 4G/5G
  - Cellular-based data networks designed to take advantage of communications over large geographic areas
  - High mobility bandwidth (trains and cars) of 4G system is 100 Mbps
  - Low mobility (pedestrians and stationary users) of 4G systems is 1 Gbps
  - 4G provides support for voice, IP telephony, mobile Internet access, video calling, gaming services, cloud computing, high-definition mobile TV, and mobile 3D TV.
  - Long Term Evolution (LTE) and WiMAX (IEEE 802.16e) are two popular 4G systems.
  - LTE 4G technology release 13e includes the standardization of NarrowBand IoT (NB-IoT) - an LPWAN technology.
  - Next Generation Mobile Networks Alliance defining the standards and requirements for 5G

Connecting Things to the Network

Wireless Technologies (cont’d)

- LoRaWAN
  - Wireless technology designed to provide wireless WAN connections to power constricted devices.
  - targets key requirements of the Internet of Things such as secure bi-directional communication, mobility and localization services.
  - Architecture is often an extended star topology in which gateways relay messages between end-devices and a central network server is located in the backend.
  - Data rates range from 0.3 kbps to 50 kbps
  - Security is built into the LoRaWAN standard, implemented in a multi-layer encryption scheme.
    - Unique keys are used in the Application, Network, and Device layers.

4.2 Fog and Cloud Computing

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4.2.1 Fog and Cloud Services

- Cloud Computing Model
  - On-demand access to a shared pool of configurable computing resources.
  - Resources can be made available quickly with minimal management effort.
  - Cloud service providers use data centers for their cloud services and cloud-based resources.
  - “Pay-as-you-go” model treats computing and storage expenses as a utility.
  - Enables access to organizational data and applications anywhere and at any time
  - Reduces cost for equipment, energy, physical plant requirements, and personnel training needs
  - Cloud services offered: Infrastructure as a Service (IaaS), Platform and mobile Platform as a Service (PaaS) (mPaaS), Software as a Service (SaaS)

Connecting Things to the Network

Fog and Cloud Services (cont'd)

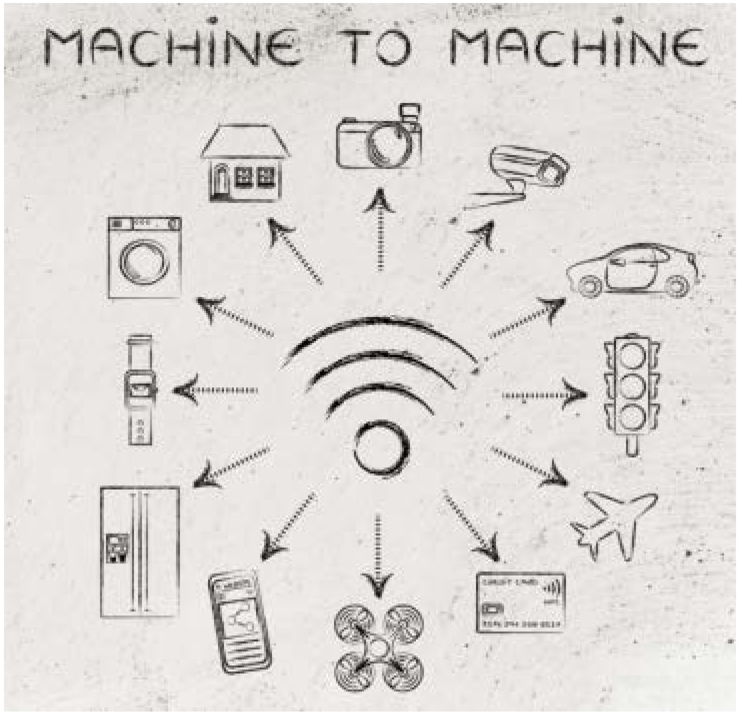
- Cloud Services
  - Cloud customers have access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort.
  - Extends functionality of an IoT system: data processing and storage done in the cloud instead of in the IoT devices.
  - Data and resources - always available to any device in the system as long as the device has Internet connectivity
  - Cloud service providers are also very serious about security, ensuring customer data is kept safe and secure..
  - Examples of cloud services: Amazon AWS, IFTTT, Zapier, Built.io, Cisco Spark

Connecting Things to the Network

Fog and Cloud Services (cont'd)

Fog and Cloud Services (cont’d)

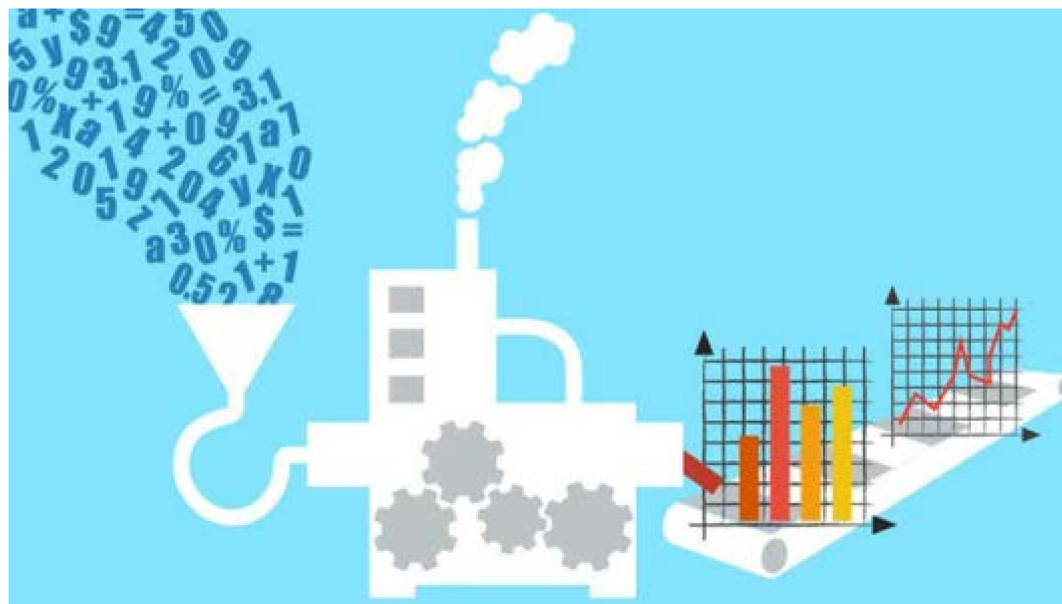
- Fog Computing Model
  - Distributed computing infrastructure closer to the network edge.
  - Edge devices run applications locally and make immediate decisions
  - Reduces the data burden on networks as raw data not sent over network connections.
  - Enhances security - keeping sensitive data from being transported beyond the edge where it is needed.
  - Fog applications monitor or analyze real-time data from network-connected things and then take action such as locking a door, changing equipment settings, applying the brakes on a train, zooming in with a video camera,
  - The action can involve machine-to-machine (M2M) communications and machine-to-people (M2P) interaction
  - Cisco predicts that 40% of IoT-created data will be processed in the fog by 2018



Connecting Things to the Network

4.2.2 Big Data (cont’d)

- Data Growth
  - Number of sensors and other IoT end devices growing exponentially and collecting a constant stream of data.
  - Consumer behavior is changing requires anytime, anywhere, on-demand access.- fitness monitors, smartphones, medical devices
  - Smart cities and smart grids, connected trains, cars – growing in frequency
  - Problems arise in terms of the requirements for storage, analysis, and security



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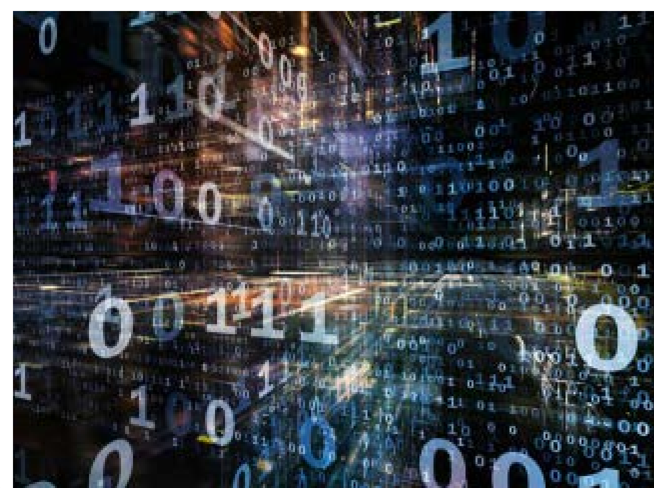
4.2.2 Big Data (cont’d)

- It is All About the Data
  - Big data is data that is so vast and complex it is difficult to store, process, and analyze using traditional data storage and analytics applications.
  - Typically characterized in three dimensions: volume, velocity, and variety
    - Volume - the amount of data being transported and stored
    - Velocity - the rate at which this data is generated
    - Variety - the type of data, which is rarely in a state that is perfectly ready for processing and analysis
  - Apache Hadoop, Spark, Cassandra, and Kafka – examples of open source projects dealing with Big Data



Connecting Things to the Network

4.2.3 Security Concerns in the IoT

- Data Storage
  - IoT devices may store data for a period of time before sending it out for processing. – especially for devices that do not maintain constant connections to their gateways or controllers.
  - Critical that all IoT storage devices encrypt data for storage to avoid data tampering or theft
  - Self-encrypting drives have encryption capability built into the drive controller - encryption and decryption done by the drive itself, independent of the operating system.
  - Self-encrypting flash memory – manufacturers beginning to release new devices with self-encrypting flash memory

Connecting Things to the Network

4.2.3 Security Concerns in the IoT (cont'd)

- Data Transmission
  - If data is not properly secured through encryption, it can be intercepted, captured or manipulated while in transit.
  - Modern encryption algorithms may require more processing power than what is available in the IoT device.
  - As well as physical security, IoT devices must be able to protect its own firmware and the data it transmits.
  - Ensure that IoT devices are running the latest version of their firmware and protocols.
  - Common attack: trick devices into using sub-optimal security parameters under which the connection can be exploited
  - Servers, cloud endpoints, intermediary devices should also be secured and use strong encryption algorithms before communicating with IoT devices.

4.3 Chapter Summary

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Summary

- Personal information related to health, location, wealth, personal preferences and behaviors is passing through the IoT devices in increasing volumes. This increase in volume elevates the relevance of increasing the attention on data privacy and data protection.
- New wireless technologies and protocols, such as ZigBee, Bluetooth, 4G/4G, and LoRaWAN, have been developed to accommodate the diversity of IoT devices. Wireless technology is selected based on the range of coverage, bandwidth requirements, power consumption, and deployment location.
- Wireless security considerations include: selecting a secure protocol, protection for management frames, identification of frequency jamming, detecting rogue access points, and using security at the application layer.
- Cloud computing is a service that offers off-premise, on-demand access to a shared pool of configurable computing resources. Cloud computing offers services such as IaaS, PaaS, mPaaS and SaaS.
- A fog computing model identifies a distributed computing infrastructure closer to the network edge. It enables edge devices to run applications locally and make immediate decisions.
- The proliferation of devices in the IoT is one of the primary reasons for the exponential growth in data generation. Data can be deemed at rest or in motion. Big Data is typically characterized in three dimensions: volume, velocity, and variety.
- Data stored in servers must be encrypted to avoid data tampering or theft. Regular backups are mandatory to minimize losses in case of a disaster
- IoT devices should run the latest version of firmware and protocols and any communication between devices should be done using protocols that provide secure encryption by default.

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Instructor Materials
Chapter 6 Create an IoT Solution

IoT Fundamentals

Connecting Things v2.0

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Chapter 6 - Sections & Objectives

- 6.1 Become a Global Problem Solver
  - Investigate real-world social or environmental problems.
- 6.2 Design a Solution
  - Design an IoT solution that addresses a real-world social or environmental problem.
- 6.3 Build, Test & Document a simple IoT System
  - Create an IoT system.
- 6.4 The Business Aspects
  - Design a plan to market an IoT solution.
- 6.5 What is Next?
  - Explain how to continue your learning about the IoT.

6.1 Become a Global Problem Solver

6.1.1 Solving Global Problems

- Organizations Doing Global Good
  - Global problems include the burning of fossil fuels, air pollution, oceans becoming more acidic, climate change, poverty, hunger, disease, gender inequality, and access to water and sanitation.
  - Some companies and organizations provide funds to help these global problems such as the Bill & Melinda Gates Foundation and The Musk Foundation.
- The Millennium development Goals
  - In 2000, leaders from 189 countries made a list of 8 goals to be achieved in 15 years.
  - These eight goals were called the Millennium Development Goals (MDGs).
  - United Nations Development Programme (UNDP) is working on fulfilling these goals.
- Progress on MDGs so far:
  - People who live on less than $1.25 per day has dropped by more than half.
  - Young children going to school is up by almost half.
  - People receiving HIV treatment increased by over 15 times.
  - Lowered child mortality rate by almost half.
    - .

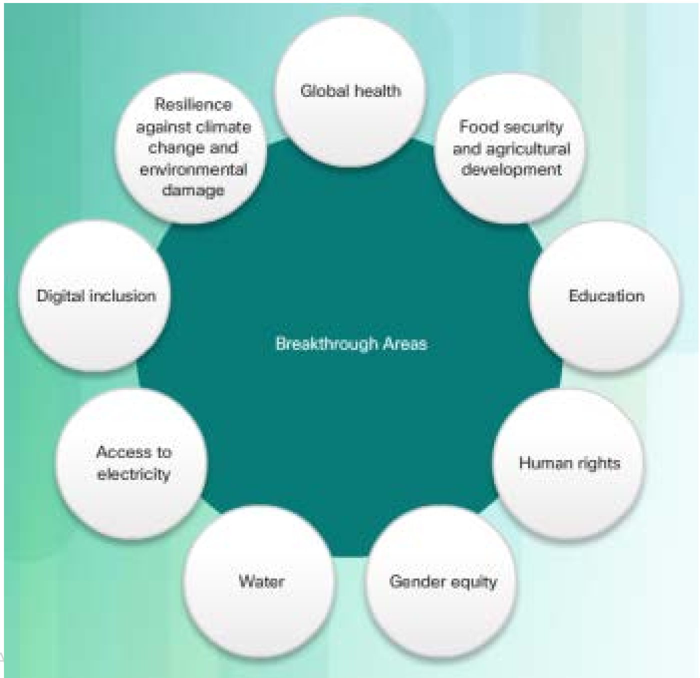
Solving Global Problems (Cont.)

- The Sustainable Development Goals
  - In 2015, 189 world leaders at the United Nations Sustainable Development Summit unanimously adopted the 2030 Agenda for Sustainable Development.
  - The result was a set of 17 Sustainable Development Goals (SDGs).
  - These new SDGs go much further than the MDGs.
  - They are addressing the root causes of poverty and the universal need for development that works for all people.

Become a Global Problem Solver

6.1.2 Globally Transformative Breakthrough Technologies

- Lawrence Berkeley National Lab
  - The Lawrence Berkeley National Lab (LBNL).
  - The Institute of Globally Transformative Technologies (LIGTT) (pronounced ‘light’) is part of LBNL and was created in 2012.
  - The goal of LIGTT is to leverage LBNL’s resources to develop and deploy breakthrough technologies for sustainable global development.
- Institute of Globally Transformative Technologies
  - The LIGTT released a top "50 Breakthroughs" study in 2014.
  - Identified some of the most important breakthrough technologies that are required for sustainable global development.
  - LIGTT aims to develop many of these breakthroughs. Achieving this will make substantial impacts on poverty.
  - Breakthrough #42 is directly related to using the IoT to enable new services.



6.2 Designing a Solution

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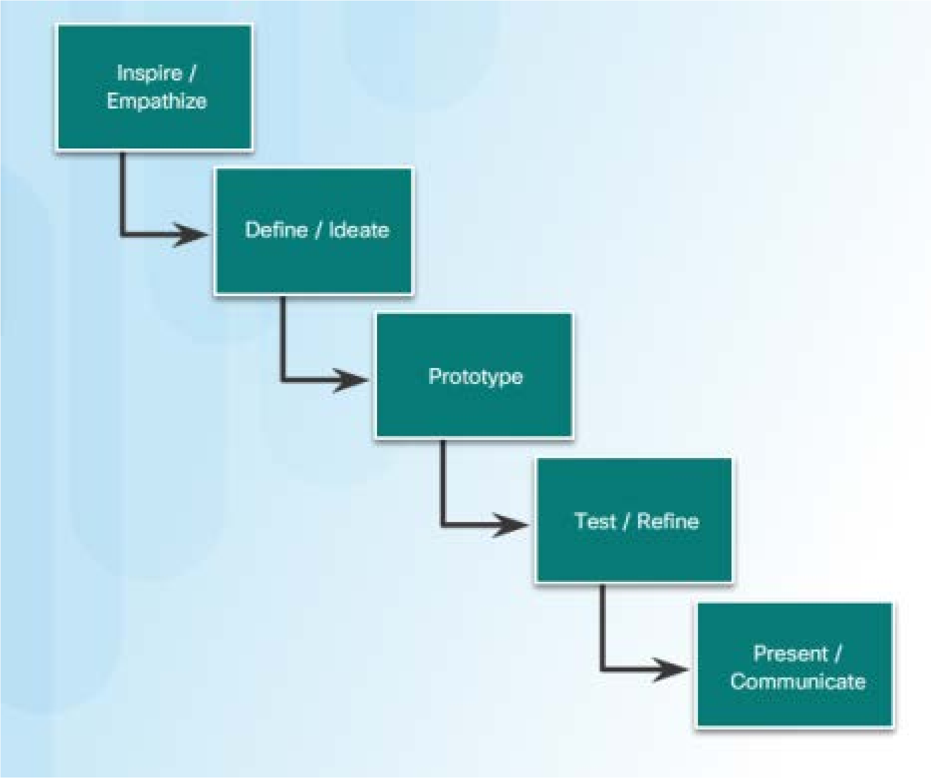
Become a Global Problem Solver
6.2.1 Designing Solutions

- The Engineering Design Process
  - How can we help solve global challenges?
  - The engineering design process is a proven method.
  - The five steps are cyclical which means that they can be repeated as many times as needed to make improvements in the design process.
    - Inspire/Empathize
    - Define/Ideate
    - Prototype
    - Test/Refine
    - Present/Communicate.



Become a Global Problem Solver

6.2.1 Designing Solutions (Cont.)

- Security Design
  - Security should be included from the beginning, in the design phase.
  - Ensure new devices facilitate software updates and all hidden backdoors are removed
  - On pre-manufactured devices used in projects ensure the following:
    - Default passwords/usernames are changed.
    - UPnP is disabled on IoT devices if possible.
    - Remote device management is protected with strong passwords and access limited to trusted personnel.
    - Ensure all devices are updated with the latest software updates and patches.
    - Ensure all devices support and use encryption and certificates.
    - Secure the physical location of IoT devices as much as possible.

6.3 Create an IoT System

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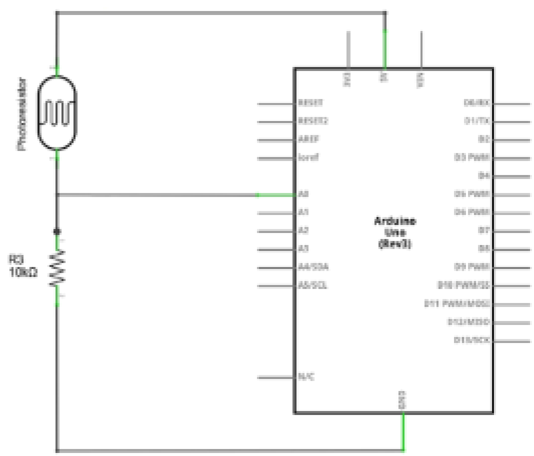
Create an IoT System

6.3.1 THE IoT System Project

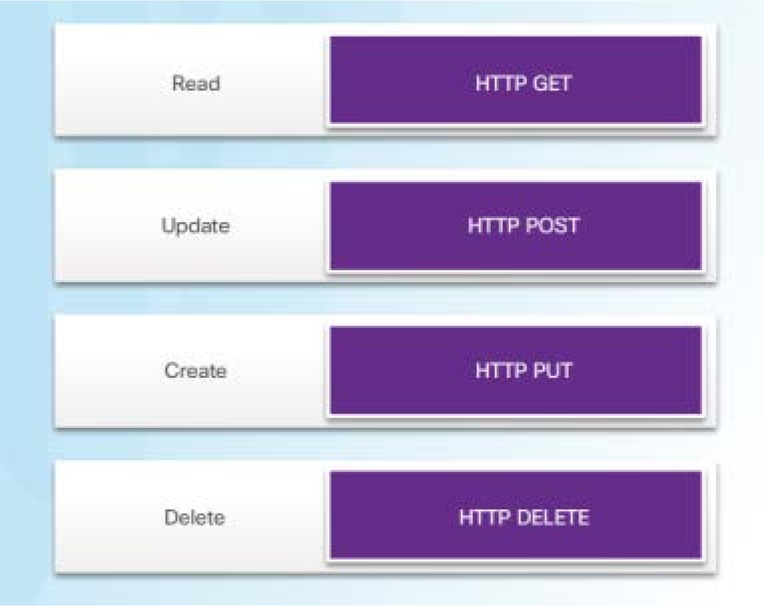
- Project Overview
  - Identify a problem that can be solved by an IoT device.
  - Example used: building a device that senses the amount of and determines sunrise and sunset.
- The Circuit Layout
  - Electronic components have specific power, polarity, and connection requirements.
  - The circuit layout identifies/describes these requirements.
  - Sunrise/sunset example requires a voltage divider - produces an output voltage that is a fraction of its input voltage by distributing the input voltage among the components of the divider.



Create an IoT System

6.3.1 THE IoT System Project (cont'd)

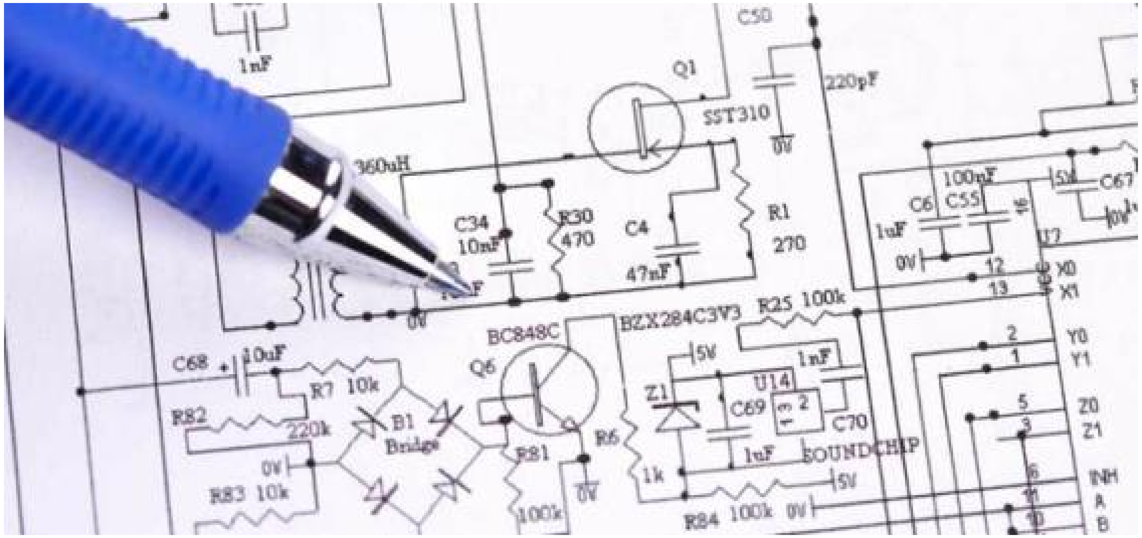
- REST API in an IoT System
  - REST APIs use HTTP methods to exchange data between systems or applications
  - RESTful systems use Uniform Resource Identifiers (URIs) to represent their services to external systems.
  - Sample URIs:
    - GET /people/michael to receive Michael's user profile dataset
    - POST /people/michael to update Michael's profile with new data.

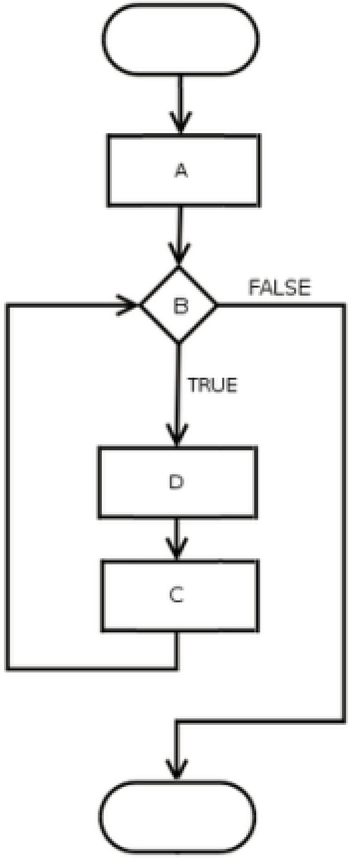


  - The IFTTT web service allows for special resource URIs to be created and mapped to specific IFTTT actions.
  - Example IFTTT URI - **https://maker.ifttt.com/trigger/SunRise/with/key/**
  - The sunrise/sunset example uses both IFTTT and Google Calendar services

6.3.1 THE IoT System Project (cont'd)

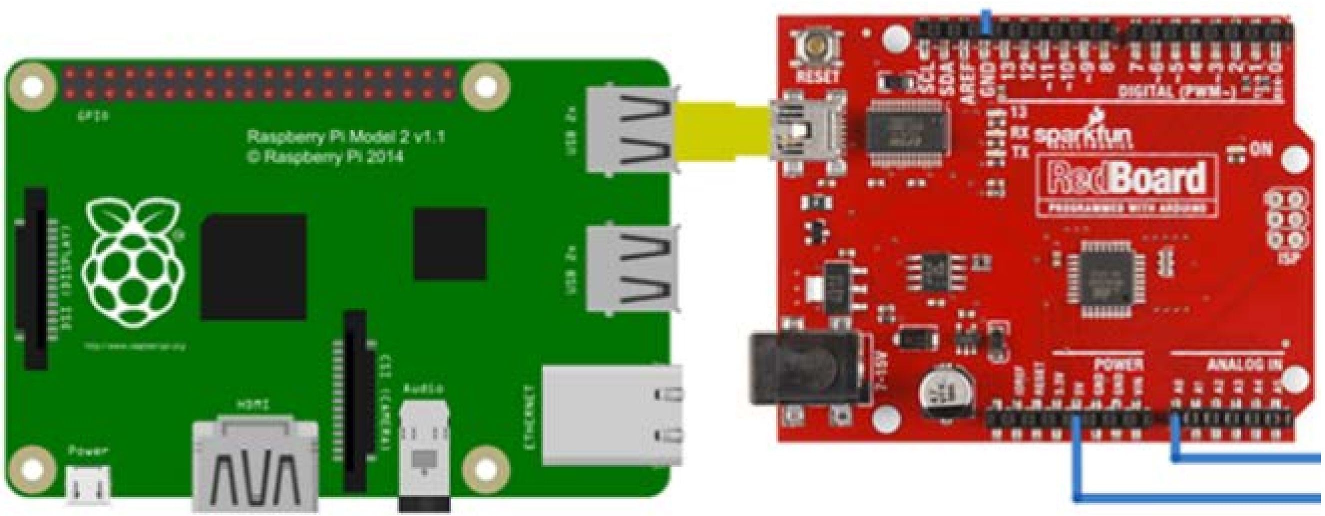
- Flowcharts, Electronic Schematics, and Sequence Diagrams
  - Documenting project is very important for building the devices, testing, troubleshooting, and creating a business model.
  - Flowcharts use standardized symbols to represent the processes and workflows.
  - Electronic schematics is a graphical representation of a circuit diagram using internationally standardized components.
  - Sequence diagrams represent interactions between entities along a timeline.





6.3.1 THE IoT System Project (cont'd)

- The Code
  - The sunrise/sunset example is written in Python using a Raspberry Pi
  - The Arduino is connected to the Raspberry Pi.
  - The programming is done on the Raspberry Pi to send the level of voltage drop from the Arduino to the RaPi.
  - Firmata, a generic protocol for communicating with microcontrollers, is used to communicate between the Arduino firmware and the RaPi.
  - The Python code used for the sunrise/sunset example is explained line by line.



6.3.2 THE IoT System Prototype

- Overview of the Problem
  - Simple problem identified that can be solved by an IoT system: remote access to determine if garage door is open or closed
    - Switch can determine if a door is open or closed
    - Switch attaches to a controller – which keeps track of switch status
    - Controller connected to Internet to provide remote access

- Prototyping and testing System
  - Create electronic schematic, flowchart, and sequence diagram for prototype
  - Packet Tracer 7 used to create and test the prototype.
  - Update documentation once prototype works successfully.
  - Documenting is important not only for future reference but also for situations where marketing material or patent applications are to be created.

6.4 Business Model Canvas

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Business Model Canvas

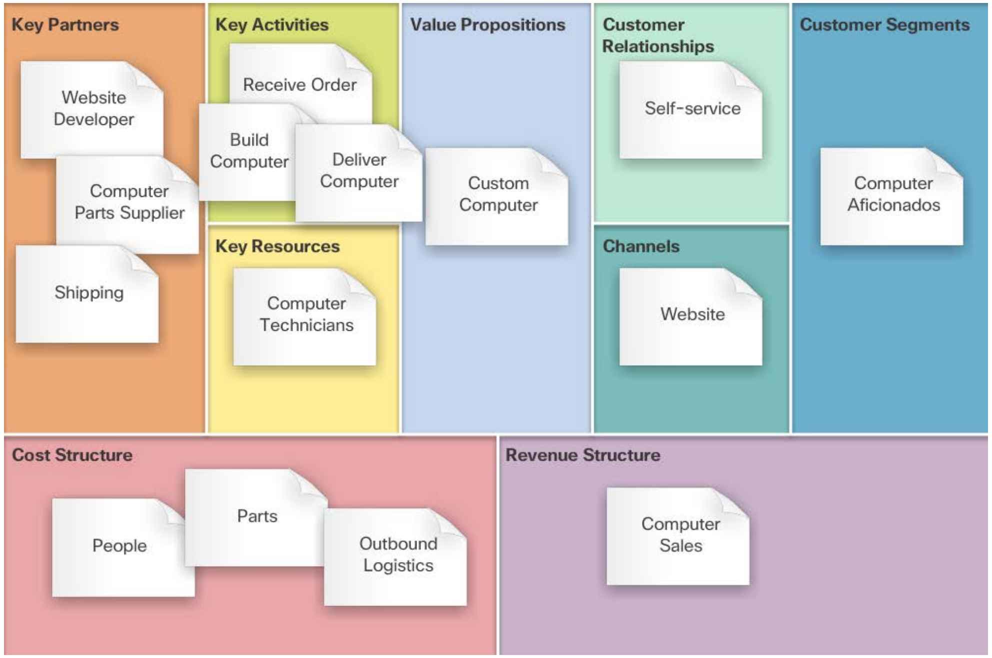
6.4.1 Business Model Canvas

- Business Model Canvas Overview
  - Helps organizations and entrepreneurs map, discuss, design, and invent new business models.
  - A business model consists of nine building blocks:
    - Customer Segments, Value Proposition, Channels, Customer Relationships, Revenue Stream, Key Resources, Key Activities, Key Partnerships and Cost Structure.
- Customer Interface
  - Customer Interface is comprised by Customer Segments, Value Proposition, Channels, Customer Relationship.
- Infrastructure Management
  - Defines how to build the value proposition.
  - Key Resources, Key Activities, and Key Partnerships make up the Infrastructure Management.

6.4.1 Business Model Canvas (Cont.)

- Business Finances
  - Include the cost structure and revenue streams created by the value proposition.

- Business Model Canvas Example
  - Example of a completed business model canvas for a custom computer manufacturer.



6.5 What is Next?

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What is Next?
6.5.1 Lifelong Learning

- 21^{st} Century Skills
  - 21st century job market is now looking for employees who can accomplish one or more job roles such as: design a project, prototype a device, create and maintain documentation, and create a business plan.
- IoT employees also need learning and innovation skills
  - Creativity and innovation
  - Critical thinking and problem solving
  - Communication
  - Collaboration

What is Next?
6.5.1 Lifelong Learning (cont'd)

- Resources for Continued Learning
  - There are many resources available to enable you to continue learning about the IoT including:
    - Cisco Networking Academy
    - Cisco Learning Network
    - Cisco DevNet
    - IEEE Computer Society (IEEE-CS) and the Association for Computing Machinery (ACM)
    - Many other online resources including forums, wikis, blogs, and more
    - There are also IoT communities of practice consisting of other like-minded individuals who want to share ideas with others.

6.6 Chapter Summary

Chapter Summary
Summary

- There are many global social and environmental problems that can be solved by IoT systems. The Institute for Globally Transformative Technologies (LIGTT) has compiled a list of 50 breakthrough technologies that will drastically improve the work on these global problems.
- The Engineering Design Process is a proven method to develop a product.
- The first step to design an IoT solution is to identify a problem that can be solved with an IoT device. To test the idea, a prototype could be built simply by using a Raspberry Pi with an attached Arduino. To provide an example, a sunrise/sunset tracker was built.
- Another prototype was designed on Packet Tracer to remotely check to see if the garage door was open or closed..
- Documentation is very important component of any project. Flowcharts, Electronic Schematics and sequence diagrams are often used to provide documentation.
- The **Business Model Canvas** helps organizations and entrepreneurs map, discuss, design, and invent new business models based on a value proposition, customer interface, infrastructure management, and finances
- IoT professionals should be individuals who espouse life-long learning. They need to be flexible, take the initiative, lead when necessary, and be able to produce something new and useful

Cisco | Networking Academy®
Mind Wide Open™

Internet of Everything (IoE)

Mobility

Timothy W. Smith
Architect, Office of the CTO APJC

January 15, 2014

Today's Topics

- IoE Review
- Smart Objects and LLNs
- Secure Mobility
- Cisco Mobile Experience
- Architectures and Examples

IoT Review

A History of Connections

- 170 Years Ago: Invention of the Telegraph
- 100 Years Ago: Invention of the Radio
- 70 Years Ago: First general purpose electronic computer
- 40 Years Ago: First Internet connection
- 20 Years Ago: World Wide Web

Today

- 2003: **0.5B** Connected Devices
- 2005: IP Traffic: 29 exabytes
- 2005: First Smartphone
- 2008: Video Traffic: 21 exabytes
- 2010: **0.5B** Smartphones
- 2010: **7B** Connected Devices
- 2011: **90M** Smartmeters
- 2012: **50M** Connecte

The Internet of Everything

Networked Connection of People, Process, Data, Things

People

Connecting people in more relevant, valuable ways

Process

Delivering the right information to the right person (or machine) at the right time

Data

Leveraging data into more useful information for decision making

Things

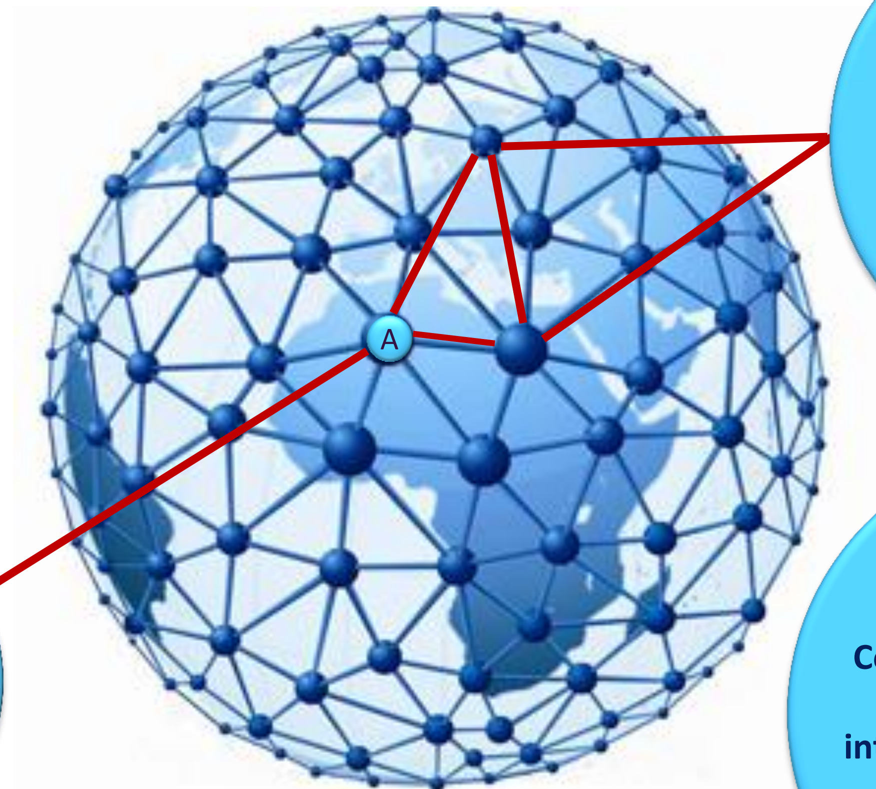
Physical devices and objects connected to the Internet and each other for intelligent decision making; often called Internet of Things (IoT)

Defining Properties of the IoE

1

Unique addressable object

A



2

Unique location within a network (wireless/fixed/public/private)

3

Information-processing by machines surpasses humans as networks join up

4

Complex interoperability of networks will require intelligent analytics, security and management

5

Time and location takes on new meaning as real-time ambient intelligence becomes the norm

Source: Cisco 2011

Driving the Internet of Everything

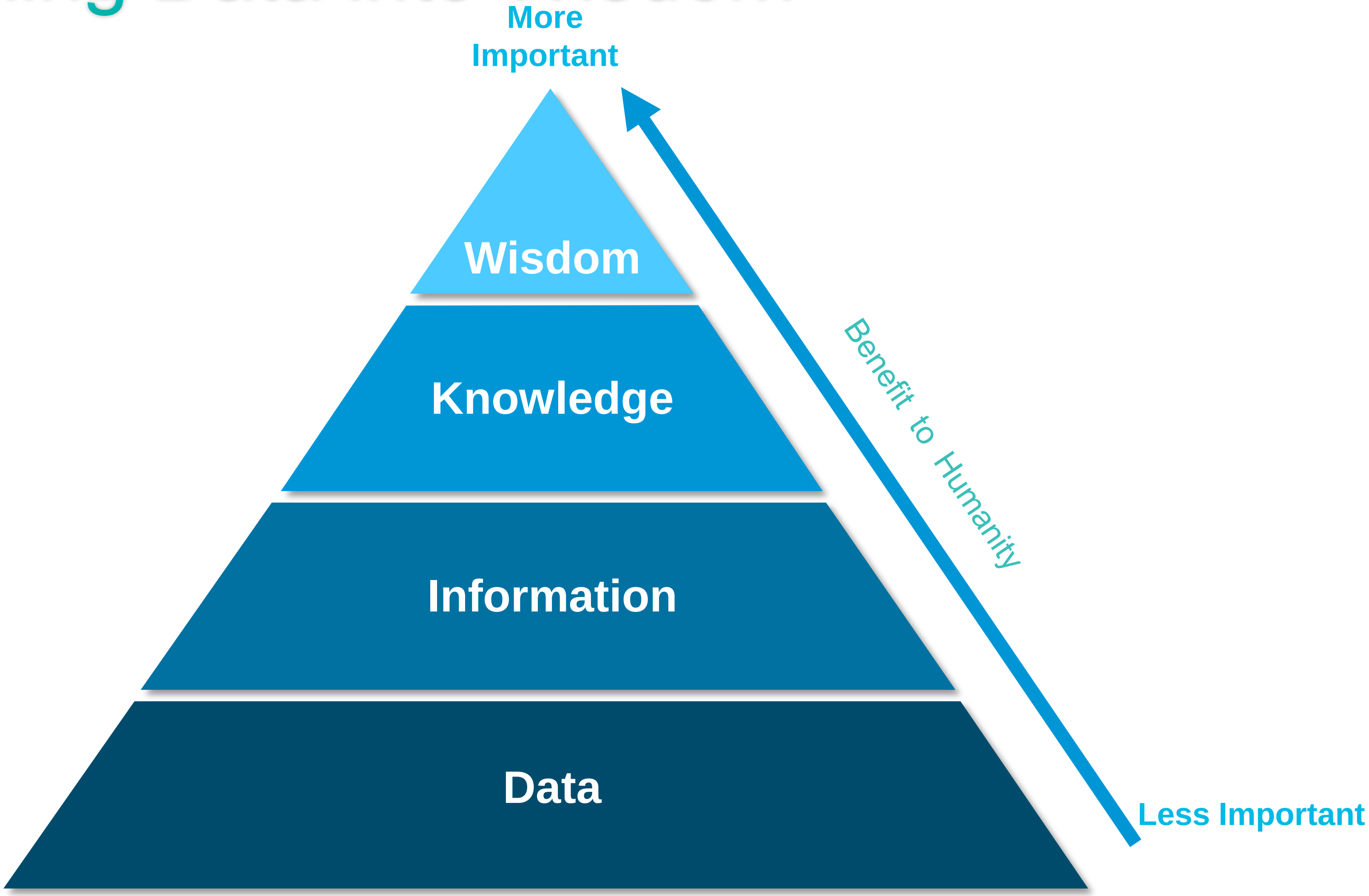
Remote Monitoring and Management

Big Data/Analytics

Plant/Store/Hospital Automation

New Connected Assets

The Opportunity: Turning Data into Wisdom



Source: Cisco IBSG, 2011

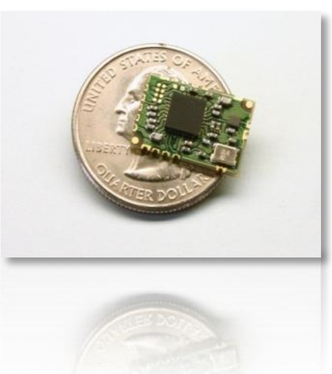
Smart Objects & LLNs

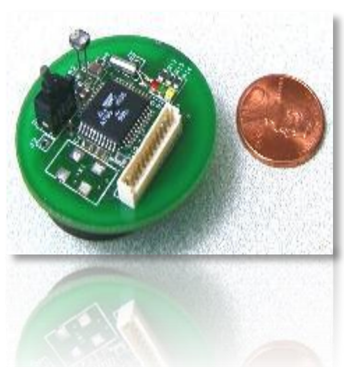
Characteristics of Smart Objects

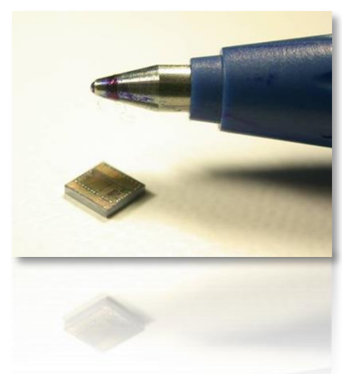
- These devices are **highly constrained** in terms of
  - Physical size
  - CPU power
  - Memory (few tens of kilobytes)
  - Bandwidth (Maximum of 250 KB/s, lower rates the norm)
- Power consumption is critical
  - If it is battery powered then energy efficiency is paramount, batteries might have to last for years
- May operate in harsh environments
  - Challenging physical environment (heat, dust, moisture, interference)
- Wireless capabilities based on Low Power & Lossy Network (LLNs) technology
  - Predominantly IEEE 802.15.4 (2.4 GHz and 900 MHz)
  - Newer RF technologies IEEE 802.15.4g Smart Utility Network (SUN)
- May also run over wired technologies such as IEEE P1901.2 PLC (Power Line)

What is a Low Power Lossy Network (LLN)?

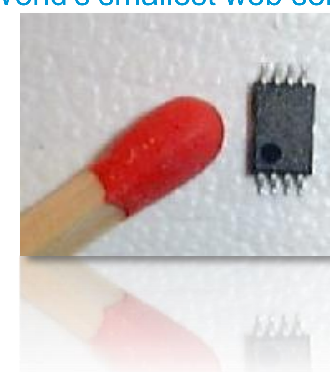
- LLNs comprise a large number of highly constrained devices (smart objects) interconnected by predominantly wireless links of unpredictable quality
- LLNs cover a wide scope of applications
  - Industrial Monitoring, Building Automation, Connected Home, Healthcare, Environmental Monitoring, Urban Sensor Networks, Energy Management, Asset Tracking, Refrigeration
- Several IETF working groups and Industry Alliance addressing LLNs
  - IETF - CoRE, 6Lowpan, ROLL
  - Alliances - IP for Smart Objects Alliance (IPSO)







World’s smallest web server

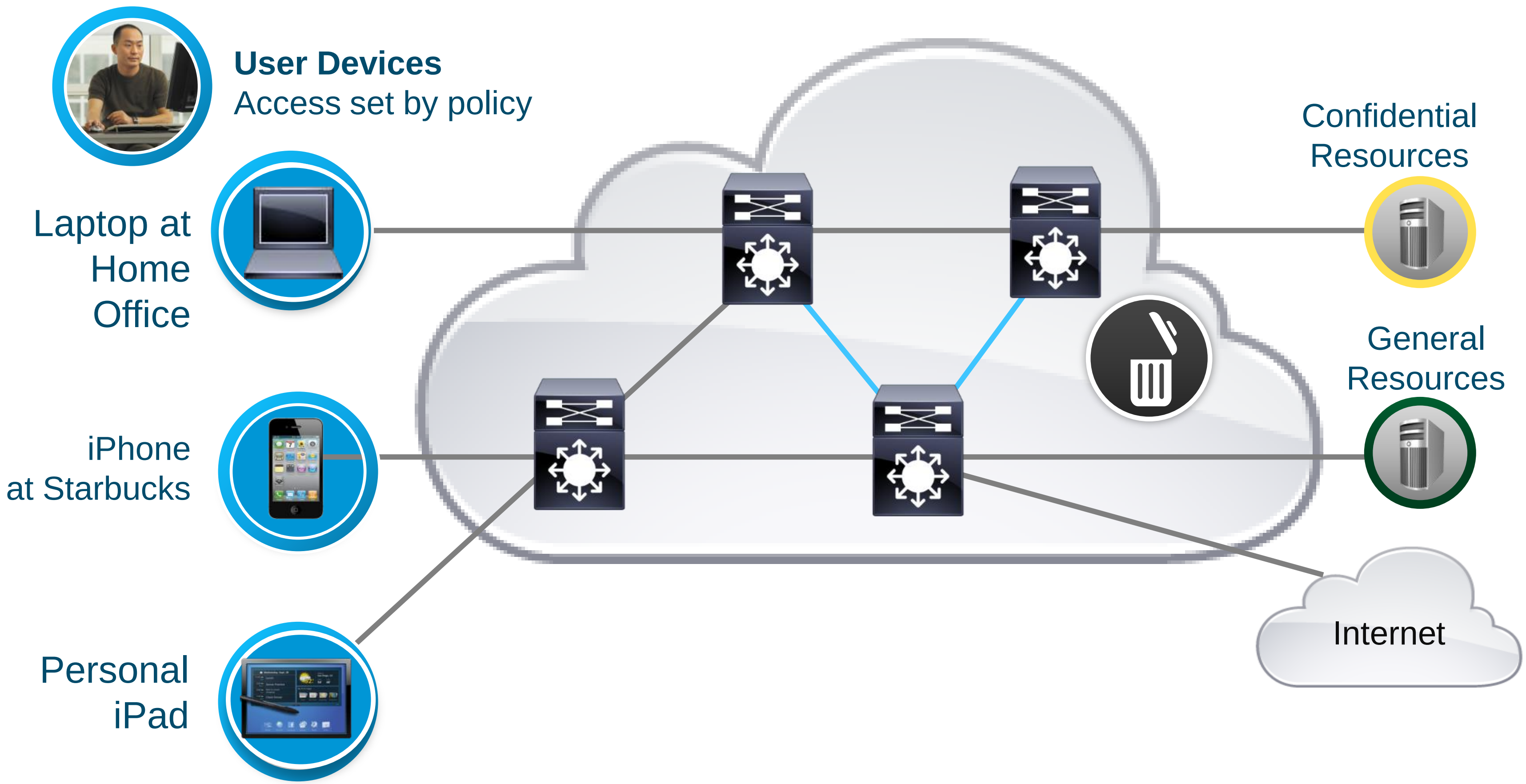


Characteristics of Internet vs Smart Object Networks

Current Internet	Smart Object Networks
Nodes are routers	Nodes are sensor/actuators and routers
IGP with typically few hundreds of 100 nodes	An order of magnitude larger in nodes
Links and Nodes are stable	Links are highly unstable Nodes fail more frequently
Node and link bandwidth constraints are generally non-issues	Nodes & links are highly constrained
Routing is not application aware	Application-aware routing, in-Band processing is a MUST

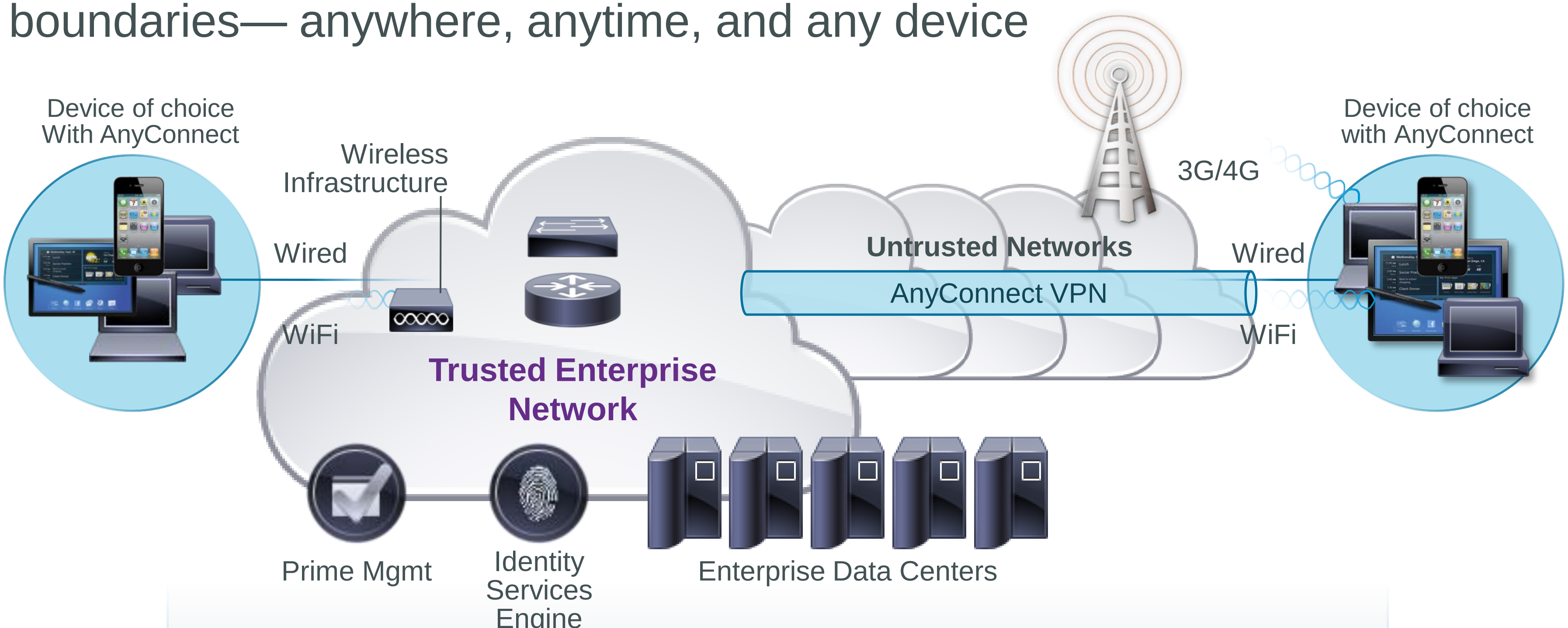
Secure Mobility

Secure Mobility in Everyday Life



Cisco's Secure Mobility Solution

Extend access to trusted networks and resources across untrusted boundaries— anywhere, anytime, and any device



Benefits

- Mobile users work easily and predictably, whenever and from wherever
- Network managers easily set policy and manage the network to allow secure access to the appropriate resources

Solution Products and Services

Cisco technologies provide best-in-class solution for users & IT managers

Cisco Core Network Infrastructure
Standard features contribute to Secure Mobility

Wireless Infrastructure & Services
Best-of-Breed Mobility Technology

Identity Services Engine (ISE)
Security & Policy Administration

Prime Network Management
Access Management for Wired and Wireless

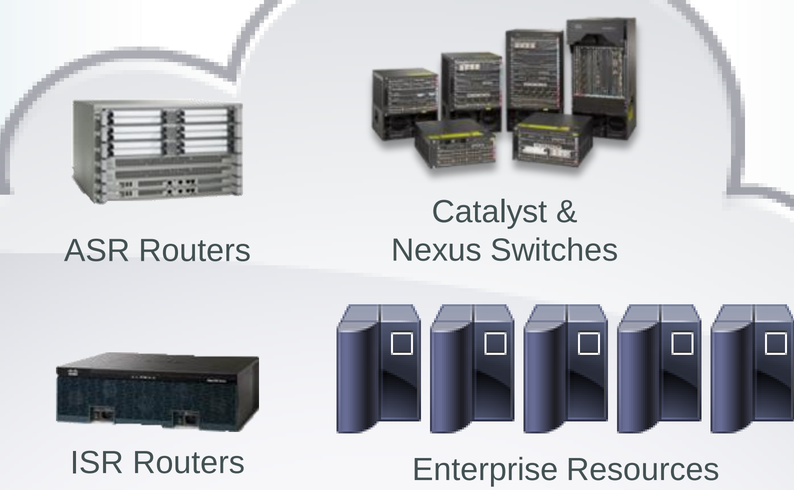
AnyConnect Mobility Client
Secure, Consistent Access for Voice, Video, Data and Applications

Cisco Advanced Services
Secure Mobility Network Strategy and Architecture Workshop

Cisco Core Network Infrastructure

NetFlow
Traffic accounting and monitoring of packet flow on network

Embedded Event Manager
Powerful sub-system to provide real time network event triggers and automation



Application Visibility & Control
Intelligently apply policy to network traffic based on mission and business priorities

TrustSec
Security enabling features included in applicable Cisco products (802.1x, 802.1ae, SGT, etc.)

Cisco Secure Wireless

Mobility Services Engine

- Wired and wireless location tracking
- Open platform for wireless IPS and other software

Wireless IPS

- Detection of wireless anomalies, un-authorized access, and RF attacks
- RF environment awareness

Wireless Encryption

- Scalable
- Built into hardware
- WPA , WPA2 with AES

Optimal User Experience

- CleanAir
- ClientLink
- IPv6 support
- BandSelect
- VideoStream

Cisco Identity Services Engine
Security & Policy Administration

Consolidated Services, Software Packages

NAC Manager
ACS
NAC Profiler
NAC Server
NAC Guest
ISE

Simplify Deployment and Admin

Session Directory

User ID

Access Rights

Location

Device (and IP/MAC)

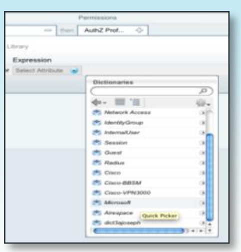
Tracks Active Users and Devices

Flexible Service Deployment

All-in-One HA Pair
Admin Console
M&T
Distributed PDPs

Optimize Where Services Run

Policy Extensibility



Link in Policy Information Points

Manage Security Group Access

SGT	Public	Private
Staff	Permit	Permit
Guest	Permit	Deny

Keep Existing Logical Design

System-wide Monitoring and Troubleshooting

Consolidate Data, Three-Click Drill-In

Single Unified Appliance to set, monitor and report on policy

Cisco Prime Network Management

Access Management for Wired and Wireless

- Prime Infrastructure – One Package for Lifecycle Management

  All components to do lifecycle management for WLAN's, wired infrastructure and branches, in a single user interface framework

- Prime Assurance Manager

  Correlated and homogenized information from many network instrumentation sources, including NetFlow, NAM, SNMP, and probes

- New Branch Network Management

  Manage ISR G2 routers, Catalyst switches, and ASR 1000 in one workflow – included in Prime Infrastructure package

Prime Assurance Manager

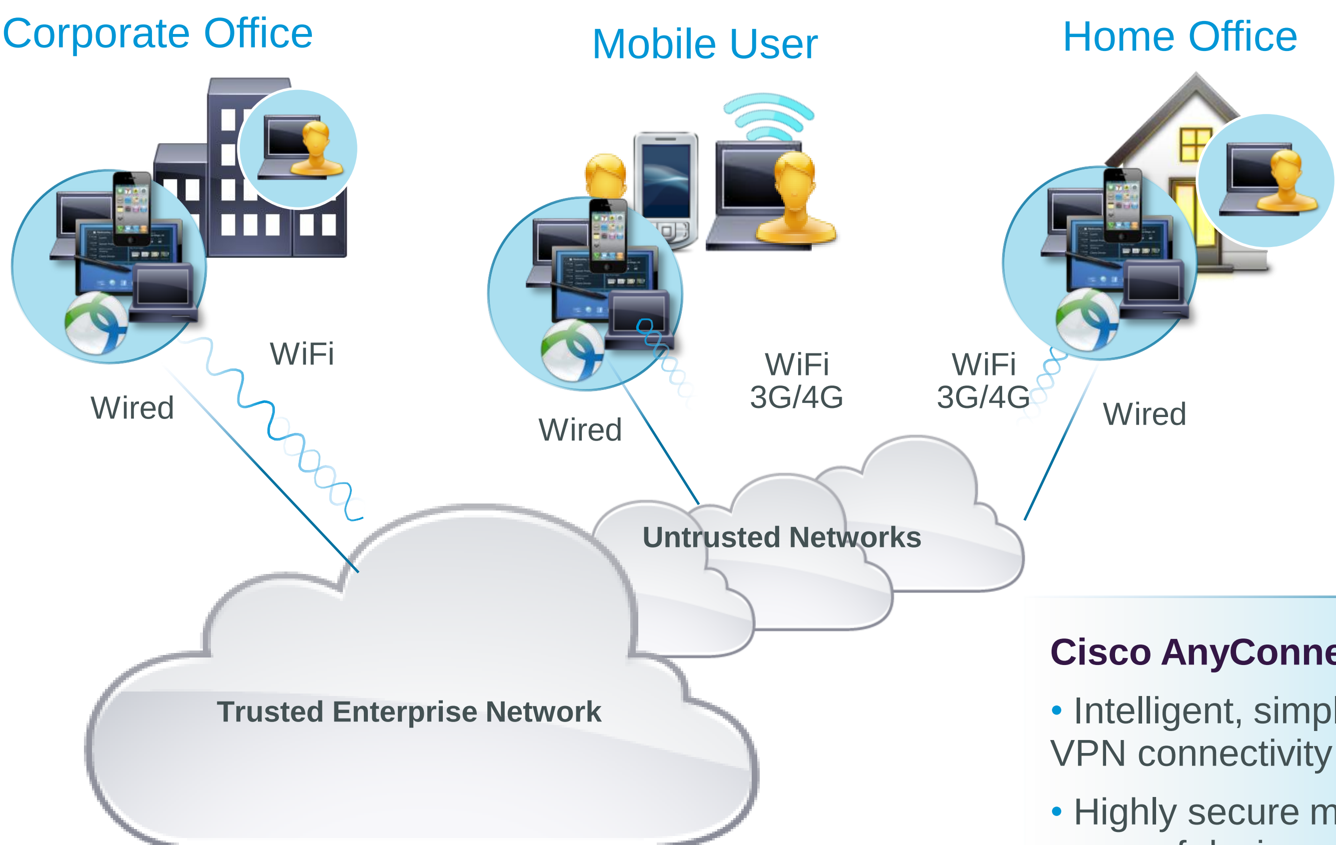
Prime Modules

(**NCS**) Cisco Prime Network Control System
(**LMS**) Cisco Prime LAN Management Solution
(**CM**) Cisco Prime Collaboration Manager
(**NAM**) Cisco Prime Network Analysis Module

Improved Network Visibility • Faster Troubleshooting • Eliminate Configuration Errors

Cisco AnyConnect Secure Mobility Client

Secure, Consistent Access for Voice, Video, Data and Applications



Cisco AnyConnect offers

- Intelligent, simple, and always-on VPN connectivity
- Highly secure mobility for wide range of devices

Spectrum of Customer Deployment Strategies

✓ **Adoption Policy**	Restrict, Limit, Allow, Embrace
✓ **Device Ownership**	Corp, Employee, Hybrid, Guests
✓ **Support Model**	IT Manage, IT Assist, Self-Supported
✓ **Support Level**	Production, Guest, Guest+, Best Effort
✓ **Data Security**	Written Policy, MDM, Virtual, Advanced

Limit	Basic	Advanced	Embrace
Environment requires tight controls	**Basic access for additional devices**	**Any device, anywhere, enhanced security**	**Any device, anywhere, anyone**
IT chosen devices	Broader device set	Wide range of devices	Wide range of devices
IT managed devices with mainly on-site access	IT managed devices with mainly on-site access	Corp and employee owned devices with full on-site and off-site access	Corp and employee owned devices with full on-site and off-site access
All other devices prohibited	Employee owned and Guest devices with Internet only	Device-side security	Device-side security
		Guest devices with Internet only	Custom Native applications
			Guest/Customer devices with enhanced services

Future State: More Integrated Security

CLOUD-BASED THREAT INTEL & DEFENSE (SIO)

- ATTACKS
- APPLICATION REPUTATION
- SITE REPUTATION
- MALWARE

COMMON POLICY, MANAGEMENT & CONTEXT

- COMMON MANAGEMENT
- SHARED POLICY
- ROLES BASED CONTROLS

NETWORK ENFORCED POLICY

- ACCESS
- FW
- IPS
- VPN
- WEB
- EMAIL

- APPLIANCES
- ROUTERS
- SWITCHES
- WIRELESS
- VIRTUAL

VISIBILITY

CONTROL

Why Identity Is Important

Authentication

1

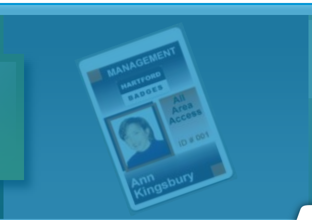
Who are you?

802.1X (or supplementary method) authenticates the user

Keep the Outsiders Out

Authorization

2



Where can you go?

Based on authentication, user is placed in correct VLAN or given access to network resources

Keep the Insiders Honest

3

What service level to you receive?

The user can be given per-user services (ACLs today, more to come)

Personalize the Network

Visibility/Accounting

4

What are you doing?

The user's identity and location can be used for tracking and accounting

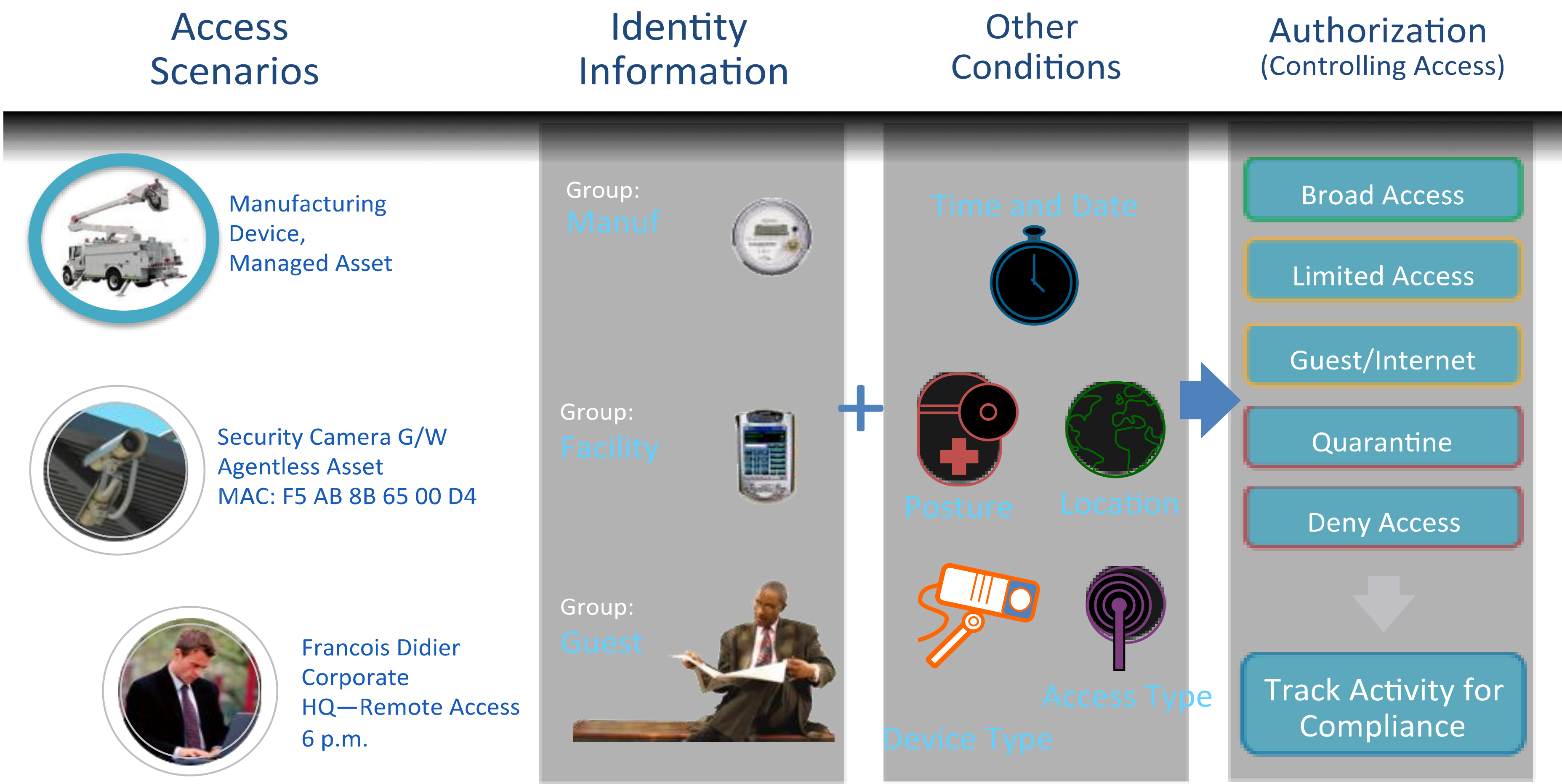
Increase Network Visibility

Leveraging the TrustSec Architecture

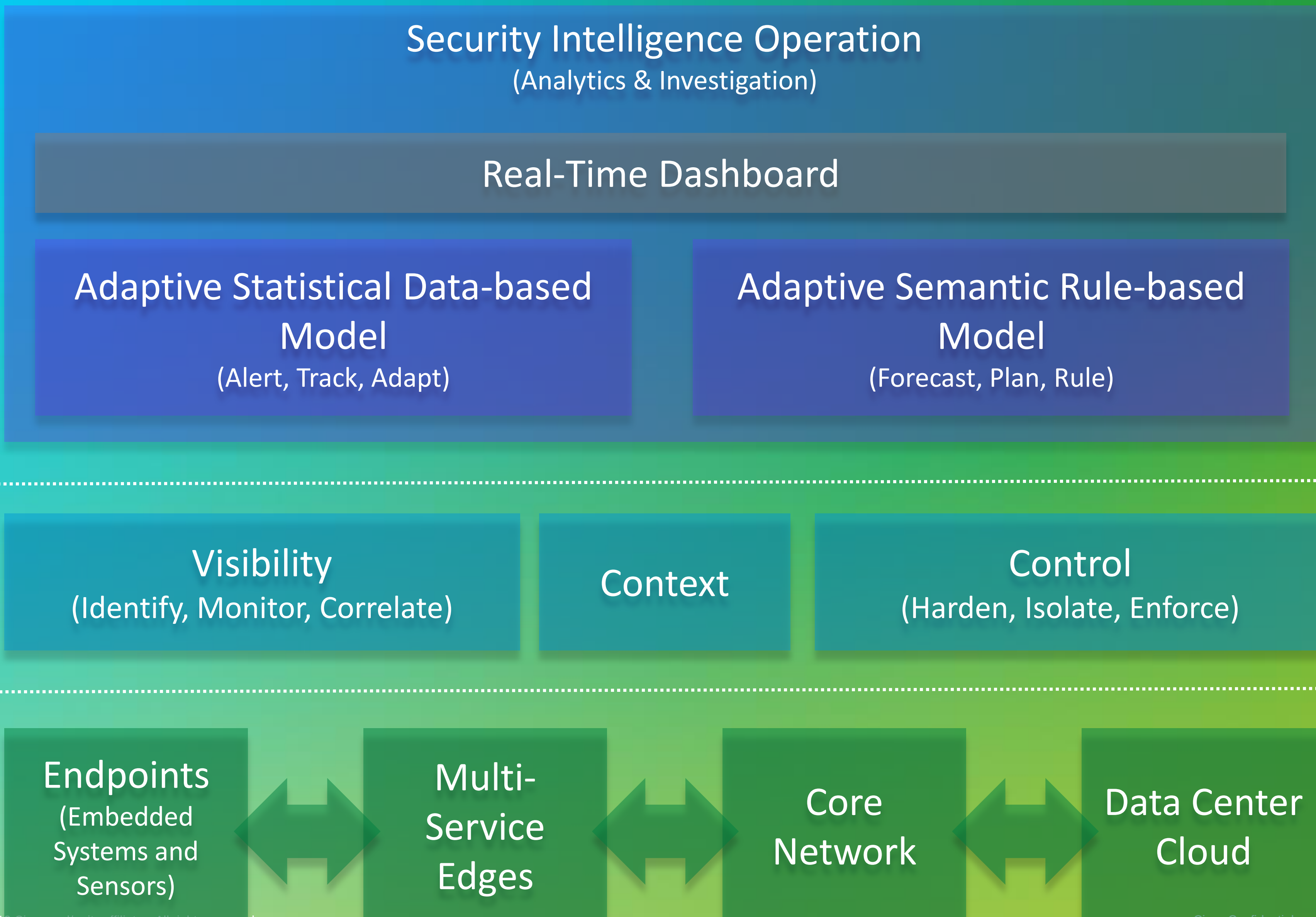
Common Policy

Value Added Services	Device Posture	Device Profiling	Guest Access	802.1AE MACsec
Authorization	ACL	VLAN	Security Group Tag	
Authentication	802.1X	WebAuth	MAB	Appliance (in-band, out-of-band)

Policy Driven Authentication & Authorization



Visibility, Control and SIO



CISCO SIO

SensorBase

4 TB
DATA RECEIVED PER DAY

30B HTTP://
WEB REQUESTS

750,000+
GLOBALLY DEPLOYED DEVICES

35%
WORLDWIDE TRAFFIC

100M
EMAIL MESSAGES

Dynamic Updates

6,500+
IPS SIGNATURES PRODUCED

3 to 5
MINUTE UPDATES

8M+
RULES per DAY

20+
PUBLICATIONS PRODUCED

200+
PARAMETERS TRACKED

Real-Time Dashboard

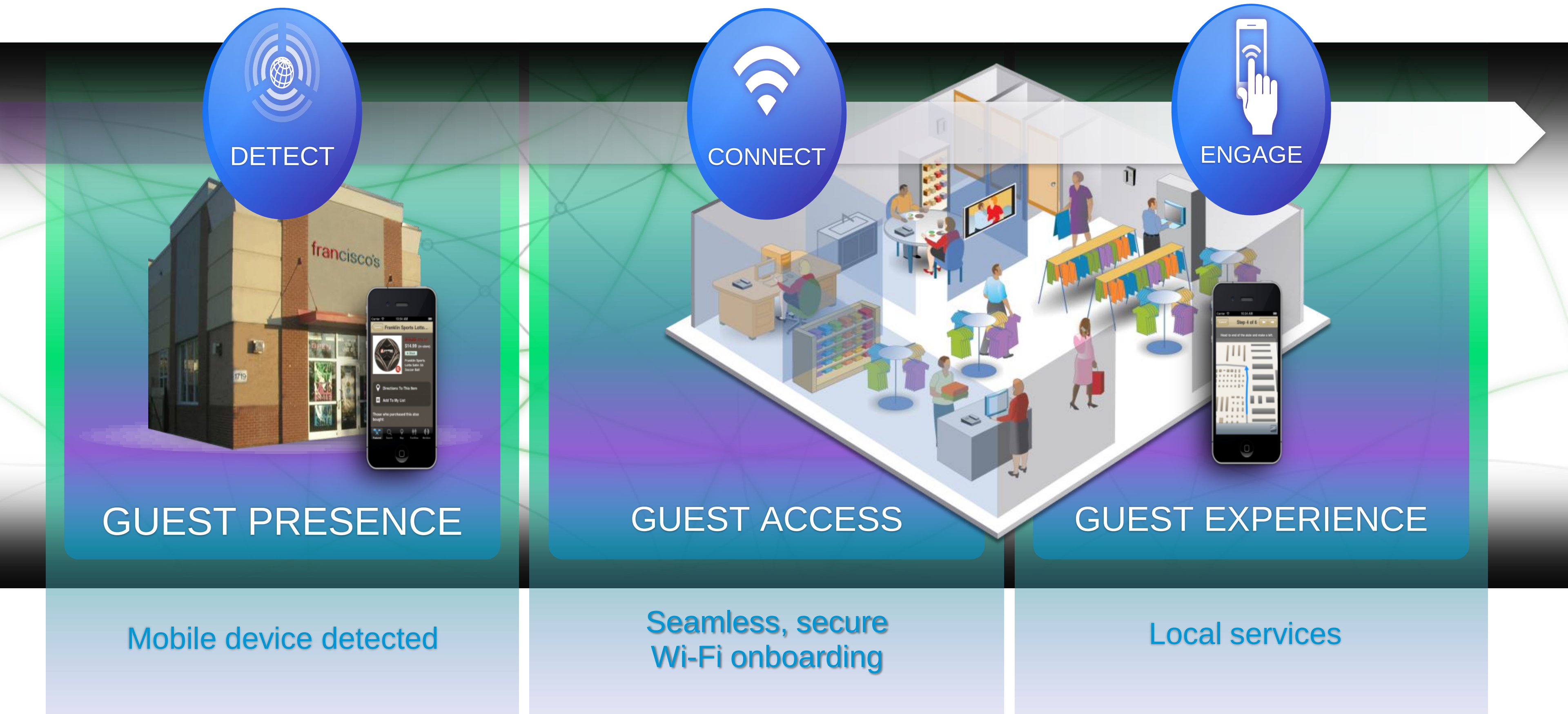
- Real-Time
- Informative
- Interactive

- Automation
- Recommendation
- Robustness

Acknowledgement to Cisco SIO concept demo

Cisco Mobile Experience - CMX

What Is CMX?



ANALYTICS – Onsite, Online & Social

Connected Mobile Experiences

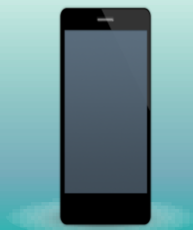
Leveraging Location-Based Services for Unprecedented Business Value

INDOOR GPS

- “Turn-by-turn” directions within venue to any location (departments, products, rooms, cafeteria, gift shop, ATM, etc.)

TARGETED MESSAGING

- Targeted personalized messaging based on customer location
- Location-based push notifications



LOCATION-SPECIFC ON-BOARDING

- Targeted information for guests based on their location (captive portal)
- Automatically connect to the dedicated wireless SSID network

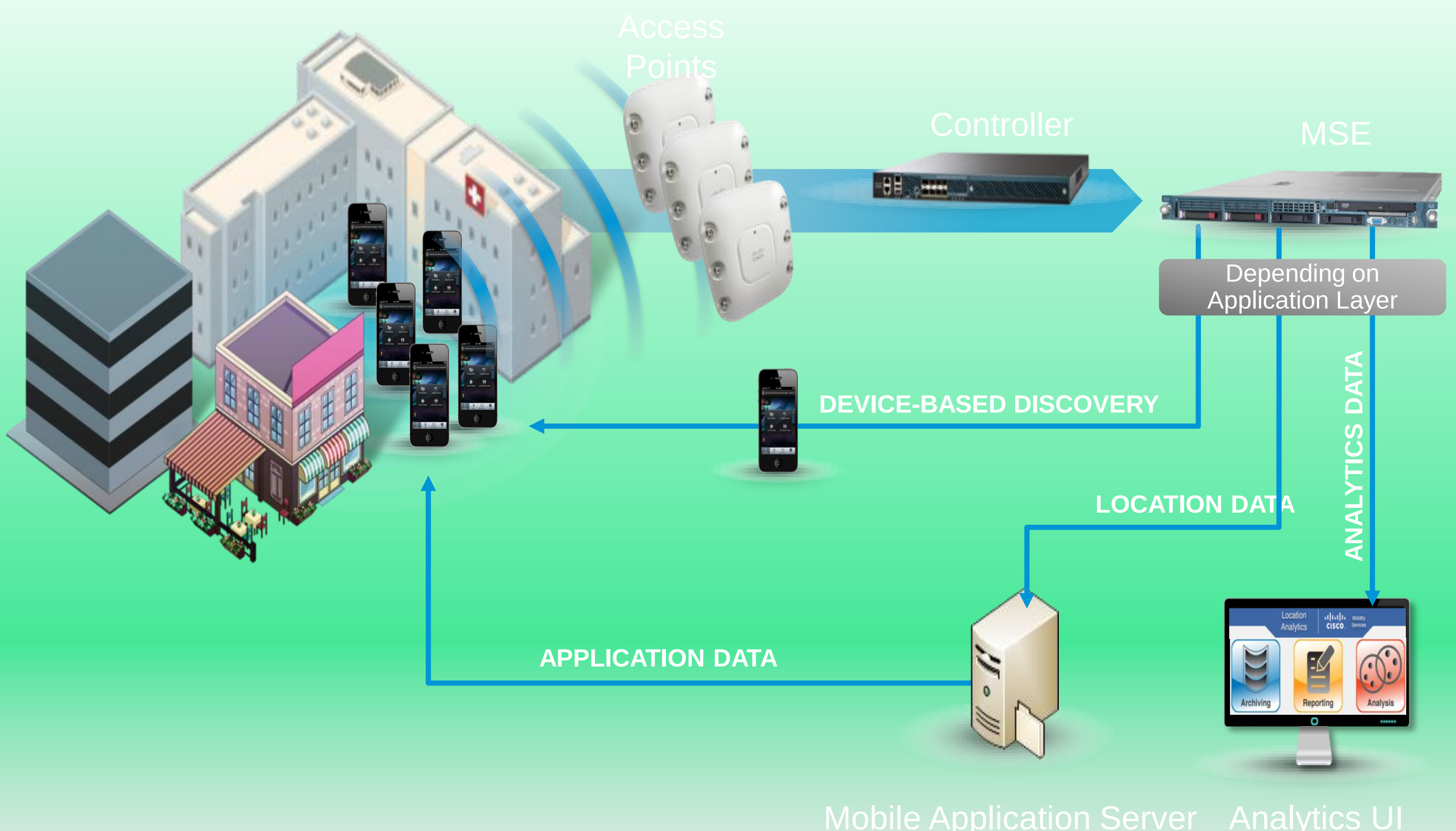
SYSTEM INTEGRATIONS

- Integration with systems including registration, property-management systems, product databases, and other location-based service applications

ANALYTICS

- Use gathered data to run reports and gain insight into online, onsite and social customer trends
- Analyze aggregate locations, URLs, and demographics

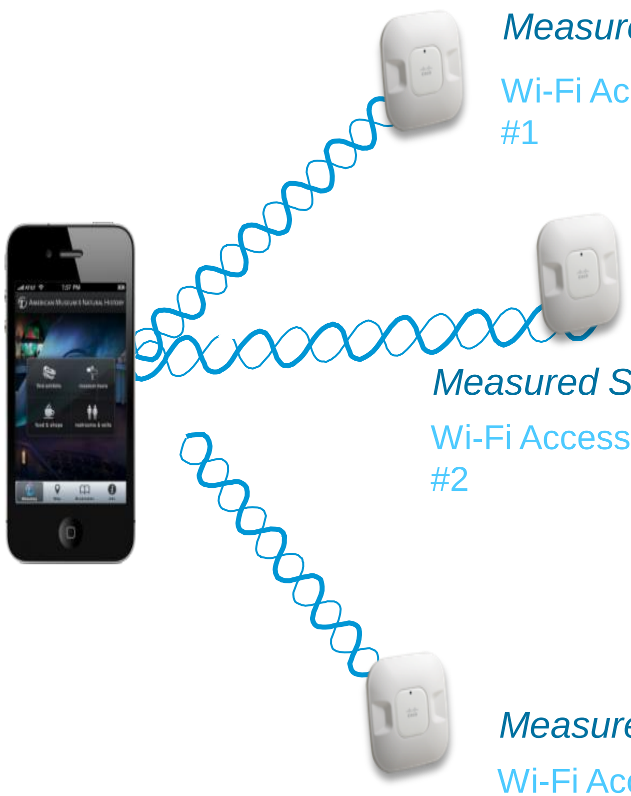
How Does CMX Work?



How Location is Calculated

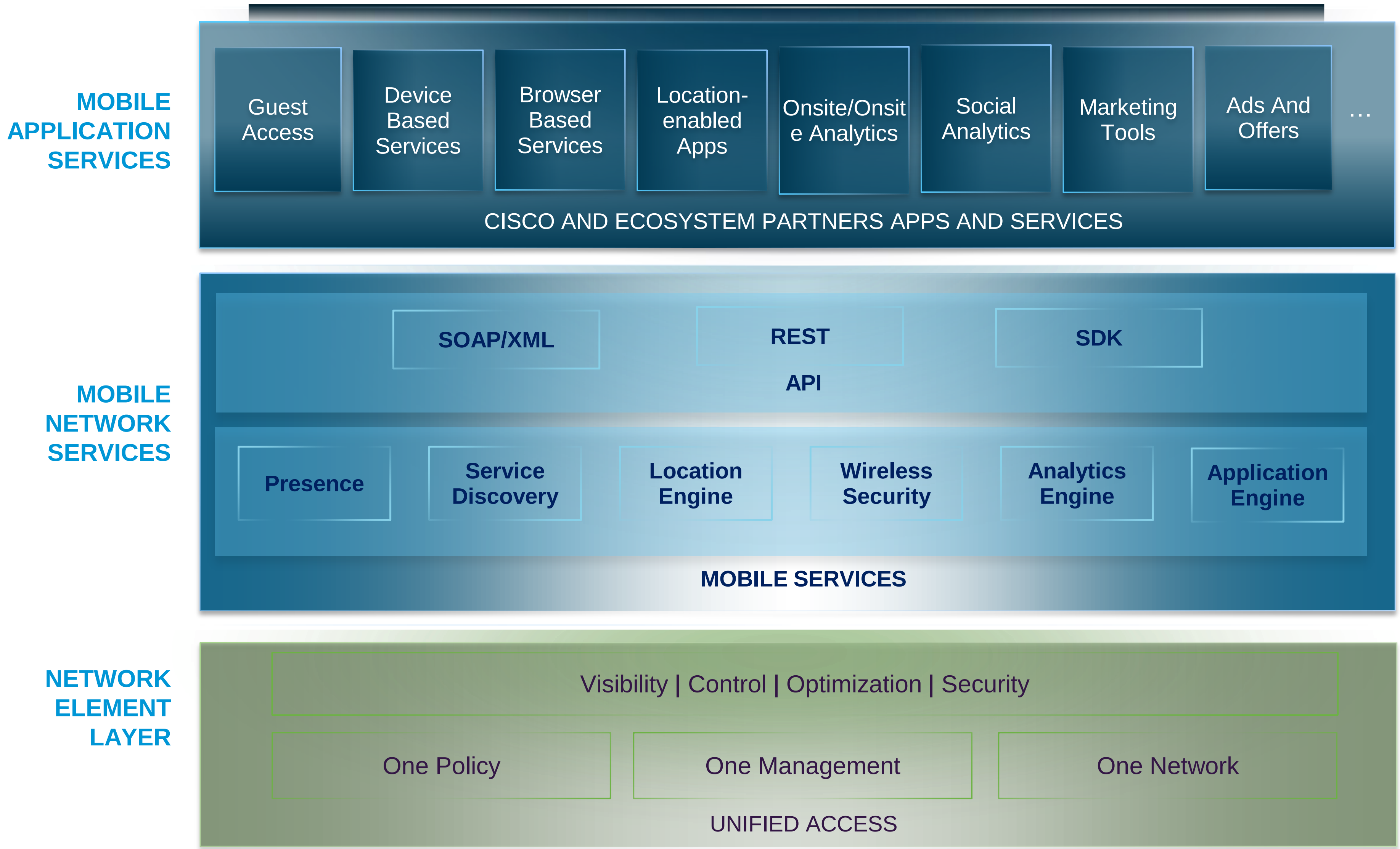
Out of Data Path for Higher Scalability

1. APs detect signal strength from mobile device beacon
2. Signal strengths sent by Controllers to the Cisco MSE
3. RF fingerprinting / triangulation based on signal strengths; calculates device location

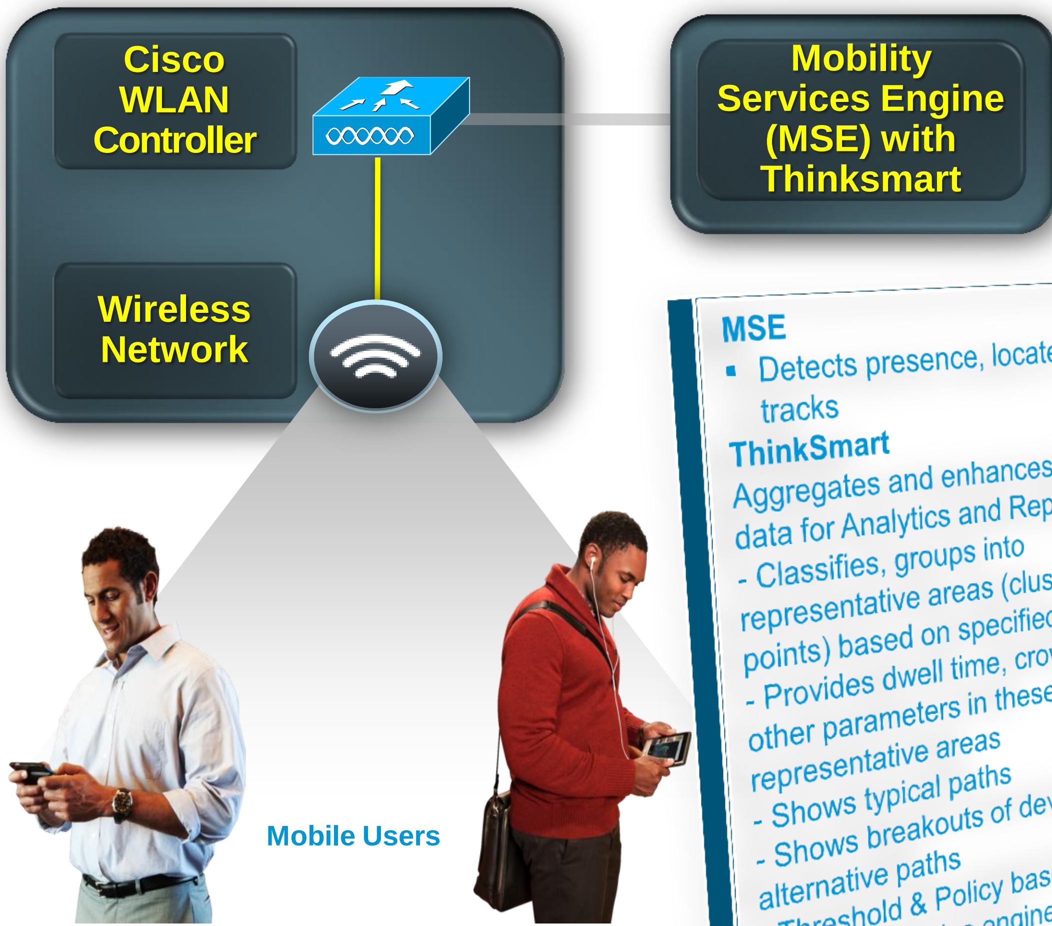


Connected Mobile Experiences

Solution Architecture



ThinkSmart Location Analytics



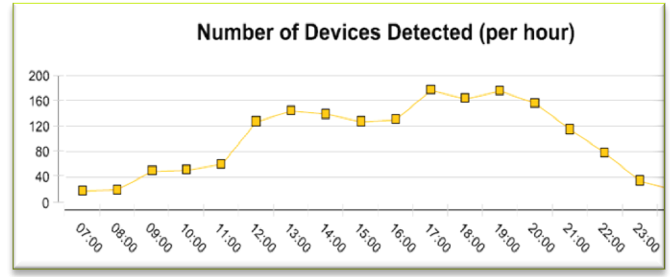
MSE

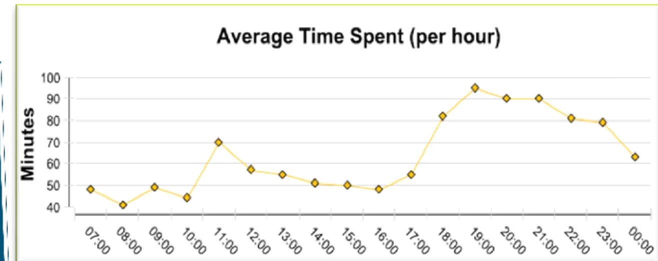
- Detects presence, locates & tracks

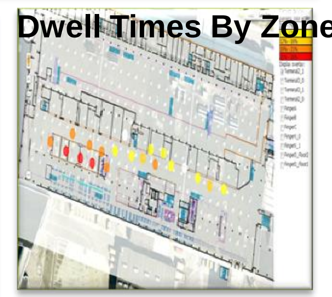
ThinkSmart

Aggregates and enhances location data for Analytics and Reporting

- Classifies, groups into representative areas (cluster points) based on specified criteria
- Provides dwell time, crowding and other parameters in these representative areas
- Shows typical paths
- Shows breakouts of devices along alternative paths
- Threshold & Policy based alerting
- Reporting (rules engine)



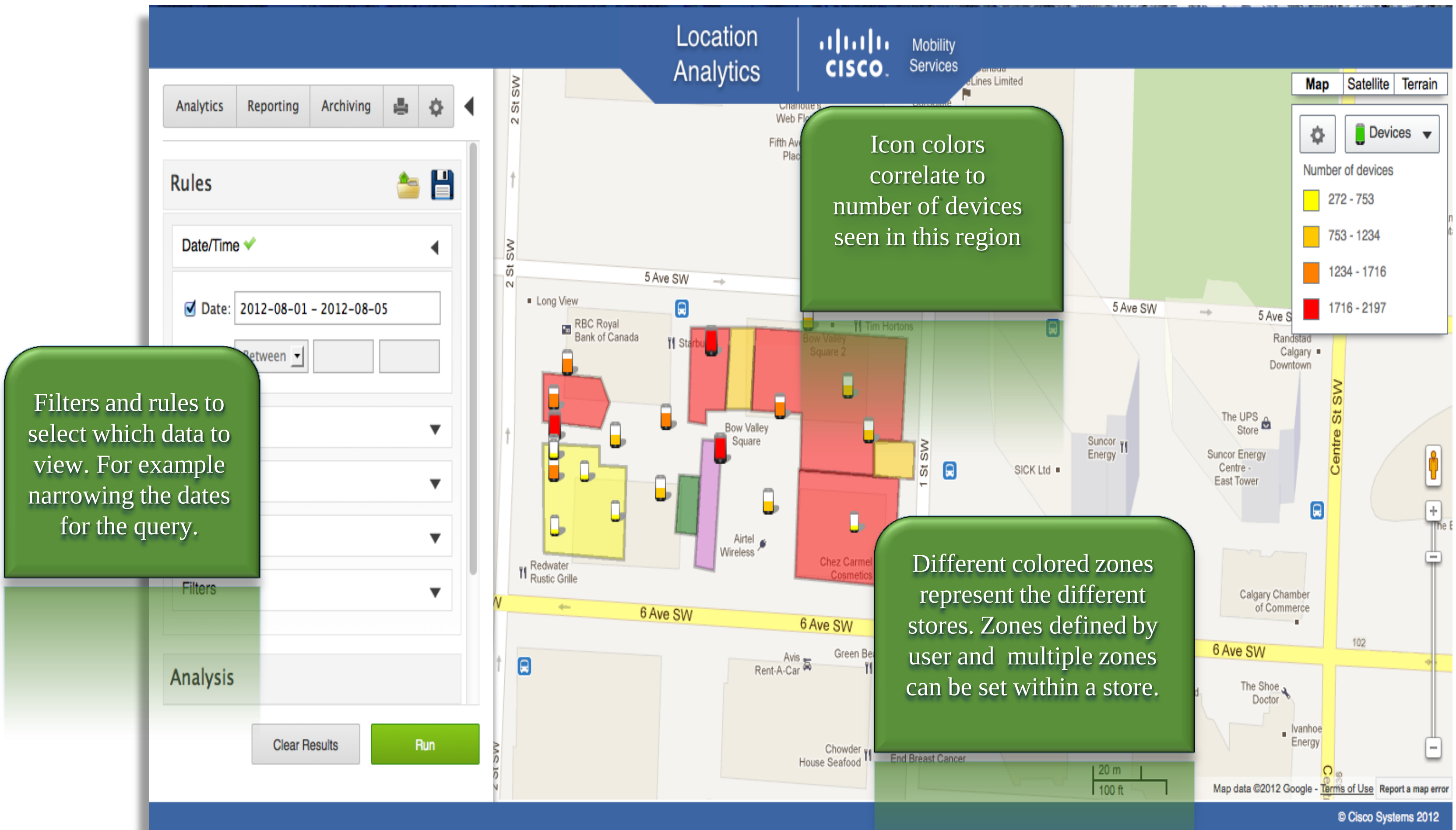




ThinkSmart Analytics

Improving Customer Experience Through Location Analytics

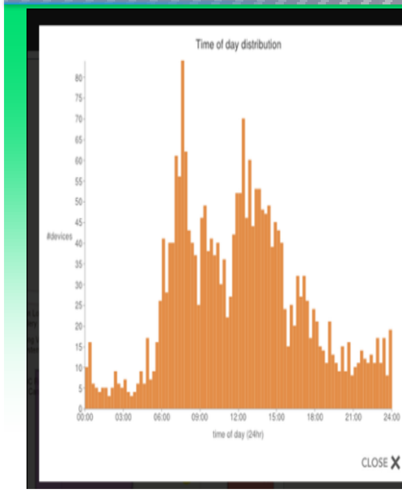
ThinkSmart Location Analytics



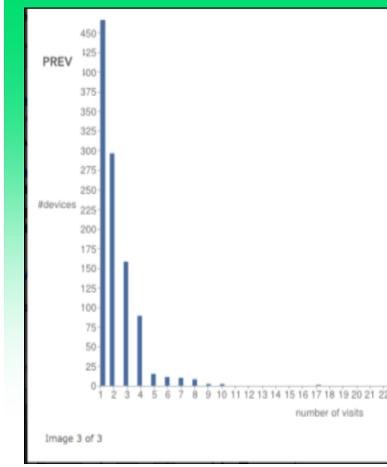
Analytics that Aid Business Decisions

Which Area Did People Spend Time At?

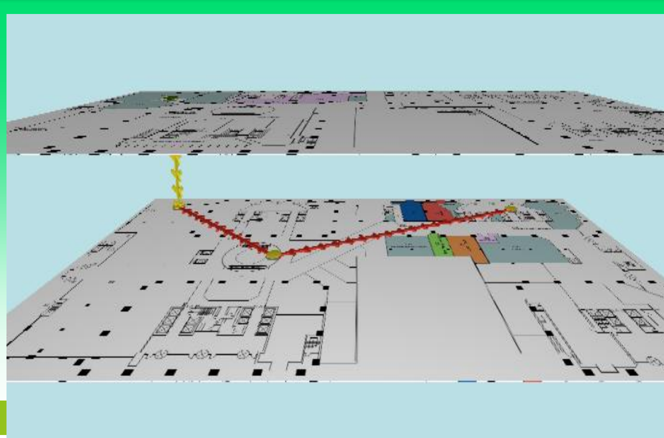
Peak Times in the Venue?



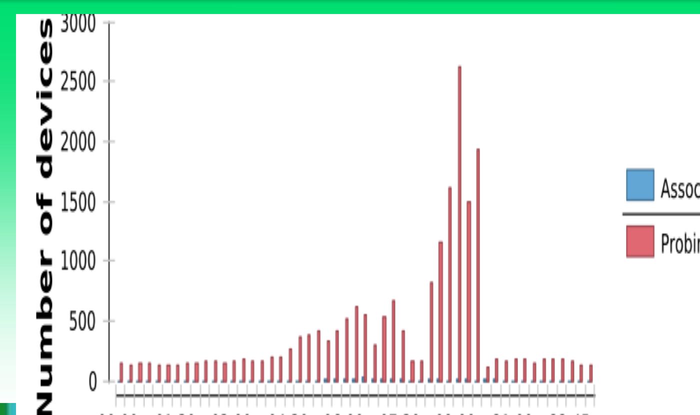
New or Repeat Customers?



Most Frequently Used Paths in the Venue



WiFi Stats: Associated vs Non-associated Devices



CMX Partner Ecosystem

Guest Access	Device Based Services	Browser-Based Services	Location-Enabled Apps	Onsite/ Online Analytics	Social Analytics	Marketing Tools	Ads And Offers
BroadHop	QUALCOMM	MazeMap	PHUNWARE	RETAILNEXT	facebook	shopkick	shopkick
SINGLE DIGITS	BROADCOM.	frontporch	Point Inside	Nomi		SOLOMO	SOLOMO
			aisle411	euclid		JOINGO	JOINGO
			Connexient	SITA		PHUNWARE	
						frontporch	
						aisle411	

Cisco and Ecosystem Partners Apps and Services

We've Only Just Begun …


Solve Environmental Challenges


Thrive in Smart Communities


Live Enriched, Healthier Lives


Redefine Work Models


Focus on Improved Safety

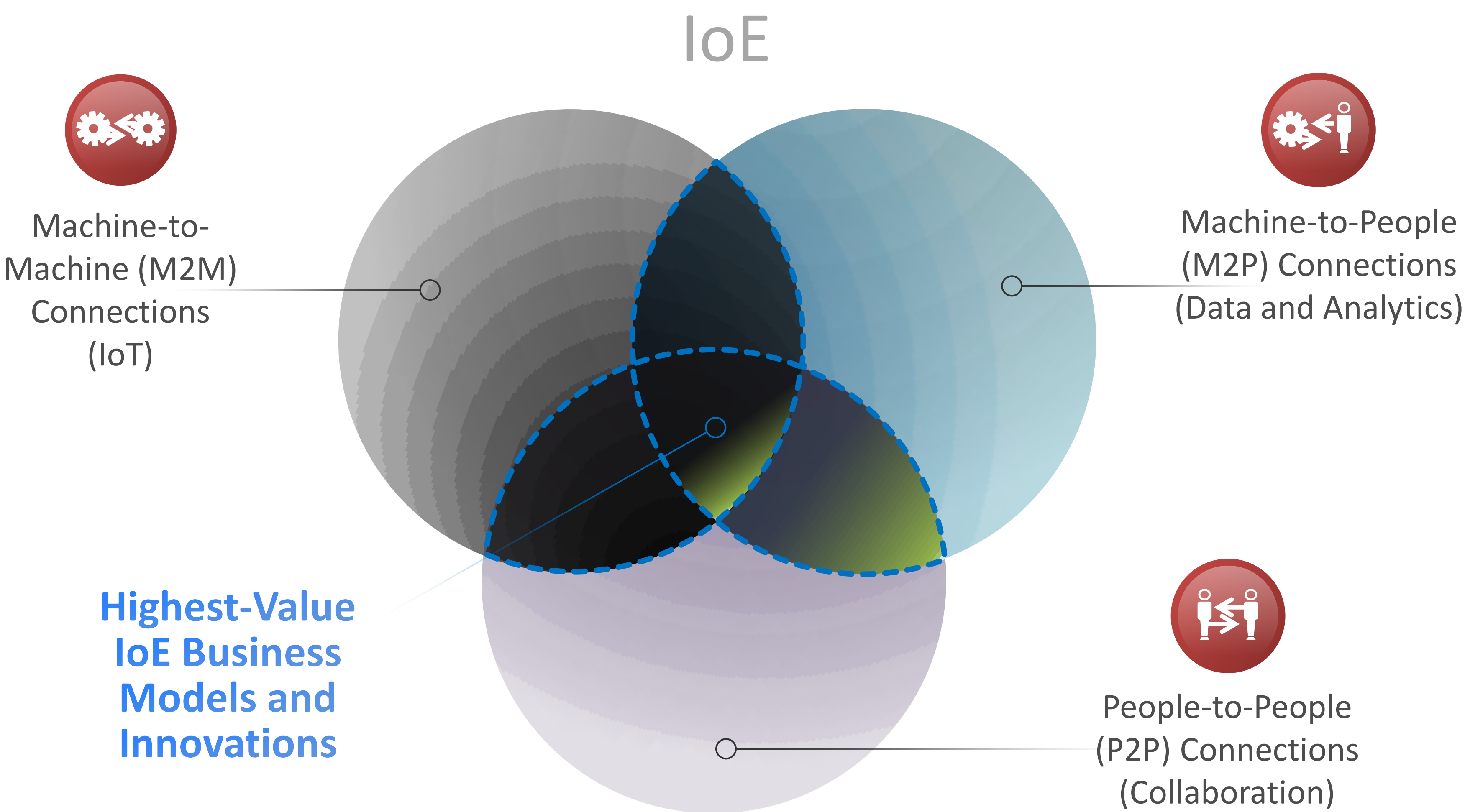

Achieve Energy Efficiency

… to change the way the world works, lives, plays, and learns

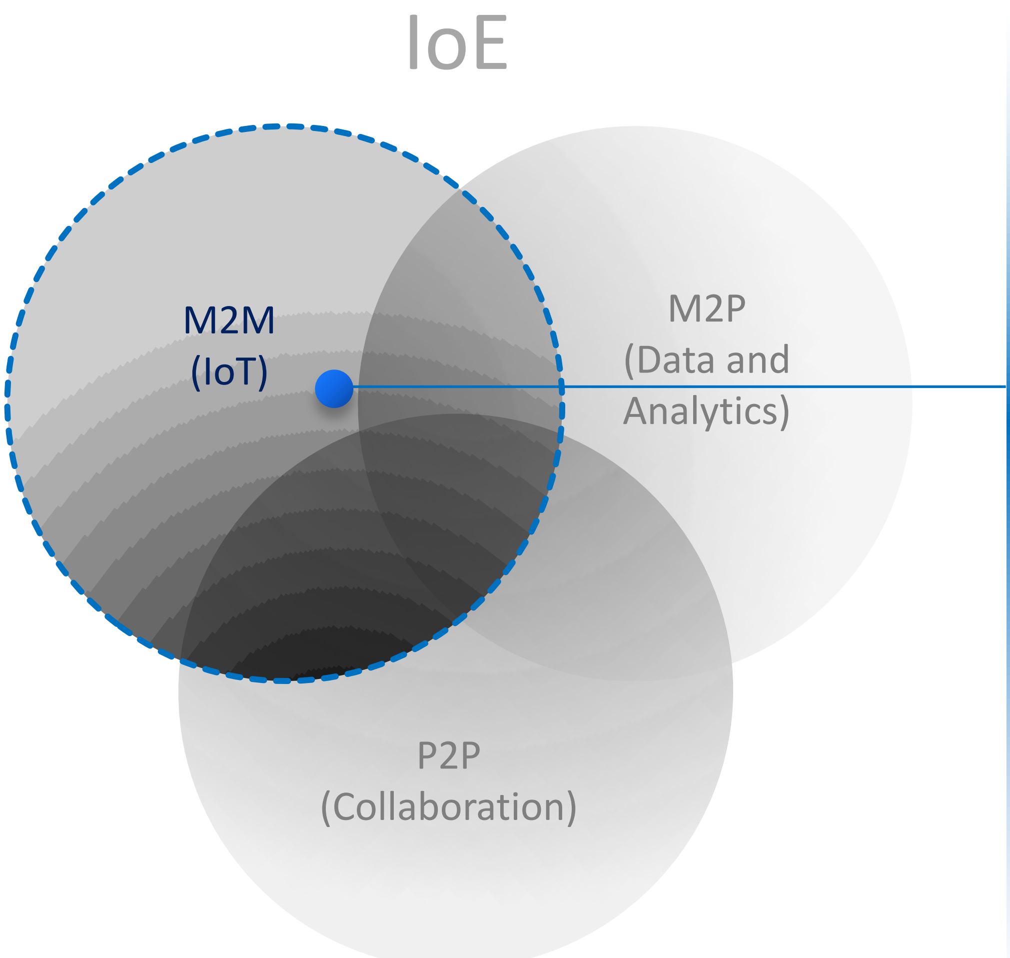
CISCO

Thank you.

IoE: Connecting the Unconnected to Generate Business Value



IoE Value in Action: Using M2M Connections to Monitor Assets

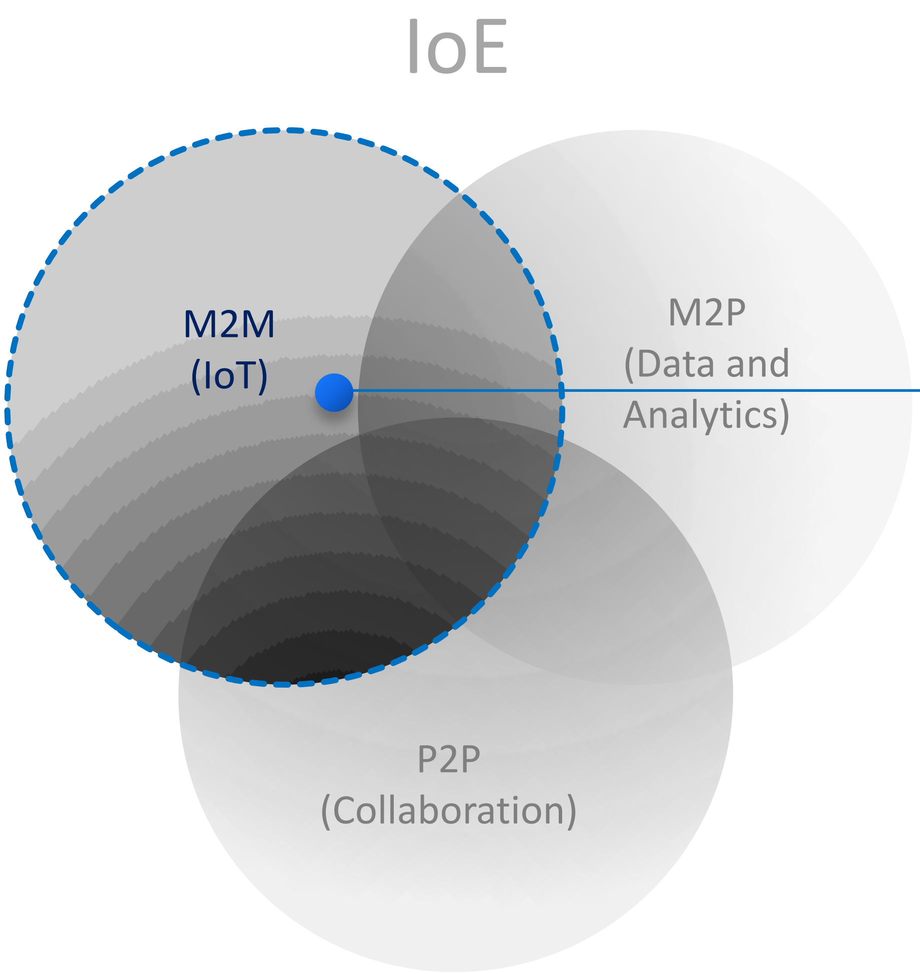


Asset Monitoring

Business Problems Solved

- Value from "lighting up" "dark" assets?
- What's their condition?
- Are they secure?

Asset Monitoring: Tire Manufacturer Increases Efficiency With Real Time



Challenge

- Increase production and efficiency in its North America manufacturing plant

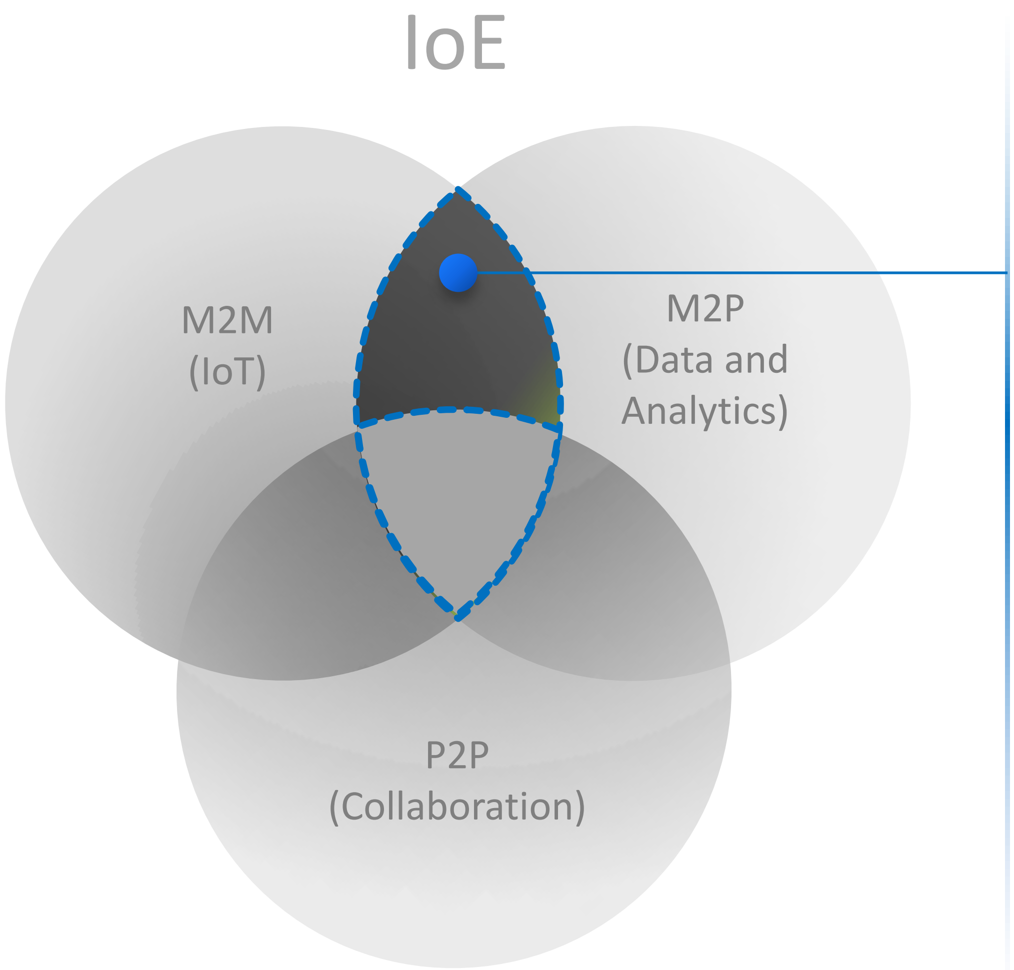
Solution

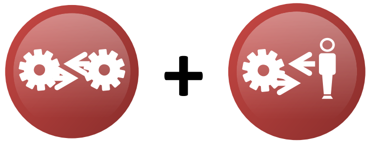
- Use **RFID sensors** to monitor production inventory on plant floor

Business Value

- Reduced production delays
- Real-time inventory visibility on plant floor
- Cut lost inventory by 20%

IoE in Action: Combining Connections for Greater Value



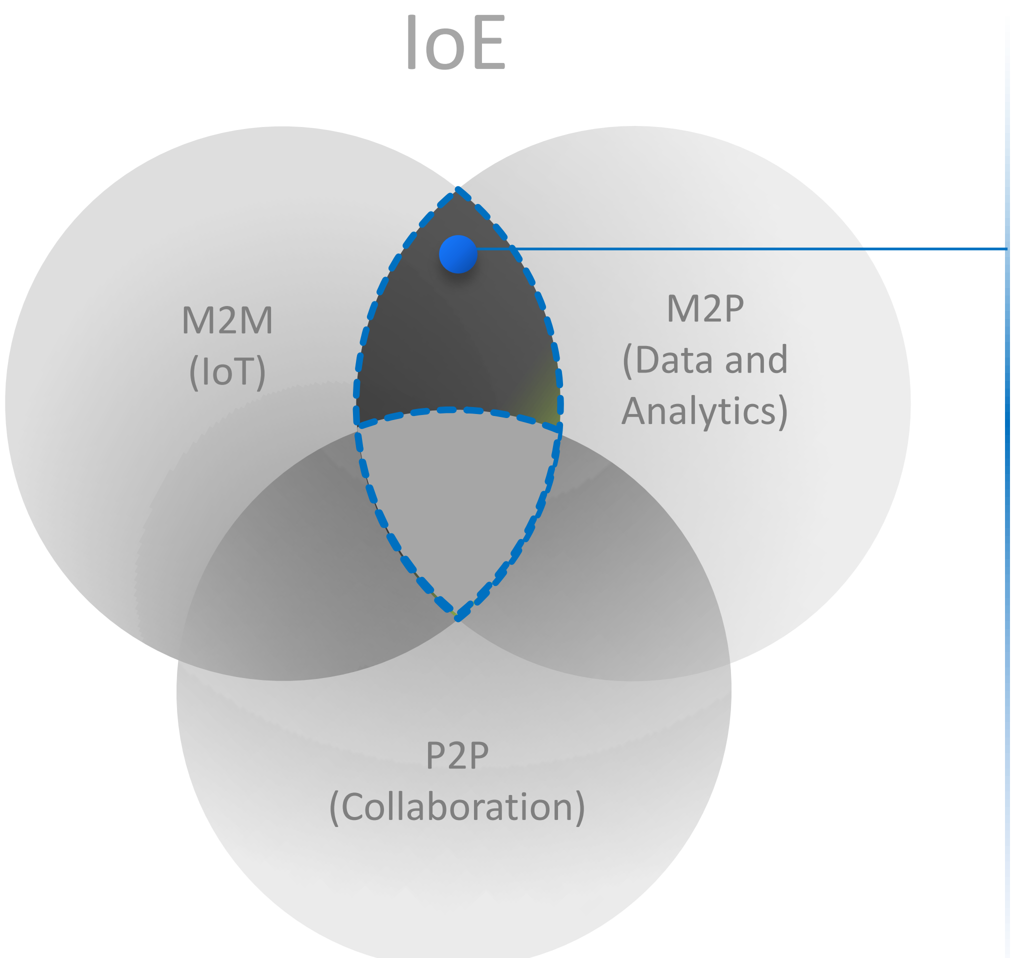


Predictive Monitoring

Business Problems Solved

- How can I maximize the productivity and availability of my assets?
- How can I prevent disruptions in the production/availability of my products and services?

Predictive Maintenance: Rail Road



Challenge

- Prevent train derailments, which cause delays and millions in damages

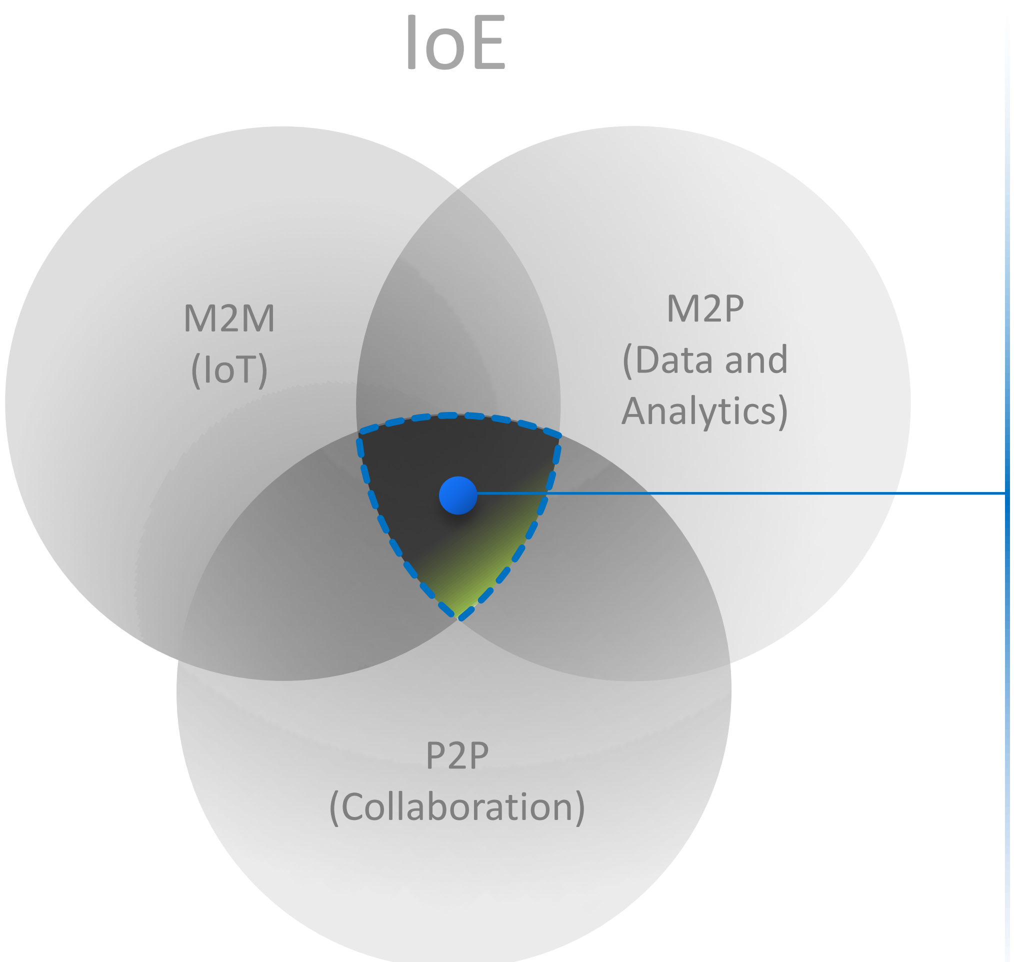
Solution

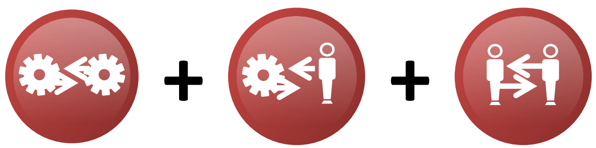
- Placed **sensors** every 20 miles of track check for overheating
- **Data analytics** predict which wheels need repairs, alert driver

Business Value

- They cut bearing-related derailments by 75%

IoE in Action: Enabling New Business Models Through Multiple Connections



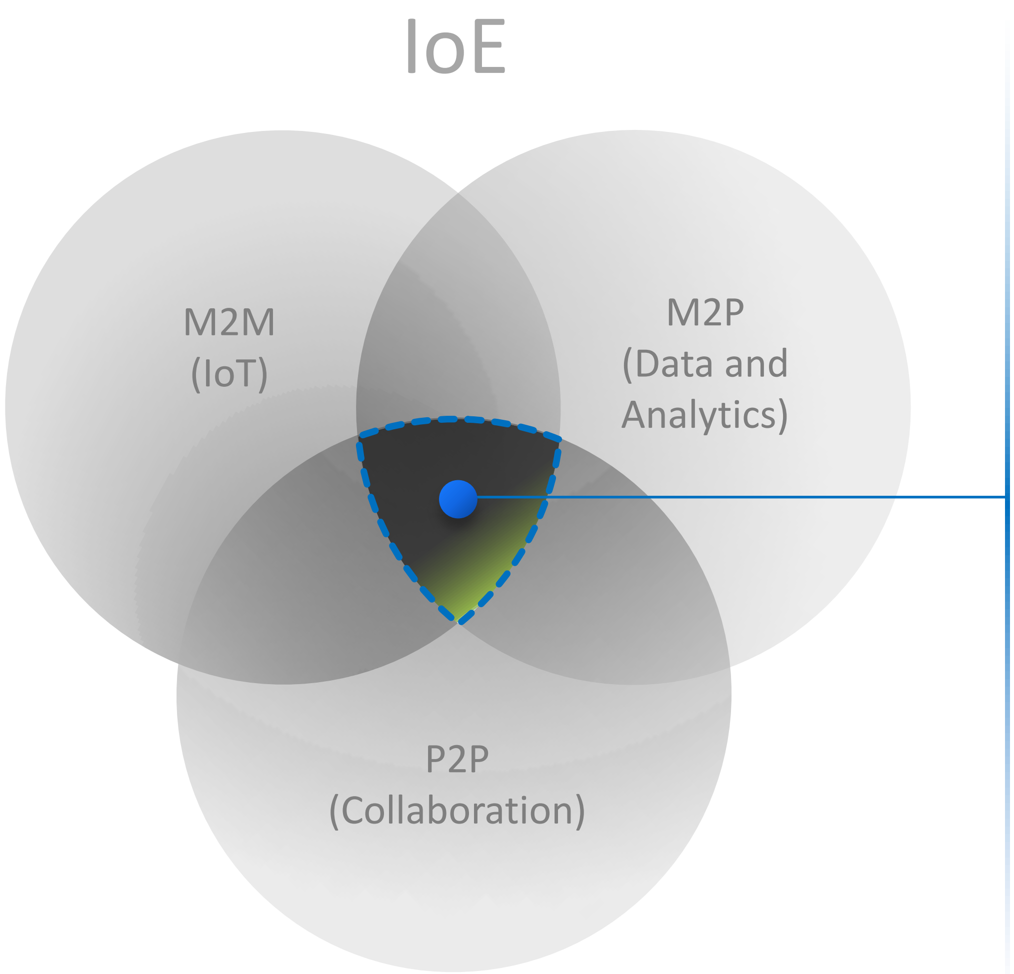


Turning Products Into Services

Business Problems Solved

- How can I differentiate myself from competitors?
- How can I create new ways for customers to consume my products and services?
- How can I turn the purchase of a product into an annuity revenue stream?

Capital Equipment-as-a-Service: Aircraft Engine Manufacturer



Challenge

- Create new business model for selling and maintaining aircraft engines

Solution

- TotalCare service for aircraft engines combines **sensors**, **predictive analytics**, and **collaboration**

Business Value

- 73% of RR's civil aircraft engines, and 92% sold to airlines, now covered by TotalCare