CS433: Internet of Things
NCS463: Internet of Things

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Chapter 1:
Things and Connections

IoT Fundamentals

Connecting Things 2.01

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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.

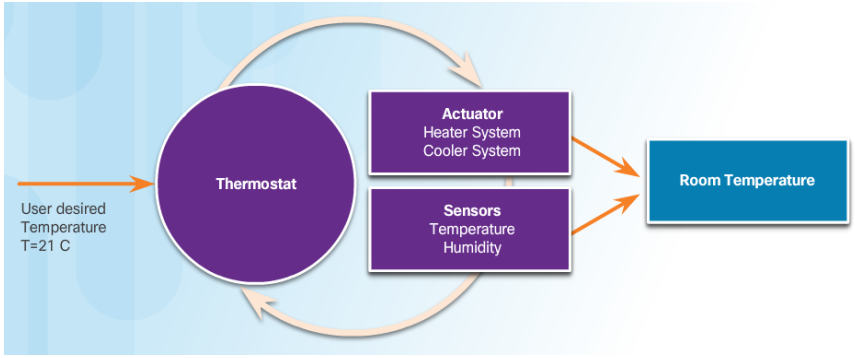
What are Things?

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

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.

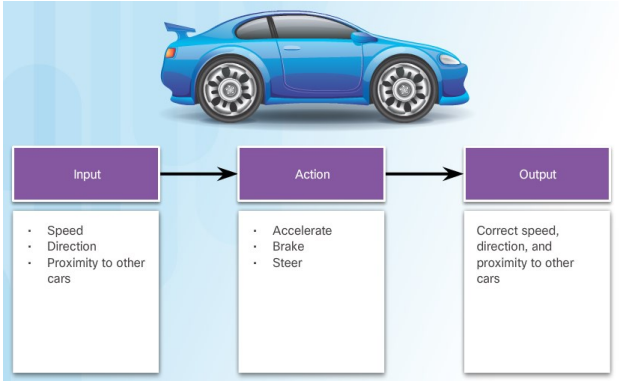


Building Blocks of an IoT System (Cont.)

- 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.

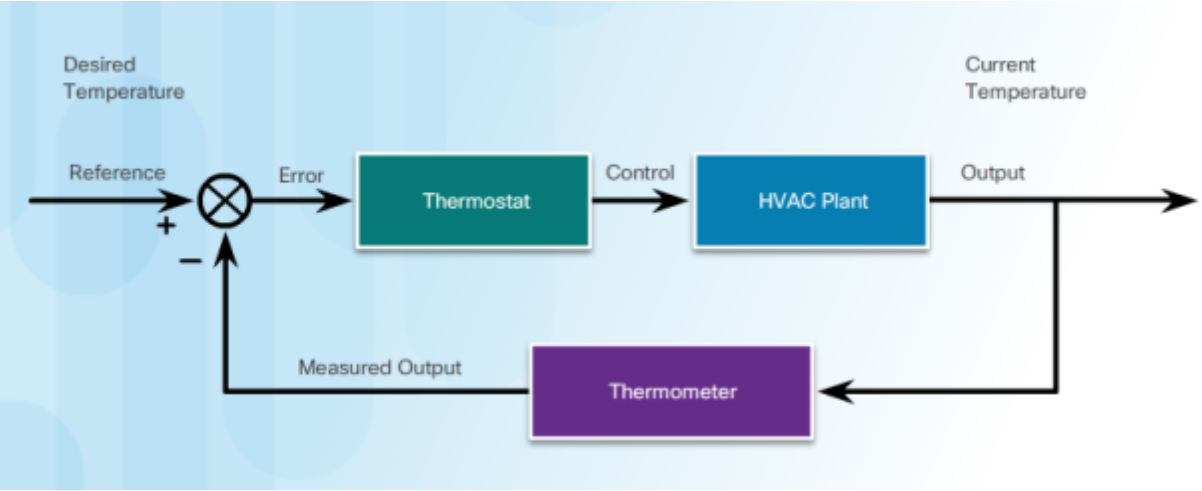
Processes in Controlled Systems



- 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.

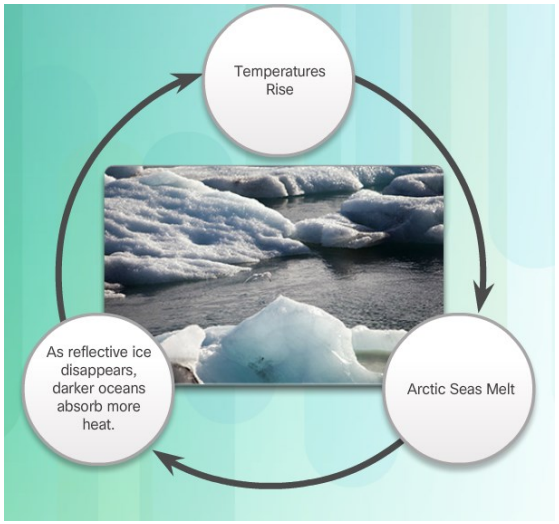
Processes in Controlled Systems (Cont.)

- 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.



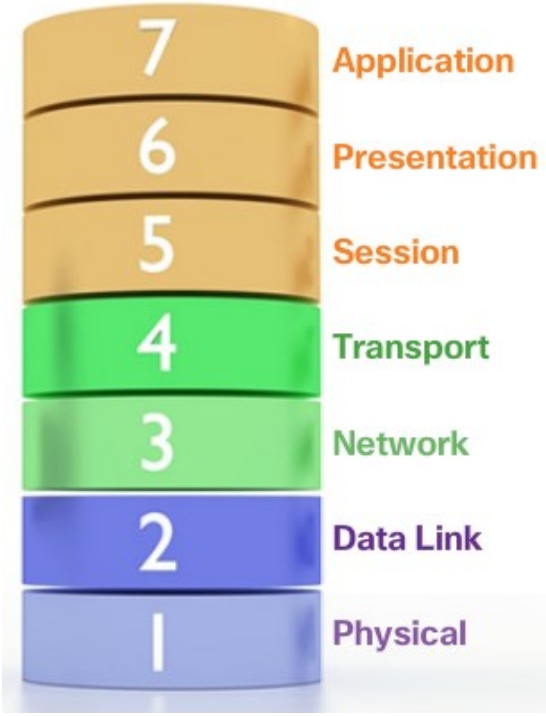
Processes in Controlled Systems (Cont.)

- 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.



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.

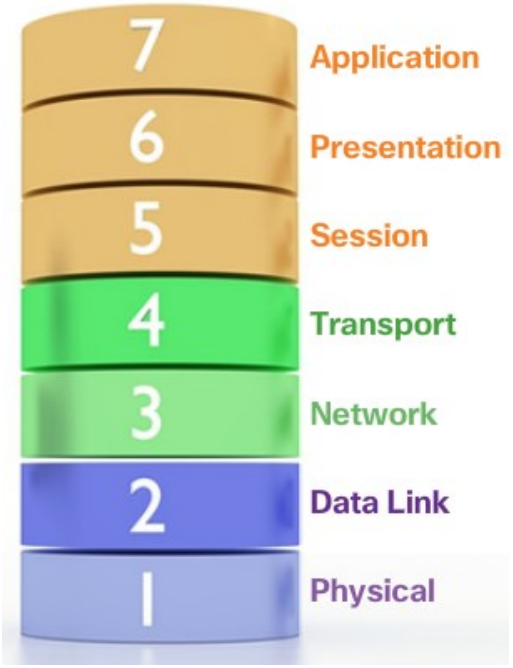


Models of Communication (cont'd)

- 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.

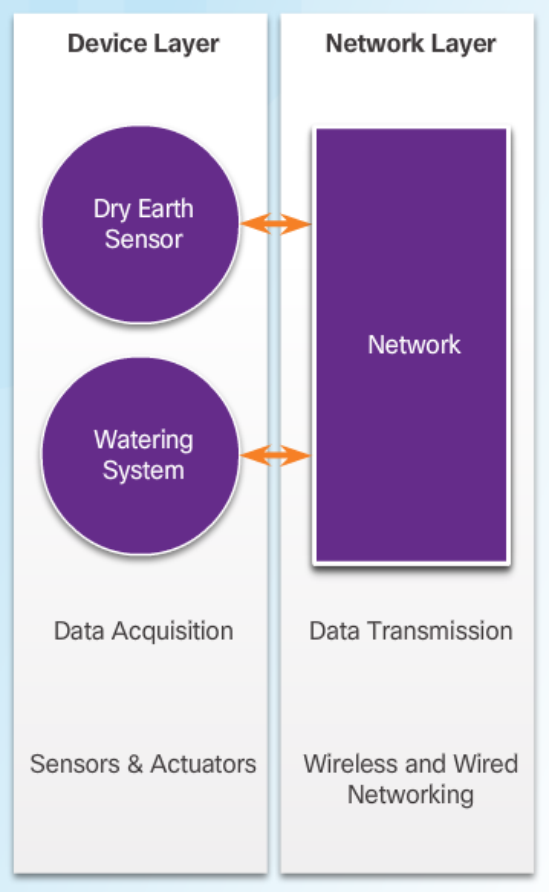
Models of Communication (Cont.)

- 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.



Models of Communication (Cont.)

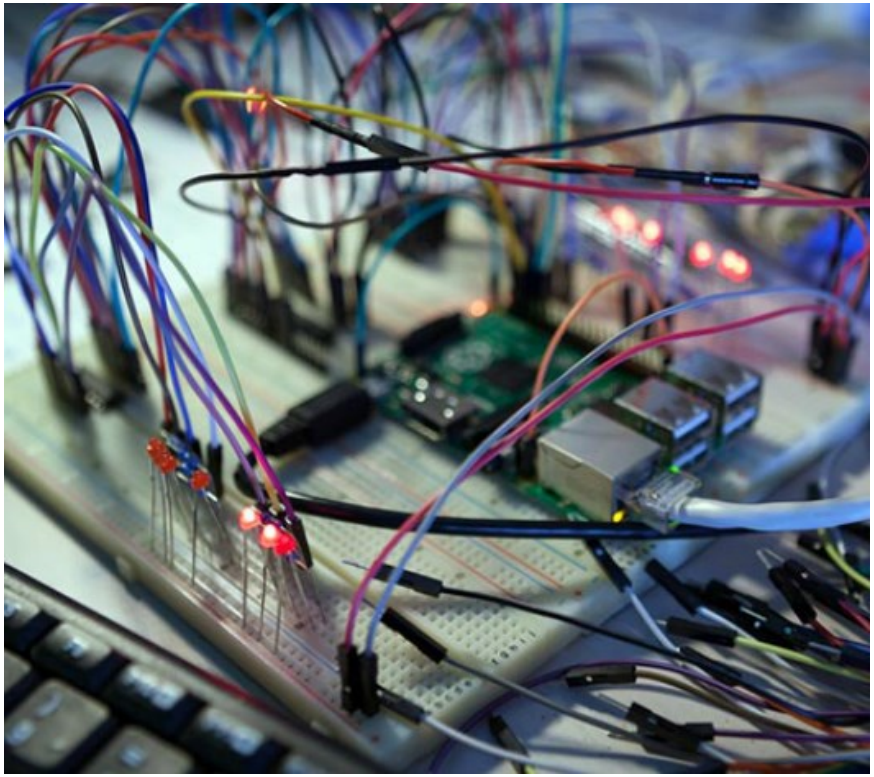
- Simplified IoT Architecture
  - Several architectures exist to help facilitate the design and creation of IoT systems.
  - The OSI model, TCP/IP model, and the IoT World Forum Reference model have been presented as examples.
  - A simpler approach is based on connection levels. The levels are:
   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



What are Connections?

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.

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

Chapter 2: Sensors, Actuators, and Microcontrollers

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Chapter 2 - Sections & Objectives

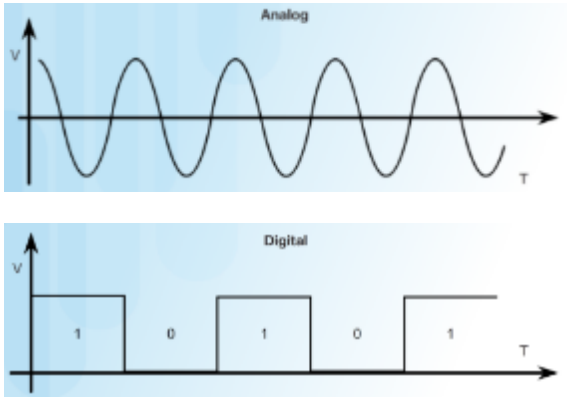
- 2.1 Learn Electronics
  - Explain how components and devices are used to build and measure values in electronic circuits.
- 2.2 Microcontrollers: The SparkFun Inventor's Kit
  - Create circuits and microcontroller programs with the Arduino and a variety of components.
- 2.3 Packet Tracer 7.0 and the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

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)

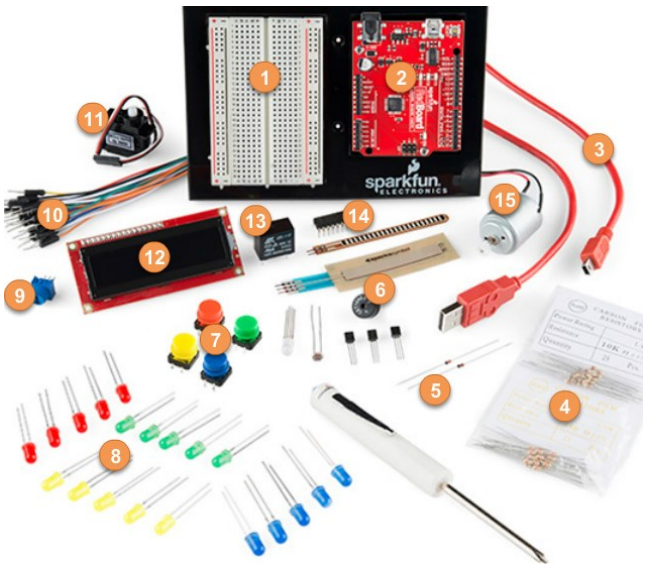
- Analog Circuits vs. Digital Circuits
  - Analog Circuits**:** Circuits in which signals vary continuously with time.
  - Digital circuits: Circuits in which signals that take one of two discrete values.
- Components
  - Electronic components are specialized devices used in a circuit to control current.
  - 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.



2.2 Microcontrollers: The SparkFun Inventors Kit

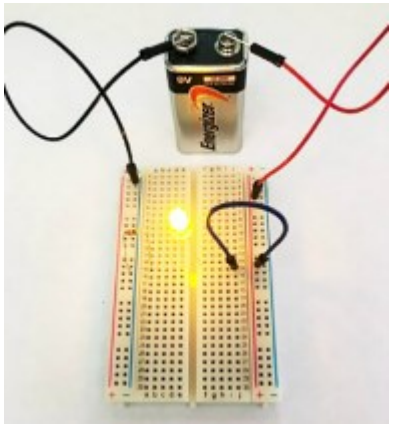
Introducing the Kit

- 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.



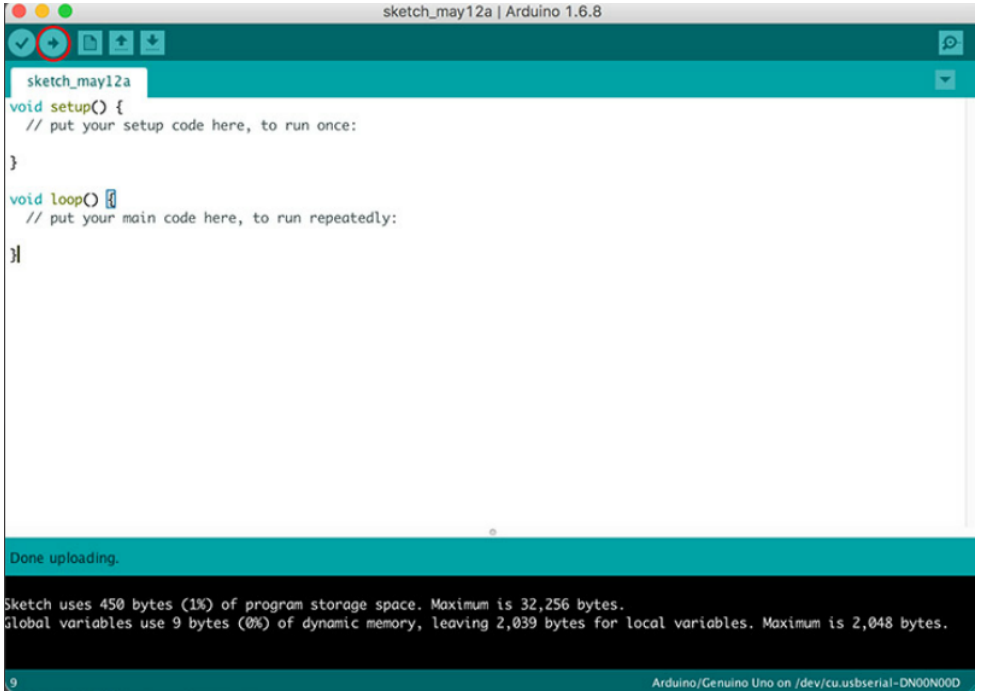
Simple Circuits

- 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.



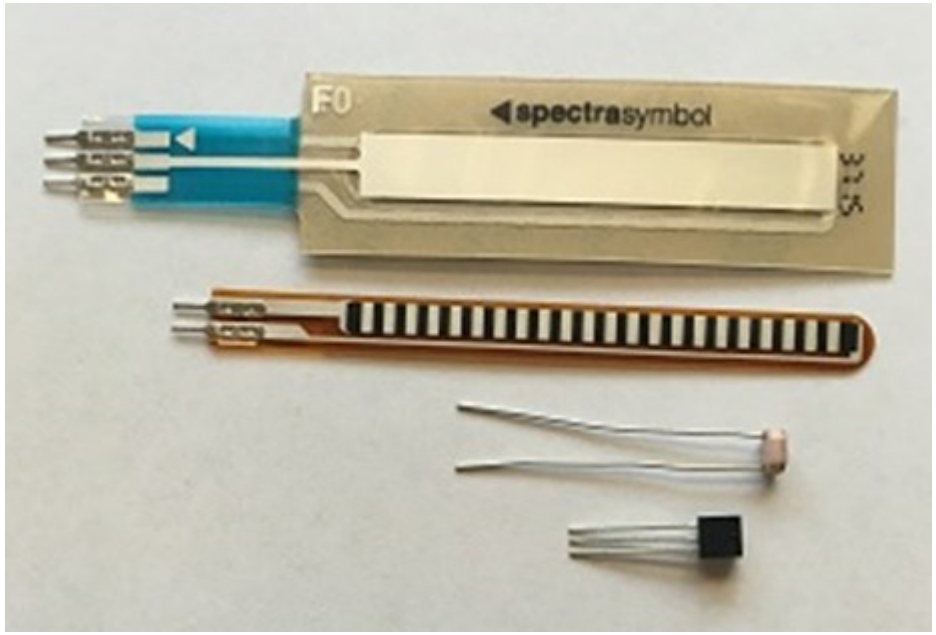
Simple Circuits (cont'd)

- 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 (⇨)



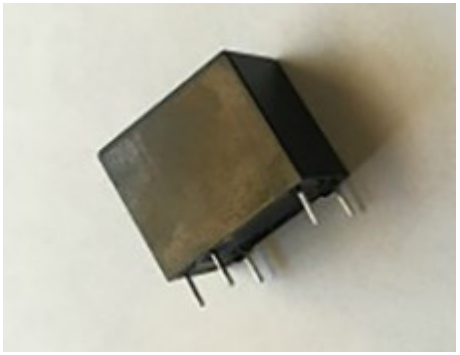
Sensing the Environment

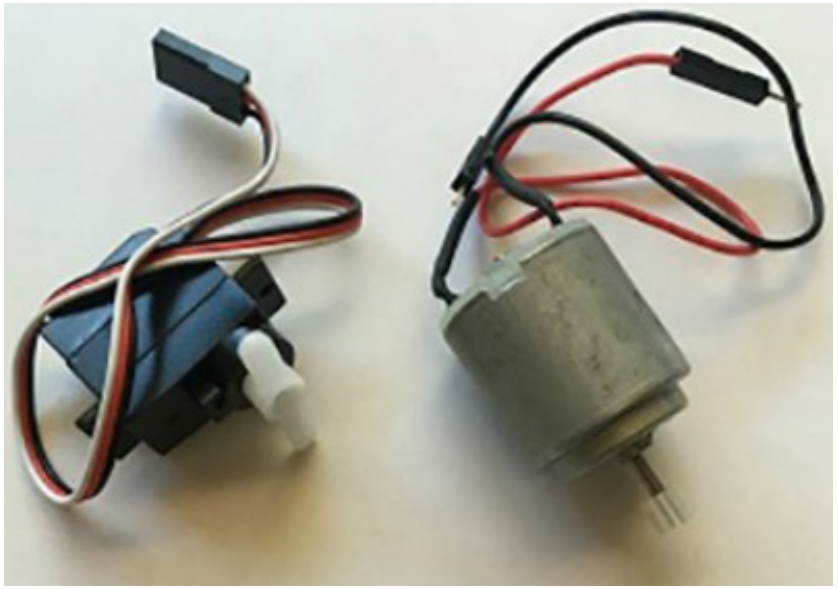
- Sensors
  - Devices that detect an event from the physical environment and respond with electrical or optical signals as output.
  - The SIK contains various sensors including Soft potentiometer, Flex sensor, Photo resistor and Temperature sensor.



Making it Happen

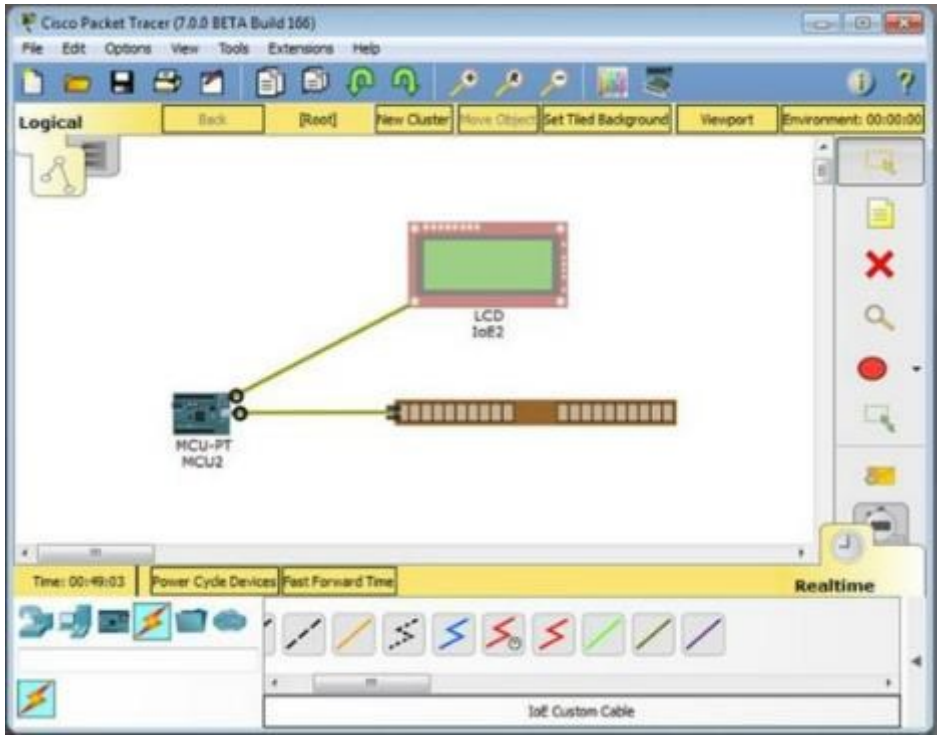
- Actuators and Relays
  - An actuator is a type of motor that is responsible for creating movement.
  - The SIK includes two types of electric actuators that convert electrical energy into mechanical torque.
  - A relay is an electrically controlled mechanical switch.
  - The SIK includes a plastic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





PT 7.x – 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 7.1 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.



Chapter 3: Software is Everywhere

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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.

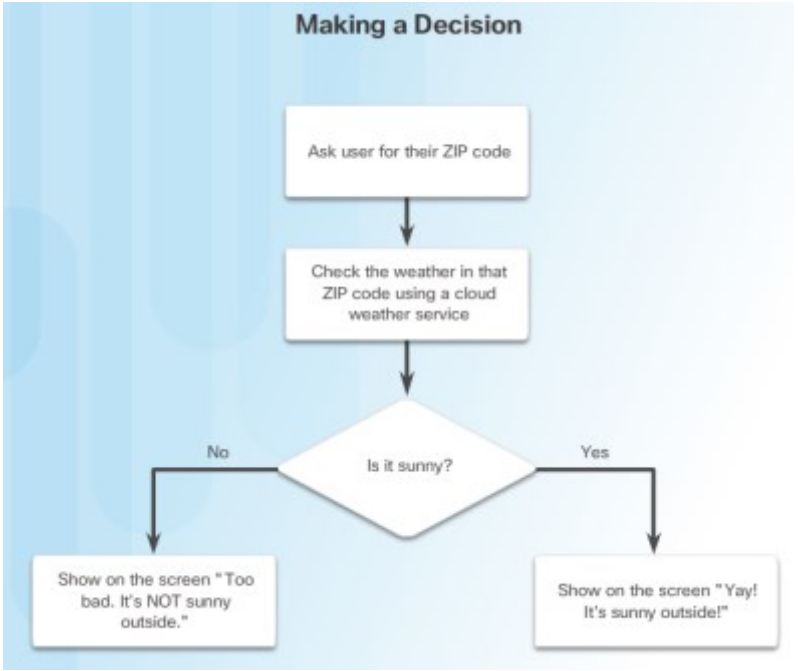
Code Does the Job!

- 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;
}
```

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.

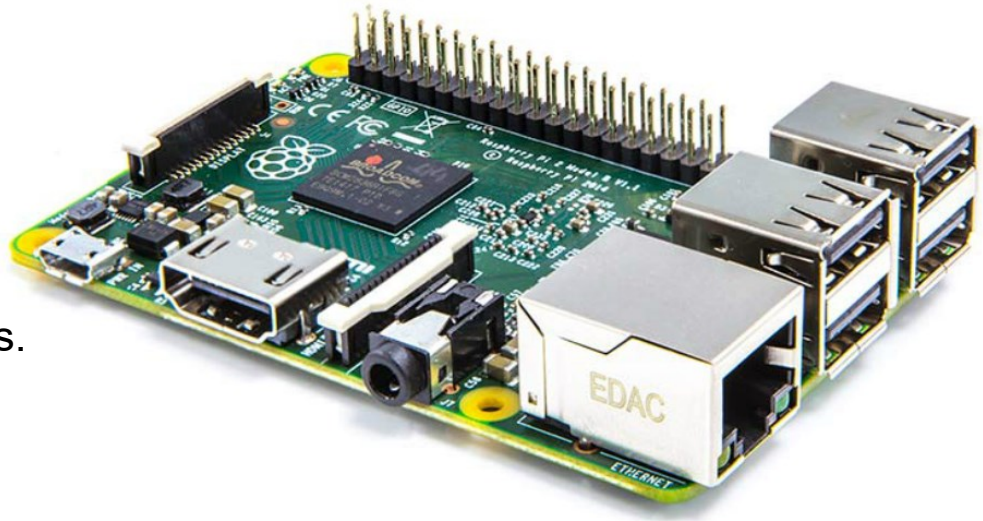


Raspberry Pi Hardware

- 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)

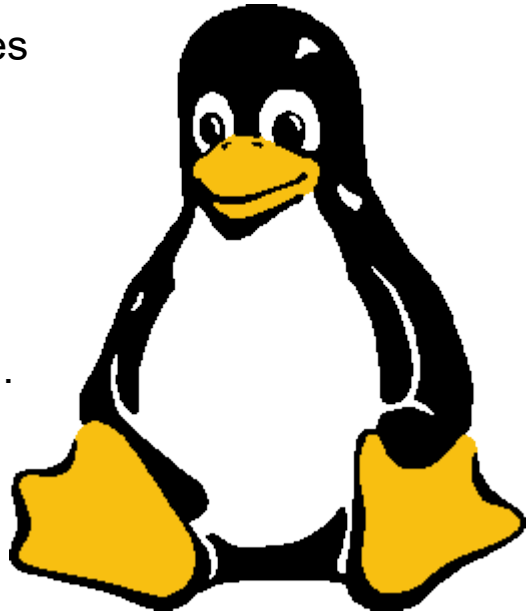
- The Pi can run a number of operating systems, including Linux and Windows.



The Raspberry Pi Single Board Computer (SBC)

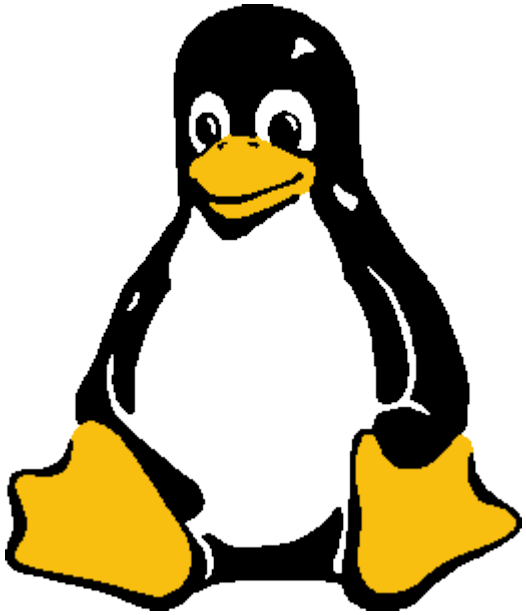
Using the Linux Operating System

- 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



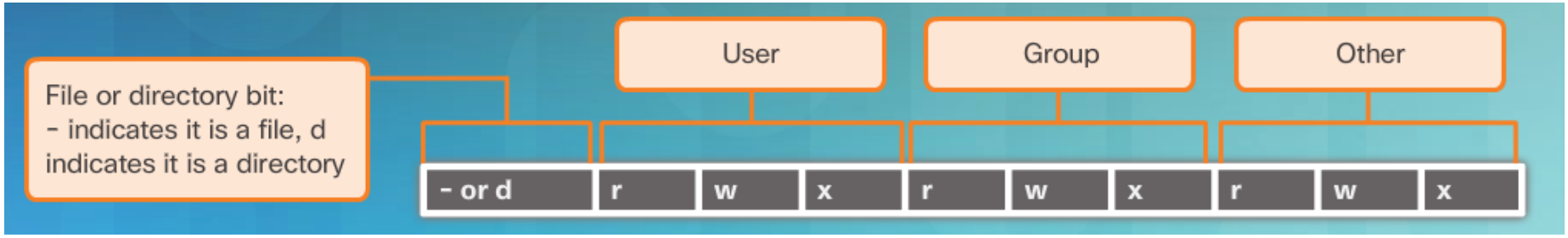
Using the Linux Operating System (Cont.)

- 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.



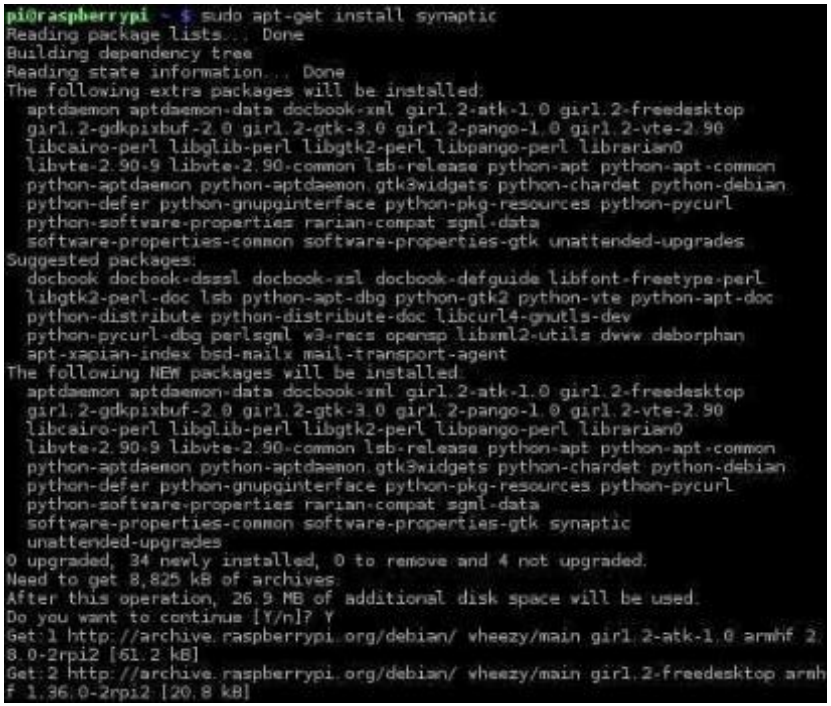
Using the Linux Operating System (Cont.)

- 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.

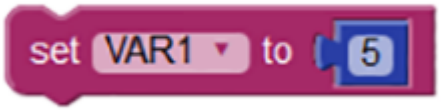


Using the Linux Operating System (Cont.)

- 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.

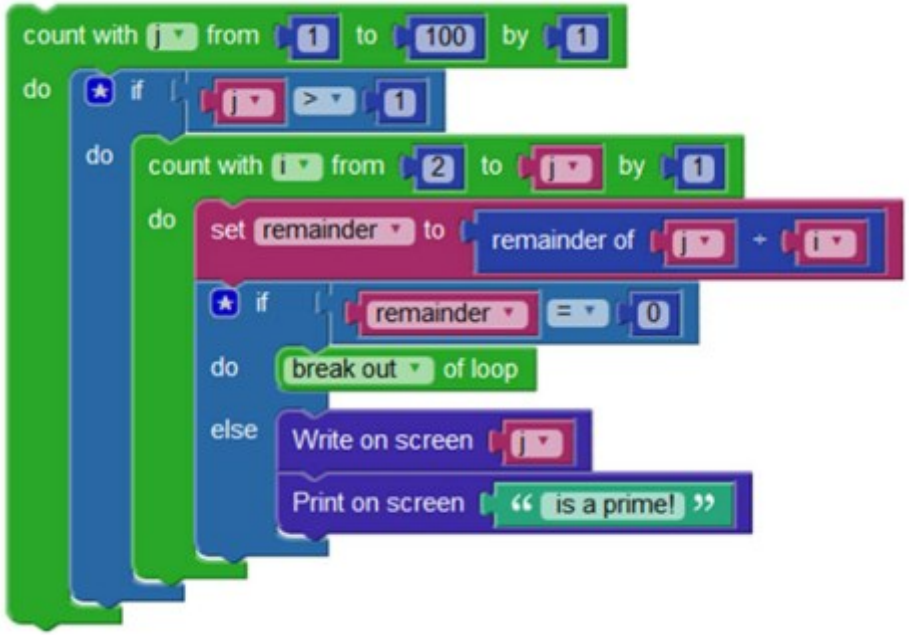


Blockly



- 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.



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 3.4.2 (default, Oct 19 2014, 13:31:11)

Type "help", "copyright", "credits" or "license" for more information.
>>>
```

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

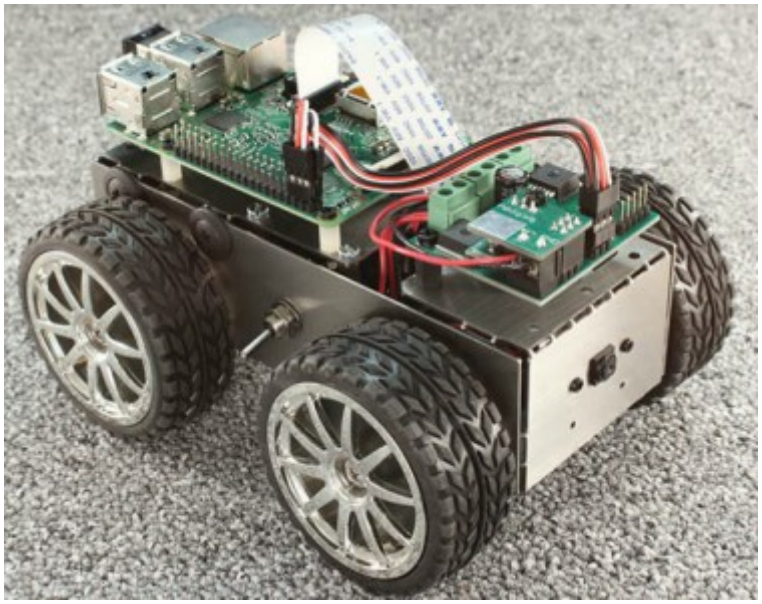
```
list1 = ['car', 'train', 47, 2016];
list2 = [1, 2, 3, 4, 5, 6, 7 ];
print ('list1[0]: ', list1[0])
print ('list2[1:5]: ', list2[1:5])

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)

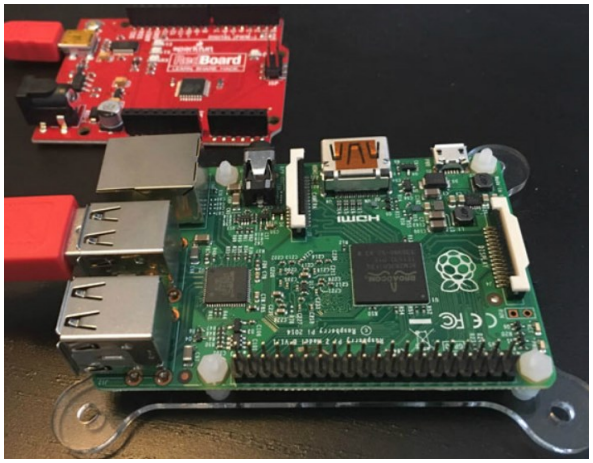
- Importing Modules Into Your Code
  - Use the **import <module>** keyword to import pre-written code into your programs.
- IF THEN In Python
  - Allows the execution a block of code based on the result of an expression.
- FOR Loops in Python
  - Iterates through the items of any sequence
- WHILE Loops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

```
>>>
>>> x = int(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
```

Uses of the Raspberry Pi

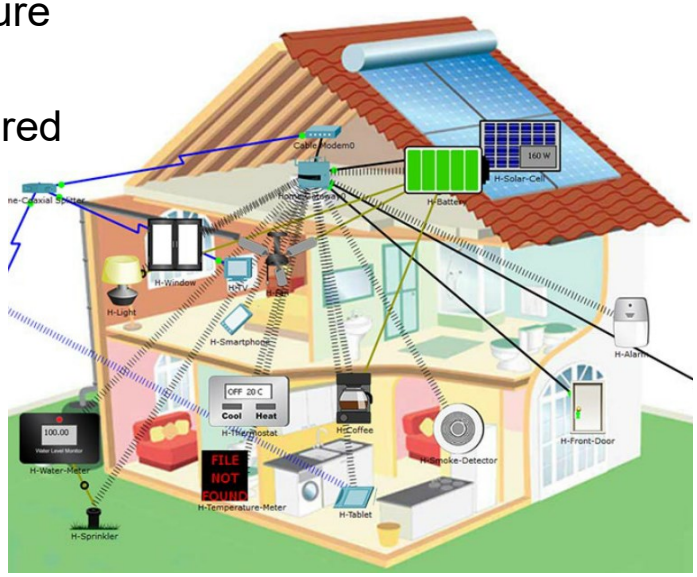


- Artificial Raspberry Pi Pancreas
  - Dana Lewis and her husband used a Raspberry Pi to build an artificial pancreas.
  - It was possible due to the Pi's small size and low power requirements.
- 4Borg Pi Robot
  - PiBorg is an affordable robot kit built around a Raspberry Pi.
  - It is both fun and 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.



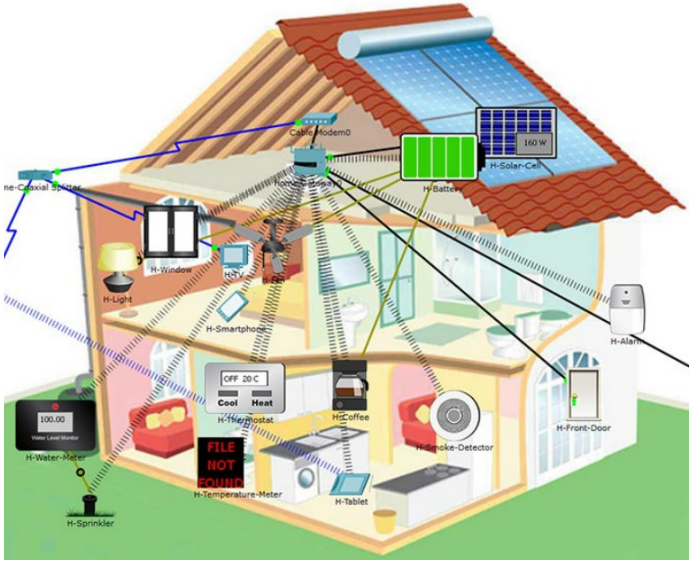
A Model of an IoT System

- 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.



Chapter 4: Networks, Fog and Cloud Computing

IoT Fundamentals

Connecting Things 2.01

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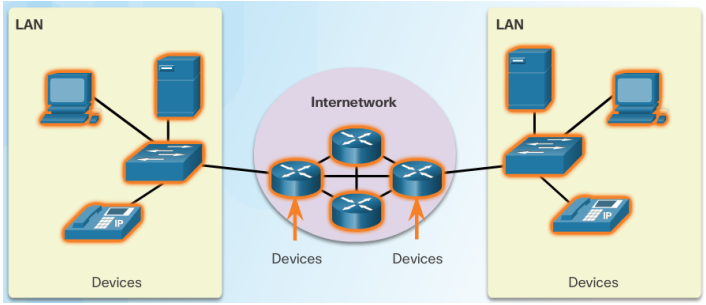
Chapter 4 - Sections & Objectives

- 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.

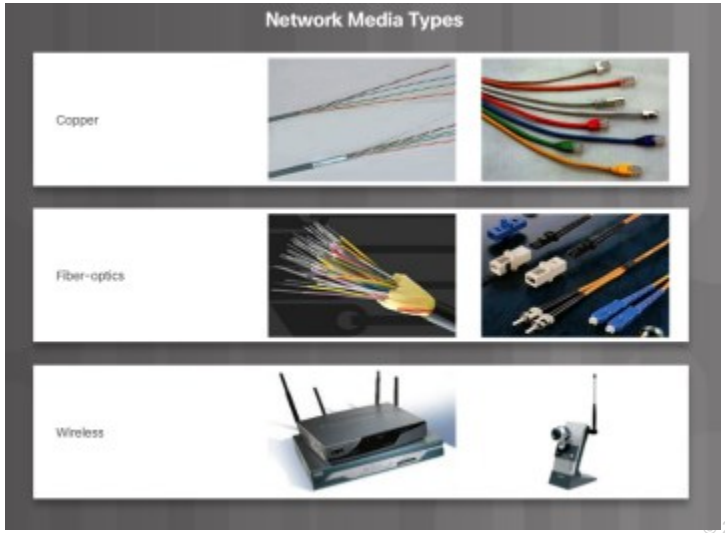
The Role of the Network

- 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



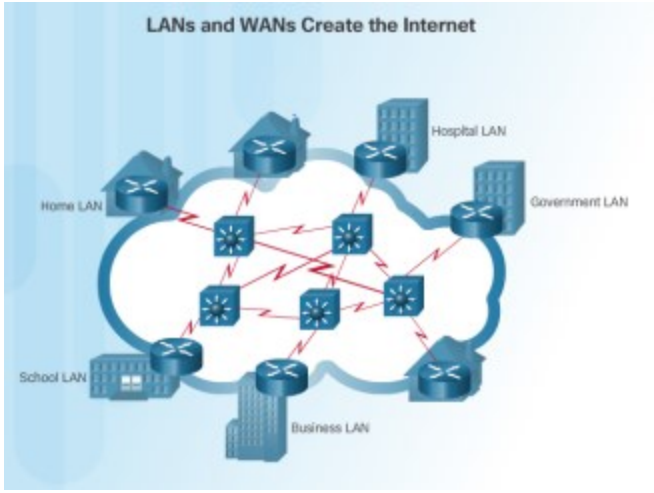
The Role of the Network (Cont.)

- 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.



The Role of the Network (Cont.)

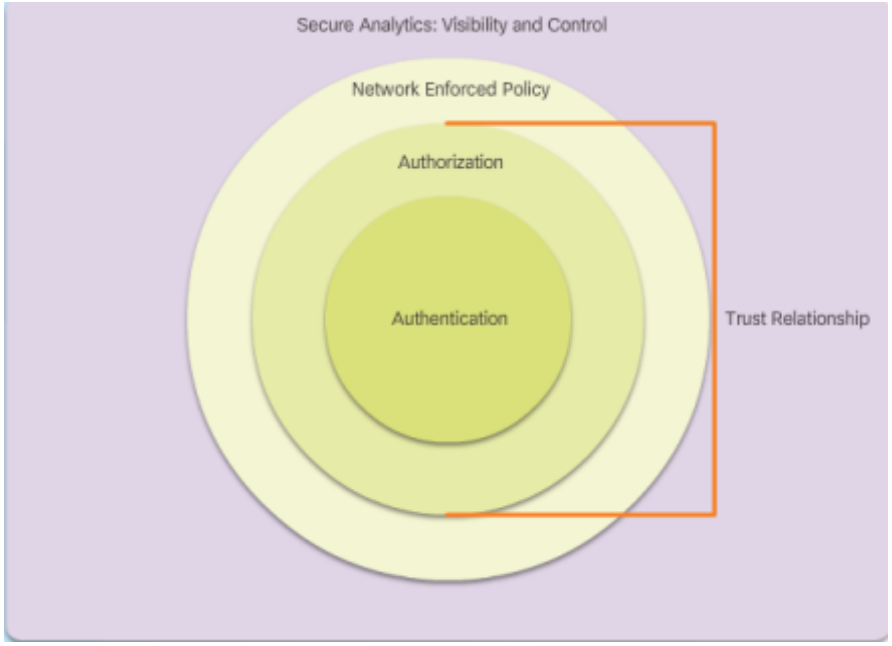
- Network Protocols
  - Devices must conform to common protocols before they can communicate.
  - Two very important network protocols are Ethernet and IP.
  - Ethernet rules enable communication between local devices.
  - IP enable communication between remote devices.
- Basic Routing
  - Network packets 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.)

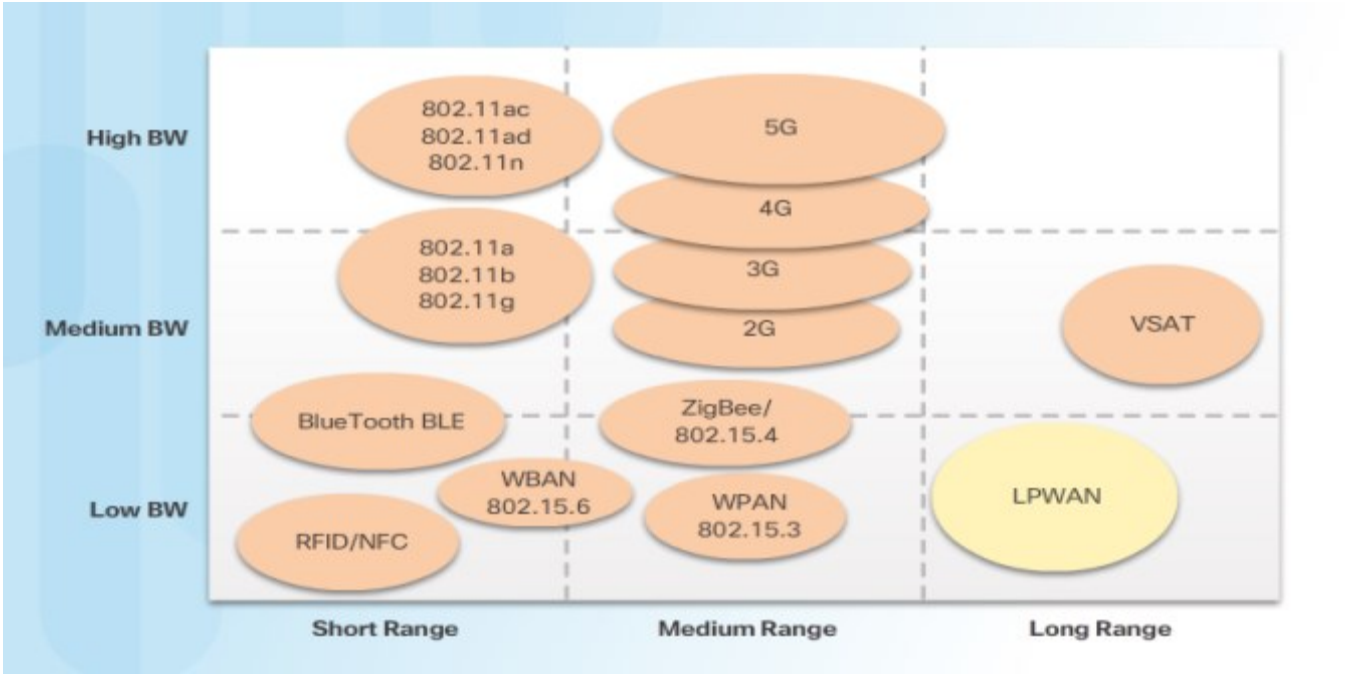
- IoT Protocols
  - IoT Devices are often embedded devices designed to work in sub-optimal conditions.
  - These devices require specialized protocols to function with low power and limited connectivity.
  - IoT devices use CoAP (Constrained Application Protocol) and MQTT (Message Queuing Telemetry Transport).

- 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)



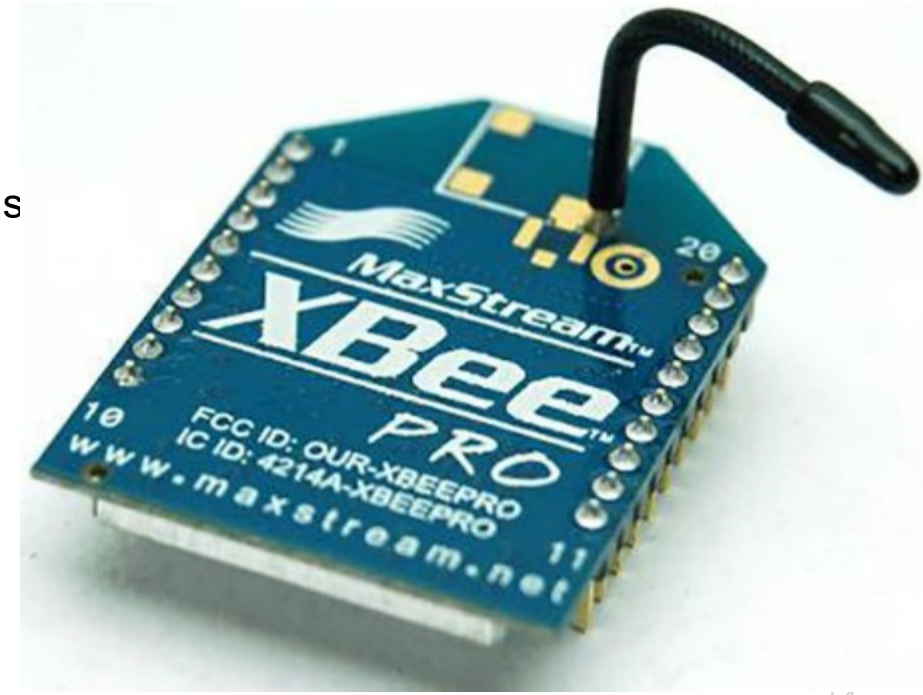
Wireless Technologies

- 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



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.

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)

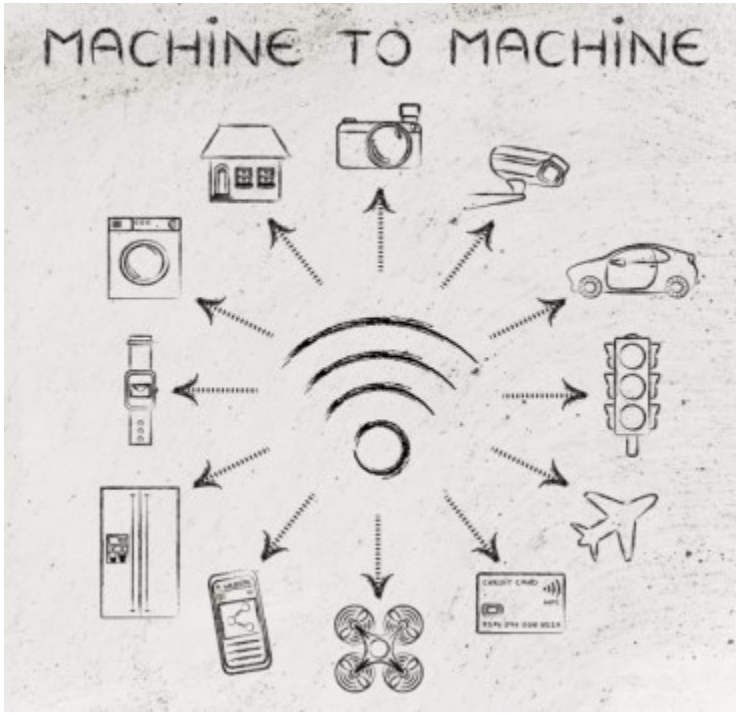
Fog and Cloud Services (cont'd)

- 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, Webex Teams

Fog and Cloud Services (cont'd)

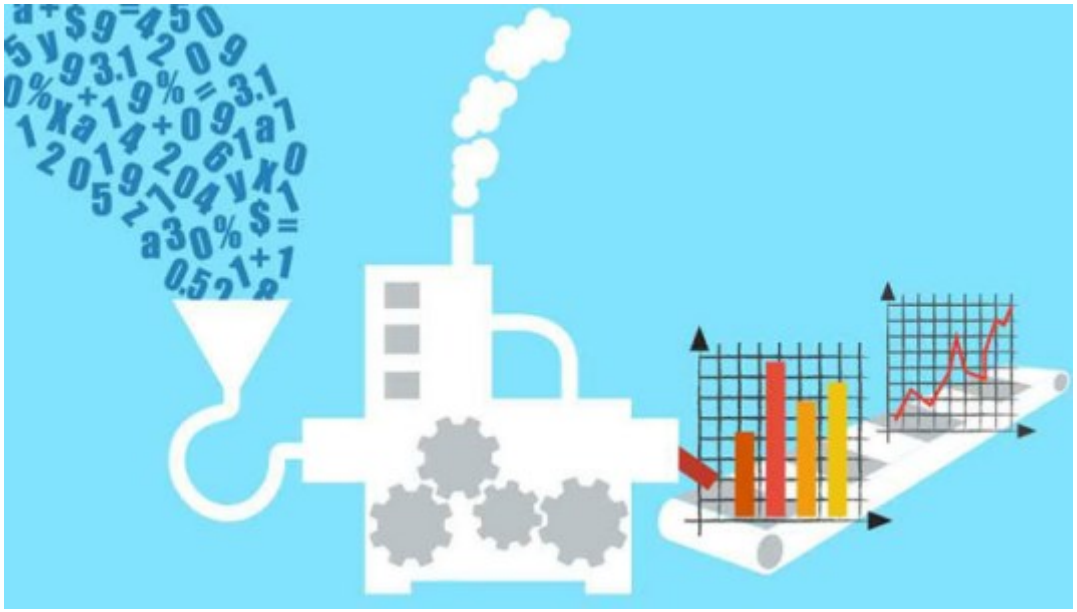
Fog and Cloud Services (cont'd)

- 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



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



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, Webex Teams, Cassandra and Kafka – examples of open source projects dealing with Big Data

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

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.

Chapter 5: IoT Applications in Business

IoT Fundamentals

Connecting Things v2.01

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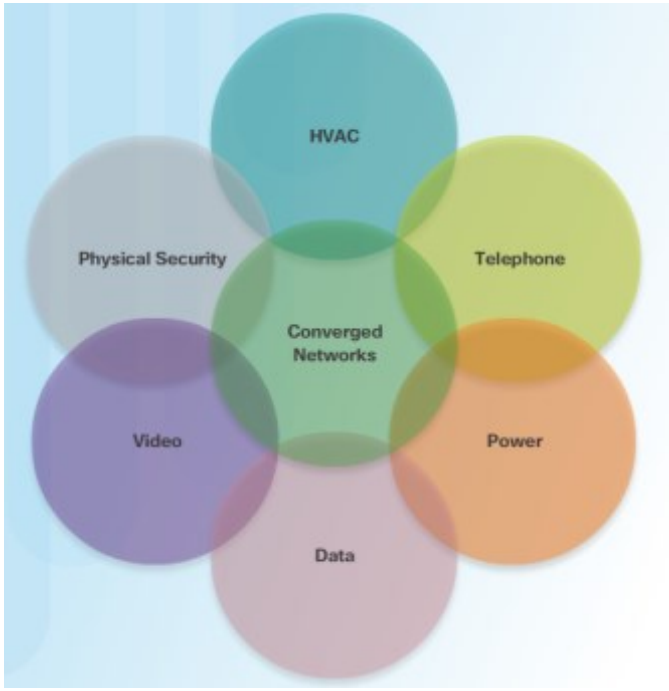
Chapter 5 - Sections & Objectives

- 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.

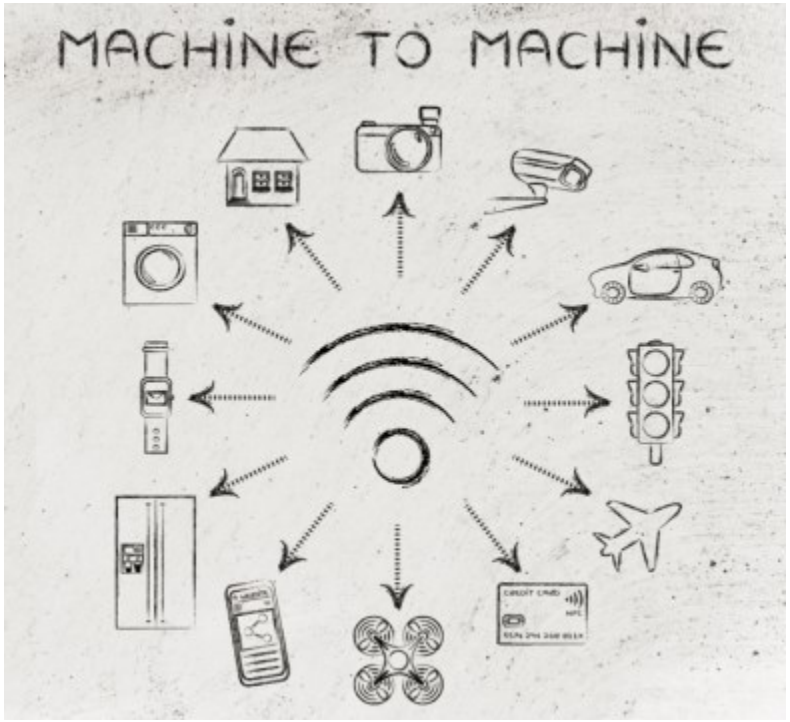
Cisco IoT System Overview

- 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.



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.



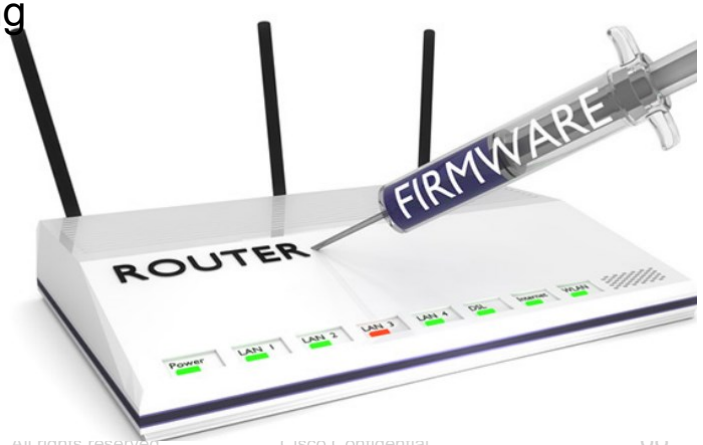
- Challenges to Connecting Things
  - How to integrate millions of things from different vendors?
  - How to integrate new things into the existing network infrastructure?
  - How to secure these new devices, each configured with varying levels of security?

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.



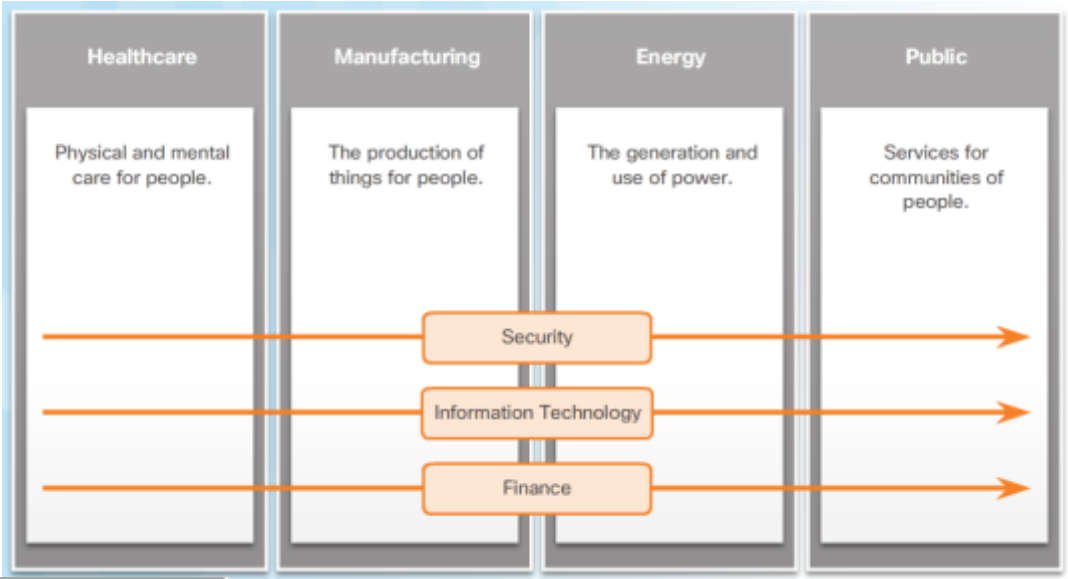
IoT Security (Cont.)

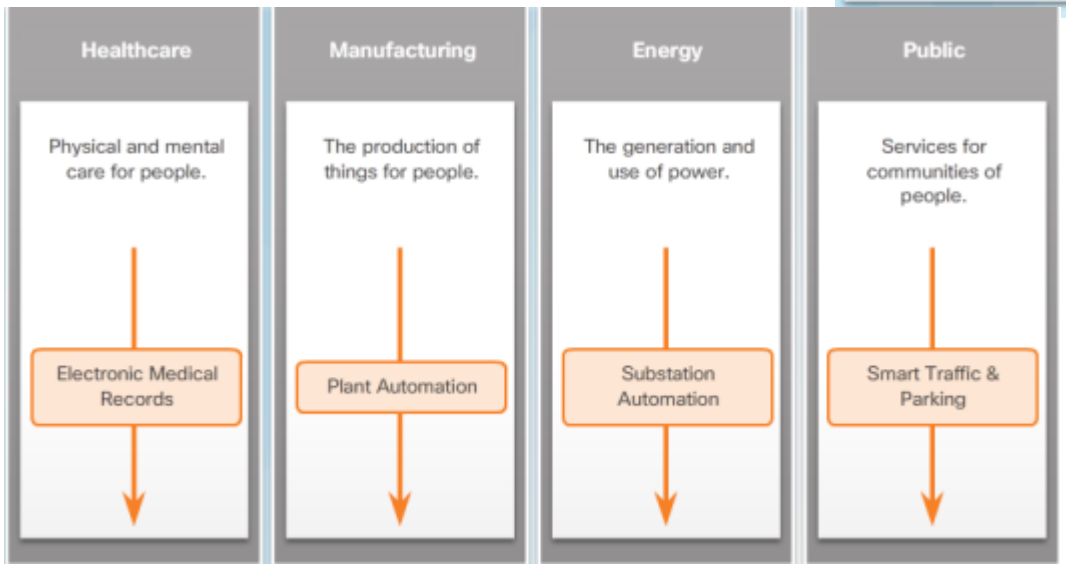
- Securing the Control, Data, and Management Planes in IoT (cont'd)
  - A few recommendations:
    - Make sure the new IoT device can be easily updated.
    - Buy from a reputable manufacturer.
    - Segment IoT devices to a different network or VLAN.
    - Check for updates regularly.
    - Default 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

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..

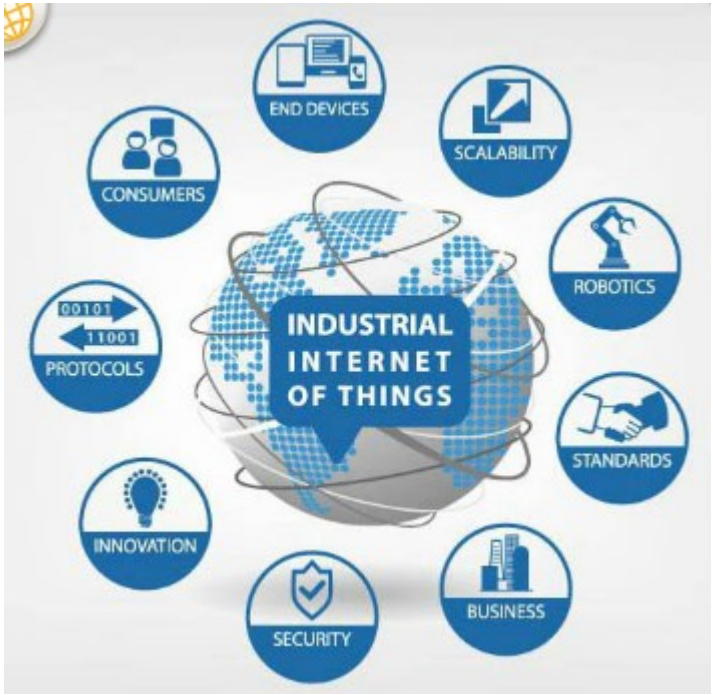




- Vertical Markets
  - Offer goods and services to a set of customers with specialized needs.
  - Automotive, banking, education, healthcare, retail, and technology are considered vertical markets.

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.



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

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

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.

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, CO2 and O2, 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.

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.

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

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

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

Instructor Materials
Chapter 6 Create an IoT Solution

IoT Fundamentals

Connecting Things v2.01

Cisco | Networking Academy®
Mind Wide Open™

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.

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.)

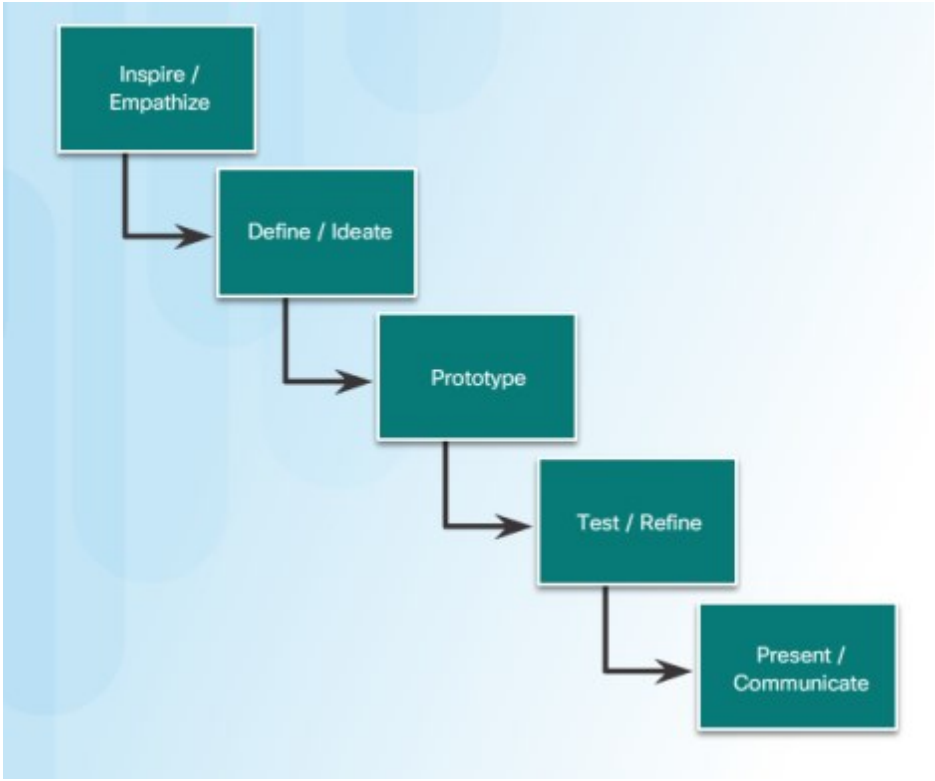
- The Sustainable Development Goals
  - In 2015, 189 world leaders at the United Nations Sustainable Development Summit unanimously adopted the 2030 Agenda for Sustainable Development.
  - The result was a set of 17 Sustainable Development Goals (SDGs).
  - These new SDGs go much further than the MDGs.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

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.

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.

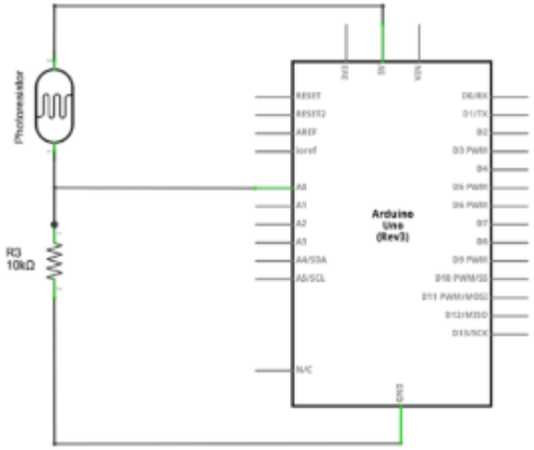


Designing Solutions (Cont.)

- 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.

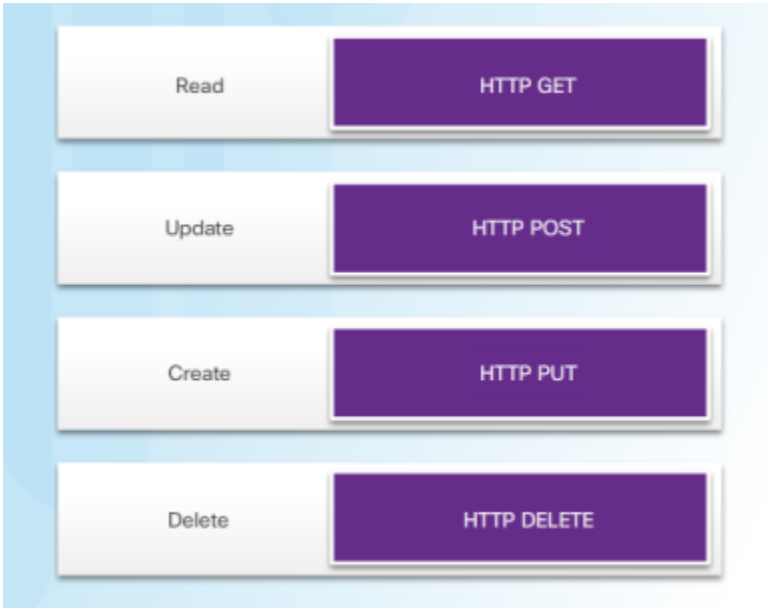
THE IoT System Project

- 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.



THE IoT System Project (cont'd)

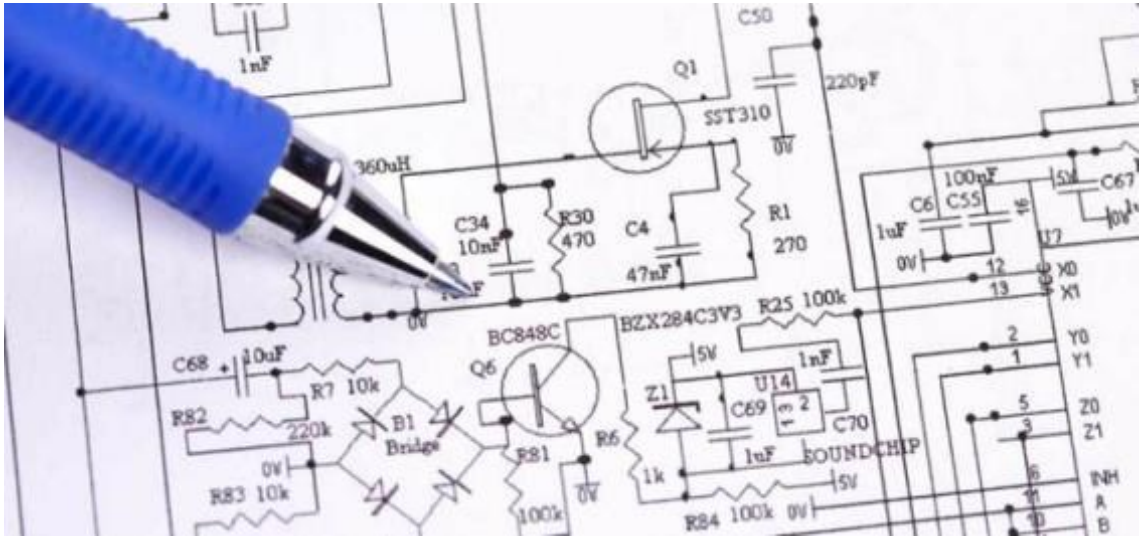
- REST API in an IoT System
  - REST APIs use HTTP methods to exchange data between systems or applications
  - RESTful systems use Uniform Resource Identifiers (URIs) to represent their services to external systems.
  - Sample URIs:
    - GET /people/michael to receive Michael's user profile dataset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

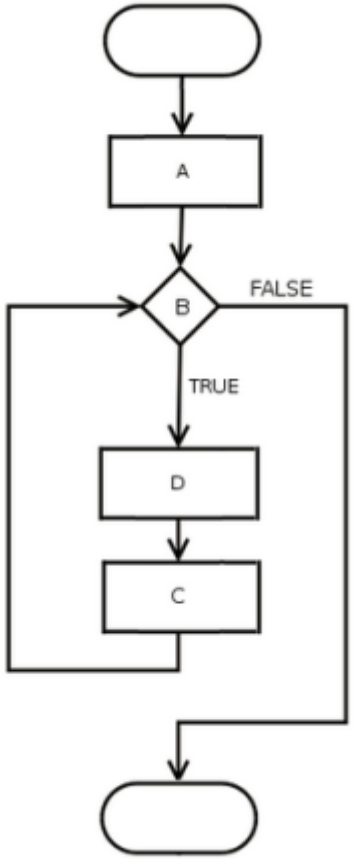


- The IFTTT web service allows for special resource URIs to be created and mapped to specific IFTTT actions.
- Example IFTTT URI - **https://maker.ifttt.com/trigger/SunRise/with/key/**
- The sunrise/sunset example uses both IFTTT and Google Calendar services

THE IoT System Project (cont'd)

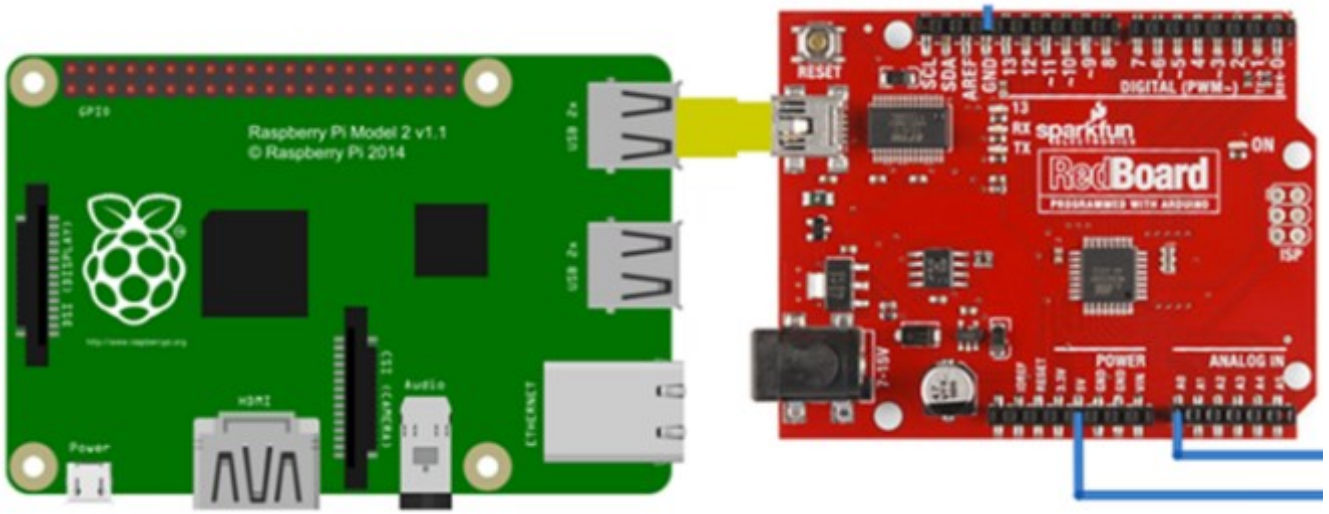
- Flowcharts, Electronic Schematics, and Sequence Diagrams
  - Documenting project is very important for building the devices, testing, troubleshooting, and creating a business model.
  - Flowcharts use standardized symbols to represent the processes and workflows.
  - Electronic schematics is a graphical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





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.



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.

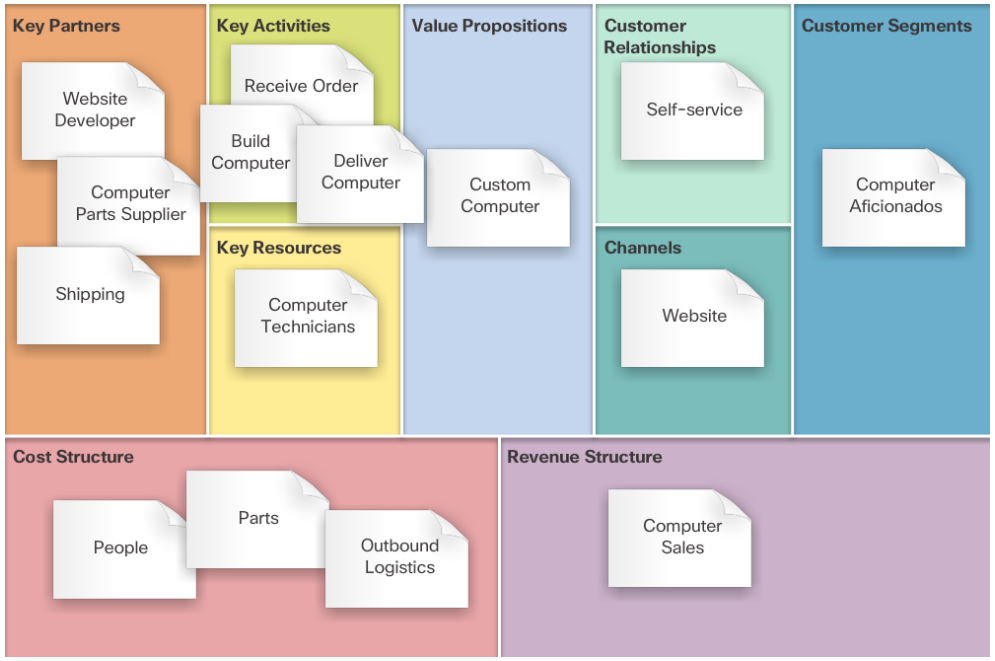
Business Model Canvas

- 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 (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.



What is Next?
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?
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.