



# Instructor Materials

## Chapter 3: Software is Everywhere



## IoT Fundamentals

### Connecting Things v2.01

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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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# 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;
}
```



# Programming

## 3.1.3 Lending Intelligence

### ■ IOT Devices and Data Processing

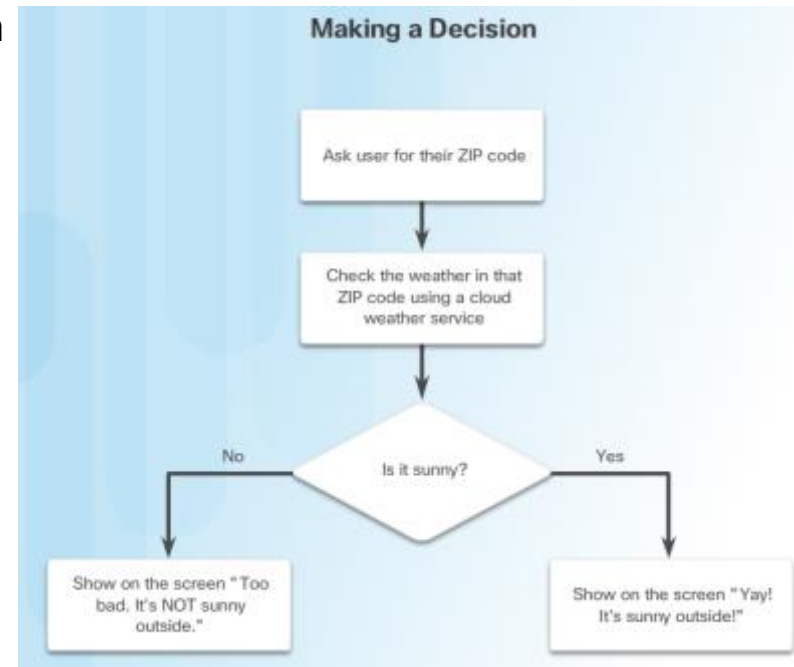
- A common IoT application uses sensors to collect data.
- Data is often not useful until it has been processed. Collected data is often transported and stored in the cloud for processing at a later date.

### ■ 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)



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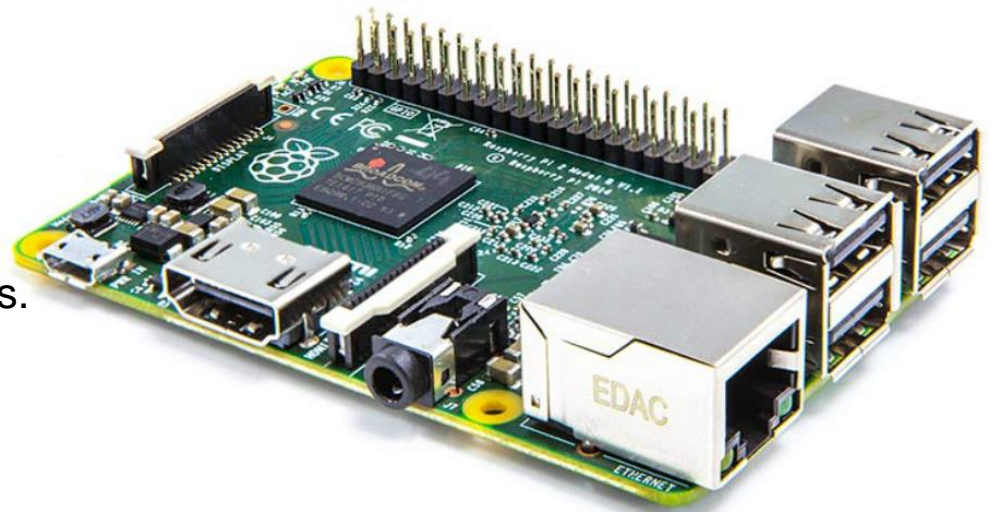


# The Raspberry Pi Single Board Computer (SBC)

## 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.

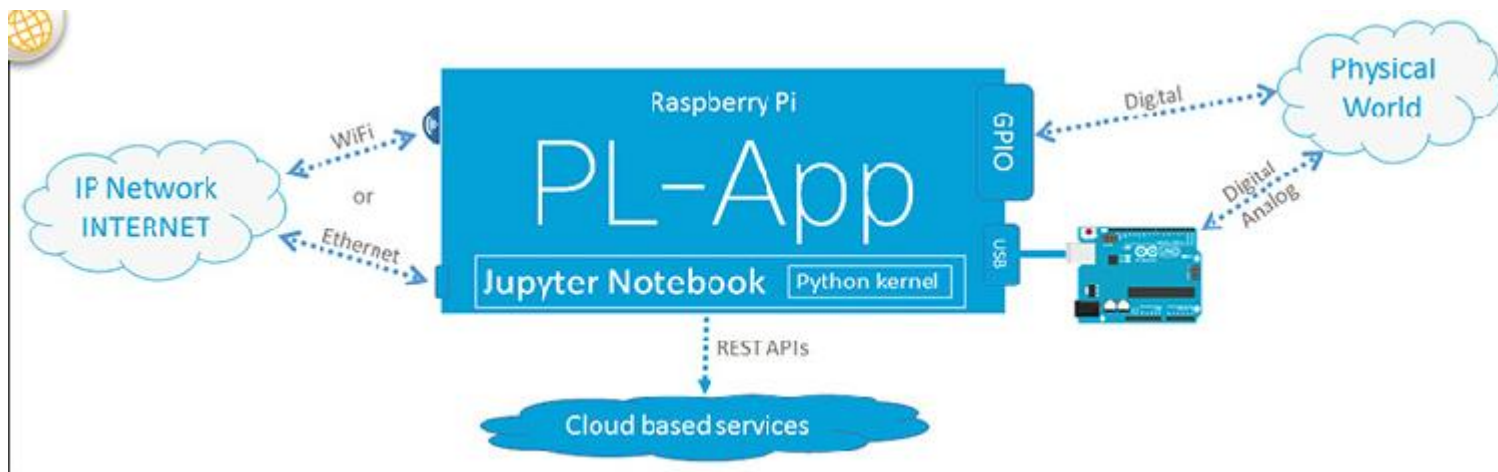




# The Raspberry Pi Single Board Computer (SBC)

## 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





## The Raspberry Pi Single Board Computer (SBC)

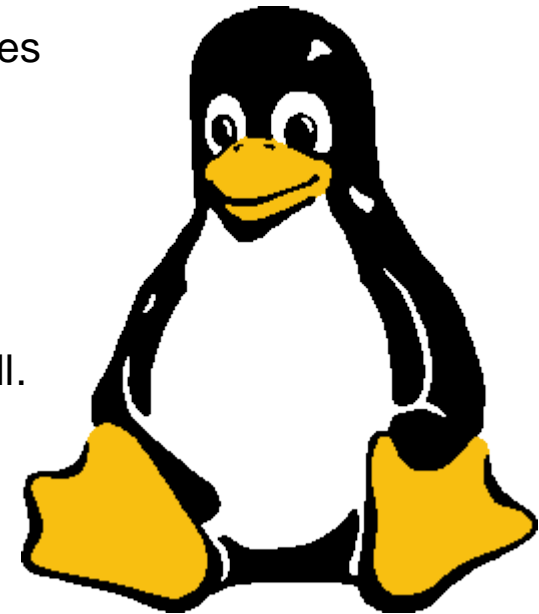
# 3.2.3 Using the Linux Operating System

### ■ 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)





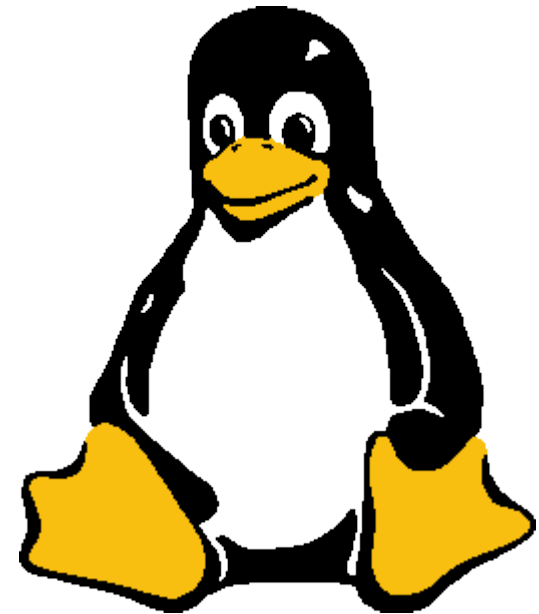
# The Raspberry Pi Single Board Computer (SBC) Using the Linux Operating System (Cont.)

## ■ 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.





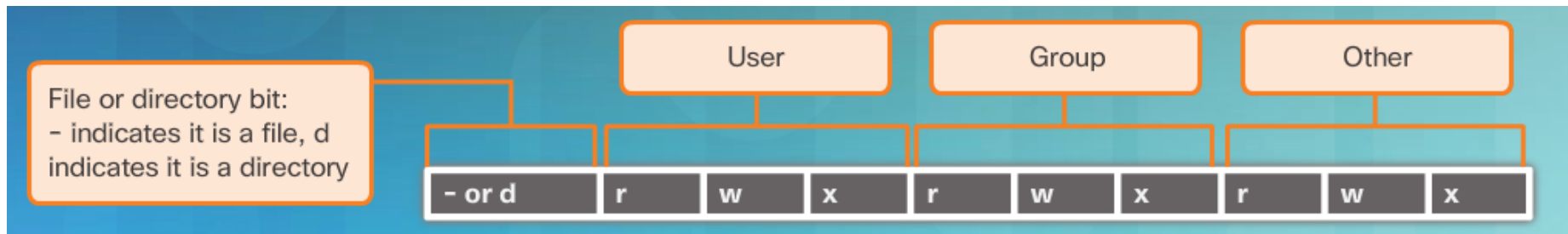
# The Raspberry Pi Single Board Computer (SBC) Using the Linux Operating System (Cont.)

## ■ 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.







# 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.

```
pi@raspberrypi ~ $ sudo apt-get install synaptic
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following extra packages will be installed:
  aptdaemon aptdaemon-data docbook-xsl glib2.0-atk-1.0 glib2.0-freedesktop
  glib2.0-gdkpixbuf-2.0 glib2.0-gtk-3.0 glib2.0-pango-1.0 glib2.0-vte-2.90
  libcairo-perl libglib-perl libgtk2-perl libpango-perl librarian0
  libvte-2.90-9 libvte-2.90-common lsb-release python-apt python-apt-common
  python-aptdaemon python-aptdaemon-gtk3widgets python-chardet python-debian
  python-defer python-gnupginterface python-pkg-resources python-pycurl
  python-software-properties rarian-compat sgml-data
  software-properties-common software-properties-gtk unattended-upgrades
Suggested packages:
  docbook docbook-dsssl docbook-xsl docbook-defguide libfont-freetype-perl
  libgtk2-perl-doc lsb python-apt-dbg python-gtk2 python-vte python-apt-doc
  python-distribute python-distribute-doc libcurl4-gnutls-dev
  python-pycurl-dbg perlsgml w3-recs opensp libxml2-utils dwww deborphan
  apt-xapian-index bsd-mailx mail-transport-agent
The following NEW packages will be installed:
  aptdaemon aptdaemon-data docbook-xsl glib2.0-atk-1.0 glib2.0-freedesktop
  glib2.0-gdkpixbuf-2.0 glib2.0-gtk-3.0 glib2.0-pango-1.0 glib2.0-vte-2.90
  libcairo-perl libglib-perl libgtk2-perl libpango-perl librarian0
  libvte-2.90-9 libvte-2.90-common lsb-release python-apt python-apt-common
  python-aptdaemon python-aptdaemon-gtk3widgets python-chardet python-debian
  python-defer python-gnupginterface python-pkg-resources python-pycurl
  python-software-properties rarian-compat sgml-data
  software-properties-common software-properties-gtk synaptic
  unattended-upgrades
0 upgraded, 34 newly installed, 0 to remove and 4 not upgraded.
Need to get 8,825 kB of archives.
After this operation, 26.9 MB of additional disk space will be used.
Do you want to continue [Y/n]? Y
Get:1 http://archive.raspberrypi.org/debian/ wheezy/main glib2.0-atk-1.0 armhf 2.
8.0-2rpi2 [61.2 kB]
Get:2 http://archive.raspberrypi.org/debian/ wheezy/main glib2.0-freedesktop armhf
1.36.0-2rpi2 [20.8 kB]
```



## 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

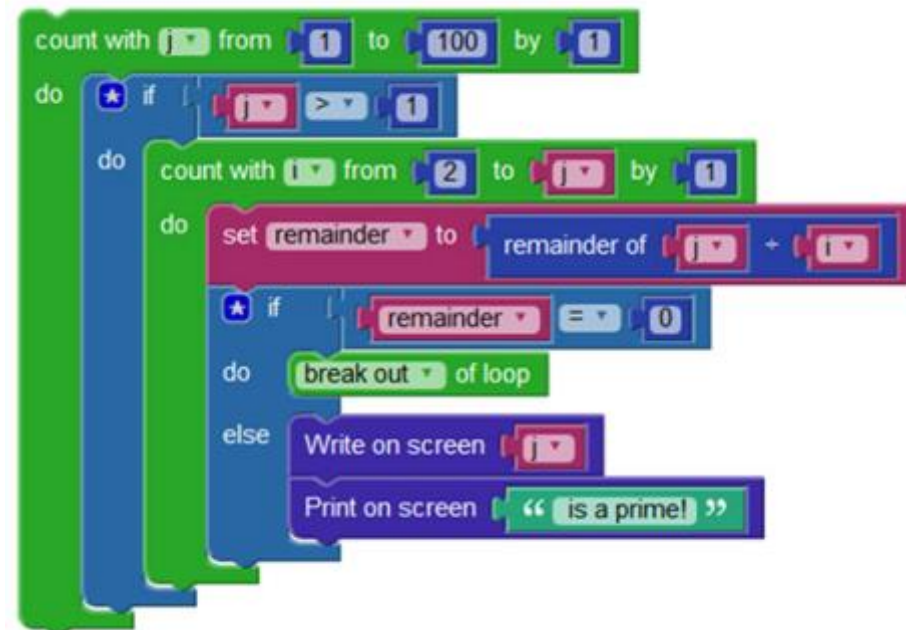
- Used to allow the code to make decisions.

#### ■ 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 Blockly 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.
>>>
```



# 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(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.
  - Webex Teams
    - Webex Teams 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 Webex Teams via the Webex Teams REST API.
    - Webex Teams REST API can include automated Webex Teams messages based on real-world events that occur in a popular application/program

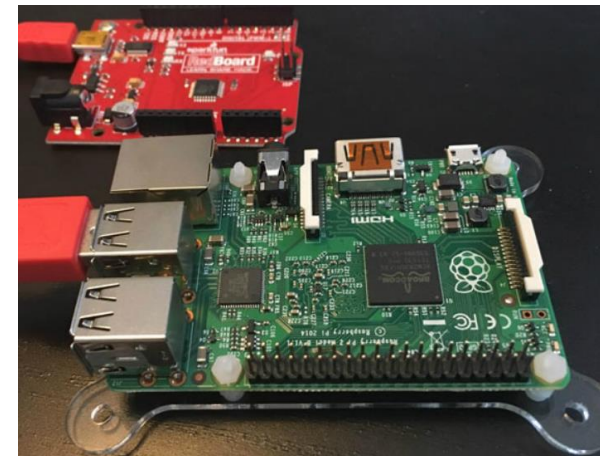
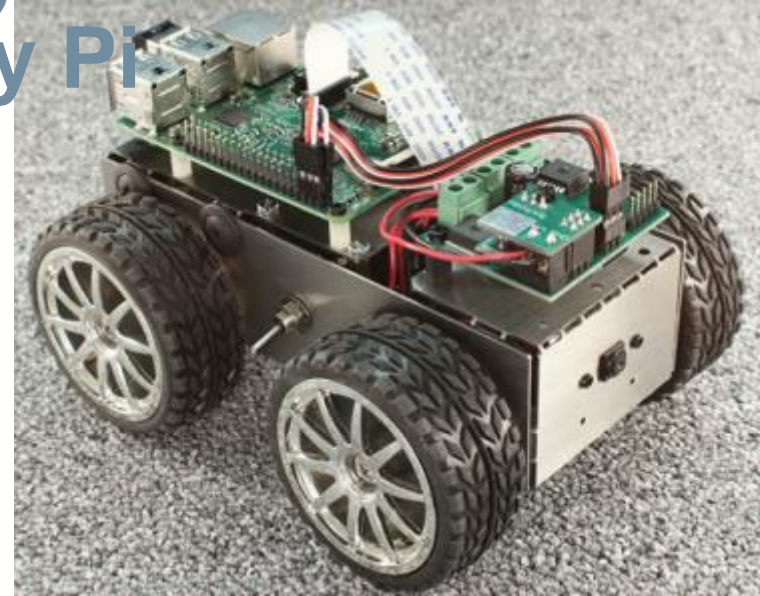




## The Raspberry Pi Single Board Computer (SBC)

### 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

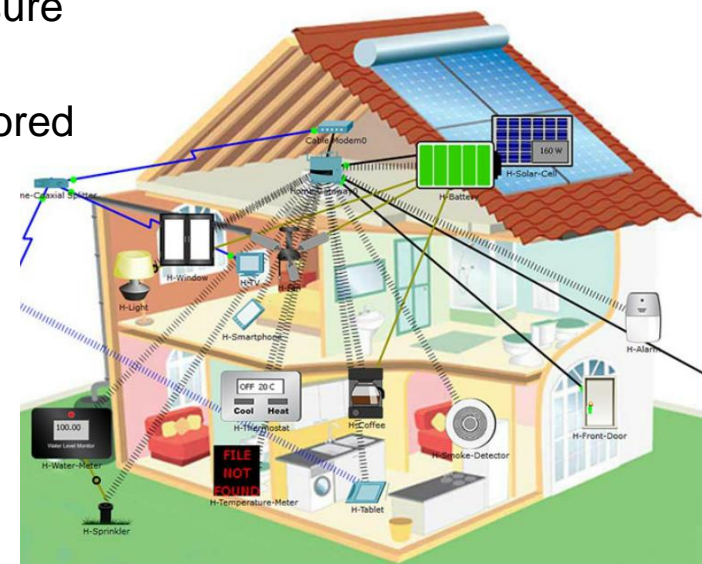
## 3.3.1 A Model of an IoT System

### ■ 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.



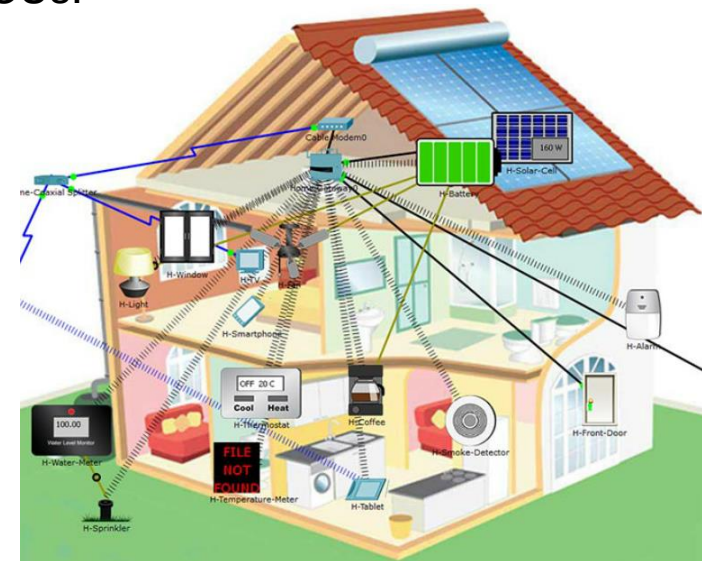


# Building Models of IoT Systems in Packet Tracer

## 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-world 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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# Chapter Summary

## 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.



