School of Engineering

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Fundamentals of Industrial Internet of Things

Worksheet for Lesson Package 1: Introduction to Internet of Things (IoT)

1. In 2018, the Internet of Things (IoT) has been identified as one of the key pillars driving Singapore's Smart Nation vision (https://www.businesstimes.com.sg/companies-markets/the-internet-of-things-and-its-possibilities), and till this day, it still is. It is also one of the most important and disruptive digital transformation technologies as the world becomes ever more connected.

Figure 1

[Nicky Lung. (2018, March 26). Minister for Foreign Affairs and Minister-in-Charge of Smart Nation Dr Vivian Balakrishnan speaking at the IoT Asia 2018 Conference. Retrieved from https://www.opengovasia.com/minister-in-charge-of-smart-nationoutlines-singapores-approach-to-iot/]

Watch the video https://youtu.be/6mBO2vqLv38 to learn more about what is IoT.

Based on what you have heard or read so far, in your own words, explain what you know of this technology called the Internet of Things.

Answer :

1. IoT is a conception where objects can be operated by transferring data to the cloud using the help of the internet.
2. IoT can help humans operate and maintain various devices without having to operate the equipment directly.
3. IoT to the rapidly growing network of connected objects that are able to collect and exchange data in real time using embedded sensors.
4. The goal behind the Internet of things is to have devices that self report in real-time, improving efficiency and bringing important information to the surface more quickly than a system depending on human intervention.

2. Some of the technologies found in IoT are not new and has been available many years before. For example, online data access in the form of websites and hyperlinks took off in 1990 with the invention of the World Wide Web, digital mobile telecommunications technology started supporting relatively high bit rate with the introduction of 3G networks in late 1990s, and the world's first smartphone (iPhone) have been around for more than a decade. However, it is only in recent years, that the Internet of Things proliferated and went mainstream.

   Some of the drivers of the Internet of Things are listed below:

   - Cost
   - Increase device proliferation
   - Maturity of online platforms

   a) Explain how these have contributed to the growth of the Internet of Things.

   b) What are other drivers that contributed to the growth of IoT? Explain.

Answer

a) New feature innovations allow people to operate the device without having to operate it directly, which can make the device cost less expensive.Also with the internet people can maximize the use of features on the device, can also operate remotely with smart devices such as smartphones with the help of the internet.

b) Reduction of memory, storage and processing costs; sensor upgrades; cloud and big data, and the convergence of the Internet and industrial networks. technology that can unify and operate various things without having to bother operating them directly, the motivation to make devices that can be operated remotely appears to make it easier for humans to do many things.

3. The growth of IoT has reshaped many industries and the world we are living in. There are two fundamental opportunities for the Internet of Things to create value within an enterprise:
    - **Connected Products:** Companies can engineer new IoT-enabled features and services into new connected products to differentiate and improve experiences.
    - **Connected Business Processes:** Companies can use IoT to improve their operations with better, smarter information.

    List 3 applications of IoT each in the categories of Connected Products and Connected Business Processes.

    Answer :

- **Connected Products**

    1. Robot Cleaner
    2. Google Glass
    3. Smart Watch

- **Connected Business Processes**

    1. Voice Controller
    2. Smart Lamp
    3. Smart Security System

4. In order to enable connected products and connected business processes, various components are needed. IoT does not refer to just a single device. It consists of many components. For example, to simply turn on a smart light using your phone, many supporting components are necessary. IoT makes our lives simple, but IoT is far from simple.

   IoT is made up of the components shown in the diagram below.

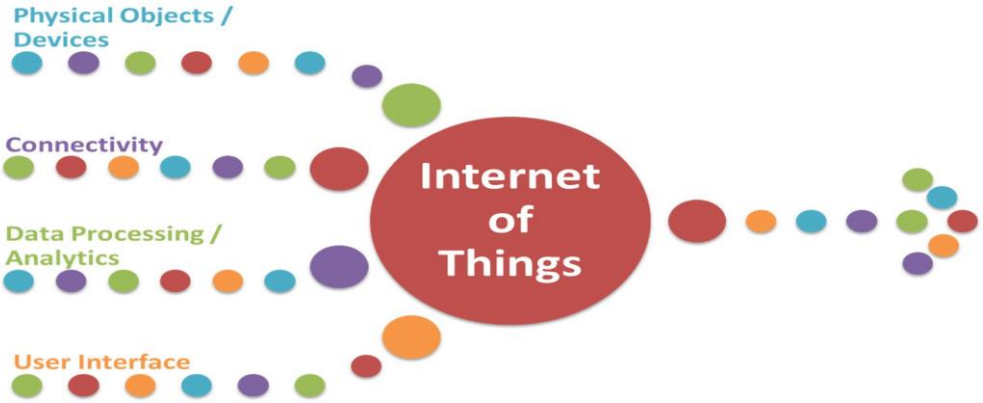

Figure 2

Explain what each of the components do, and how they are related to each other

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Answer :

- **Physical objects/devices:** IoT-operated devices or intermediary devices to operate other IoT-enabled devices
- **Connectivity:**Media to send device data to the cloud
- **Data processing / analytics:** Processing data to determine device behavior
- **User interface:** Display of applications the user is using

IoT-based device operation flow

1. Humans send commands with operating applications (user interfaces) installed on certain devices (eg.smartphone) connected to the internet (connectivity, e.g. WIFI),
2. The command data from the application is sent to the cloud. then the cloud will processing data
3. The data is sent to the device to be operated using the internet help.

5. With exponential increase in the number of connected devices, the number of network connections and amount of traffic generated by IoT will dwarf the number of connections and traffic generated by internet today, hence a new IoT reference network architecture is needed to describe network, compute, application, and data management architectures that are IoT-ready.

   Below is a table of issues and its descriptions. Match the list of change required to the corresponding issue (the first one has been done for you):

   - Using IPv6 that supports significantly larger address space.
   - Security is required at every level of IoT network.
   - IoT networks need to have mechanism that supports legacy protocols, such as Ethernet and IP.
   - Analytics software needs to be positioned closer to the edge and should support real-time streaming analytics.
   - New last-mile wireless technologies are needed to support constrained IoT devices over long distances.
   - Data analytics capabilities need to be distributed throughout the IoT network, from the edge to the cloud.

Table 1

Issues	Description	Change Required
Massive Scale of IoT	IPv4 address space has reach exhaustion.	**Using IPv6 that supports significantly larger address space.**
Devices and network constrained by power, CPU, memory and link speed	Due to massive scale, and longer distances, the network are often constrained, lossy, and capable of supporting only minimal data rates (tens of bps to hundreds of Kbps).	**New last-mile wireless technologies are needed to support constrained IoT devices over long distances.**
Massive volume of data generated	Sensors generate massive amount of data on a daily basis, causing network bottlenecks and slow analytics in the cloud.	**Data analytics capabilities need to be distributed throughout the IoT network, from the edge to the cloud.**

Support for legacy devices	IoT network often comprises a collection of modern IP-capable endpoints as well as legacy, non-IP devices that rely on serial or propriety protocols.	**IoT networks need to have mechanism that supports legacy protocols, such as Ethernet and IP.**
Need for data to be analysed in real time	Traditional IT networks perform scheduled batch processing of data, IoT data needs to be analysed and responded to in real-time.	**Analytics software needs to be positioned closer to the edge and should support real-time streaming analytics.**
Security	IoT devices, especially those on WSN (wireless sensor network) are often physically exposed to the world.	**Security is required at every level of IoT network.**

6. To address the issues and considerations of the IoT network architecture, the IoT World Forum (IoTWF) architectural committee led by Cisco, IBM, Rockwell Automation, and other major companies worldwide is formed.

   The IoTWF architectural committee published a 7-layer IoT architectural reference model in 2014 shown in the figure below. Read more about it at:

   - http://cdn.iotwf.com/resources/72/IoT_Reference_Model_04_June_2014.pdf
   - http://cdn.iotwf.com/resources/71/IoT_Reference_Model_White_Paper_June_4_2014.pdf

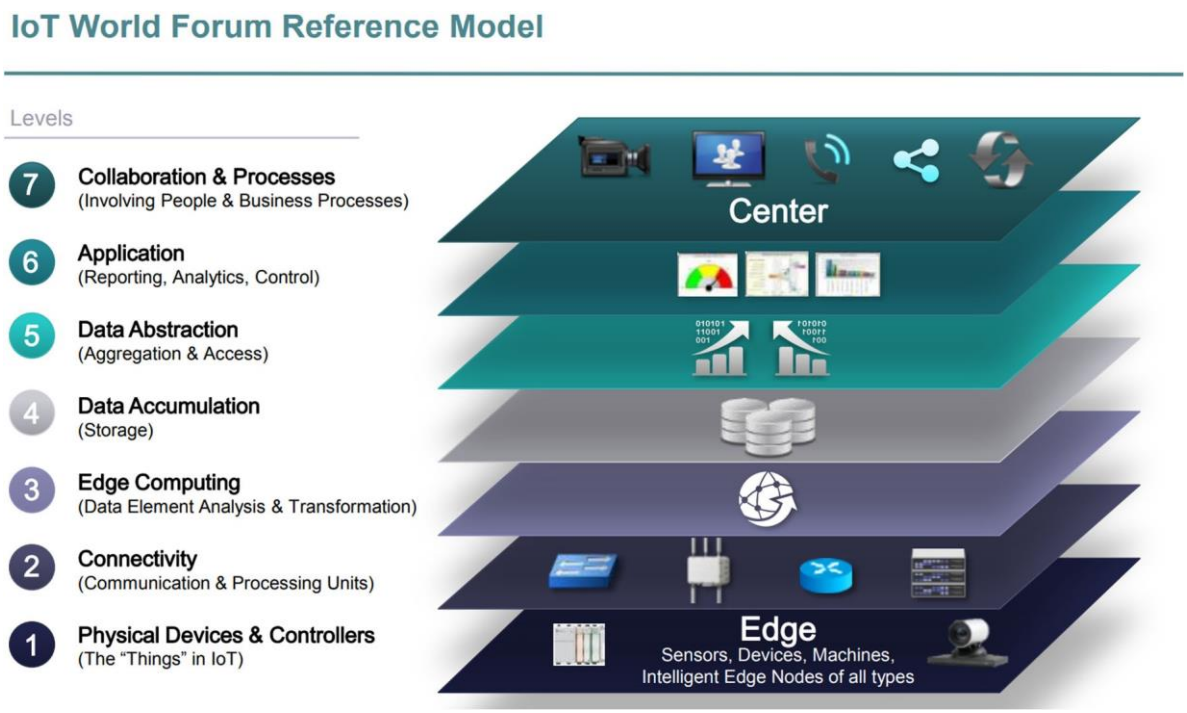

Figure 3

The IoT Reference Model provides clear definitions and descriptions that can be applied accurately to elements and functions of IoT systems and applications.

a) Based on the statement on the basic premises of the reference model, fill in the blank boxes below.

Devices

send and receive data interacting with the

Network

where the data is transmitted, normalized, and filtered using

Edge Computing

before landing in

Data Storage / Database

accessible by

Applicatio

which process it and provide it to people who will

Collaborate & act

b) The table below lists the benefits of the reference model. Fill in the descriptions.

Table 2

Benefit	Description
Simplifies	Helps to break down complex systems so that each part is more understable
Clarifies	Provides additional information to precisely identify levels of IoT and establish common terminology
Identifies	Identifies where specific types of processing is optimised across different parts of the system
Standardises	Provides a first step in enabling vendors to create IoT product that work with each other
Organises	Makes IoT real and approachable, instead of simply conceptual

7. The Things in IoT are mostly made up of electronics devices and controllers.

   When it comes to thinking about the electronics, it is useful to split them into two main categories, namely sensors and actuators.

   a) Explain in your own words what are sensors and actuators.

   b) List some examples of sensors and actuators. Describe the usage of the examples listed.

Answer :

a) **Sensors:** Is a device that can detect events and convert them into information that is sent to the connected device.

   Actuator: Is a device that controls and drives a connected mechanism

b) List Example Of Sensors and Actuators

Sensors

1. **Sound sensor**: Detects the Sound Level entering the device
2. **Accelerometer sensor**: Detects Changes in Position, Tilt
3. **Temperature sensor:** Detects and predicts temperature

Actuators

1. **Smart door lock:** Door Security
2. **Smart light:** Automate lamp and lamp color
3. **Smart water pump:** Automate pump and Control

8. Other than sensors and actuators, computing platforms are also critical in IoT applications. IoT devices take advantage of the more tightly integrated and miniaturised solutions — from the most basic level of microcontrollers to more powerful System-on-Chip (SoC) modules. These microcontrollers are the engines of countless sensors and automated factory machinery.

Figure 4

Watch the video https://youtu.be/dcNk0urQsQM to learn more about microcontrollers and microprocessors.

a) Compare and contrast the differences between a desktop PC and a microcontroller and fill in the table below.

Table 3

Desktop PC	Microcontroller
Desktop PCs are huge and consist of collection of discrete modules (processor, RAM, hard disk)	Microcontroller are smaller and the modules are housed together (RAM, processor, etc)
Desktop PCs provide general-purpose functionality	Perform specific tasks
Desktop PCs are almost always plugged into a wall socket consuming 10 of Watts of electricity	Using low power and can use battery

b) The Arduino is an open-source electronics platform based on easy-to-use hardware and software that allows easy connectivity of sensors, LEDs, motors to the microcontrollers. Because these platforms are usually focused on performing single task, there would not be any operating systems on such devices.

Of course, other than commercially available microcontroller platforms, you can customise your own microcontroller platform (as shown in figure below) depending on your system requirements.

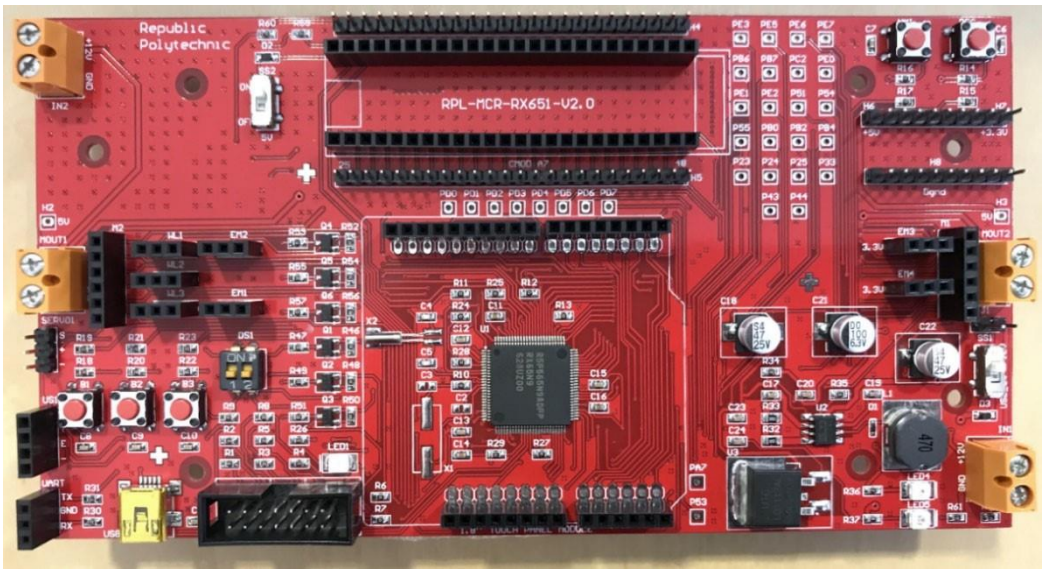

Figure 5

List at least 3 other commercially available microcontroller platforms that can be used for IoT purposes.

Answer :

1. ATMEGA32 series
2. ESP8266
3. PIC18 series (including PIC12 and PIC16)
4. LPC series (ARM Cortex-M0)
5. SimpleLink series (ARM Cortex M4)
6. Adafruit
7. Raspberry Pi

c) In between the low-end microcontroller and a full-blown PC sits the SoC. One commercially available SoC platform that is very popular is the Raspberry Pi as shown below.

Figure 6

Watch the video at https://youtu.be/FUhCrWoNA2c to learn more about SoC. Explain the differences between microcontroller and SoC.

Answer :

Differences between Microcontroller and SoC

Microcontroller

- Perform specific task
- CPU, memory, I/O
- Example: Camera, washing machine

SoC

- Perform many tasks with low consumption battery
- CPU, GPU, DSP, Connectivity module, memory, other (camera, location,etc)
- Example: smartphone

9. The diagram below lists some popular wireless standards used in IoT communication network. The PDF of this image is also provided in file attached.

iBwave.pdf

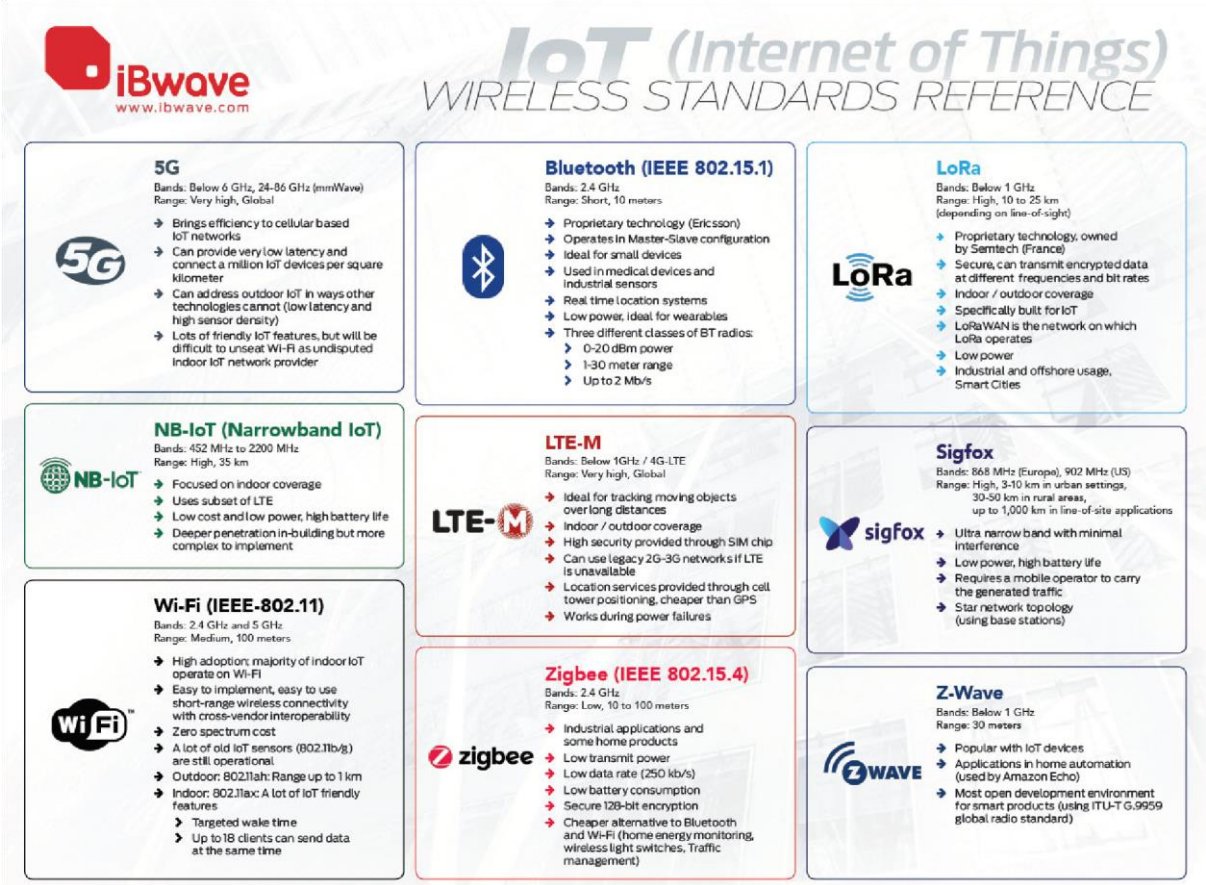

Figure 7

a) Classify these communication standards according to the range of transmission distances in the table below.

Table 4

PAN (Personal Area Network) **Few metres**	**HAN** (Home Area Network) **Few tens of metres**	**LAN** (Local Area Network) **Up to 100m**	**WAN** (Wide Area Network) **More than few kilometres**
Bluetooth (IEEE 802.15.1)	- Zigbee - Z-wave	- Wi-Fi	- 5G - LoRa - NB-IoT - LTE-M - Sigfox

b) Find out the transmission rate of each of the communication standards and fill in the table below.

Table 5

Communication Standards	Transmission Rate / bps
Bluetooth (IEEE 802.15.1)	**Up to 2 Mb/s**
Zigbee (IEEE.802.15.4)	**250 kb/s**
Z-wave	**250 kb/s**
Wifi (IEEE 802.11)	**5GHz: 1300 Mb/s** **2.4GHz: 450 Mb/s**
5G	**10 Gb/s**
NB-IoT	**27.2 kb/s to 62.5 kb/s**
LTE-M	**Up to 1 Mb/s**
LoRa	**Up to 27 kb/s**
Sigfox	**100 to 600 b/s**

c) When selecting the network technology to be used for IoT, it may be tempting to simply choose the technology with the longest range and highest throughput. However, this is often not true. Discuss in your teams what are the various factors that may affect the choice of network technology in an IoT application, and explain why.

Answer :

- **Distance When using device:** If the device is used only in the vicinity of the person, it is better to use close range. If the device is used even in the absence of humans, it is better to use remotely.

- **Device Monitored:** If the device needs to be monitored all the time, it would be better to use a remote network.

10. IoT platforms allows the massive data/information gathered by the things to be stored, processed, analysed and get information from.

    An IoT platform is a commercial software product that offers some combination of the following capabilities

    - Connect to IoT endpoints
    - Manage IoT endpoints/identities
    - Ingest and process IoT data
    - Visualize and analyze IoT data
    - Build IoT applications
    - Integrate IoT data into existing applications

    List some IoT platforms that are currently popular on the market and what are some of the services that these platforms provide.

Answer :

- Microsoft Azure
- Amazon Web Services (AWS)
- Oracle Cloud Infrastructure (OCI)
- Google Cloud Platform (GCP)

End of Worksheet