Network Security

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Week - 12

Lecture - 71

Security of the Internet of Things (IoT), Hardware Security: Part 1

Hello, the Internet of Things (IoT) is becoming very popular these days. In this lecture and the next few lectures, we will discuss the security of the Internet of Things, or IoT. We will also discuss hardware security. As we read in the news all the time, IoT is an emerging and promising technology with a variety of applications. We'll discuss several of the applications of IoT in the next few slides.

Different aspects of IoT are being extensively researched. For example, sensors for IoT, communication aspects, networking aspects, antennas, batteries for IoT devices, and so on. What is IoT? Traditionally, internet connectivity was only available to powerful devices such as desktop computers, laptops, and smartphones. IoT extends internet connectivity to resource-constrained devices such as sensors, actuators, and everyday objects such as refrigerators, air conditioners, and so on.

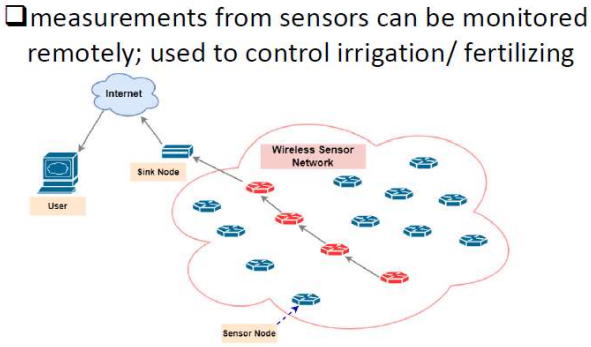
Hence, the name Internet of Things. Internet connectivity is made available to things such as sensors, actuators, and everyday objects. What is the advantage of connecting these things to the internet? It allows remote monitoring and control of such devices. For example, if a sensor is connected to the internet, we can remotely monitor whatever data the sensor is reading.

And also, we can control devices. For example, we can switch on an air conditioner remotely. So, such devices are called IoT nodes. IoT nodes also communicate among themselves with minimal or no human intervention. And that's another key technology known as Machine-to-Machine communication (M2M) communication.

Let us discuss different applications of IoT. One application is precision agriculture. The idea of precision agriculture is that we utilize resources such as water, fertilizer, and pesticides very judiciously. We just apply them as required. We don't simply flood the

entire farm with water, pesticides, or fertilizer, but we apply them judiciously based on the readings of sensors.

So, sensors are deployed at multiple points in a farm. This cloud is a farm, and all these devices that are deployed in the farm, they are sensors. These sensors monitor quantities such as soil moisture, composition, temperature, humidity, and so on. And these measurements from sensors can be monitored remotely and used to control irrigation, fertilizing, and so on. So, as an example, the information collected by this sensor is transferred to the internet via this path, which is shown here.



This sensor is not in the direct wireless range of this sync node, which is the collector of data collected by the sensors. So, this node transfers its collected data to this neighboring node, which forwards it to this node along with its own collected data. And this node forwards it to this node, and this forwards it to this sync node. The sync node is connected to the internet, and a user can remotely monitor the data that is collected by all these sensors. So, these measurements from sensors, such as soil moisture composition, temperature, humidity, and so on, can be used to control irrigation and fertilization.

For example, if this sensor shows that the soil moisture level in this region is low, in that case, water can be sprayed in this region. Whereas if this sensor shows that the soil moisture is high, then there is no need to spray water here. In this way, resources such as water and fertilizer can be applied judiciously, and that's the principle of precision agriculture. This application is possible because sensors are connected to the internet. So, this is an instance of the Internet of Things.

Some agricultural and environmental IoT use cases are as follows. One is smart irrigation and fertilization techniques to improve yield, which we already discussed on the previous slide. Then, livestock health and asset tracking. Some sensors can be attached to the bodies

of livestock; they can monitor the health of livestock and send the collected readings to a sync node, and the health of the livestock can be remotely monitored. And also, we can track livestock as well as different objects, such as tractors, by attaching sensors to them.

These tracking devices may be GPS-enabled, and they track the assets on the farm. Another use case is preventative maintenance on remote farming equipment. We can attach sensors to farming equipment, and they detect if the equipment needs repair. In that case, maintenance can be performed by using the readings of these sensors. Then another example is drone-based land service.

Drones can survey farms, and they can detect if the crops are infected by some pests or diseases, and so on. They can take images of the leaves and find out if there is some infection by a disease, and so on. And these drones are connected to the internet. So, there are communication devices in the drones and they transmit the collected images to a sync. This is another instance of IoT because these drones are connected to the internet.

Then, robotic farming- robots can be deployed in farms to reduce the need for manual labor. These robots are connected to the internet. So, they can communicate with the remote controller. Another example in the context of the environment is this. Sensors are floated at various altitudes in the atmosphere to sense temperature, air quality, and so on. So, that way we can perform monitoring of the environment.

These sensors collect quantities such as temperature, air quality, and so on, and they send these collected quantities to a sync where they can be monitored. Another example in the environmental context is volcanic and fault line monitoring. So, volcanoes can be monitored, and fault lines, which are the lines between different plates in the earth's crust, these can also be monitored using sensors, and these sensors can again send the collected readings over the internet to someone who observes the readings. Then another class of applications of IoT is smart healthcare. Here sensor devices are attached to a patient's body.

They collect medical data and vital signs such as blood pressure, temperature, cholesterol level, heart rate, and so on from the patient. And this enables the automatic diagnosis of conditions and tracking of progress. If a patient is just about to get some acute condition or heart attack and so on, these sensors will detect that, and they send alerts to a healthcare provider. And if some treatment has been provided to a patient, such as a surgery has been performed, in that case how the patient is recovering from the surgery, that can be detected by all these sensors. Any anomalies can be indicated directly to the healthcare provider without significant human involvement.

Some use cases in the context of smart healthcare are as follows. One is in-home patient care. Since sensors can be attached to the bodies of patients, their health can be monitored remotely. So, they do not need to be admitted to a hospital. They can be at home, and one can arrange for their care. Then another similar use case is dementia and elderly care and tracking and patient fall indicators.

Some sensors can detect if a patient just fell down, and they can send an alert to a healthcare provider. Then another class of applications is smart home. One example within the class of smart home is an automatic lighting system senses the presence of human beings, for example, via proximity sensors, and switches on the lights only in specific areas of the house accordingly. So, lights can be switched on only where humans are present, and wherever there are no humans, the lights can be switched off. And this is possible because sensors detect the presence of human beings and communicate the corrected information to a switch, and this switch controls the lights.

Similar to the control of lights, we can also control heating and air conditioning. So, only when humans are present we switch it on; otherwise, we switch off heating or cooling. So, again, this is possible because we can use temperature sensors and so on. We can use temperature sensors to detect the temperature, and also we can use sensors to detect the presence of humans. And these sensors are connected to the internet.

Another example is smart appliances can be remotely switched on or off over the internet. For example, a person who is traveling to their home, they can switch on the air conditioner about 15 minutes before they reach home so that the temperature is at a comfortable level when they reach home. So, this is possible because AC is connected to the internet, and it can be controlled remotely. Another example is in the context of security: motion sensors can sense intrusion by burglars and transmit alerts to the homeowner's smartphone. This is possible because these motion sensors are connected to the internet.

This is another application of IoT. Then, home automation for the elderly and disabled. We can make it easier for the elderly and disabled to remain at home safely and comfortably instead of being moved to a healthcare facility. This is again possible because of the use of sensors. Another application is infrastructure and machine monitoring and preventive maintenance.

Sensors are fixed to machines in a factory, walls of buildings, bridges, and so on, which sense vibration patterns, acoustics, and so on. These sensors emit specific vibration patterns or acoustics when these machines are about to fail. So, in that case, they send alerts when

maintenance is required and then some technician can be deployed and these machines can be repaired. Then, another example is industrial automation. Here, one use case is safety systems such as thermal sensing, pressure sensing, and gas leaks in the context of a factory.

Then, another application is wildfire control. Here, sensors equipped with thermometers and GPS are dropped from an airplane into a forest. And they collectively produce a temperature map of the forest. That is, this map shows where the temperature is high and where it is low. So, this map can assist firefighters.

The construction of this map is possible because each thermometer senses the temperature in its vicinity, and it knows its location due to the GPS device in it. So, we know the temperature at each location in the forest, and this temperature map can assist firefighters in effectively dousing the fire. Another application is consumer IoT. Some examples are smart home gadgets. We can perform smart irrigation in gardens.

Then, garage doors can be automatically controlled. Similarly, locks can be automatically controlled. We have smart locks, smart lights, smart thermostats, smart security (for example, burglary alarms, which we discussed earlier), Alexa assistants, and smart set-top boxes. So, these are all possible because sensors and actuators are connected to the internet. Another class is wearables, such as health and movement trackers, smart clothing, and wearable devices.

Then pet location systems; for example, we can attach devices with GPS on pets and track their movement and smart kennel doors. There are also several retail, finance, and marketing IoT use cases. So, one example is targeted advertising, such as locating known or potential customers by proximity and providing sales information. Then, another example is asset tracking, such as inventory control, loss prevention, and supply chain optimization. So, we can attach devices such as RFID tags to inventory, and we can track inventory.

So, this way, if there is any loss in inventory, that can be detected, and the supply chain can be optimized. Cold storage monitoring, such as analysis of cold storage of perishable inventory. So, again, we can attach devices such as RFID tags to this inventory and monitor it. Another example is beaconing systems within entertainment venues, conferences, concerts, amusement parks, and museums. Sensors can detect the presence of humans, and consider the example of a museum.

When a visitor is near an artifact in the museum, in that case information about that artifact can be played on the mobile device that is carried by the visitor. That is, the visitor may be wearing headphones, and relevant information about the artifact can be played out on the headphones. This is possible because of the use of beaconing system, which detects the presence of humans. Then another application is intelligent transportation and logistics systems. One example is free tracking and location awareness.

So, devices with GPS and communication capability are attached to trucks and other vehicles, and we can track them and be aware of their location. Then another example is municipal vehicle planning, routing, and monitoring for snow removal and waste disposal. So, sensors can detect the presence of snow and waste, and this information can be used to plan the movement of municipal vehicles, and that is possible because of the monitoring enabled by these sensors. Another example is railcar identification and tracking. Again, devices like RFID tags can be attached to railcars, and they can be tracked.

Asset and package tracking within fleets. We can attach identifying devices such as RFID tags to packages within fleets. These can send information about the packages so that we can track them. This information is useful to the customers to whom these packages are being sent. Preventative maintenance of vehicles on the road is another example.

Here, sensors attached to vehicles can detect when there's some problem in them. Especially this is useful for self-driving vehicles. So, these sensors can send alerts if some maintenance is required. Then another class of applications is smart cities. Pollution control and regulatory analysis through environmental sensing.

Sensors are deployed at different points in the atmosphere, and they sense pollution and air quality, and so on. Then microclimate weather predictions using citywide sensor networks. Sensor networks can be densely deployed in cities, and they can monitor the weather at a fine granularity. Then waste management can be optimized just as we discussed in a previous slide. So, smart traffic light control can be used.

Traffic lights are controlled based on the number of vehicles on different roads. The number of vehicles on different roads can be sensed using sensors, and this information can be used to control traffic lights. So, that results in improved traffic flow and fuel economy. Another example is energy efficiency of city lighting by switching lights on demand. Similar to the smart home example, we can use proximity sensors to sense the presence of humans and control the lights in the city automatically using the sense information.

Smart snow plowing based on real-time road demand, weather conditions, and nearby plows. This we discussed earlier in a different context. Another example is smart education of parks and public spaces depending on weather and current usage. Smart cameras, such as CCTV cameras, to watch for crime. So, these cameras can be connected to the internet.

Smart parking lots that automatically find the best parking spaces on demand. So, these are possible because sensors can sense the presence of vehicles, and they can identify empty lots and guide vehicles towards best parking spaces. Bridge, street, and infrastructure wear and usage monitors to improve longevity and service. Then we have government and military IoT use cases. One example is terror threat analysis through IoT device pattern analysis and beacons.

So, a large amount of data from different kinds of sensors can be monitored, and this can be used to issue terror threats, issue warnings about any terror events. Swarm sensors through drones—that's another example where drones have sensors which monitor different quantities, and this collected information can be sent over the internet. Another example is sensor networks deployed in the battlefield to monitor threats. Government asset tracking systems—sensors can be attached to government assets along with GPS devices or other location tracking devices, and these can be used for tracking. Then, real-time military personnel tracking and location services—that's another example, similar to the examples that we discussed earlier.

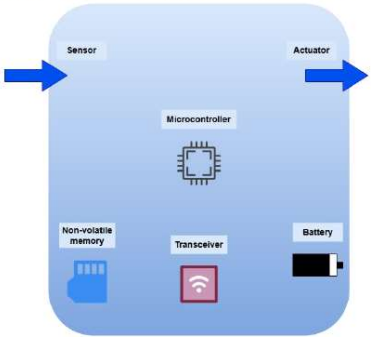
Sensors can be used to effectively monitor hostile environments where it's difficult to deploy people for monitoring. We can use sensors to do this monitoring, and they can send the collected information over the internet. Water level monitoring to measure dam and flood containment. The opening and closing of dams can be done automatically based on the monitoring by sensors. We can see that there are a large number of use cases and applications of IoT, which shows the importance of IoT.

We now discuss the components of IoT-enabled things. This figure shows the key components of an IoT-enabled device. These components are the following: sensor, actuator, microcontroller, transceiver, and power supply. The sensor, which is shown here, measures some parameter of interest, such as temperature, moisture, and so on, and delivers an electrical signal proportional to the observed characteristic. We can get the value of the quantity being sensed.

The sensor output is typically input to a microcontroller, which is shown here, or another management element. An actuator performs certain actions based on commands from the

microcontroller. For example, it can turn a valve ON or OFF, switch a light ON or OFF, and so on. So, these actions can be performed by actuators. An actuator receives an electrical signal from a controller and interacts with its environment to produce an effect on some parameter of a physical, chemical, or biological entity.

- **Actuator**:
  - ❑ Receives an electronic signal from a controller and responds by interacting with its environment to produce an effect on some parameter of a physical, chemical, or biological entity
- **Microcontroller**
- **Transceiver**:
  - ❑ Contains the electronics needed to transmit and receive data
  - ❑ Most IoT devices contain a wireless transceiver, which communicates using Wi-Fi, ZigBee, etc.
- **Power Supply**:
  - ❑ Typically, this is a battery



The next component is a microcontroller, which receives the information collected by the sensor and sends commands to the actuator to take different actions. It also is connected to the memory, and so where data is stored and programming data are stored in the memory. Another component is the transceiver. That is shown here. It contains the electronics required to transmit and receive data.

We have seen in the various IoT applications that we discussed that the IoT devices need to send the sensed data to a remote agent, or they need to receive data from the agent, such as commands to control the actuator in a certain way. This transceiver can be used to communicate with remote devices. Most IoT devices contain a wireless transceiver that communicates using various technologies such as Wi-Fi, ZigBee, and so on. Then we have a power supply. This power supply is typically a battery.

So, these are the components of IoT-enabled things. So, in summary, we started our discussion on IoT security and hardware security. We discussed various applications of IoT. We discussed that there are various applications in different domains. Then, we discussed the components of IoT-enabled things.

We'll continue our discussion on IoT and its security in the next lecture. Thank you.