Internet of Things Workshops for High School Students

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Abstract

The Internet of Things (IoT) is an upcoming technology domain used in many environments including smart infrastructures, medicine, manufacturing, logistics, and environmental monitoring. The realization of IoT is being driven by efficient cloud technologies that enable businesses, research institutions and users to manage, aggregate and analyze data resulting in increased efficiencies and predictive analytics.

It is necessary for juniors and senior high school students to grasp the inner working of IoT technologies and methods used to develop smart applications. Students studying computer science or information technology may be exposed to most of the technologies used in building IoT applications individually, it is necessary to show how they are integrated when developing an IoT solution. Through this workshop, we will introduce students to embedded systems used to develop sensing infrastructures with physical sensors. They will also develop backend data management and visualization servers to represent the data collected from the physical environment to the virtual world. The goal of this workshop is to enhance student capabilities to work in a multi-disciplinary environment; provide an opportunity for students to reinforce and apply the theoretical constructs learned in previous coursework, and enhance their retention capabilities.

Internet of Things

The advent of modern web technology has transformed economies and societies. The release of HTML 1.0 followed by HTML 2.0 in the 1990s' were not revolutionary by today's standards. However, simple web pages with text and pictures formed the foundation of advanced web-based processes and applications that are now realized through advanced applications and tools. People have instant communication across the world using "free" applications that only require a simple registration. Online shopping is changing how people purchase goods and services. The world's top three corporations as measured by market cap (White, 2015) are technology companies that include Apple, Google and Microsoft. The Internet of Things (IoT) is expected to be the next technological leap that has a "revolutionary" impact across business and society. IoT was founded on the integration of smart and not so smart sensors using RFID; internet-based technologies that integrate sensors; and devices that are capable of communication and cooperation (Atzori, Iera, & Morabito, 2010). An invisible and embedded communications and data network is being developed and imagined across business and research institutions (Atzori et al., 2010; Gondi, White, Gemmill, & Post, 2016; Gubbi, Buyya, Marusic, & Palaniswami, 2013; Li, Wang, Dai, Wang, & Zhao, 2016; Miorandi, Sicari, De Pellegrini, & Chlamtac, 2012).

IoT end to end systems involve multiple components and are interconnected through multiple systems performing specific tasks to accomplish their objectives in real-time (Karimi & Atkinson, 2014). The IoT is divided into three different layers: Perception Layer, Communication Layer, and Application Layer (Khan, Khan, Zaheer, & Khan, 2012). The IoT system layers and individual components and protocol stacks associated with the layers are shown in Fig 1. The IoT system architecture involving sensing infrastructures, communication infrastructure, and backbone data processing and application servers is shown in Fig 2.

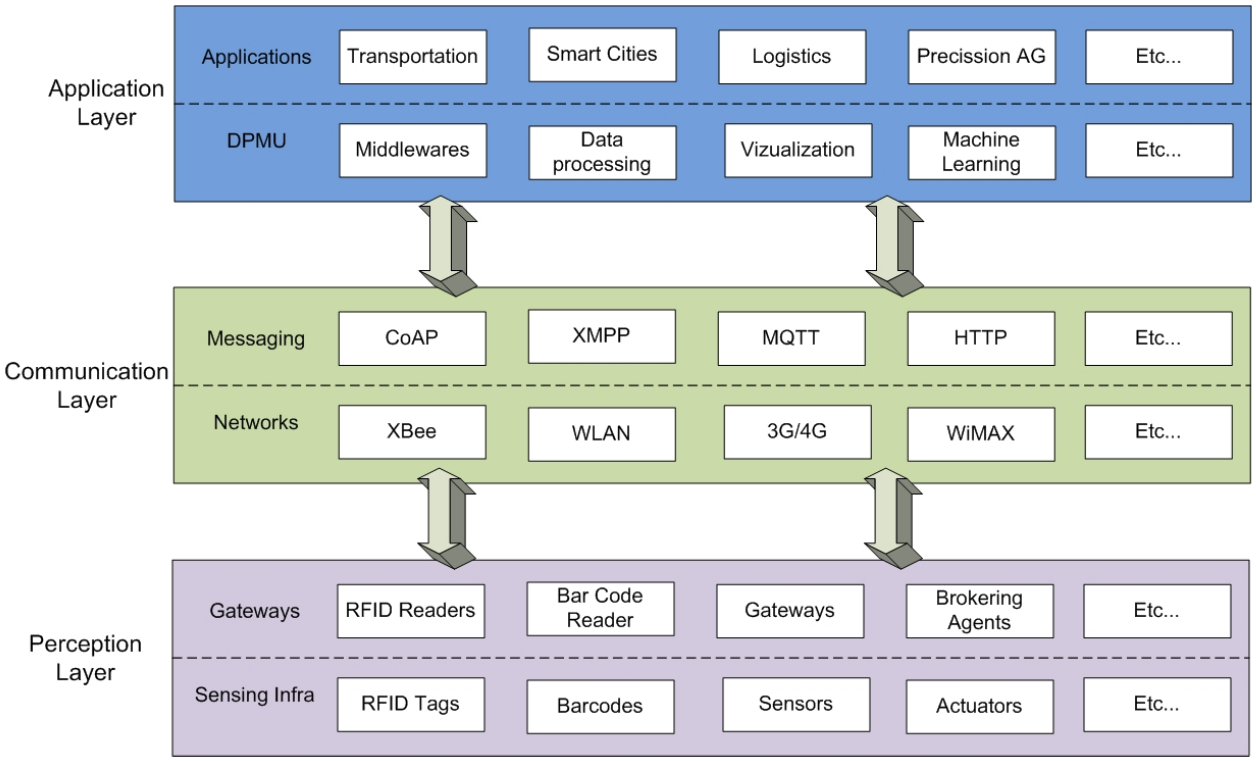

Fig 1. IoT system layers and components

Perception Layer
The perception layer is the foundational sensing layer. This layer utilizes physical sensing devices comprising of sensors, RFID tags, bar codes, and actuators coupled to applications to integrate systems to the communications and application components. The collected sensor data is sent to the back-end systems through gateways that include tag readers, and sensor gateways.

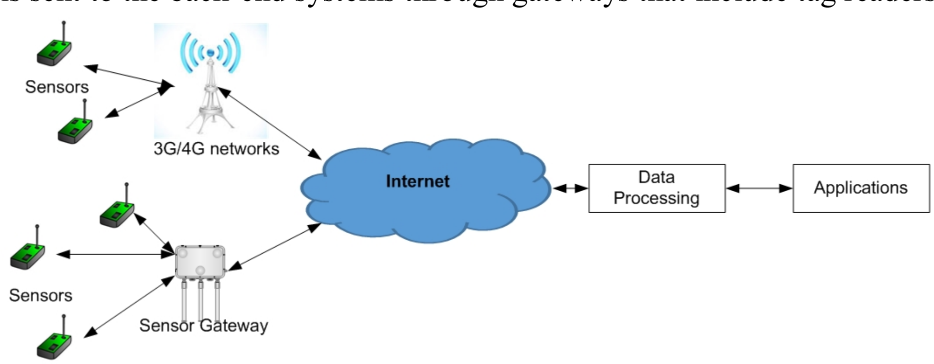

Fig 2. IoT system architecture

Communication Layer
Collected data from the perception layer is sent through ubiquitous networking infrastructures such as XBee, WLAN, Cellular Networks, and WiMAX to the backend systems. IoT uses traditional HTTP messaging protocols as well as custom IoT messaging protocols such as MQTT, CoAP and XMPP to transmit data to back-end data stores and application servers (Al-Fuqaha, Guizani, Mohammadi, Aledhari, & Ayyash, 2015). Custom IoT protocols are widely used for IoT messaging over traditional HTTP based messaging systems due to resource-constrained operational scenario(s).

Application Layer
Data is routed to the application layer and sent to the data processing and management units. These units initially validate data integrity, process the data, and then analyze it in the later steps. The data is represented in the application format, where the application uses these "sets" for the decision making through custom application algorithms. The outcome is represented to the end-users in a human-readable format or in a decision-based format for a M2M (machine to machine) scenarios. The results are stored for historical purposes and can be retrieved based on system and/or user requirements.

Workshop and Content
The intent is to conduct 1-week workshops with high school students. This project will impact two tiers of students, college students, and high school students. The college students will be trained on the content and delivery of the workshops that will be conducted with the high school students.

The objective of the workshops is to have the high school students develop three of the IoT layers described in the previous section. The workshops will be organized in four sections in which they will be learning the concepts, skills, and components used to develop IoT systems.

- Operating System (OS), Networking and Embedded Computing
- IoT Protocols
- Database Management
- Visualization Tools and Data Management

The workshops will be conducted for a duration of 4 hours over a span of 5 days. On the first two days, the students will be familiarized with the hardware, systems components, and protocols. The last three days they will be developing the APIs to integrate physical sensors with embedded platforms. Wireless networks will be used as the communication channel. Using MQTT as an IoT protocol, they will publish the real-time data in RabbitMQ queues. The students will use NoSQL to develop a database for storing and retrieving the data collected and transmitted by their sensor arrays.

OS, Networking and Embedded Computing

In this section, we will provide students with Raspberry Pi kits with microSD memory card. The students will be porting an embedded Linux on to the micro SD card and mount on the embedded platform using instructions provided during the workshop session. Once the Raspberry Pi's boot with to the Raspbian OS, students will be able to differentiate between ordinary Linux and embedded Linux, asked to execute commands to learn the capability of the Raspberry Pi. They will then learn how to use Python libraries to enable GPIO (general purpose input and output) pins on the Raspberry Pi. This will allow them to send and receive data through these ports to attached physical sensors.

The students will also configure wireless networks on Raspberry Pi to communicate with the backend infrastructure where the published data will be collected from the physical sensors.

IoT Protocols

The objective of the second session will be to enable MQTT libraries on the Raspberry Pi. The students will learn how to configure the system to collect data from the sensors and prepare an MQTT packet to send the data to the backend server.

NoSQL Database

Students will be provided with the MongoDB libraries and scripts for installing and configuring the server on their personal laptops during the third session. Once the system is enabled with the required software and students will learn about the query language used to collect the data coming out of the Raspberry Pi

Visualization Tools and Management

To this point, the students will not have been able to see the output of the system that they have developed. Students will learn how to use time series analysis to visualize the collected data during the final workshop session.

Hardware and Software

To conduct this workshop, specific hardware and software resources will be needed. Students will be provided with:

> Hardware: Raspberry Pi with Micro SD cards, AC to DC power adapter, Mini HDMI to HDMI cable, physical sensors to the students for developing IoT applications.
>
> Software: Raspbian OS, MongoDB, RabbitMQ, MQTT, Python.

For the equipment purchases, and conducting the workshop for 10 students an estimated $1000 is needed, the details are discussed below.

Product	**Unit Price**	**Qty**	**Total**
Raspberry Pi 3 Model B Motherboard	$35.70	10	$357
Power Supply	$7.99	10	$79.90
Samsung EVO 32GB Class 10 Micro SDHC Card with Adapter	$9.99	10	$99.90

Micro USB OTG to USB 2.0 Adapter; SD/Micro SD Card Reader with standard USB Male & Micro USB Male Connector	$7.99	1	$7.99
Sabrent 4-Port USB 2.0 Rotatable Hub [90°/180° Degree Rotatable]	$5.99	4	$23.96
SunFounder 37 Modules Sensor Kit V2.0 for Raspberry Pi 3, 2, Zero & RPi 1 Model B+, A+ 40Pin GPIO Extension Board Jump wires	$98.99	4	$395.96
		Total Cost	$964.71

Learning Outcomes

At the end of the workshop students will be able to:

1. Summarize the concepts involved in developing smart applications using IoT systems and components
2. Design an architecture for smart applications using the IoT 3-layer architecture
3. Develop an IoT enabled Raspberry Pi that will communicate with a physical sensor and collect data in real-time
4. Create software code and scripts to collect and send data from an IoT enabled device to the backend data infrastructure
5. Setup a backend infrastructure to collect data from the deployed physical devices in real-time
6. Develop visualization techniques to extract data from database and represent it with time series analysis
7. Compute the latency between collecting data from physical sensor and the data published in the database

Conclusion

With the provided training and availability of the hardware procured for the workshop, students will be able to develop projects with the assistance from the faculty and college student mentors. This workshop will enhance student employability with additional skills developed through creating smart applications using IoT.

The workshop encourages the use of open-source software, which is essential for computer students for developing their own solutions and contributing to the computing community. The workshop also enhances software tool application capabilities and develops advanced software coding techniques which are necessary for future software developers. Finally, through this workshop, key skills of software design and system architecture design will be developed.

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