COURSE OUTLINE

1. COURSE INFORMATION

Course Name: IoT Devices and Networks

Course Code: SMRTTECH 4ID3

Session Offered: Term 2, Winter semester

Calendar Description: This course teaches how the Internet of Things IoT works. Students learn about IoT networks and how things connect to networks, including whether the connection and processing is local (fog computing), is on the network edge (edge computing), or is remote (cloud computing). In addition, students learn IoT data networks, connection types, layer models and IoT network protocols and standards.

Format: Lecture (3 hours / week) + Laboratory (3 hours / week)

Instructor(s): Salman Bawa

Email: bawask@mcmaster.ca

Office Hours/Location: MS Teams | In-person with appointment

IA: Adam Sokacz
E-mail: sokacza@mcmaster.ca

TA: Harshil Rana
E-mail: ranah18@mcmaster.ca

Class Schedule	Day(s):	Mondays	Time:	11:30 am – 01:30 pm	Location: PGCLL M24
		Thursdays		09:30 am – 10:30 am	MDCL 1009
Lab Schedule	Day(s):	Wednesdays	Time:	05:30 pm – 08:30 pm	Location: ETB 537
		Thursdays		02:30 pm – 05:30 pm	ETB 537
		Fridays		03:30 pm – 06:30 pm	ETB 537

1a. COURSE OBJECTIVES

The course teaches engineering technology students to appreciate and learn:
- Internet of Things as applied in both industry and government, and across various applications, including but not limited to health care, city infrastructure, agriculture, manufacturing and standard of living,
- Contemporary challenges that impact our society, and attempt to address these challenges from the lens of Internet of Things via a course project,
- IoT Devices, including sensors, actuators, and smart objects, and their networks and communication protocols,
- IoT Network architecture and design, including comparing IoT architectures and hierarchy,
- Communications criteria for connecting IoT devices, including several access technologies, including M2M, LPWAN, WiFi, Bluetooth, ZigBee, Z-Wave, SigFox, LoRaWan, and NB-IoT,
- Internet Protocol (IP) as IOT Network Layer, including the need for optimization,
- Application Protocols for the IOT Transport Layer, including MQTT, CoAP, AMQP, DDS, HTTP, and WebSocket, and
- Connecting the dots via overview of devices, networks, and protocols.

1b. 2023 CLASS LOCATION

As above in the "Course Information" section.

MS Teams / Zoom may be used on certain occasions; students will be notified.

Students are responsible to continually check Avenue to Learn and associated MS Teams for notifications, announcements, assignments, feedback, grading, etc.

2. SCHEDULE

WEEK 1 **Week of Mon. 08 Jan.**	**Inspirational video and discussion on IoT applications focused on benefits to society: healthcare, smart cities, agriculture, manufacturing, standard of living** **IoT Challenges: introduction to course project, sources of challenges, examples of challenges** **Explanation of course outline** **What to expect: IQ (technical knowledge) vs EQ (community knowledge)** **LAB 01: Introduction to lab work and projects; community-engaged project idea generation; team formation and challenge identification**	**IoT Project Deliverable: Team formation; challenge identification**
WEEK 2 **Week of Mon. 15 Jan.**	**Inspirational applications-based case studies: healthcare, manufacturing, oil and gas, utilities, smart & connected cities, transportation, mining, public safety, agriculture, filming, etc.** **Guest speakers: IRIS R&D, City of Hamilton, Axibo** **LAB 02: Introduction to IoT [Sensors, WiFi, MQTT, Cloud, Node-Red]**	**IoT Project Deliverable: Team formation; challenge identification**
WEEK 3 **Week of Mon. 22 Jan.**	**IoT Devices: the "things" in IoT** - **Sensors, actuators, and smart objects** - **Sensor networks, including communication protocols for wireless sensor networks** **LAB 03: Understanding coding; Bluetooth**	**IoT Project Deliverable: Team formation; challenge identification**
WEEK 4 **Week of Mon. 29 Jan.**	**IoT Network Architecture and Design** - **OSI Model** - **Drivers: scale, security, constraints, data, legacy supports** - **IoT Architecture: OneM2M & IoT World Forum** **LAB 04: Project pitches and resources needed**	**IoT Project Deliverable: Submit Project Challenge DRAFT**

WEEK 5 **Week of Mon. 05 Feb.**	**IoT Network Architecture and Design** - **IoT Functional Stack: Layers** - **IoT Data Management & Compute Stack: Fog, Edge, and Cloud** **LAB 05: LoRa; Addressing concerns with Project Challenge**	**IoT Project Deliverable: Addressing concerns with Project Challenge**
WEEK 6 **Week of Mon. 12 Feb.**	**Considerations in connecting smart objects: range, frequency bands, power consumption, topology, constrained devices, constrained-node networks, data range and throughput, latency and determinism, overhead and payload** **LAB 06: LoRaWAN; Addressing concerns with Project Challenge**	**IoT Project Deliverable: Submit Project Challenge FINAL**
WEEK 7 **Week of Mon. 19 Feb.**	**Mid-term recess(es)**	
WEEK 8 **Week of Mon. 26 Feb.**	**MID TERM in class** **LAB 07: ZigBee; Projects**	
WEEK 9 **Week of Mon. 04 Mar.**	**IoT Access Technologies: 802.11ah (WiFi), LoRaWAN, NB-IoT, Bluetooth, ZigBee, Z-Wave, SigFox, M2M** **LAB 08: Projects**	**Assignment: Needs-based Project Scenarios**
WEEK 10 **Week of Mon. 11 Mar.**	**IoT Access Technologies: 802.15.4 (LR-WPAN), 802.15.4e (LR-WPAN for industrial applications), 802.15.4g (LR-WPAN for smart grid utility networks), 1901.2a (IPv6 support), LTE variations** **LAB 09: Projects**	**Assignment: Needs-based Project Scenarios DRAFT**
WEEK 11 **Week of Mon. 18 Mar.**	**IP as IoT Network Layer** - **Business case** - **Optimization** **Application protocols for IoT** - **Transport layer, and protocols: SCADA, MQTT, CoAP** **LAB 10: Projects**	
WEEK 12 **Week of Mon. 25 Mar.**	**Application protocols for IoT** - **Transport layer, and protocols: AMQP, DDS, HTTP, WebSocket** **LAB 11: Projects; Project Presentations Dry run**	**Assignment: Needs-based Project Scenarios FINAL**

Week 13 **Week of Mon. 01 Apr.**	**Connecting the dots: overview of devices, networks, and protocols** **LAB 12: PROJECT PRESENTATIONS**	
Week 14 **Week of Mon. 08 Apr.**	**FINAL EXAM in class** **LAB 13: PROJECT PRESENTATIONS**	

3. COURSE SPECIFIC POLICIES

Students are encouraged to connect with the TA(s), IA(s), and/or instructor(s) with their queries.

All assignments are available to the students at the beginning of the course. Students are responsible to submit their assignments by the due date and time.

Mark Deduction Scheme	
Assignment Submission Delay	**Percentage Deduction**
Before due date and time	No deduction
Post due date and time, but before close of Dropbox on Avenue to Learn	-2.5%
Within 24 hours of close of Avenue to Learn Dropbox (1 day)	-5%
Between 24 hours and 48 hours (2 days)	-10%
Between 48 hours and 72 hours (3 days)	-20%
Between 72 hours and 96 hours (4 days)	-30%
Between 96 hours and 120 hours (5 days)	-40%
Between 120 hours and 144 hours (6 days)	-50%

4. ASSESSMENT OF LEARNING	WEIGHT %
Assignment: Needs-based Project Scenarios	20
Weekly Labs	20
Project	20
Mid term exam	20
Final exam	20

5. LEARNING OUTCOMES

The course teaches engineering technology students to appreciate and learn about:

1. Internet of Things as applied in both industry and government, and across various applications, including but not limited to health care, city infrastructure, agriculture, manufacturing and standard of living,
2. Contemporary challenges that impact our society, and attempt to address these challenges from the lens of Internet of Things via a course project,
3. Inspirational IoT-based case studies, including via interaction with guest speakers,
4. IoT Devices, including sensors, actuators, and smart objects, and their networks and communication protocols,
5. IoT Network architecture and design, including comparing IoT architectures and hierarchy,
6. Communications criteria for connecting IoT devices, including several access technologies, including M2M, LPWAN, WiFi, Bluetooth, ZigBee, Z-Wave, SigFox, LoRaWan, and NB-IoT,
7. Internet Protocol (IP) as IOT Network Layer, including the need for optimization,
8. Application Protocols for the IOT Transport Layer, including MQTT, CoAP, AMQP, DDS, HTTP, and WebSocket,
9. Connecting the dots via overview of devices, networks, and protocols, and

10. Lab-based simple experiments for practice and interaction with IoT.

6. COMMUNICATIONS

It is the student's responsibility to:

- Maintain current contact information with the University, including address, phone numbers, and emergency contact information.
- Use the University provided e-mail address or maintain a valid forwarding e-mail address.
- Regularly check the official University communications channels. Official University communications are considered received if sent by postal mail, by fax, or by e-mail to the student's designated primary e-mail account via their "@mcmaster.ca" alias.
- Accept that forwarded e-mails may be lost and that e-mail is considered received if sent via the student's @mcmaster.ca alias.
- Check the McMaster/Avenue email and course websites on a regular basis during the term.

7. POLICIES – COURSE OUTLINE – APPROVED ADVISORY STATEMENTS

ACADEMIC INTEGRITY

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. **It is your responsibility to understand what constitutes academic dishonesty.**

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university. For information on the various types of academic dishonesty please refer to the *Academic Integrity Policy*, located at https://secretariat.mcmaster.ca/university-policies-procedures- guidelines/

The following illustrates only three forms of academic dishonesty:

- plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
- improper collaboration in group work.
- copying or using unauthorized aids in tests and examinations.

AUTHENTICITY / PLAGIARISM DETECTION

Some courses may use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. A2L, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.

Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software. **All submitted work is subject to normal verification that standards of academic integrity have been upheld** (e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

COURSES WITH AN ON-LINE ELEMENT

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn (A2L), LearnLink, web pages, capa, Moodle, ThinkingCap, etc.). Students should be aware that, when they access the electronic components of a course using these elements, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in a course that uses on-line elements will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure please discuss this with the course instructor.

ONLINE PROCTORING

Some courses may use online proctoring software for tests and exams. This software may require students to turn on their video camera, present identification, monitor and record their computer activities, and/or lock/restrict their browser or other applications/software during tests or exams. This software may be required to be installed before the test/exam begins.

CONDUCT EXPECTATIONS

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the *Code of Student Rights & Responsibilities* (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, **whether in person or online**.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students' access to these platforms.

ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's *Academic Accommodation of Students with Disabilities* policy.

PROTECTION OF PRIVACY ACT (FIPPA)

The Freedom of Information and Protection of Privacy Act (FIPPA) applies to universities. Instructors should take care to protect student names, student numbers, grades and all other personal information at all times. For example, the submission and return of assignments and the posting of grades must be done in a manner that ensures confidentiality - see http://www.mcmaster.ca/univsec/fippa/fippa.cfm

REQUESTS FOR RELIEF FOR MISSED ACADEMIC TERM WORK

McMaster Student Absence Form (MSAF): In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar "Requests for Relief for Missed Academic Term Work".

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students should submit their request to their Faculty Office ***normally within 10 working days*** of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, **including lectures** by University instructors

The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.

REQUESTS FOR RELIEF FOR MISSED ACADEMIC TERM WORK – MSAF (ASSIGNMENTS, MID-TERMS, ETC)

The McMaster Student Absence Form is a self reporting tool for **Undergraduate Students** to report absences that last up to 5 days and provides the ability to request accommodation for any missed academic work. Please note, this tool cannot be used during any final examination period.

You may submit a maximum of 1 Academic Work Missed requests per term. It is YOUR responsibility to follow up with your Instructor immediately regarding the nature of the accommodation.

If you are absent more than 5 days or exceed 1 request per term you MUST visit your Associate Dean's Office (Faculty Office). You may be required to provide supporting documentation.

This form should be filled out immediately when you are about to return to class after your absence. http://www.mcmaster.ca/msaf/

ANTI-DISCRIMINATION

The Faculty of Engineering is concerned with ensuring an environment that is free of all discrimination. If there is a problem, individuals are reminded that they should contact the Department Chair, the Sexual Harassment Officer or the Human Rights Consultant, as soon as possible.
https://www.mcmaster.ca/policy/General/HR/Discrimination_and_Harassment.pdf

EXTREME CIRCUMSTANCES

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8. MCMASTER GRADING SCALE

Grade	Equivalent Grade Point	Equivalent Percentages
A+	12	90-100
A	11	85-89
A-	10	80-84
B+	9	77-79
B	8	73-76
B-	7	70-72
C+	6	67-69
C	5	63-66
C-	4	60-62
D+	3	57-59
D	2	53-56
D-	1	50-52
F	0	0-49

SMRTTECH 4ID3 SCHEDULE OF LABS

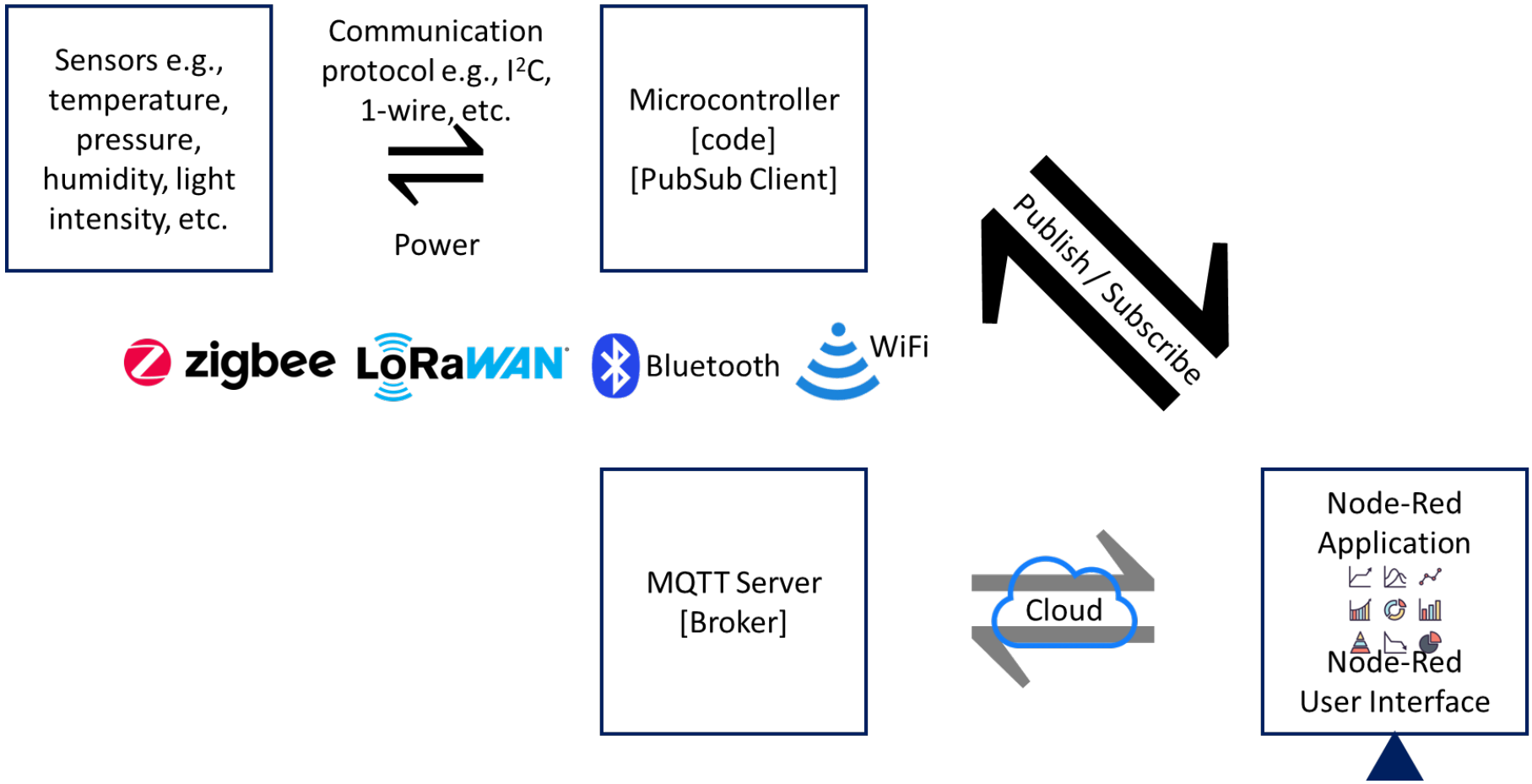

Figure: 01 A Typical Internet of Things Setup with Focus on varying Access Layer Technologies; communication enabled via MQTT Application Protocol

Lab #	Lab Title	Purpose/Objective	Learning Outcome
WEEK 1 Lab 01 Week of Mon. 08 Jan.	Introduction to Lab Work and Projects	An understanding of how labs and projects work and are related, along with initiating community-based research for project challenge identification, and forming project teams.	Students learn how to research for and draft a community-based project challenge using a theme-based approach to narrow down to a proof-of-concept project. Additionally, students form their project teams.
WEEK 2 Lab 02 Week of Mon. 15 Jan.	Introduction to IoT WiFi	A practice-based understanding on the "things" of the Internet of Things, and the "Internet" of the Internet of Things, including temperature, pressure, humidity, and light intensity sensors, connected to a microcontroller (with Publication-Subscription client), communicating over **802.11ah WiFi** to an MQTT server on cloud, corresponding with Node-Red application, showcasing outcome in a Node-Red user interface.	Students learn appreciation for Node-Red, Mosquitto, MQTT, various common sensors, ESP 8266 microcontroller, Arduino IDE, and its specific uses for a typical IoT Setup (**Figure 01**). Additionally, students learn to install programs on their computers and smart phones. Students learn about WiFi as an Access Technology, and appreciate the criteria for choosing WiFi for a given application.
WEEK 3 Lab 03 Week of Mon. 22 Jan.	Understanding coding Bluetooth	Thorough understanding of the code in Lab 01 including variations that may follow A practice-based understanding on the "things" of the Internet of Things, and the "Internet" of the Internet of Things, including temperature, pressure, humidity, and light intensity sensors, connected to a microcontroller (with Publication-Subscription client), communicating over **Bluetooth** to an MQTT server on cloud, corresponding with Node-Red application, showcasing outcome in a Node-Red user interface.	Students lean, line-by-line, explanation of a generic code, enabling them to edit code as needed for lab and/or project work. Students learn about Bluetooth as an Access Technology, and appreciate the criteria for choosing Bluetooth for a given application.
WEEK 4 Lab 04 Week of Mon. 29 Jan.	Project pitches and resources needed	Project pitches from each student team A collective identification of technical resources needed; bill of materials; budget	Students learn to pitch their project proposals, including identifying project requirements/needs for a demonstratable presentation.
WEEK 5 Lab 05 Week of Mon. 05 Feb.	LoRa Addressing concerns with Project Challenge	A practice-based understanding on the "things" of the Internet of Things, and the "Internet" of the Internet of Things, including temperature, pressure, humidity, and light intensity sensors, connected to a microcontroller (with Publication-Subscription client), communicating over **LoRa** to an MQTT server on cloud, corresponding with Node-Red application, showcasing outcome in a Node-Red user interface. Finalizing technical resources needed; bill of materials; budget	Students learn about LoRa as an Access Technology, and appreciate the criteria for choosing LoRa for a given application. Students learn to pitch their project proposals, including identifying project requirements/needs for a demonstratable presentation.

WEEK 6 Lab 06 Week of Mon. 12 Feb.	LoRaWAN Addressing concerns with Project Challenge	A practice-based understanding on the "things" of the Internet of Things, and the "Internet" of the Internet of Things, including temperature, pressure, humidity, and light intensity sensors, connected to a microcontroller (with Publication-Subscription client), communicating over **LoRaWAN** to an MQTT server on cloud, corresponding with Node-Red application, showcasing outcome in a Node-Red user interface. Finalizing technical resources needed; bill of materials; budget	Students learn about LoRaWAN as an Access Technology, and appreciate the criteria for choosing LoRaWAN for a given application. Students learn to pitch their project proposals, including identifying project requirements/needs for a demonstratable presentation.
WEEK 7 Week of Mon. 19 Feb.	Mid-term recess(es)		
WEEK 8 Lab 07 Week of Mon. 26 Feb.	ZigBee Projects	A practice-based understanding on the "things" of the Internet of Things, and the "Internet" of the Internet of Things, including temperature, pressure, humidity, and light intensity sensors, connected to a microcontroller (with Publication-Subscription client), communicating over **ZigBee** to an MQTT server on cloud, corresponding with Node-Red application, showcasing outcome in a Node-Red user interface. Begin project work in labs	Students learn about ZigBee as an Access Technology, and appreciate the criteria for choosing ZigBee for a given application. Students initiate project work in labs, learning real world problems of troubleshooting in IoT-based projects.
WEEK 9 Lab 08 Week of Mon. 04 Mar.	Projects	Continuing project work in labs Troubleshooting project work in labs Catering to individual project needs	Students continue project work in labs, learning real world problems of troubleshooting in IoT-based projects, including troubleshooting specifics based on chosen project.
WEEK 10 Lab 09 Week of Mon. 11 Mar.	Projects	Continuing project work in labs Troubleshooting project work in labs Catering to individual project needs	Students continue project work in labs, learning real world problems of troubleshooting in IoT-based projects, including troubleshooting specifics based on chosen project.
WEEK 11 Lab 10 Week of Mon. 18 Mar.	Projects	Continuing project work in labs Troubleshooting project work in labs Catering to individual project needs	Students continue project work in labs, learning real world problems of troubleshooting in IoT-based projects, including troubleshooting specifics based on chosen project.
WEEK 12 Lab 11 Week of Mon. 25 Mar.	Projects Project Presentations Dry run	Continuing project work in labs Troubleshooting project work in labs Catering to individual project needs Final Project Presentation Dry run	Students continue project work in labs, learning real world problems of troubleshooting in IoT-based projects, including troubleshooting specifics based on chosen project.

			Students learn to rehearse for final presentations, including showcasing accomplished work, and acknowledging need for continuing work.
Week 13 Lab 12 Week of Mon. 03 Apr.	Project Presentations	Final Project Presentations	Students learn to present high level objectives of the project, starting with community pain points, and proposed proof-of-concept; presenting work accomplished as part of proof-of-concept; demo of functional project; articulating future work needed.
Week 14 Lab 13 Week of Mon. 08 Apr.	Project Presentations	Final Project Presentations	Students learn to present high level objectives of the project, starting with community pain points, and proposed proof-of-concept; presenting work accomplished as part of proof-of-concept; demo of functional project; articulating future work needed.