QUESTION 1

Member Names: Lt Cdr Vijay Singh Sisodiya, Abhay Kumar Dwivedi
Member Emails: vijayss22@iitk.ac.in, abhaykd@iitk.ac.in
Member Roll Numbers: 22111089, 22111001
Date: September 4, 2022

---

1. **Introduction** : First of all, it is important for us to understand what are IoT development boards. In layman language, they are simply the printed circuit boards with hardware components in order to perform input, processing and output operations to assist in IoT experiments/ projects. Formally, summarising the IoT development board, it comprises of Power circuit, Programming interface, basic input/ output in forms of buttons and LEDs respectively and I/O pins.

2. One must choose a particular IoT Development Boards based on its features. Following features may be considered while filtering out which IoT Development suits end results: -
(a) Memory
(b) Processing Power
(c) Scalability
(d) Wireless Connectivity Superiority (in terms of built in wifi, bluetooth functionality, ethernet etc)
(e) OS Support
(f) Library support for different hardware
(g) Open source designs
(h) Remote connectivity

3. Classification of IoT Boards : IoT Development boards are grouped in three categories: -
(a) Microcontroller based boards: They generally comprises of a small computer developed on a metal oxide semiconductor circuit chip. These are mainly in use by programming enthusiasts for DIY projects/ learning purposes.

(b) Single-board Computers (SBC): It comprises of many components like audio receiver, memory, peripherals like USB, PCI and SATA, microprocessor etc into a single Si Chip. These are prominently aimed for applications in medical field in design of nano robots.

(c) System on Chip (SOC) boards: They comprises of all the features of a functional computer such as memory, microprocessor, I/O etc

4. **Study of different IoT Boards**:

Parameters	UDOO X86 ULTRA [4]	BeagleBone Black [1]	Particle Photon [2] [3]	Arduino 101 [7] [8]	Raspberry Pi4 [7] [8]	Teensy 4.0 [5] [6]
Hardware Details	CPU Intel Pentium N3710 2.56 GHZ, Intel HD Graphics 405 up to 700 MHz, Standard SATA connector, M.2 Key B SSD slot, Micro SD card slot, Gigabit Ethernet connector, M.2 Key E slot for optional Wireless modules, 3 x USB 3.0 type-A sockets	AM335x 1GHz ARM® Cortex-A8, 3D graphics accelerator, NEON floating-point accelerator, 2x PRU 32-bit microcontrollers	STM32F205 RGY6 120Mhz ARM Cortex M3, On-board RGB status LED	14 digital input output pins, 6 analog inputs, a USB connector for serial communication and sketch upload, a power jack, an ICSP header with SPI signals and I2C dedicated pins	Broadcom BCM2711, 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, 2 USB 3.0 ports, 2 USB 2.0 ports, 2 × micro-HDMI ports, 2-lane MIPI DSI display port, 2-lane MIPI CSI camera port, 4-pole stereo audio and composite video port, 5V DC via USB-C connector, 5V DC via GPIO header	ARM Cortex-M7 at 600 MHz, 2 I2S/TDM and 1 S/PDIF digital audio port, 3 CAN Bus (1 with CAN FD), 32 general purpose DMA channels
On Board Storage	32GB eMMC storage, 8 GB DDR3L Dual Channel	512MB DDR3 RAM, 4GB 8-bit eMMC on-board flash storage	1MB flash, 128KB RAM	Can use 196 kB out of 384 kB (flash memory) and 24 kB out of 80 kB (SRAM)	1GB, 2GB, 4GB or 8GB LPDDR4-3200 SDRAM (depending on model)	1984K Flash, 1024K RAM (512K tightly coupled), 1K EEPROM (emulated)
Power consumption	5 or 6 Watt	5V DC - MicroUSB, Barrel Jack	Typical average current consumption is 80mA with 5V	A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 1500 mA	A good quality 2.5A power supply can be used if downstream USB peripherals consume less than 500mA in total	When running at 600 MHz, Teensy 4.0 consumes approximately 100 mA current
Supported OS	Windows 10, 8.1, 7 Any Linux Distribution for X86 platform Android	Debian, Android, Ubuntu	Real-time operating system (FreeRTOS)	-	Raspberry pi os	ubuntu

Parameters	UDOO X86 ULTRA [4]	BeagleBone Black [1]	Particle Photon [2] [3]	Arduino 101 [7] [8]	Raspberry Pi4 [7] [8]	Teensy 4.0 [5] [6]
Communicati -on	IEEE 802.11, BT	IEEE 802.3, USB host, HDMI	Broadcom BCM43362 Wi-Fi chip, 802.11b/g/n Wi-Fi	Bluetooth LE	2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0, BLE	usb
I/O Connectivity and GPIO	Up to 23 digital I/O (7 PWM), 12 Analog input	2x 46 pin headers	18 Mixed-signal GPIO and advanced peripherals	14 (of which 4 provide PWM output)	Raspberry Pi standard 40 Pins, USB-2 USB 3.0 Ports, 2 USB 2.0 ports	40 digital input/output pins, 31 PWM output pins
Cost of board	$363	$72.92	$19.65	$39.95	$35.55	$22.80
Limitations	It is quite expensive for an SBC and has poor wireless connectivity	The BeagleBoard is not the best bet for complex multimedia and Linux-based projects	Photons need to be connected to wifi and the cloud to flash code	processing power is weaker	lack internal storage	a lot of its output pins seem to be in the form of tiny pads on the bottom

5. **Summary** : As we have studied different IoT development boards, most of the boards offer huge support communities and groups to support any project. It merits attention that with the advancement in IoT field, development boards in various sizes and specifications/ functionalities are now available in the market. It depends primarily on the project demand as to which Board is suitable to get the end product. In order to have better understanding of selection process of a IoT system, here are few comparison studies of some of the development board based on their advantages and disadvantages:

(a) Arduino Uno Rev :

Advantages:
(i) Low-cost IoT board with high standards.
(ii) A wide range of third-party libraries and sensors are available for Arduino Uno.
(iii) A huge community of users along with easily available resources.

Disadvantages :
(i) Processing and task performance speed are lower when compared with other competitors.
(ii)Arduino Uno has a big structure which requires large sized PCB, other competitors like ATmega works well for IoT development.

(b) UDOO X86 :

Advantages:

(i) It has a huge processing power.

(ii) fanless and energy efficient Disadvantages:

(i) It is quite expensive and has poor wireless connectivity.

(c) BeagleBone Black :

Advantages:

(i) The beaglebone black is very convenient and reliable in usage.

(ii) The board doesn't require additional cooling equipment and has low power consumption.

Disadvantages:

(i) It has a basic structure suitable for beginners in electronic programming.

(ii) Lacks audio and graphical capabilities.

(d) Raspberry Pi3 :

Advantages:

(i) Cost friendly and the board category is largely available in the market.

(ii) Consists of General-purpose Input-Output pins.

Disadvantages:

(i) Raspberry Pi 3 isn't as fast when it comes to CPU processing speed and has less memory than a Mac or a laptop.

(ii) Low fault tolerance, the board is prone to damage in case pins are inserted incorrectly.

(e) Particle Photon :

Advantages:

(i) It's easy to use

Disadvantages:

(i) Photons need to be connected to wifi .

(f) Teensy 4.0 :

Advantages:

(i) It's 10-15 times faster on benchmarks

Disadvantages:

(i) a lot of its output pins seem to be in the form of tiny pads on the bottom

Introduction to IoT and Its Industrial Applications (CS667A)
Indian Institute of Technology Kanpur
Assignment 1

QUESTION 2

Member Names: Lt Cdr Vijay Singh Sisodiya, Abhay Kumar Dwivedi
Member Emails: vijayss22@iitk.ac.in, abhaykd@iitk.ac.in
Member Roll Numbers: 22111089, 22111001
Date: September 4, 2022

Question 2(a) - Summary of the contributions of the paper

- The name of the protocol LoRaBLE itself says that it is the combination of the two exisiting protocols - BLE (Bluetooth Low Energy) and LoRa(Long Range).
- Both these protocol have their own advantages and disadvantages but combining them gave a new protocol which aims long range real time inter cluster communications with bounded delay.
- The first protocol which is BLE mainly focuses on intra-cluster communication via BLE master–slave intra-cluster communications within a cluster.
- BLE is able to provide bounded delay in intra-cluster communication through a star topology.
- BLE nodes does not communicate to each other directly, instead they send the message to BLE-LoRa Cluster Bridge (CB) and CB then forwards the data.
- The inter-cluster scheduler is responsible for inter-cluster communication, it is a stationary node which is placed at the centroid of the sensing area.
- In inter-cluster communication, two clusters communicate in a single hop as this paper assumes that for any CB, all the rest of CB's are within the range of it which is the core reason why the inter-cluster communication delay is bounded.
- Collision avoidance is assured using TDMA where the two lora end nodes sends message in dedicated slots of time in the superframe and starting of a superframe is indicated by a beacon which also consumes a time slot.
- Also new generation lora chips will be used in this protocol to make this protocol scalable.
- Overall the contribution of the paper is, that it has found out a way of getting bounded delays in long range communication (periodic as well as aperiodic) using LoRa protocol across the BLE nodes. Also this protocol is simple enough to be embedded into devices with constrained resources.

Question 2(b) - Enlist the benefits and drawbacks of the the proposed LoRaBLE protocol

Benefits of LoRaBLE protocol :

1. With LoRaBLE protocol, the benefits of both short and long range communication with bounded delays have been instituted utilising the BLE and LoRa protocols respectively, in order to meet time constraints of real- time industrial traffic flows.

2. The use of clusters to bind group neighbouring nodes which frequently communicates with each other has enabled communication without incurring network workload. This intra-cluster communication is also power saving as it is based on the BLE protocol. Further, Cellular network independency is the key benefit to reach distant far flung areas to monitor parameters from various IoT sensors.

3. It mentions about the time-constrained communications between a LoRa end node and another LoRa end node. Earlier approaches that have been proposed in the literature so far, mention are only able to provide bounded delays to time-constrained communications from a LoRa end node to the LoRa sink. Therefore, LoRaBLE fills a gap as far as real-time communications over LoRa networks are concerned.

4. BLE acts a backup for sensors who are unable to send data due to low coverage or some defect in it, which prevents loss of valuable data.

Drawbacks of LoRaBLE Protocol :

1. Model is based on the assumption that each CB is located within the coverage range of all other CBs. It is known that the use of a high spreading factor value increases the Time of Arrival, and therefore exists a trade-off between bit rate and communication range. This will further limit the deployment of LoRaBLE protocol based IoT network to be applicable for soft real time applications, with cycle times in the order of tens of seconds.

2. It is also mentioned that the protocol is based on the based that nearby nodes are organized in one cluster. However, if the no of nodes exceeds the maximum permissible limit, it would cause network congestion. No discussion with regards to structure, protocol, topology to cater for multiple clusters is defined in the paper.

3. Communication between cluster takes place over LoRa protocol via master of LoRaBLE cluster. In the event of failure of this master, there is no reliability for inter communication between clusters.

4. Also, on failure of inter-cluster node, the scheduler non-availability will lead to crashing of whole system.

Question 2(c) -

Lorable Topology :

- As we have studied, that the two protocols viz. LoRa and BLE both have their pros and cons. However, this protocol is designed to derive the best of features of both BLE and LoRa protocol in order to realise a network efficient, wide scale network with bounded time delay for soft real time network.
- The topology is based on a hybrid model which includes clusters of BLE nodes and a LoRa inter-cluster scheduler. The BLE-LoRa bridges called as Cluster Bridges(CBs) messages between clusters.
- A BLE node exchanges messages with its Cluster Bridges where the similar function nodes assigned in nearby locations forms a cluster and are linked with LoRa device which is Master for that particular cluster.
- These multiple clusters perform inter-cluster communication unidirectionally or bidirectionally using TDMA approach. This inter-cluster communication is governed by a inter cluster scheduler which periodically sends a beacon that synchronizes all the CB's and indicates the start of the super frame.

Methods to improve existing Protocol :

- By putting two LoRa nodes in a cluster as primary and secondary master node to add reliability factor. In this case, the data from BLE nodes will be replicated between both the LoRa nodes. In case of failure of primary, which can be detected by absence of beacon signal from it, secondary LoRa node will take over duties of master of cluster.
- Similarly, putting a secondary Inter-cluster node to perform task of scheduler is essential to backup the system incase of failure of primary inter-cluster node. This will enhance the reliability in the network and thus enable seamless network flow.

References

[1] https://beagleboard.org/black. In *Beagle Bone Black Documentation*.

[2] https://docs.particle.io/photon/. In *Particle Photon Documentation*.

[3] https://docs.particle.io/reference/datasheets/wi-fi/photon-datasheet/. In *Particle Photon Datasheet*.

[4] https://shop.udoo.org/en/udoo-x86-ii-ultra.html. In *Udoo Documentation*.

[5] https://www.pjrc.com/store/teensy40.html. In *Teensy 4.0 by PJRC*.

[6] https://www.sparkfun.com/products/15583. In *Teensy 4.0 by sparkfun*.

[7] https://www.verypossible.com/insights/top-10-iot-boards-for-development-prototyping-in-2022. In *Very Possible Article : top 10 iot boards for development prototyping in 2022*.

[8] https://www.youngwonks.com/blog/top-10-iot-boards-for-2019. In *Young Wonk Article : Top 10 IoT boards for 2019*.