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BONAFIDE CERTIFICATE

This to certify that this Internship titled "**IoT DEVELOPMENT USING KEIL MDK - ARM/ ARM MBED** is a bonafide work done by **SUDHARSAN.R (142221104136)** in the **DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING** in **SRM VALLIAMMAI ENGINEERING COLLEGE** affiliated to **ANNA UNIVERSITY.** Certified that the best of our knowledge, the work reported here does not occur in the form of any other thesis or dissertation of any other candidate.

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CONTENTS

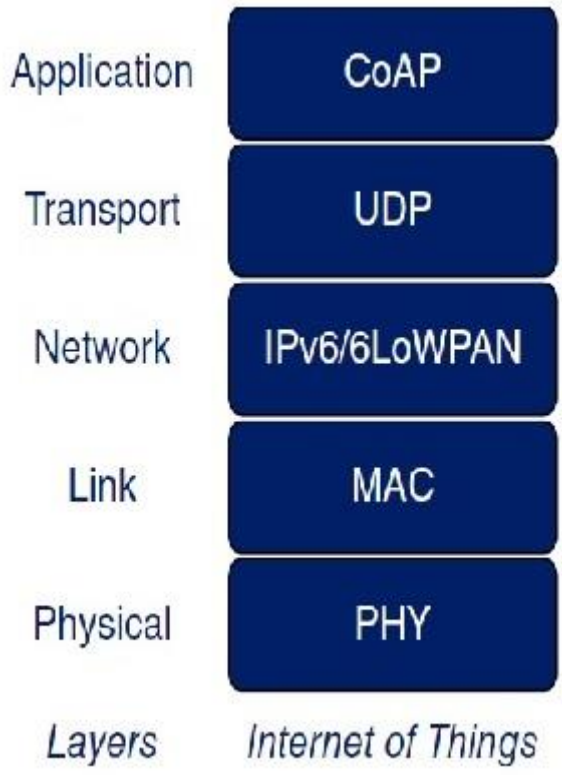
INTRODUCTION TO IoT

The Internet of Things (IoT) encapsulates a vision of a world in which billions of objects with embedded intelligence, communication means, and sensing and actuation capabilities will connect over IP (Internet Protocol) networks. Our current internet has undergone a fundamental transition, from hardware – driven (computers, fibers, ethernet cables) to market – seamingly disjoint intranets with strong horizontal software capabilities. The IoT calls for open environments and an integrated architecture of inter-operable platforms.

Smart objects and cyber – physical systems – or just "things" – are the new IoT entities: the objects of everyday life, augmented with micro-controller, optical and radio transceivers, sensors, actuators and protocol stacks suitable for communication in constrained environments where target hardware has limited resources, allowing them to gather data from the environment and act upon it, and giving them an interface to the physical world.

IoT PROTOCOL LAYERS

The IoT protocol layers consists of **Physical layer, Network layer, Application layer and Transport layer** as shown in the figure below:



IoT PROTOCOL STACK

IoT PHYSICAL LAYER COMMUNICATION TECHNOLOGIES

* **Short – range technologies (Bluetooth,ZigBee/802.15.4)**
* **Long – range technologies (LoRa, cellular)**

SHORT-RANGE TECHNOLOGIES

BLUETOOTH:

Bluetooth is a standard wire – replacement communications protocol primarily designed for low-power consumption and short communication ranges. The transmission range is power dependent. **Bluetooth low energy is previously known as Wibree.**

Starting from version 4.2 , IoT-oriented features have been introduced into Bluetooth

* Low energy secure connection with data packet length extension(v4.2);
* Link layer privacy (v4.2)
* IP support profile (v6.0)
* Readiness for Bluetooth smart things to support connected homes (v4.2);
* Connectionless services such as location-relevant navigation of low-energy bluetooth connections (v5.0)

ZIGBEE/802.15.4:

The physical layer of IEEE 802.15.4 foresees the use of one of **three possible unlicensed frequency bands** :

* **868.0-868.6 MHz** is used in Europe and allows 1 communication channel
* **902-928 MHz** is used in North America up to ten channels extended to 30
* **2400-2483.5 MHz** is used worldwide with up to 16 channels

Near Field Communication (NFC):

NFC is a special type of contactless technology in the IoT because it communicates over a very short range (0 – 5 cm) for security. It is present in most iOS and android mobile phones. Users simply approach a mobile to a tag to connect (no codes , or addresses)

LONG RANGE TECHNOLOGIES

LoRa (Long Range):

LoRa is a physical proprietary radio communication technique. It is based on spread spectrum modulation techniques derived from chirp spread spectrum technology. It was developed by Cycleo , a company of Grenoble, France, later acquired by Semtech. LoRaWAN defines the communication protocol and system architecture.

CELLULAR:

Cellular IoT is the technology that connects physical objects to the internet utilizing the same cellular network currently used by smartphones. In other words , this technology can connect IoT devices using existing mobile networks.

ADVANTAGES:

It has increased capacity. It consumes less power. It can be distributed to larger coverage area. It reduces interference from other signals.

IPv6/6LoWPAN – IoT NETWORK LAYER

IPv6:

IPv6 with 128 bits address-space has its ability to allocate addresses to all the IoT devices in the world for decades to come. IPv6 uses 128-bit (16-bytes) addresses in hexadecimal notation (i.e., each entry corresponds to 4 bits), for example 3FFE:F200:0234:AB00. The basic architecture is 64 bits for the network number and 64 bits for the host number.

The 6LoWPAN ADAPTATION LAYER:

Low – power Wireless Personal Area Networks (WPANs) have special characteristics, that set them apart from earlier link-layer technologies. These include limited packet size (a maximum 127 bytes for IEEE 802.15.4 specifications. The IETF 6LoWPAN working group developed such a standard in 2007. 6LoWPAN is the specification of mapping services required to maintain an IPv6 network over low – power WPANs. The standard provides header compression to reduce the transmission overhead, fragmentation to meet the IPv6 MTU requirement , and forwading to link – layer to support multi-hop delivery. In general , the goal of 6LoWPAN is to transmit a small IPv6 datagram over a single IEEE 802.15.4 hop.

UDP – IoT TRANSPORT LAYER

UDP:

Source UDP port (2 bytes) and destination UDP port (2 bytes) numbers are the communication endpoints for sending and receiving devices. The length field (2 bytes) in a UDP header

represents the total size of each datagram, including both header and data. This field ranges in value from a minimum of 8 bytes (the required header size) to sizes above 65,000 bytes. Similar to TCP, a UDP checksum (2 bytes) allows receivers to cross-check incoming data for any corrupted to cross-check incoming data for any corrupted bits.

CoAP/MQTT – IoT APPLICATION LAYER

CoAP:

LoWPANs are typically characterized by:

Small packet size , Low bandwidth , Low power , Low cost , Unreliability , Duty cycling

Small packet size :

Since the maximum physical layer packet for IEEE 802.15.4 is 127 bytes, the resulting maximum frame size at the MAC layer is 102 octets. Link – layer security imposes a further overhead, which, in the maximum case leaves only 81 octets for data packets.

Low bandwidth:

The limited bandwidth does not allow for data to be transferred at high rates. It is important to exchange as little data as possible to minimize latency of transmission.

Low power:

Some devices are battery operated , so energy consumption is a critical issue. Since radio-related operations are the most energy – consuming , it is desirable to minimize the amount of data to be transferred to keep radio utilization as low as possible.

Low cost:

Devices are typically associated with sensors, switches , and so on. Numerical values for "low" are not given on purpose: costs tend to change over time.

Unreliability:

Devices are subject to uncertain radio connectivity , battery drain , device lockups , and physical tampering.

Duty cycling:

Devices connected to a LoWPAN may sleep for long periods of time in order to save energy, and are thus unable to communicate during these sleep periods.

MQTT:

Message Queue Telemetry Transport is a lightweight, open-source, TCP-based pub protocol. MQTT is a standard of the organization for the advancement of structured information standards. The current version of MQTT is 3.1.1. A sensor-network oriented version of MQTT, called MQTT-SN, has been defined for use in low-power and lossy networks, such as IEEE 802.15.4 networks. MQTT-SN has been designed to allow implementation on low-cost, battery operated devices.

IoT PLATFORM – STM

* **KEIL MDK – ARM**

* **ARM MBED OS**

KEIL MDK – ARM :

Arm Keil MDK is a complete software development solution to create , build , and debug embedded applications for Arm – based microcontrollers. The knewVision IDE provides a best-in-class experience for Cortex-M based development.

FEATURES AND BENEFITS

* **Leading Device Support:**

With its rapidly increasing database of 9500+ Arm-based microcontroller devices supported out-of-the-box, Keil MDK get developers started in seconds regardless of the MCU of choice.

* More than just a toolchain:

Greater productivity and faster time to market are enabled by Keil MDK's software pack manager and its professionally developed, royalty-free middleware components. That's software reuse made simple.

* **Optimized code generation**

Arm compiler for embedded , included in Keil MDK, leads the way in performance , code density, architectural accuracy and safety for bare-metal and real-time OS applications on Arm.

More Features :

* Tailored for Embedded

* Faster Development

* Safety Qualification

* IoT Networking Support

* Power and Performance Analysis

ARM MBED OS :

It is an open source, easy-to-use operating system for the IoT. Mbed OS includes all the features you need to develop a connected product quickly based on an Arm Cortex-M microcontroller, including security , storage , connectivity, an RTOS, device management and drivers for sensors and I/O devices.

MBED OS FEATURES:

* Modular
* Secure
* Connected

TOOLCHAIN AND IDE SUPPORT:

* Mbed Studio
* Toolchains
* Compatibility

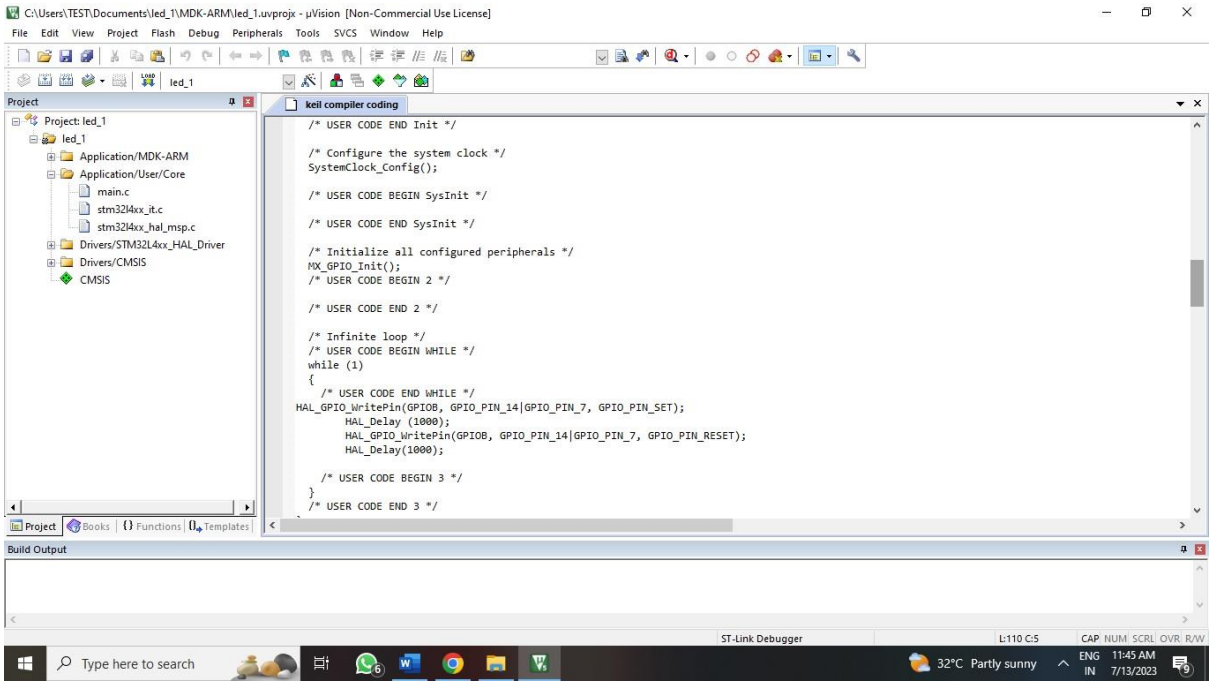
MBED OS CONNECTIVITY:

A broad range of connectivity options are available in Mbed OS , supported with software libraries, development hardware , tutorials and examples.

Bluetooth LE , Wi-Fi , Ethernet , Cellular , NFC , RFID , LoRa LPWAN , 6LoWPAN Sub-GHz Mesh.

IoT HANDS-ON EXERCISES

KEIL COMPILER:



The industry – standard Keil C Compilers support all 8051 derivatives and help you get your projects completed on schedule. The Keil 8051 Development Tools are designed to solve the complex problems facing embedded software developers

The C programming language is a general purpose programming language that provides code efficiency, elements of structured programming , and a rich set of operators.

STM32L4R5ZIT6 NUCLEO – 144 BOARD:

* ARM Cortex – M4 core at 120MHz
* 2 Mbytes of Flash memory, 640 Kbytes of SRAM

Two extension types:

* ST Zio connector including support for Arduino Uno V3
* ST morpho extension pin header footprints for full access to all STM32 I/Os
* USB OTG user connectivity
* Embedded ST-LINK/V2-1 debugger/programmer

CONCLUSION:

The internet of things encapsulates a vision of a world in which billions of objects with embedded intelligence , communication means , and sensing and actuation capabilities will connect over IP (internet protocol) networks. As the IoT and its applications are expected to progressively become an integral part of our day-to-day lives. In this report , we have looked at various IoT protocols , communication standards relevant for developing IoT applications. During the internship , I was introduced to learn on the concept of IoT and hands-on exercises using the STM32 Nucleo board.

REFERENCES:

[1] Internet of Things : Architectures , Protocols and Standards by Simone Cirani , Gianluigi Ferrari , Marco Picone , Luca Veltri was published by John Wiley & Sons on 12.11.2018 used for Technology and Engineering.