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Internet of Things for Embedded Systems

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ABSTRACT
This paper briefly summarizes about the IoT for embedded systems and selection of components. The main components needed to build a complete integrated network of Internet of Things have been discussed. The application like smart-manufacturing, smart-healthcare for elderly, intelligent transportation, smart city, safety monitoring of buildings and bridges have in discussed in this paper.

INTRODUCTION

The new paradigm in present industrial evolution is Internet of Things (IoT) in which without human intervention the computers are able to contact with the environment and objects. IoT extends the machine to machine communication or machine to person communication or machine to things communication by accessing data from things through sensors (JianguoMa, 2014). It is a worldwide network of interconnected objects and the new technologies like Wireless Sensor Networks, Cloud computing, Information sensing plays a key role for data collection of interconnected objects.

The Internet of Things is a technological revolution that represents the future of communications and computing and its development depends on dynamic technical innovation in a number of important fields from wireless sensor to nanotechnology. According to Cisco, around 25 billion devices are connected to IoT in 2015 and 50 billion devices by 2020 creating $14.4 trillion of value at stake for companies and industries. Companies that already have an IoT division include Intel, Oracle, Cisco, Samsung, Google, Hitachi, etc. (Shifeng Fang, 2014),

The "Internet of Things" covers a huge scope of industries and applications (Qingping Chi, 2014). Some of the technologies that are driving the topic, from popular communication options to the different software and data brokerage platforms managing the data exhaust from these systems are discussed.

II Iot For Embedded Systems:

Embedded systems are the backbone of IOT and play a crucial role. There are four main components needed to build a complete integrated network of Internet of Things (http://micrium.com/iot).

- The Thing itself (the device)
- The Local Network; this can include a gateway, which translates proprietary communication protocols to Internet Protocol
- The Internet
- Back-End Services; enterprise data systems, or PCs and mobile devices

Though IOT seems to be simple, Designing and building are complex task comparatively. Many hardware and software tools are being developed for IOT systems but the usage in reality applications are less.

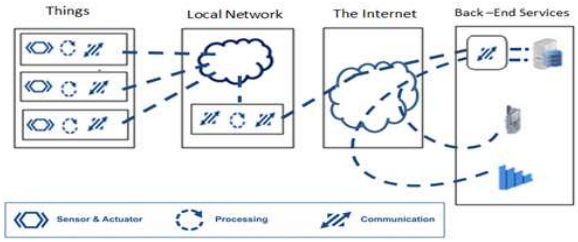

Fig. 1: Internet of things for embedded systems.

The applications of IoT can be broadly classified into two categories:

- Industrial IoT- the network is formed based on the technologies which include wireless sensor networks or different technologies. The IoT devices are connected to global internet through IP network.
- Commercial IoT- wired or wireless network like Bluetooth, Zigbee, Ethernet etc., and Communication will be only with local devices.

IoT Devices and Local Networks:

The communication is the main part to build the IoT devices as it decides the hardware devices and cost. An industrial IoT needs enormous sensors and actuators connected to each other over a wide area so; wireless sensor networks technology is used (Ajith Kumar, S., 2014). Small area is covered for commercial IoT so; short distance communications are used.

A. Wireless sensor networks:

WSN is collection of sensors distributed over a wide area that monitors physical or environmental conditions such as temperature, moisture, sound and other quantities. The data's collected by the sensors passes through the nodes to the network. WSN nodes are the basic elements of the WSN which are of low cost and operate in low power. Nodes run on battery or even use energy harvesting.

Table 1: Wireless Radio Technologies.

Wireless radio technologies			
Standard	IEE 802.15.4	Bluetooth	WiFi
Frequency	868/915 MHZ, 2.4 GHZ	2.4 GHz	2.4, 5.8 Ghz
Data rate	250 Kpbs	723 Kpbs	11 to 105 Mpbs
Range	10 to 300 m	10 m	10 to 100 m
Power	Very Low	Low	High
Battery Operation	Alkaline (months to years)	Rechargeable (days to weeks)	Rechargeable (hours)

WSN edge node is the node that has internet protocol connectivity and acts as a connecting node between the IP network and WSN. The gateway provides processing, storage and provides user interface. WSN networking technology uses various protocols. There are multiple candidates.

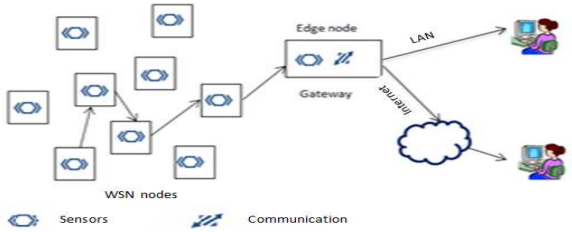

Fig. 2: wireless sensor network installed in a factory, connected to the internet via a gateway.

B. Wi-Fi:

The most used networking technology for IoT devices is Wi-Fi as it provides good solution for many applications. Almost everyone uses internet in the home which provides facility for Wi-Fi router. But Wi-Fi consumes considerably power.

C. IEEE 802.15.4:

One of the major IoT enablers is the IEEE 802.15.4 radio standard. It has a physical layer and MAC for wireless personal area network. Zigbee, WirelessHART has the basis from this standard. It is used with 6LoWPAN and standard protocols to form wireless embedded network

D. 6LoWPAN:

The devices should perform their task in possible shortest time for energy harvesting which means communication of message must be small. 6LoWPAN (IPv6 over Low power Wireless Personal Area Networks) protocol provides the facility. Hence it is adopted by ARM and Cisco and also for briefer transmission lines it provides encapsulation and header compression mechanism. There are many wireless networks available some are show with description in TABLE 1.

The protocol that has IP packets has advantage over all other protocols. Single technology cannot meet the connectivity of wide area IoT devices and also satisfy the requirements like size, cost, and energy. For WSNs and light IP-based protocols 6LoWPAN can be used. This wireless protocol is useful for local IoT networks and M2M. For a remotely controlled device or to transmit data over internet, IPv6 can be used.

E. IPv6:

IPv6 is a key for IoT as it provides the global communication. IoT network LANs, PANs uses all the internet protocols IP, UDP, TCP, HTTP, and SSL and so on. The current protocol IPv4 has some disadvantages like global addressing shortage, poor global mobility and also only limited support for multicast. IPv6 provides more address nearly 10^{30} addresses per person. So IPv6 is efficient for peer-to-peer communication whereas non-IP networks need a gateway to reach internet.

IPv6 is efficient for peer-to-peer communication whereas non-IP networks need a gateway to reach internet.6LowPAN has advantages over all other personal area network as it has IPv6 with compressed header and also PTP communication can be easily built among the device.

IV Embedded systems:

Embedded systems are the combination of hardware and software running in a device for an application. Embedded systems are based on microcontrollers (MCUs) with software like android systems. Most commonly used MCUs are 8 bit and 16 bit processors where software is written in foreground or background. With 32 bit processor, RTOS- real time operating systems are preferred as it is more flexible software. With RTOS, troubleshooting and adding new features are simple and it occupies less than 1MB space.

A. Processor for the things:

Wireless SoC are being built by many companies, self-contained RF modules providing UDP, TCP, and IP on chip. The Soc also embrace built in security features and allows adding communication facilities with RF expertise. The processors prototyping boards and platforms for IoT are available in market according to applications which vary with size, programming software and language.

The selection of IoT hardware should be maintained to be in low cost. But having low cost processor the entire requirement cannot be achieved, so IP networking should be added to the account. While considering IP, two main things needed taken care.

- Taking liberties TCP/IP standards, stacks fit within 32 KB of code space that causes problems. So processor should operate on vast majority of IP network.
- To work efficiently TCP requires network buffers which require RAM.
- Devices requires RTOS to run Java virtual machine

The low cost IoT processor should be selected on the above criteria based on application. The most preferred processors for IoT by embedded engineers are

- For an ARM processor in the IoT device, the Cortex-M0 is used and for gateways, the ARM Cortex-M3/M4 or Cortex-A are good choices because of their greater processing capabilities.
- For non-ARM processors, Renesas RL78 or RX100 for the IoT device, and the Renesas RX600 or RZ for the gateway.

The new processors with more flash memory and more RAM appear on the market regularly, and always at a lower cost.

B. Programming Language:

The embedded system uses C, C++ and java as their core programming language.

Java runs on the top of operating system. The requirements

- Support for 6LoWPAN, IPv6, RPL, TCP, and UDP
- Built for maximum energy-efficiency and low resource requirements: Min RAM (~ 1.5kB) and Min ROM (~ 5kB)

- Ability to operate on several platforms (Embedded devices and common PCs)
- Standard programming in C or C++ and can run both 16 and 32-bit platforms

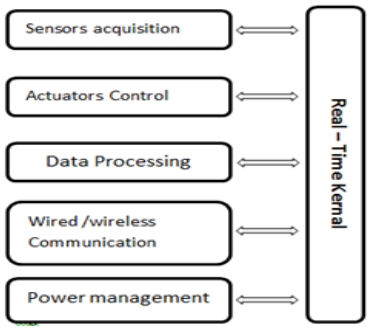

Fig. 3: IoT device software architecture.

A few Single processors can run the complete task but are quite costly. However embedded engineers use two processors, a low cost for physical world interface and another processor for network interface. The second processor is often places separately with communication protocols that run RTOS.

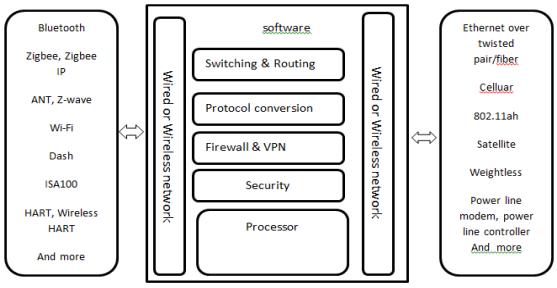

Fig. 4: Gateway architecture.

V Internet Usage and Protocols:

Internet usage is different between people and embedded devices. People uses internet through World Wide Web, social network. In IoT, information is exchanged through the Internet.

A. ***TCP/IP Protocol Stack:***

The TCP/IP stack is represented by OSI seven layers which is the heart of internet as illustrated in Fig 5.

TCP is most commonly used protocol for human interaction at the transport layer. It provides logical connection, acknowledgement and retransmission for packets and flow control. For embedded systems, UDP is used for sensor acquisition and remote control. UDP is better suited for real time data applications as the retransmission is not useful since the data has to be received on time. Delayed data is not required in IoT systems.

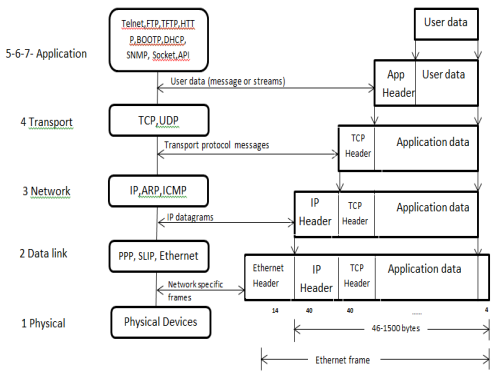

Fig. 5: TCP/IP stack reference model.

B. The IoT Protocols:

The common standard protocols used are HTTP and Web sockets which used to deliver XML or JavaScript Object Notation (JSON) in the payload.

1) HTTP:

HTTP is a client-server model used in internet. The most secure method to implement HTTP is to initiate connection and not to receive

2) WebSocket:

WebSocket is a protocol that provides full-duplex communication over a single TCP connection between client and server. The WebSocket standard simplifies much of the complexity around bi-directional Web communication and connection management.

3) XMPP:

The Extensible Messaging and Presence Protocol (XMPP) is an open technology for real-time communication, which powers a wide range of applications including instant messaging, presence, multi-party chat, voice and video calls, collaboration, lightweight middleware, content syndication, and generalized routing of XML data.

4) CoAP:

Constrained Application Protocol (CoAP) is a software protocol intended to be used in very simple electronics devices that allows them to communicate interactively over the Internet. It is particularly targeted for small low power sensors, switches, valves and similar components that need to be controlled or supervised remotely, through standard Internet networks.

CoAP is an application layer protocol that is intended for use in resource-constrained internet devices, such as WSN nodes. CoAP is designed to easily translate to HTTP for simplified integration with the web, while also meeting specialized requirements such as multicast support, very low overhead, and simplicity.

5) MQTT:

Message Queue Telemetry Transport (MQTT) is an open message protocol for M2M communications that enables the transfer of telemetry-style data in the form of messages from pervasive devices, along high latency or constrained networks, to a server or small message broker.

C. Comparing IoT Protocols and web:

The TABLE2 contains a summary of the IoT protocol landscape.

VI The Role of the Cloud in IoT:

Cloud computing is an array of networked computers that allows to offload processing or storage from embedded sytems. Apple's iCloud, Google Cloud Platform, Microsoft One Drive, and others have tried and simplified the complexities underlying in cloud computing. These clouds computing are intended to use with personal computers and embedded systems need the similar systems to manage the data. The data can be managed and processed by either developing own proprietary solutions or rely on third parties.

Table 2: Summary Of Iot Protocols.

Protocol	CoAP	XMPP	RESTful HTTP	MQTT
Transport	UDP	TCP	TCP	TCP
Messaging	Request/Response	Publish/Subscribe Request/Response	Request/Response	Publish/Subscribe Request/Response
2G, 3G, 4G Suitability (1000s nodes)	Excellent	Excellent	Excellent	Excellent
LLN Suitability (1000s nodes)	Excellent	Fair	Fair	Fair
Compute Resources	10Ks RAM/Flash	10Ks RAM/Flash	10Ks RAM/Flash	10Ks RAM/Flash
Success Stories	Utility Field Area Networks	Remote management of consumer white goods	Smart Energy Profile 2 (premise energy management, home services)	Extending enterprise messaging into IoT applications

The IoT devices will generate more data (approx.5,200 gigabytes of data for every human on the planet by 2020) than individual web applications. Cloud computing addresses these staggering requirements.

A. Data Analysis:

Big data is correlating the data with information which is stored either for big data as they can be flooded because they are not programmed. They can scrutinize structured and unstructured information such as database, medical imaging social media content respectively. To maintain database disturbed database system is needed. Cassandra is an open source distributed database system that is designed for storing and managing large amounts of data across commodity servers.

Applications:

IoT is integration of all devices into the network which can be managed with internet and provides real time information by allowing interaction with people.

A. Education:

Education has grown rapidly among these years which developed from e-learning, m-learning up to u-learning which is a leap to the pervasiveness of knowledge (Jorge, G´omeza, 2013). The authors have proposed a system that allows the students to interact with the set of physical objects in the surrounding and learn about the working principal, uses, etc. The objects are augmented with the visual tags Near Field Communication (NFC) and QRCODE which contains the unique data to identify the system. The mobile device has an interface that allows interaction with the objects. The experimental studies have performed between two groups; control group uses theory and experimental group uses proposed method. The experimental group performance has been better than the control group.

B. Health care:

Due to lack of availability of medical information about the patient, errors occur at the high rate in medication. The IoT based health care approach enables the RFID based identification, querying and retrieving medical data from health care information system (Cristina Elena Turcua, Cornel Octavian Turcua, 2013) The RFID tags present in the living and non-living things provides the information about the health care, medical equipment's, shortage of things needed for patients along with the medicine timings and information. This helps patients and also attender to get reminder about medicine. These research aims to integrate multi-agent and RFID technologies into an Internet of Things platform for healthcare.

C. Public safety:

The internet of things has the function of perception and reliable transmission of the system which helps in urban public safety emergency management. IoT has great significance for improving the technical content of the city emergency response platform and emergency response abilities (Du Chunquana, Zhu Shunbinga, 2012). Also it can improve the city's ability to withstand sudden public events.

The system consists of series of AVR and ARM coupled with wireless communication protocol. The sensing system uses various sensors to sense the data. The data collected are transmitted to the transport layer and the specified notification is sent to the public warning system. This uses wireless sensor network for immediate and fast transportation of data.

D. Image icing:

In very cold climatic conditions, icing phenomenon happens in electrical circuits. In high voltage transmission lines detecting icing parameters is harder that too in rural areas. Icing mechanism is complex and diversity of icing weather models there is no description and is deduced on long observations. Author (Isabel Laranjoa, 2012) has proposed a new method on detecting icing situation through image processing. The designed includes CCD image capture, sensor detection; Zigbee, DSP image processing and GPRS centralized transmission. The image captured is decoded by the wireless technology and DSP processor through Zigbee communication module. GPRS provides the exact location for the icing condition.

Conclusion:

The paper discusses about the techniques, hardware and software components, internet protocols and the applications of embedded systems IoT. The further development of IoT will be driven by the existing urgent demands, namely smart-manufacturing, smart-healthcare for elderly, intelligent transportation, smart city, safety monitoring of buildings and bridges as well as industrial factories. In future, IoT can be used in various area like agriculture, railways, banking etc.

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