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An Implementation of Cloud Services Using Internet of Things

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Abstract: *Internet of Things (IoT) was an emerging technology where things of everyday objects could be connected to Internet. We presented 60 IoT applications in different domains. Cloud computing is an important technology for IoT. We proposed six levels of IoT architectures with respect to cloud and these architectures describes about storage, controlling and monitoring of various sensors and actuators in IoT application. We have given various examples for each IoT application based on their functionalities and working nature. Better selection of protocols produce better results for constrained IoT environment. In this paper we analyzed IoT architecture levels with respect to cloud, various IoT applications and layer wise protocols which compatible for the constrained IoT environment.*

Key Word: *Internet of Things IoT, Cloud, MQTT, COAP.*

I. INTRODUCTION

THE Internet of Thing is a new revolution of the Internet. Statistics says that in coming few years the total number of things or devices connected to Internet will become 50 billion. These billions of devices or things are being connected to the Internet through the Gateways. In IoT technology, things from heterogeneous network can communicate and exchange data. These devices include hardware and software components, hubs or control centers. The IoT technology enables the physical object as an intelligent device which results the device or thing can visualize, hear, take decisions and perform actions. The underlying technologies of IoT are WSN, pervasive computing, embedded devices, cloud computing, big data, RFID tags, mobile technology, web, internet protocols, communication technologies and applications [1]. The Gartner and Ericson analysis shows that the deployment of interconnected sensor devices are up to 28 billion by 2020.[2][3]

In IoT the communication patterns mainly classified into two categories, first one is communication between machines excluding humans for instance smart home. And the second category communication between devices including humans for instance smart health system. In both categories based on the nature of the devices three communication possibilities may occur: machine-to-machine (M2M), machine-to-server (M2S) and server-to-server.(S2S)

IoT applications

There are different IoT applications which would be implemented in many areas. In this paper we described 60 IoT applications classified into 12 groups. The brief description about the each IoT application is as follows

Smart Health

- Smart fridge: Vaccines and medicines can be monitored with respect to temperature and alerts could be generated pertaining to the expiry date
- Patient surveillance: The health conditions of the patients and old peoples can be monitored inside and outside the hospital.
- Warning systems: Peoples can be warned about the harmful UV sun rays or other weather conditions.
- M-Health: Mobile health assistance and monitoring the health conditions of the sportsman.
- Assistance for disabled persons

1) Smart Cities

- Smart structures: Monitoring the strength of the material conditions in buildings, vibrations or conditions of brides and historical structures.
- Noise monitoring system: Monitoring the sound pollution in the city.
- Smart Traffic or Smart Roads: Monitoring the vehicle traffic system in the city.
- Intelligent parking system: Monitoring the parking places available in the city.
- Smart lighting: Intelligent and weather adaptive street light monitoring system.
- Garbage management system
- Smart security: Monitoring the security and privacy systems using sensors and surveillance cameras mounted all over the places in the city.

2) Smart Environment
- Forest fire detection system
- Monitoring the air pollution
- Snow Fall detection system
- Earth-quake Monitoring system
- Monitoring the land slides, soil moisture, earth density to prevent avalanche.
- Monitoring Air pollution: Controlling of CO_2, controlling the pollution emitted by cars and other vehicles.

3) Smart Metering
- Smart Grid: Monitoring the energy consumption and generation
- Smart Tank: Controlling the oil, gas, water in storage tanks.
- Photovoltaic installation: Monitoring and optimization of performance in solar energy plants.
- Water flow: Measuring the water flow in the water transporting system.
- Silos stock calculation: Measurement of emptiness level and weights of the goods.

4) Smart Retail
- NFC payment: Smart NFC (Near Field Communication) payment based on location or activity.
- Supply chain control: Smart monitoring of storage conditions along the supply chain and product tracking
- Intelligent product management: Controlling the rotation of products in shelves and warehouses to automate restocking processes.
- Smart shopping applications: Getting advices in the point of sale according to customer habits, preferences, presence of allergic components for them and information about expiring dates.

5) Smart Logistics
- Tracking Item location: Searching the individual items in the big locations like warehouses and harbors.
- Quality of shipment conditions: while shipping the goods in a container, monitoring should be done pertaining to vibrations, strokes, container openings, cold chain maintenance for insurance purpose.
- Detection of storage incompatibility: Alerts or warning emission on containers storing inflammable goods closed to other explosive materials.
- Smart fleet tracking: Monitoring and controlling of routes for delicate things like medical drugs, jewels, and merchandises.

6) Smart Security and Emergencies
- Tracking liquid presence: Detecting liquid in datacenters, warehouses, and sensitive building grounds to prevent breakdowns and corrosion.
- Monitoring Perimeter access control: Monitoring the access control to restricted areas and detecting the people in non authorized places.
- Monitoring Radiation levels: Distributed measurement of radiation levels of nuclear power stations surroundings to generate leakage alerts.
- Managing explosive and Hazardous Gases: Identification of gas levels and leakages in industrial environments, surrounding and chemical factories and inside mines.

7) Smart Irrigation
- Smart Green Houses: Monitoring the micro-climate conditions to maximize production of fruits and vegetables and its quality.
- Smart Golf courses: selective irrigation in dry zones to reduce the water resources required in the green.
- Smart Compost: Controlling of moisture, temperature, and humidity in hay, strew etc, to prevent fungus and other microbial contaminants.
- Smart Hydroponics: Controlling the exact conditions of plants grown in water to get the highest efficiency crops.
- Meteorological Station Networks: Study of weather conditions in the fields to forecast ice formation, snow, rain, draught or wind changes.
- Monitoring wine quality enhancing: Monitoring soil moisture and trunk diameter in vineyards to control the amount of sugar in grapes and grapevine health.

8) Smart Industry
- Smart Vehicle diagnosis: Collecting information from CanBus to send real time advices to drivers.
- Machine-to-Machine applications: Managing the machine auto control and assets diagnosis.
- Monitoring Temperature: Controlling the temperature inside the industrial and medical fridges.
- Controlling Ozone presence: Monitoring the Ozone levels during the drying process of meat in food factories.
- Monitoring Indoor locations: Asset Indoor location by zigbee, RFID tags.
- Indoor air quality: Monitoring of toxic gas and oxygen levels inside chemical plants to ensure goods and workers safety.

9) Home Automation

- Smart intrusion detection system: Monitoring or detecting of windows and door openings or violation to prevent intruders.
- Controlling home appliances remotely: Appliances would be operated remotely to save energy and avoid accidents.
- Monitoring energy and water use: Controlling the energy and water use to save cost.
- Preserving art and goods: Controlling the conditions in the museum to monitor the art and goods

10) Smart Animal Farming

- Animal tracking: Identification and location of animals grazing in open pastures
- Monitoring toxic gas levels: Controlling of ventilation and air quality in forms and identification of harmful gasses from excrements.
- Offspring care: Control of growing conditions of the offspring in animal forms to ensure its survival and health.

11) Smart Watering System

- Monitoring River Floods: Monitoring of water level variations in rivers, dams and reservoirs.
- Leakage detection of chemical or other harmful things in rivers.
- Monitoring the quality of portable tap water in cities.
- Controlling the swimming pool water remotely.
- Monitoring the pollution level in sea: Controlling the real time leakage of chemicals and water in the sea.
- Monitoring water leakages: Detection of liquid presence outside tanks and pressure variations along pipes.

This paper organizes as follow, section II describes related work. In Section III is about six IoT architecture levels with respect to cloud. Section IV implementing smart Gateway using Raspberry Pi. Section V is about implementing a smart irrigation using our Gateway Pi and Section VI is conclusion and future work.

II.RELATED WORK

This section describes related work addressing Internet of Things application layer protocols and their performances and also addresses the technologies related to various M2M communications and their limitations. In [4] the authors proposed a Machine-to-Machine communication through the wireless gateway. And this gateway is limited to REST quires in the application layer and provides dynamic device discovery, connection management of non smart devices. The authors [5] proposed a mechanism for M2M communication but the conversation is limited to only HTTP to CoAP. In [6] the authors proposed a gateway and Semantic Web enabled IoT architecture, here a multi-protocol proxy brings the interoperability of messaging protocols such as XMPP, CoAP, and MQTT. The proposed multi protocol proxy architecture is complex. The authors [7] proposed a service oriented things broker, this broker does provide REST-ful interface for the smart objects and limited to twitter based communication model.

Some authors implemented layered structure for IoT. In [8][9] authors proposed three layer architecture consisting of application, network and perception layer and not described about the feasible protocols for IoT applications. A new technology SDN (Software Defined Networking) have come into picture and takes an important role for various IoT communications[10][11] but the problem with SDN is, the whole network is controlled by software and it is venerable to get bugs and one more problem is, the dynamic reconfiguration of network could not be possible with software operated device . Researchers were also developed SNMP (Simple Network Management Protocol) protocol to address the QoS of internet but this protocol were too complex to use in the context of IoT with constrained devices. The authors in [12] proposed Session Initiation Protocol (SIP), an alternative protocol for Machine-to-Machine communication as part of feasible solution pertaining to reliable and security issues. The authors in [13] dedicated special focus on JSON (Java Script Object Notation) and Goggle’s Protocol Buffer Data Formats for M2M communication and they also performed analysis of message header structure in each protocol. The authors in [14][15] compared and tested performances of IoT application layer protocols and noted that MQTT gives lower latency for lower packet loss than CoAP and higher latency for higher packet loss. And WebSocket version outperforms HTTP. The performance of XMPP was also tested.

III.IOT AND CLOUD COMPUTING

By including cloud computing technology in IoT comprises six levels of IoT structures.

Level 1: IoT Structure without Cloud

Level 1 is excluding cloud computing technology and consisting of a local database, controller and a monitoring node capable of performing analysis and storing. The job of a controller is continuously monitoring the IoT nodes embedding with sensors and actuators. The level 1 structure is useful for low cost and low complexity IoT applications. For example home automation. In this IoT structure a single node does control the lights, fans and other home appliances remotely by enhancing relay switches. The status of the each appliance would be stored in local status data base. A controller service continuously monitors the state of each appliance in the home and triggers the relay switches accordingly. For user interaction this level would also be having local and remote user interfaces.

Level 2: IoT with Cloud Storage

In this level the IoT structure is connected with the cloud. But cloud would be only used for storing the data. By ensuring analysis is not computationally intensive and can be done locally. This is level is suitable for IoT applications where the data involved is big. Example for level 2 IoT structure is smart irrigation. This structure is also be having a single node which monitors the soil moisture level through the sensors and controls the irrigation. The controller service continuously monitors the soil moisture and also sends the sensed data into cloud. A cloud based REST web service is used for storing and retrieving moisture data which is stored in cloud database. And a cloud based application is used for visualizing the moisture levels over a period of time, this helps in making decisions about irrigation schedules. Figure 1 shows smart watering system for plant which is an example for level2.

Level 3: IoT with Cloud Storage and analysis

In this level the IoT application would be cloud based. It consists of a single monitoring node that performs analysis. This level is suitable for the IoT applications with more data and computationally intensive. Example smart logistics, here the package tracking system consists of a single node for package that monitors the vibration levels for a package being shipped. This system uses accelerometer and gyroscope sensors for monitoring vibration levels for a package. In this level the data must be real time so it is better to use web socket service instead REST for real time communications. The analysis components in the cloud can trigger alerts if vibration levels become greater than threshold.

Level 4: IoT with Cloud and multiple nodes

This level is similar to level 3, and differ in the structure with multiple nodes and each node is associated with its own controlling service. The observer node performs the web based communication REST or web socket between IoT nodes and cloud depends on application. Example is noise monitoring system with multiple nodes placed in various locations for monitoring voice levels These nodes have been equipped with noise sensors and independent to each other. Analysis of data collected from each node could be done in cloud. A cloud based application is used to visualizing the aggregated data.

Level 5: IoT with Cloud and coordinate nodes

This level is also having multiple nodes similar to level 4. A coordinate node would be used to collect the data from end node and send to cloud. Here the coordinate node will act as a gateway. Example for level 5 is forest fire detection system. Here end node would be placed in various locations gathers the sensed information pertaining temperature, humidity and carbon dioxide levels in a forest. The coordinate node collects this information and sends to the cloud. Analysis could be done in the cloud to aggregate the data and precautionary measures could be made based on the predictions

Level 6: IoT with Cloud and centralized controller

This level is suitable for complex IoT applications. There will be centralized controller which is aware of status of end nodes and sends the control commands. Example is weather monitoring system. The Centralized controller would perform all necessary actions to reduce the processing at end nodes.

Following table 1 describes the summary of all IoT architecture levels including storage and analysis or Controlling information between IoT and cloud .

Table 1: Summary of IoT Architecture levels with cloud

IoT Architecture level	Cloud Computing	Storage	Analysis &Monitoring	Example of IoT Application
Level 1	Excluding	Local	Local Controller	Home Automation
Level 2	Including	Cloud	Local Node	Smart Irrigation
Level 3	Including	Cloud	Cloud (Single Node)	Smart Logistics
Level 4	Including	Cloud	Cloud (Multiple Nodes)	Noise Monitoring System
Level 5	Including	Cloud	Cloud (Multiple Nodes & Coordinate Node)	Smart Fire detection System
Level 6	Including	Cloud	Cloud & Centralized Controller	Weather Monitoring System

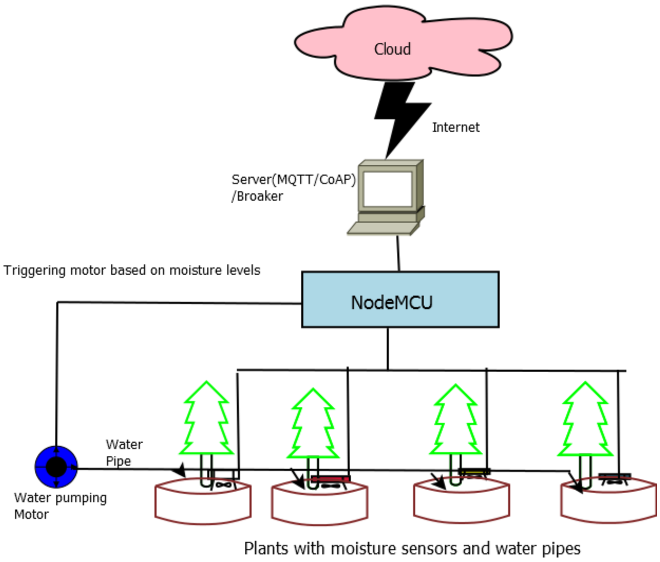

Figure 1: Smart watering system IoT Cloud Level 2 architecture

IV. OPTIMIZING PROTOCOL SUITES

IoT Protocols

Most of the efficiency of an application comes with better utilization of protocols. But the fact is there are no universal standard protocols for all use cases for an IoT structure. Here we are proposing optimizing protocols suits based on the IoT application requirements. The suites have been named based on the application layer protocol selections. Those are MQTT Protocol Suite and CoAP Protocol Suite. In following section we explained briefly about each IoT protocol and their functionalities in IoT applications.

1. Link Layer

In IoT technology billions of things would be interconnected, the following protocols are being used for connecting things in link layer

- IEEE 802.3 Ethernet: This protocol supports things with wired network.
- IEEE 802.11 Wifi : This protocol specifies the wireless local area network
- IEEE 802.16 WiMax: It supports wireless MAN
- IEEE 802.15.4 LRWPAN: This protocol defines operation on Low Rate Wireless Personal Area Network.
- 3G/LTE : This protocol supports fastest mobile internet communication with

2. Network Layer

For packet forwarding and routing in Internet of Things the following network layer protocols are being used.

- IPv4: It supports standard based internet working .
- IPv6: This protocol address the challenge of giving a unique identification number for billions of things in IoT.
- 6LoWPAN: This protocol provides IPv6 internet for low power devices with limited processing capabilities.

3. Transport Layer

For providing end to end transmission in IoT, the transport layer is having following IoT protocols

- TCP : It is a reliable protocol with SSL or TLS security.
- UDP: This transport layer protocol could be used for simple IoT communications. For security it supports DTLS.

4. Application Layer

It is an important layer for H2M communication (Human to machine). The protocols related to application layer deals about the data representation compatible to respective IoT applications. For my proposal protocol suits have been designed based on the properties of these application protocols.

- HTTP: Hyper Text Transfer Protocol
- CoAP: Constrained Application Protocol
- MQTT: Message Queue Telemetry Transport
- XMPP: Extensible Messaging and Presence Protocol
- DDS : Data Distribution Service protocol

The following table 2 specifies the summary of layer wise IoT protocols.

Table 2: Layer/Level wise IoT protocols

Layer/Level Name	IoT protocols
Application Layer (Data Protocols)	HTTP, CoAP, MQTT, XMPP, Web Socket, DDS
Transport Layer	TCP,UDP,DTLS,TLS,SSL
Network Layer (Infrastructure)	IPv4,IPv6,6LoWPAN, RPL
Link Layer (Communication)	IEEE 802.3, 802.11, 802.16.4, 802.15.4, LTE
Discovery Protocols	Physical Web, mDNS, DNS-SD

V.CONCLUSION AND FUTURE WORK

Selecting better protocols for IoT application is an important aspect to improve the efficiency. Basically IoT proto cols have not been standardized. Here we presented various IoT protocols which are suitable for constrained environment. We also presented six levels of IoT and cloud based on the storage analysis and controlling. We also described 60 IoT applications which have been classified into 12 groups. The respective tables summaries the above information.

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