Fuzzy Logic in Internet of Things (IoT): A New Paradigm

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***Abstract*— The internet of things (IoT) is the network of physical objects, devices, vehicles, buildings and other items embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data. The IoT make able objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit. This paper describes the concept of IoT, its applications, the concept of fuzzy logic and its applications in different fields and working mechanism and its different components.**

***Keywords*: Internet of Things, Fuzzy Logic, Fuzzy Inference System, Defuzzification, Fuzzification.**

I. Introduction

The internet of things (IoT) is the network of physical objects, devices, vehicles, buildings and other items embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data. The IoT make able object to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit. In a 2005 report the International Telecommunications Union (ITU) suggested that the "Internet of Things will connect the world's objects in both a sensory and intelligent manner" [1]. By combining various technological developments, the ITU has described four dimensions in IoT: item identification ("tagging things"), sensors and wireless sensor networks ("feeling things"), embedded systems ("thinking things") and nano-technology ("shrinking things") [2]. Nowadays the Business Process Modelling (BMP) has been at the focal point of close cooperation of amongst business and IT. The term 'Business Process Modelling' was authored in the 1960s in the field of frameworks building by S. Williams in his 1967 article 'Business Process Modelling Improves Administrative Control' [3]. His thought was that strategies for acquiring a superior comprehension of physical control frameworks could be utilized as a part of a comparable path for business forms. The term got to be distinctly prevalent in 1990 and from that point forward it has been used in practically every business including the late programming building industry. It has turned into an indispensable piece of fruitful business operations. This prominence of the BPM arrangements is generally because of the institutionalization of graphing dialect known as the Business Process Modelling Notations (BPMN) [4]. The underlying point of BPMN was to empower the business investigator to portray a business' fancied procedure through a graph and to suit the business dexterity through computerized execution of the procedure show. Service Oriented Architecture (SOA) [5] has since been at the bleeding edges of BPM arrangement executions with the guarantee of administration reuse.

The Internet of Things (IoT) is very large ecosystems comprised of billions of devices [6] which presents as atomic services themselves on the internet. The services must be available for masses in order to make their local solutions as well as to share them. This concept is known as Do-It-Yourself (DIY) paradigm and the basic purpose of it to reduce the dependency of common people on branded products. DIY is a method that without any assists of professionals or experts repairing, creating and modifying something [7].

Human nature has a strong tendency to do or try to do things itself. There are various drivers which push human towards the Do-It-Yourself (DIY) approach. The major drivers for DIY paradigm are creativity, simplification, extension, economic reasons, and the need to control things. In addition to the DIY driver, motivations, and the need for mass end-users' involvement for the realization of IoT, the current Makers Revolution is inculcating a new version of the DIY culture. In this age the mass production has become a practice, and DIY is used to differentiate your product. From the viewpoint of a global internet of things DIY IoT is presented in such a way that the end-user is able to create applications for smart environments. The DIY inspires non-technical people to create on their own. It doesn't require much training. DIY system attracts the user by providing such environment where the user can utilize and experiment with their own created components.

II. Architecture of Internet of Things

There is no single consensus on architecture for IoT, which is agreed universally. Different architectures have been proposed by different researchers. Some of the main architectures are as follows:

a) Three- and Five-Layer Architectures. The most basic architecture is three-layer architecture [8-10] as shown in

Figure 1. It was introduced in the early stages of research in this area. It has three layers, namely, the perception, network, and application layers.

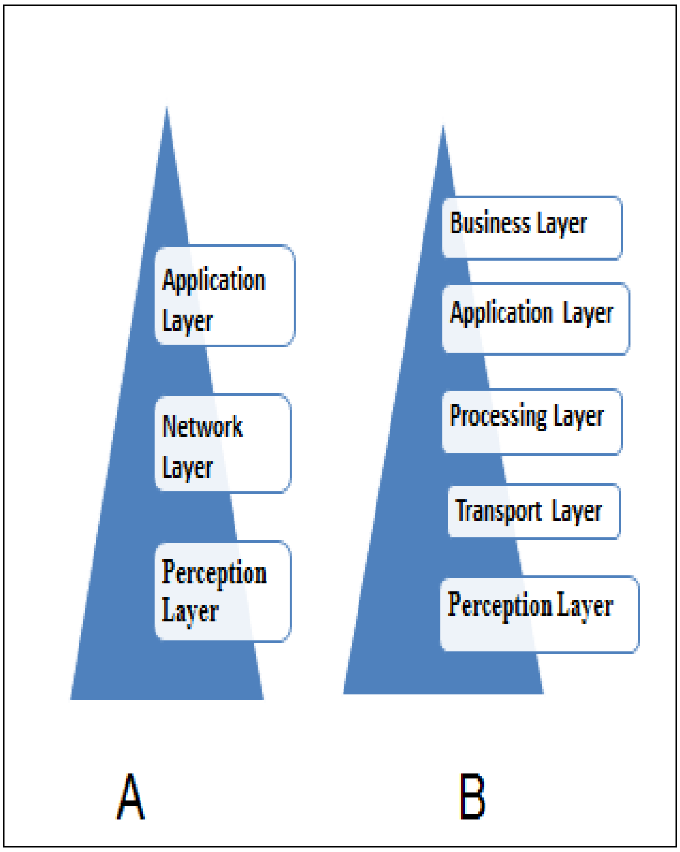

Figure 1: Architecture of IoT (A: three layers) (B: five layers)

(i) The perception layer is the physical layer, which has sensors for sensing and gathering information about the environment. It senses some physical parameters or identifies other smart objects in the environment.

(ii) The network layer is responsible for connecting to other smart things, network devices, and servers. Its features are also used for transmitting and processing sensor data.

(iii) The application layer is responsible for delivering application specific services to the user. It defines various applications in which the Internet of Things can be deployed, for example, smart homes, smart cities, and smart health.

The three-layer architecture defines the main idea of the Internet of Things, but it is not sufficient for research on IoT because research often focuses on finer aspects of the Internet of Things.

One is the five layer architecture, which additionally includes the processing and business layers [8-11]. The five layers are perception, transport, processing, application, and business layers (Figure 1). The role of the perception and application layers is the same as the architecture with three layers. (i) The transport layer transfers the sensor data from the perception layer to the processing layer and vice versa through networks such as wireless, 3G, LAN, Bluetooth, RFID, and NFC.

(ii) The processing layer is also known as the middleware layer. It stores, analyzes, and processes huge amounts of data that comes from the transport layer. It can manage and provide a diverse set of services to the lower layers. It employs many technologies such as databases, cloud computing, and big data processing modules

(iii) The business layer manages the whole IoT system, including applications, business and profit models, and users' privacy.

b) Another architecture proposed by Ning and Wang [12] is inspired by the layers of processing in the human brain. It is inspired by the intelligence and ability of human beings to think, feel, remember, make decisions, and react to the physical environment. It is constituted of three parts. First is the human brain, which is analogous to the processing and data management unit or the data center. Second is the spinal cord, which is analogous to the distributed network of data processing nodes and smart gateways. Third is the network of nerves, which corresponds to the networking components and sensors.

c) Cloud and Fog Based Architectures. Let us now discuss two kinds of systems architectures: cloud and fog computing [13]. In some system architectures the data processing is done in a large centralized fashion by cloud computers. Such a cloud centric architecture keeps the cloud at the center, applications above it, and the network of smart things below it [14]. Cloud computing is given primacy because it provides great flexibility and scalability. It offers services such as the core infrastructure, platform, software, and storage. Developers can provide their storage tools, software tools, data mining, and machine learning tools, and visualization tools through the cloud. Lately, there is a move towards system architecture, namely, fog computing [15-17], where the sensors and network gateways do a part of the data processing and analytics. Fog architecture [18] presents a layered approach as shown in Figure 2, which inserts monitoring, pre-processing, storage, and security layers between the physical and transport layers. The monitoring layer monitors power, resources, responses, and services. The pre-processing layer performs filtering, processing, and analytics of sensor data.

The temporary storage layer provides storage functionalities such as data replication, distribution, and storage. Finally, the security layer performs encryption/decryption and ensures data integrity and privacy. Monitoring and pre-processing are done on the edge of the network before sending data to the cloud.

Often the terms "fog computing" and "edge computing" are used interchangeably. The latter term predates the former and is construed to be more generic. Fog computing originally termed by Cisco refers to smart gateways and smart sensors, whereas edge computing is slightly more penetrative in nature. This paradigm envisions adding smart data pre-processing capabilities to physical devices such as motors, pumps, or lights. The aim is to do as much of pre-processing of data as possible in these devices, which are termed to be at the edge of the network. Finally, the distinction between protocol architectures and system architectures is not very crisp. Often the protocols and the system are code signed..

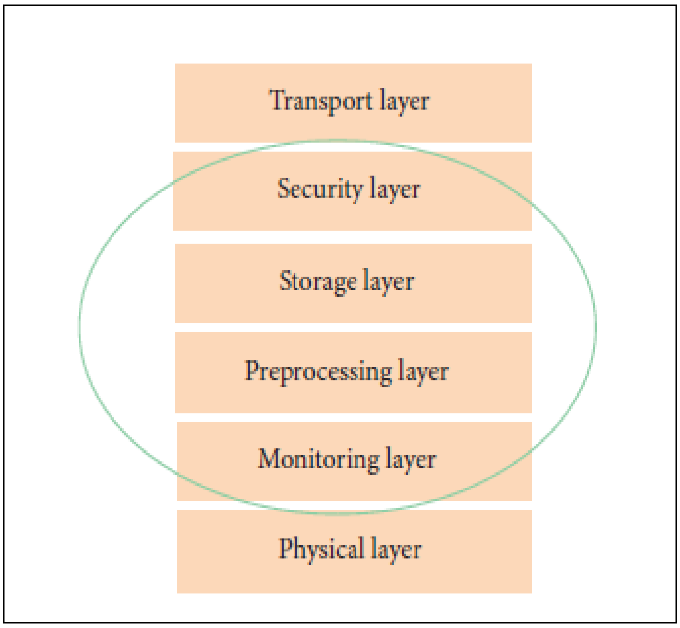

Figure 2: Fog architecture of a smart IoT gateway.

III. FUZZY LOGIC APPROACH

Fuzzy logic in the last decades has widely been used due to its successful application to control and predict the behavior of dynamic system . The fuzzy logic is well applied to define the relationship between input and output variables of a system by using a set of logics or rules. The structure of a fuzzy inference system is illustrated in figure 3.

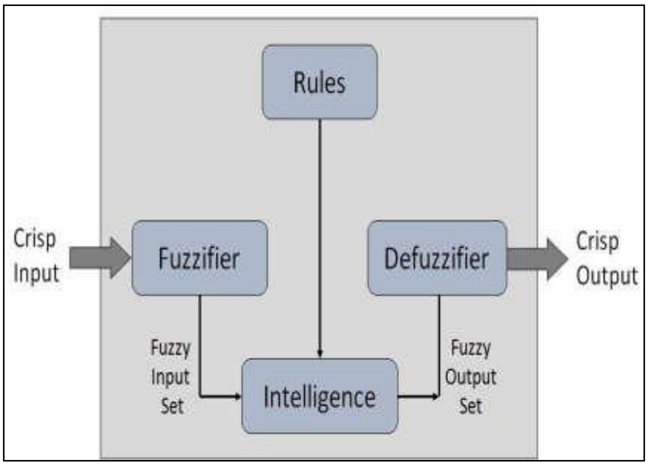

Fig.3 Structure of fuzzy inference system

In general the fuzzy inference system consists of four modules; the first one is the fuzzification module that transforms the system inputs which are crisp numbers, into fuzzy sets. The second module is called knowledge base; it stores the IF-THEN rules, the rules normally specified by experts. The third module is called the inference engine, it simulates human reasoning process by making fuzzy inference on the input inputs IF-THEN rules. The fourth and last one is called defuzzification module that by inference engine transforms the fuzzy set into a crisp value. The membership functions are used for quantification of linguistic term. The membership function signifies a fuzzy set graphically.

In order to construct fuzzy logic for a problem, the following steps should be taken into account.

- Defining linguistic variables
- Construction of membership function
- Construction of knowledge base for rules
- Deployment of fuzzification to convert crip
- values into fuzzy values
- Rule evaluation in rule base
- Integration of result from each rule
- conversion of fuzzy value into crip value in last
- Defuzzification stage

Fuzzy logic can be used in a lot of fields, such as in automotive systems, consumer electronics goods, domestic goods and environmental control. There are numerous advantages of fuzzy logic,i.e. simple mythical concept within fuzzy reasoning, fuzzy logic is very flexible and we can modify by just adding or deleting rules, this is the ability of the fuzzy logic that it can take imprecise, distorted, noisy input information.

IV. FUZZY LOGIC APPLICATION IN INTERNET OF THINGS

Many applications of IoT based on fuzzy logic are proposed by many researchers. In [19] the authors proposed that the ubiquitous Internet of Things (IoT) through RFIDs, GPS, NFC and other wireless devices is capable of sensing the activities being carried around Industrial environment so as to automate industrial processes. In almost every industry, employee performance appraisal is done manually which may lead to favouritisms. They propose a framework to perform automatic employee performance appraisal based on data sensed from IoT. The decision regarding rewarding the best employee is based on the IoT data such as employee's location, accomplishment, Team work etc., processing this data to calculate overall participation Index of employee in association to positive, negative and neutral activity. The index, profit and loss so obtained can be used for making decision using fuzzy logic. Fuzzy logic defines membership values to take accurate decision. The proposed system is capable of eliminating favouritisms, discriminatory, dissatisfaction among employees which in turn is capable of earning profit for industry.

In [20] the authors proposed an algorithm that controls the temperature humidity, and other factors remotely using sensors and Internet-of-Things technologies. Authors illustrated that the optimal levels of temperature, humidity, and air cleanliness in an apartment or house can be easily achieved by integrating all techniques aimed at solving all problems, i.e., a "smart home" system. The method of construction of a mode of regulation of temperature with low consumption of energy in conditions of uncertainty in a finding of an optimum mode of rating values of parameters of thermal systems and maintenance of an economy effort of energy is developed. The structure of an energy-saving automatic control system was developed for thermal buildings under uncertain conditions. Coordinated operation of the various sensors that monitor the weather indoors, as well as the switches, control panels, and other devices can be applied automatically without human presence to ensure maximum comfort for all family members. The costs of the design and installation of the equipment will pay off within a short period of time by saving necessary resources.

In [21] the authors proposed a new approach to control the temperature using the Internet of Things together its platforms and fuzzy logic regarding not only the indoor temperature but also the outdoor temperature and humidity in order to save energy and to set a more comfortable environment for their users. Finally, we will conclude that the fuzzy approach allows us to achieve an energy saving around 40% and thus, save money.

In [22] author proposes a fuzzy logic based mechanism that determine the sleeping time of field devices in a home automation environment based on BLE. In fact, Fuzzy Logic Controllers (FLCs) are becoming increasingly popular in everyday life and their applications can obtain significant benefits in terms of energy management. The proposed FLC determines the sleeping time field devices according to the battery level and to the ratio of Throughput to Workload (Th/Wl). Simulation results reveal that using the proposed approach the device lifetime is increased by 30% with respect to the use of fixed sleeping time.

V. CONCLUSION

The paper presents basic concept about the Internet of Things. It proposes two models of architecture of Internet of Things. The concept of fuzzy logic and application of fuzzy logic in Internet of things is presented in the paper.

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