An Adaptive Weighted Fuzzy Controller Applied on Quality of Service of Intelligent 5G Environments

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Abstract

In computational intelligence area, it is suitable to fulfill the analysis in order to interpret the concept and sources of uncertainty and the conditions of its incidence, and hence pursuit for reliable techniques of dealing with it. Dealing with uncertainties in this case is a challenging and multidisciplinary activity. So, there is a need for a capable tool for modeling, control, and analytics to test and evaluate uncertainties for different configurations of the same IoT system. This article emphasis on the analysis of the uncertainty in one of the most important technology trends, the IOT on case study of green environment, such as smart homes. In this research a Mamdani Fuzzy Inference System has been proposed with a Gaussian MFs to handle the uncertainty in intelligent environments. Taking advantage of the feedback control technology, this scheme deals with the impact of unpredictable changes in traffic load on the QoS of WSANs. It utilizes a fuzzy logic controller inside each source sensor node to adapt sampling period to the deadline miss ratio associated with data transmission from the sensor to the actuator. The deadline miss ratio is maintained at a pre-determined desired level so that the required QoS can be achieved.

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1. Introduction

Quality of service (QoS) is often heavy provision that is used to point to both the efficiency of a network corresponding to application requirements and the group of technologies that empowers a network to make performance guarantees. QoS is by far the most significant enforcement consideration. If the network QoS is not in function, IP voice or video conferencing calls will be uncertain, incompatible, and much unsatisfactory. So, a QoS mechanism has a vital role in a distributed multimedia system In the other hand, the concept the Internet of Things (IoT) concerns the connection of nearly all types of devices into a network using the Internet. This idea covers the image of the world of the future in which digital, physical equipment and items. The IoT field is an emerging technological area which presents great opportunities for development. Meanwhile the IoT is a comparatively novel field it carries a high level of uncertainty, both in relative to IoT technologies as well as to the characteristics which are correlated to this field, such as social, economic, technological, legal, etc. aspects [1]. 3GPP is working on 5G and the high-level system architecture is already formulated in the normative standard draft and includes the QoS concept for 5G. The QoS concept will be flow-based. Packets are classified and marked with QoS Flow Identifier (QFI). There will be two types of flows: One with standardized QoS profiles and the other with operator-specific QoS profiles. For the first one, only the QFI value is used in the network. For the latter one, QoS attributes are also signaled between the network elements. The 5G QoS flows are mapped in the Access Network to Data Radio Bearers (DRBs), unlike 4G where the mapping is 1:1 between EPC and radio bearers. The 3GPP work on the 5G standard is expected to refine and enrich the QoS concept over the next few years.

Main areas for applying IoT solutions encompass are Intelligent cities, smart power networks, smart health care, intelligent transportation and also Intelligent Buildings (IB)

[2]. The popularity of smart buildings has been on the rise for the last 25 years. The identification, selection and management of technologies which could address the challenges resulting from the changing needs of users, efficient resource management and minimizing the cost of the life cycle of such facilities, has become one of the current obstacles within this field. Present trends which can be pragmatic in structure manufacturing specify an improved share of automation and information technology in many branches of economy [3]. Through the construction of indoor communication network in the family, we realize the home air conditioning and other smart appliances network by power fiber optic network interconnection. Through the intelligent interactive terminals, smart sockets, smart appliances, etc., we achieve household appliances automatically collect electricity information, analysis, management; and home appliances achieve economic operation and energy control [4]. Through the telephone, cell phone, Internet and other means, the system can remote control home and other services. Through intelligent interactive terminals, we also achieve smoke detection, gas leak detection, anti-theft, emergency assistance and other home security functions, and carry out automatic collection and information management of water meters, gas meters, and support and property management center cell master network, and also achieve home security information authorized one-way transmission and other services. Fig 1 shows the structure of a smart home. Through the service interactive website to achieve customizable information on household electricity information, equipment remote control, payment, newspaper, can service guide and other interactive service functions.

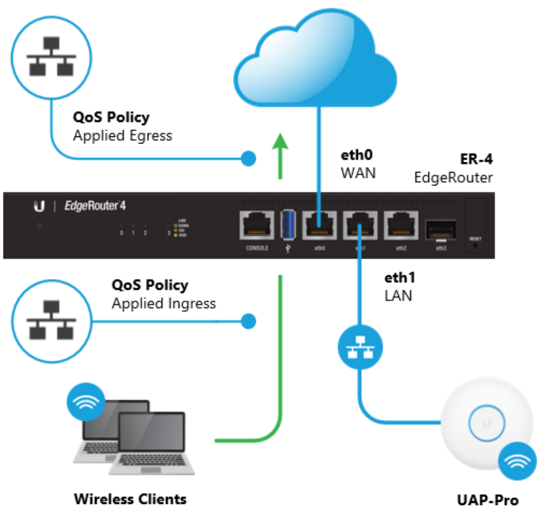

Fig. 1. The QoS Topology for an Intelligent Buildings

Smart home communication system can be divided into external network, gateway and internal network 3 parts. External network can be a cell LAN, cable television networks, telephone networks and the Internet, mostly using more mature technology. Intranet is used to interconnect the various household appliances within the family, equipment, LAN, due to the vast diversity of connected devices, the network also showed a great diversity of forms. Home networks are largely divided into three categories according to their functions: a control network for controlling functions, a data network for exchanging data messages, and a multimedia network for transmitting audio and video. The home gateway is a network connecting device that connects the home intranet and the extranet, and accesses the intranet to the extranet to provide the extranet with the control function of interconnecting devices in the home. At the same time, the home gateway allows the home to adopt different networking technologies and utilize Gateways provide bridging capabilities for different communications sub-nets.

2. Research Background

WSNs are typically used for information gathering in applications like habitat monitoring, military surveillance, agriculture and environmental sensing, and health monitoring. The primary functionality of a WSN is to sense and monitor the state of the physical world. In most cases, they are unable to affect the physical environment. However, in many applications, observing the state of the physical system is not sufficient, it is also expected to respond to the sensed events/data by performing corresponding actions on the system. This stimulates the emergence of wireless sensor/actuator networks (WSANs). Real-world WSAN applications have their requirements on the quality of service (QoS).

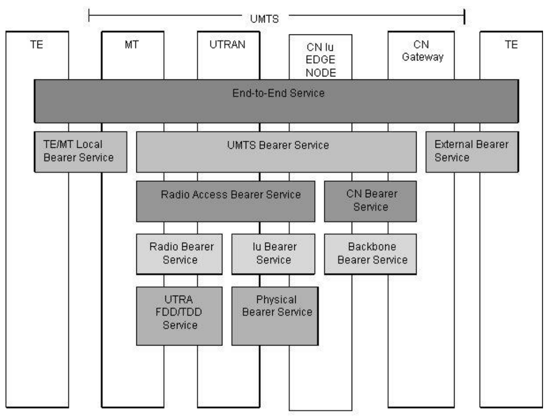

Fig. 2. The Structure of UMTS QoS

For instance, in a fire handling system built upon a WSAN, sensors need to report the occurrence of a fire to actuators in a timely and reliable fashion; then, the actuators equipped with water sprinklers will react by a certain deadline so that the situation will not become uncontrollable. Both delay in transmitting data from sensors to actuators and packet loss occurring during the course of transmission may potentially deteriorate control performance of the system, and may not be allowed in some situations where the systems are safety-critical. In a smart home, although there is no hard real-time constraint, actuators should turn on the lights in a timely fashion once receiving a report from sensors when someone enters or will enter a room where all lights are off; people would get unsatisfied if kept staying in dark for a long time waiting for lighting. In practice, QoS requirements differ from one application to another; however, they can be specified in terms of reliability, timeliness, robustness, trustworthiness, and adaptability, among others. Some QoS metrics may be used to measure the degree of satisfaction of these services. Technically, QoS can usually be characterized by, e.g., delay and jitter, packet loss, deadline miss ratio, and/or network utilization (or throughput) in the context of WSANs. WSN Features can be described following as:

1) WSANs are highly dynamic in nature. The network topology may possibly change over time due to node mobility, node failure, node addition, and exhausted battery energy. The channel capacity may also change because of the dynamic adjustment of transmission powers of the sensor/actuator nodes.

2) WSANs feature inherent node heterogeneity. Having different functionality, sensors and actuators do not share the same level of resource constraints. The coexistence of sensors and actuators makes WSANs and WSNs fundamentally distinct.

3) WSANs typically operate in unpredictable environments. With wireless radio as the medium for data transmission, most WSANs suffer from diverse radio interferences. This problem will become increasingly severer as wireless technologies are incorporated in more and more (consumer) products that are expected to become pervasive. In the other hand, Uncertainty, along with the complexity and dynamism of a system is currently treated as one of the key modules of the triad characterizing modern social systems [4]. The concept of uncertainty includes multiple characteristics and meanings. The broadly spread use of the concept of uncertainty during numerous scientific disciplines, has instigated it to attain many definitions [6]. In the Table 1, The main characteristics of IoT which influence uncertainty include in Intelligence Buildings IoT (IBIoT) has been shown respectively. When considering a global network of various intelligence objects, such as machines, applications, clothes, sensors, interacting with each other through internet protocols. The devices that are part of the network of objects are called intelligent objects or intelligent things, that distinct normal devices are able to interact within the communication system in which they are inserted since they have an active role.

Table.1.
Sources of Uncertainty in IBIoT

Sources	***Descriptions***
Heterogeneity of devices	The large number of devices used means high diversity
Scalability	Addressing, naming, connectivity of a growing number of devices being used every day.
wireless data transfer technology	Problems connected with overcoming this issue are related to transfer speeds and delays in delivery of data.
Optimum energy	The issue of power use is important.
User configuration capabilities	provide mechanisms allowing the users to configure the systems themselves.
Data management	connotation explanations of their content, applicable format and language.
Privacy protection	Because of its close relationship with the real world, IoT technologies

3. Proposed Method

A rule-based Mamdani fuzzy system contains four components rules, fuzzifier, inference, and output processor that are interconnected as shown in Figure 3 Once the rules have been established, the fuzzy system can be viewed as a mapping from inputs to outputs, and this mapping can be expressed quantitatively as:

$$y = f(x) \quad (1)$$

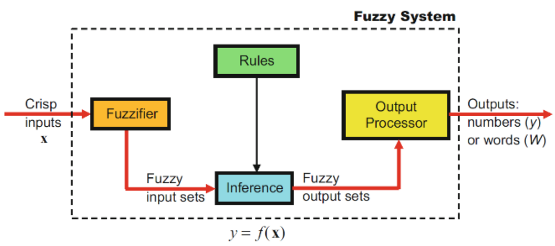

Fig. 3. Structure of Fuzzy System

Definition 1: When a fuzzy system uses Zadeh rules and a Mamdani implication operator it will be mentioned to as a Mamdani fuzzy system.

Definition 2: For a Mamdani fuzzy system, the final fuzzy set, B is determined by all M rules, and can be obtained by combining B^l and its associated MF $\mu B^l(y|X')$ for all $l = 1, \dots, M$, as:

$$B = A_{X'}[R_Z^1, \dots, R_Z^M] \tag{2}$$

If such information is uncertain and ambiguous in an intelligent central controller, then the fuzzy inference system sets all the weights equal to unity or uses a training procedure to learn optimal values for the weights of uncertainty in each part of the building as follow (3):

$$\mu B^l(y|X') = \sum_{l=1}^{M} wl \times f^l(x') \times \mu G^l(y) \tag{3}$$

Where $wl \in (0,1)$, a constraint that is needed so that, $\mu B \in (0,1)$, as is required by the MF of a fuzzy set. An easy way to achieve this constraint is to let:

$$Wl = \frac{W'_l}{\sum_{l=1}^{M} W'} \tag{4}$$

The centroid defuzzifier combines the type-1 fired-rule output fuzzy sets using union for example a t-norm, usually the maximum, and then finds the centroid, $y_c = (\boldsymbol{x}')$ of this set:

$$y_c = (\boldsymbol{x}') = \frac{\sum_{i=1}^{N} yi\, \mu B(yi|X')}{\sum_{i=1}^{N} \mu B(yi|X')} \tag{5}$$

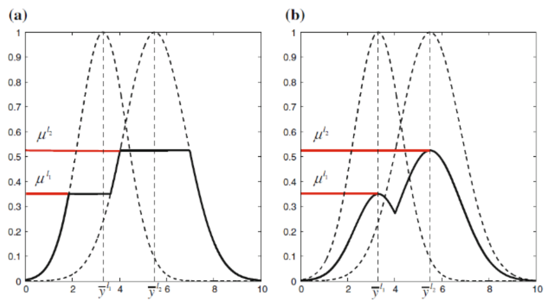

Fig. 4. (a) combined output sets for the two fired output sets and (b) combined output sets for the two fired output sets.

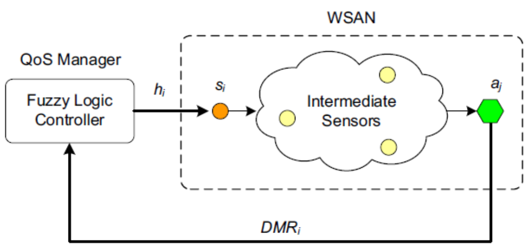

Fig. 5. Fuzzy logic control-based quality-of-service (QoS) management.

4. Experimental Results and Performance Evaluation

The tested polar channel coding technique chosen for 5G New Radio (NR) communications system. Of the two main types of code constructions specified by 3GPP. This test shows that proposed architecture has the CRC-Aided Polar (CA-Polar) coding scheme with a reliable result in different rules and different rules which associated with adaptive nodes. This example describes the main components of the polar coding scheme with individual components for code construction, encoding and decoding along-with rate-matching. It models a polar-coded QPSK-modulated link over AWGN and presents Block-Error-Rate results for different message lengths and code rates for the coding scheme. In the other side, the statistical evaluation of analytic performance in general, and specifically ROC curve and parametric ROC analysis, were conducted for evaluating the performance of weighted Mamdani fuzzy system and proposed rule-based classifiers. The confusion matrix was calculated to define the performance of the suggested approaches. The confusion matrix describes all possible results of uncertain outcomes in the table structure. The possible results of a two-class prediction be characterized as True positive (TP), True negative (TN), False Positive (FP) and False Negative (FN).

Specificity: The prospect of the test finding the correct class among all classes [10,11]:

$$\frac{TN}{TN + FP} \tag{6}$$

Accuracy: The fraction of test results those are correct:

$$\frac{TP + TN}{TP + FN + TN + FP} \tag{7}$$

Precision: Precision or positive predictive value:

$$\frac{TP}{TP + FP} \tag{8}$$

Sensitivity (Recall): Hit rate

$$\frac{TP}{Total\ Positive} \tag{9}$$

The area under the curve (AUC) and parametric ROC shown the graphical representation of comparison proposed methods in figure 5. According to the obtained results, the weighted Mamdani method give a improved performance compare to the related works for modeling uncertainty in a IoT and intelligent building, where $\mu_{(i)}$ AND $\mu_{(J)}$ are the means ROC curve average accuracy of the 10-fold cross-validation with a 90% founded as follow as [11]:

$$\mu_i = \frac{1}{10}\sum_{k=1}^{10} AUCj \tag{10}$$

Table.2.
Applied confusion matrix for proposed model in different nodes

Rules Factor	***5 Rules***	***10 Rules***	***15 Rules***	***20 Rules***
Precision	74%	83%	91%	95%
Sensitivity	72%	87%	92%	93%
Specificity	80%	86%	93%	96%
Accuracy	83%	88%	94%	96%
Confidence Interval	[80-85]	[88-90]	[90-95]	[90-95]
Nodes	Fixed	Fixed	Adaptive	Adaptive

Figure 5 shows how to generate a receiver operating characteristic (ROC) curve of a proposed system using a Monte-Carlo simulation. The receiver operating characteristic determines how well the system can detect targets while rejecting large spurious signal values when a target is absent (false alarms). A detection system will declare presence or absence of a target by comparing the received signal value to a preset threshold. The probability of detection (Pd) of a target is the probability that the instantaneous signal value is larger than the threshold whenever a target is actually present. The probability of false alarm (Pfa) is the probability that the signal value is larger than the threshold when a target is absent. In this case, the signal is due to noise and its properties depend on the noise statistics. The Monte-Carlo ROC simulation generates a very large number of signal returns with and without a target present. The simulation computes Pd and Pfa are by counting the proportion of signal values in each case that exceed the threshold [12,13].

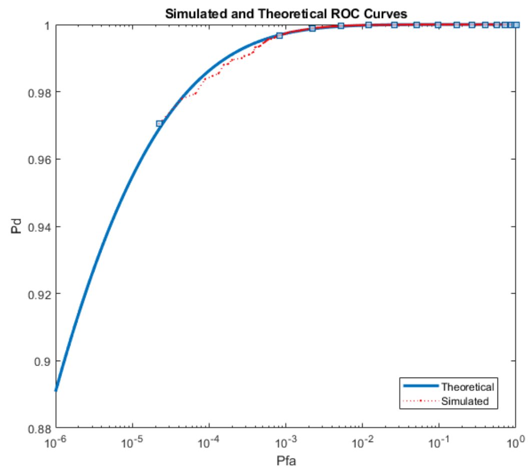

Fig. 6. ROC Curve for proposed method

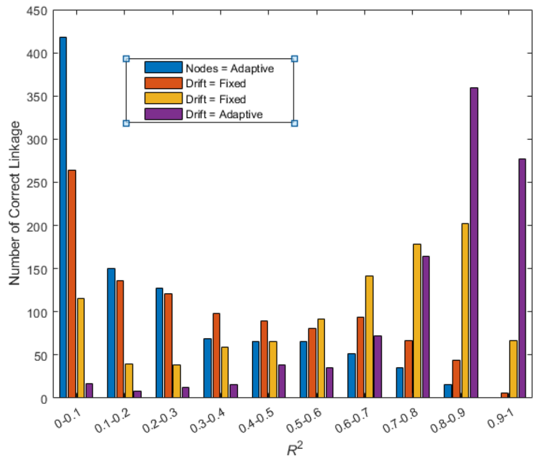

Fig. 7. Number of Correct Sink Linkages in Fixed and Proposed Adaptive Fuzzy Model

5. Conclusion

As it has been mentioned earlier in the work, the QoS characterizes highly scalable and varied uncertain architecture, so in theory it is possible to design a fuzzy system that can implement and manage any kind of uncertain rules for handling the devices or data within it. The proposed method of this work refers to the phenomenon of uncertainty in the face of high-tech trending, emerging and challenges associated with them. In this research a Weighted Fuzzy Mamdani Inference system introduced for overriding adaptable IoT in intelligent building systems under uncertainty. The main idea of this work is a flexible runtime mechanism for managing rough ascendancy scopes and enabling isolated actuations were presented to simplify enforcing such 5G polices, by effectively justifying the structure uncertainties, as demonstrated on a real-life problem application.

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