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Fuzzy Logic Tool for Imprecise Information in Wireless Communication- Another Perspective

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ABSTRACT
With the advancement in wireless communication technology, various networks exists simultaneously. The variation in wireless network parameters is imprecise in nature. To handle this imprecise data fuzzy logic can be used as an important tool for wireless network algorithms. Application of fuzzy logic/fuzzy controller in wireless communications is presented in this paper. The objective of this paper is to highlight the importance of use of fuzzy logic based algorithms in heterogeneous wireless environment. This paper will focus on application of fuzzy logic in cognitive radio, wireless sensor networks, decision making in heterogeneous wireless environment, routing in mobile Ad-hoc networks etc.

Introduction

In past few years, technologies in the area of wireless communication has shown a tremendous growth in the entire world, especially in mobile communication. With its tremendous growth the technology has evolved from 2G technologies, GSM in Europe, IS-95(CDMA) and IS-136 (TDMA) in USA, to the third generation (3G) technologies. The present generation of wireless system consist of different wireless access technologies ranging from cellular wireless network, Wi-Fi, CDMA to satellite networks. This generation of wireless system provides a wide range of services from high speed data traffic to high secure real time multimedia traffic. Since these wireless networks are complementary to each other, their integrated operation can provide always best connection quality mobile communications to the users. In the such type of environment, users are always connected to the best available networks and switch between different networks based on their service needs. In this type of environment the user can roam between a different set of wireless architectures like WLAN, cellular, and satellite network.

Figure 1 shows the architecture of heterogeneous wireless environment and figure 2 show the evolution of mobile communication system. Because the entire system is wireless system, the parameters like signal strength, data rate etc. can be effected by the surrounding and are imprecise in nature. So there is need of some tool that can analyse these parameters which are varying in nature. To deal with such type of nature fuzzy inference system/controllers can be a choice for analysis. Fuzzy Inference Systems (FISs) are also known as fuzzy rule-based systems, fuzzy model or fuzzy expert system. FIS system will help in making decision for the system. The FIS formulates suitable rules and based upon the rules the decision is made [1].

FIS uses "IF. . . THEN. . ." statements, and the connectors present in the rule statement are "OR" or "AND" to make the necessary decision rules. FIS consists of a fuzzification interface, a rule base, a database, a decision-making unit, and a defuzzification interface [1]. Fig. 3 shows FIS system. The function of each block is as follows:

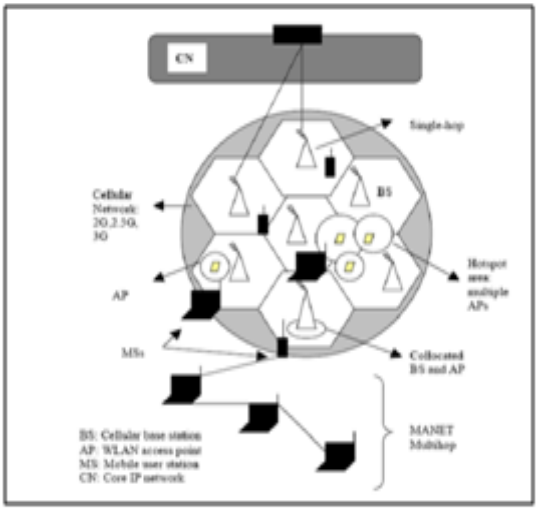

Figure 1. Heterogeneous wireless environment

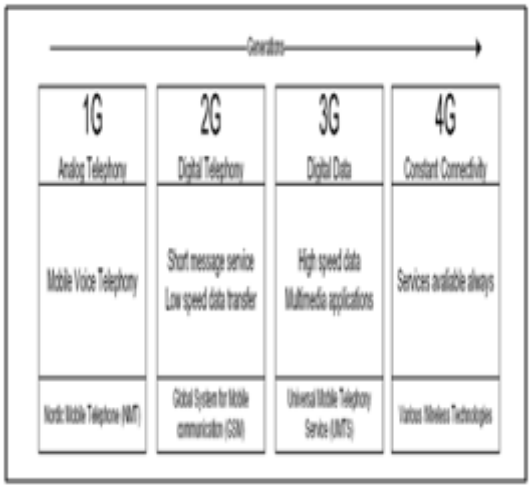

Figure 2. Evolution of mobile communication system

A rule base consists of fuzzy IF–THEN rules;

➢ A database which defines the membership functions of the fuzzy sets used in the fuzzy rules;

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- A decision-making unit which performs the inference operations on the rules;
- A fuzzification interface which transforms the crisp inputs into degrees of match with linguistic values; and
- A defuzzification interface which transforms the fuzzy results of the inference into a crisp output.

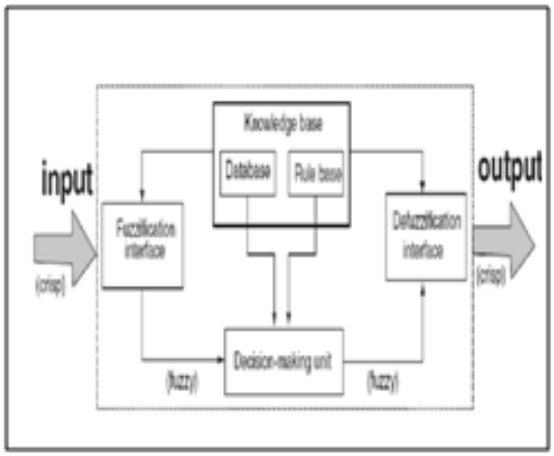

Figure 3. Schematic Diagram of Fuzzy Inference System

Advantages of Using fuzzy logic are as follows

- Fuzzy logic is conceptually easy to understand. The mathematical concepts behind fuzzy reasoning are very simple.
- Fuzzy logic is flexible. With any given system, it's easy to massage it or layer more functionality on top of it without starting again from scratch.
- Fuzzy logic can be built on top of the experience of experts. In direct contrast to neural networks, which take training data and generate opaque, impenetrable models, fuzzy logic lets you rely on the experience of people who already understand your system.
- Fuzzy logic can be blended with conventional control techniques. Fuzzy systems don't necessarily replace conventional control methods. In many cases fuzzy systems augment them and simplify their implementation.

Applications of Fuzzy Logic Algorithms in heterogeneous wireless environment

Fuzzy logic algorithms can be used to enhance the performance of different parameters in wireless environment. Different fuzzy logic based algorithms will be discussed in next section.

Fuzzy Logic Based Efficient Routing Protocols

With the advancement in wireless communication technology and Ad-hoc networks, many algorithms have been proposed for the optimization during routing decision in wireless sensor networks. From many research areas in Ad-hoc networks, routing is the area in which attempts for efficient utilization of energy have been made. Literature shows that fuzzy Logic can be used as an intelligence technique for the efficient optimization of routing in wireless sensor networks. In [2] Golnoosh G. et. al. proposed an algorithm, which consider two parameters, trust value and energy value which are defined for each node. Based on these parameters lifetime of the routes are determined. The algorithm use AODV for routing. In this algorithm each node inserts the value of two parameters i.e. trust value and energy capacity in the route request packet at the time of routing. In the algorithm fuzzy logic is used at the destination. Reliability value is generated using fuzzy logic using predefined parameters and is used for routing. A path which is having greater reliability value is preferred over the others. In [3] Taqwa Odey and A. Ali, proposes a routing algorithm using fuzzy logic controller. A fuzzy logic controller is used to calculate the lifetime of the route in the network. The input to the controller is Route Cost. The proposed scheme considers the average end to end delay, packet delivery ratio and routing load as the metrics. In [4] B. Sun et. al. propose a fuzzy logic based routing algorithm with traffic state and bandwidth as the input parameters. It used weighted round robin scheduler concept for forwarding the packets. The weights are assigned to the queues containing the data and based on these weight values, fuzzy controller determines the routing process. In [5] Tarique Haider and Mariam Yusuf proposed an algorithm that presents fuzzy logic based approach for energy-aware routing in wireless sensor networks. Their simulation results shows significant improvement in terms of reliability and efficiency. Ehsan Amiri et. al. in [6] proposed a routing algorithm wireless sensor networks using fuzzy logic ant optimization colony optimization technique. The simulation compare the result with original AODV and calculate the routing setup time, end-to-end delay for packet delivery, and the number of packets sent in the routing discovery phase and energy consumption. The proposed algorithm shows an increase in network lifetime by reducing the nodes energy consumption and the number of packets. In [7] A.Banerjee et. al. proposes an power efficient algorithm using fuzzy controller. In the proposed algorithm each node pro-actively finds out whether it is too ready to take part in a new communication session or not the fuzzy controller encourages inclusion of not-ready nodes in a communication route and also prefers the routes involving small number of nodes. This reduces the overall cost of messages and energy consumption maintaining a suitable balance of packet forwarding load in the network. Md. Manowarul Islam in [8] proposed a routing algorithm that consumes less energy and saves the network energy significantly. The proposed algorithm provides higher network throughput in terms of higher packet delivery ratio, lower data delivery delay and higher throughput and higher performance than traditional protocols. In [9] Y.Huang et. al. proposed two localized and energy-efficient approaches, called LFTC and RFTC, based on the fuzzy logic. The simulation results of the proposed algorithms are compared with three algorithms NONE, LTRT, and list based algorithms. The comparison shows that the proposed algorithms achieved desired node degree and save more energy.

Fuzzy Logic Based Vertical Handovers

With the development of wireless communication technology, various wireless networks can coexist simultaneously. In such environment, providing a seamless handoff by selecting the appropriate network is one of the key issues. Because fuzzy logic can be used to handle imprecise data so fuzzy logic can be better choice for decision making in heterogonous wireless environment. Fuzzy logic can be used a tool for making appropriate handover decision in multi network environment. Manoj Sharma & Dr. R.K.Khola in [10] proposed a fuzzy logic based vertical handover decision algorithm. Sugeno Fuzzy Inference system is used to find the decision for vertical handover. Available Bandwidth, Network Load and Signal Strength are the input parameters to inference system. Based upon the values of input parameters the handoff decision was evaluated and decide when to handoff. In [11] Yaw Nkansah-Gyekye and Johnson I. Agbinya proposed a vertical handoff decision algorithm which is cost-effective and highly useful. The proposed algorithm use fuzzy logic concepts to combine multiple metrics from the network to obtain useful handoff initiation schemes and used a genetic algorithm to optimise the selection of suitable access networks with a fuzzy multiple attribute defined wireless network selection function. In

[12] S. Kunarak and R. Suleesathira proposed network selection handoff algorithm based on signal strength prediction and fuzzy logic. Back propagation neural network model was used for signal strength prediction. Merit function evaluating network conditions and user preference are used as input parameters for handoff decision. Fuzzy logic using quantitative decision algorithm makes a final decision to select the optimal target network with the largest QDV. In [13] authors proposed an algorithm to evaluate the decision for handoff in WWAN and WLAN network. Bandwidth, RSSI and Network are parameters used for evaluating the handoff decision. By evaluating the value of Handoff Decision it can be decide whether a handoff is performed or not. In [14] V.A Naryanan et. al. proposed an approach in vertical handover decision algorithm using fuzzy logic-multiple attributes with context aware strategy enables mobile terminal to make proactive decision based on user preferences and quality of service parameters. The simulation results show that shows that the proposed approach fulfils quality of service requirements of audio, video and data in terms of packet loss, handover delay during the handover as recommended by Cisco Systems. This decision algorithm efficiently uses the network resources by switching between 3G and Wi-Fi under the different RF environmental conditions to offer best connectivity with minimal service cost to the users.

Fuzzy Logic Based Intrusion Detection Systems in Wireless Sensor Networks

With the advancement in wireless technology, now a days mobile ad hoc networks play an important role for providing communication in many areas because of its independent nature of predefined infrastructure. But in terms of security, these networks are more vulnerable than the conventional networks because firewall and gateway based security mechanisms cannot be applied on it. That's why intrusion detection systems are used as keystone in these networks. Many number of intrusion detection systems have been discovered to handle the uncertain activity in mobile ad hoc networks. Yulia Ponomarchuk and Dae-Wha Seo in [15] proposed an intrusion detection technique based on the monitoring of the packet reception rate and packet inter-arrival time, and an application of fuzzy logic in order to minimise the false positive rate and maximise the detection rate. The experimental results showed that the proposed algorithm has a high detection rate of attacks, even in dense networks with intensive traffic flow. When an attacker tries to operate in a "stealthy" manner and drops or injects a small portion of packets irregularly, he is still reliably detected by the proposed method, while commonly recommended rules, based on the assumption of a normal distribution of the arrival rate. Amin Einipour in [16] proposed an intrusion detection in computer networks using fuzzy systems and PSO algorithm. The simulation results of proposed algorithm shows that the proposed approach would be capable of classifying intrusion instances with high accuracy rate in addition to adequate interpretability of extracted rules. In [17] authors proposed an algorithm that use NSL dataset instead of KDD dataset implementation over the existing framework of Fuzzy Clustering Neural Network. The simulation result shows that using NSL with hybrid mining approach, detection of precision is higher than 90% while keeping the recall rate on average higher than 80%. Kulbhushan & Jagpreet Singh in [18] proposed a fuzzy logic based algorithm for intrusion detection. The simulation results shows that the performance of MANET under blackhole attack improves significantly. The Results that system performs better than classic AODV in all of the parameters like routing overhead, end to end delay, packet delivery ratio. The proposed algorithm not only detects the blackhole attack in early stage of communication, but also isolates it from the network. In [19] Anusha K. et. al. proposed an Intrusion detection system that monitors the traffic for detecting black hole and two types of gray hole attacks. The proposed algorithm detects the attack by using an Intrusion detection system that uses intuitionistic fuzzy logic system, which aims to detect distrust behaviour of node and identify the attacks if it seems to be an attack based on given rules.

Fuzzy Logic Based Traffic Management & Congestion Control in Heterogeneous Wireless Environment

With the advancement in information technology and advancement in wireless communication, audio, video, text or any form of information can be transmitted. With increase in traffic load, the problem of traffic congestion may occur some times. The performance of the system is degraded with congestion. Survey shows that many algorithms were proposed to avoid congestion. Under idle condition, network traffic is less whereas when an event is detected, the network traffic becomes high and may leads to congestion in the network. Fuzzy logic can be efficiently used to avoid the traffic congestion in heterogeneous wireless networks. Rekha Chakravarthi & C. Gomathy in [20] proposed a fuzzy logic based FIDP congestion control algorithm. In proposed algorithm the performance of FIDP is compared with HRCT in terms of delay and packet delivery ratio. The simulation result shows that it provides better result as compared to traditional algorithm. In [21] Cagatay Sonmez et. al. proposed an algorithm based on SUIT. SUIT has an efficient congestion detection mechanism. SUIT provides two different techniques. The first technique was adapting video frame rate at source sensor nodes. The second one was a novel congestion mitigation technique which can adapt the quality of images on-the-fly. Main contributions of the SUIT protocol are using a new combination of three congestion indicator in fuzzy logic-based congestion estimation approach, proposing a cross-layer information exchange method among different layers, and applying a quality adaptation technique which decreases the image quality while they are being transmitted. Saxena Sachin Kumar in [22] proposed a fuzzy logic based congestion control algorithm which takes advantage of current buffer occupancy and congestion detection was proposed to diagnose problem at each node level. In addition, it periodically calculates the congestion degree using fuzzy logic theory. Simulations results shows that the proposed algorithm was able to efficiently sort out the traffic and minimizes the packet loss. Simulation model also addresses the problem in order to deprive the congestion in wireless network. In [23] Rekha Chakravarthi & C. Gomathy proposed a fuzzy logic based congestion control algorithm.. The performance of the network is measured for delivery ratio with different transmission rate and the PDR is compared with CODA. The simulation results for Packet Delivery Ratio Vs Transmission rate are compared. The PDR of FHRCT is high when compared to CODA .The packet delivery ratio is 100% using Fuzzy HRCT for lower transmission rate and it reduces to 98.5% for higher transmission rate whereas packet delivery ratio is 93% using CODA for less transmission rate and it reduces to 95.5% for high transmission rate.

Conclusion

It has been shown that fuzzy logic can be used as an important tool dealing with imprecise information in heterogeneous wireless environment. Application of fuzzy logic/fuzzy controller in wireless communications is presented. Here the use of fuzzy logic based algorithms in heterogeneous wireless environment are presented. Fuzzy logic can be used in

cognitive radio, wireless sensor networks, decision making in heterogeneous wireless environment, routing in mobile Ad-hoc networks etc.

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