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Smart Handoff Framework for Seamless Connectivity in Heterogeneous and Ubiquitous Environment

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***Abstract*—**Last few epochs have witnessed a radical change in accessibility scenarios due to the immense growth of the Internet and Mobile Technologies. Further with proliferation of Internet of Things (IoT) and Internet of Everything(IoE) has brought multifaceted issues for the researchers to undertake to design Future Communication Networks for smart cities. The framework of smart city is based on the success of Internet and IoT which promises to fully renovate our lives with diverse smart applications ranging from e-commerce to m-commerce and cloud computing to analytics. This vision of future smart city is successful only if internet connectivity is provided everywhere and anytime. Hence, this paper investigates an adaptive fuzzy based handoff (AFH) strategy to provide continuous connectivity in heterogeneous networks deployed in smart cities. The AFH algorithm is based on Fuzzy logic and aids to reduce ping pong probability and corner effect during mobility in smart cities. This reduces unnecessary handoffs to facilitate smart city users to use internet services while travelling on highways from one city to another. A case study has been shown to illustrate the execution of AFH algorithm and it has been proved that AHF reduces ping pong rate and corner effect probability.

Keywords-*Handoff;ping-pong effect; corner effect; Seamless connectivity;*

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I. INTRODUCTION

Due to the rapid progress and success of wireless and mobile communication networks, the upcoming generations i.e. 5G, 6G, 7G [1] have engrossed the attention of the scholarly researchers, industry acumen and government associations. This advancement is looking forward to equip the users with high data rate with low latency, unwavering quality, transparent mobility and high reliability, which can be made reality by making a progressive change from standalone network to integration of varied access technologies. This integration of RAT's aims to provide unified connectivity to all its users by making Internet of Things (IoT) and ambient intelligent a vital application to fundamentally change our regular daily existences with an assortment of varied services online that endeavor billions of techno-savvy gadgets deployed around us [2]. IoT frameworks have extremely assorted necessities relying on the deployed network architectures for communication and connectivity on which they run. Adaptability, diversity and seamlessness are three basic necessities of IoT frameworks that can't be completely met by current system technologies. Therefore, different advancements must be incorporated in shaping a Heterogeneous Wireless domain in light of a hidden system foundation to ensure user mobility along with the service continuity. This continuum is the fundamental necessity for guaranteeing universal processing and therefore by keeping up associations while exchanging link between different access technologies, numerous new conceivable outcomes and applications can be run. Heterogeneous Wireless Network (HWN) comprises of diverse network architectures ranging from cellular networks to satellite networks providing a wide range of services such as high rate data traffic, real time multimedia traffic, handoff management, to high secure communication.

However, none of these facilities will be provided by the existing standalone wireless network, so there is a paradigm shift from homogeneous wireless infrastructure to heterogeneous infrastructure which can concurrently satisfy the high data rate, low latency along with ubiquitous coverage needs of the mobile users' service demands. And to ensure this, mobility management must be considered at priority in a heterogeneous environment. Mobility management rises out as one of the most significant issue in providing seamless connectivity with QoS provision to entire wireless and mobile communication over the Internet. It enables switching between various base stations or networks while delivering data packets and maintains connection. It is divided into two categories- Handoff management and location registration and updating. This paper focuses on handoff management in a heterogeneous and ubiquitous environment and aims at utilizing the underlying resources for providing constant connectivity as and when required and also avoiding unnecessary handoffs.

Handoff is characterized as the procedure that transfers an ongoing call from one cell to another between same or different networks depending on the mobility pattern of the user [3]. It is categorized as intra-technology and inter-technology handoff. Intra-technology handoff refers to handoff between cells belonging to same kind of system interface. Inter-technology handoff occurs amongst cells belonging to varied networks. It is further categorized as: upward and downward inter-technology handoff. An upward inter-technology handoff occurs when a mobile node is being switches from a cell with minor radio coverage to a cell with broader coverage and a downward inter-technology handoff happens in the reverse direction of an upward inter-technology handoff [4].

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Ping-Pong effect: - Different types of hindrances cause fluctuations in the signal strength due to which there is variation in RSSI value receives by the mobile node. When a user travels across two cell edges, then the value of RSSI keeps switching back and forth due to random movement of the user. So, when handoff takes place repeatedly due to fluctuating value of RSSI, this is called ping-pong effect.

Corner effect: - When a mobile node travels across the street corners, then due to different types of obstructions, RSSI value drops around 20 to 25dbm.every time user takes a turn around corner, signal strength falls due to which services are interrupted. This is called corner effect.

II. Related Work

In [5] the authors have proposed a new handoff initiation algorithm for data transmission in WLAN. They have combined association time, system load and signal/noise ratio (SNR) together to decide whether mobile node should handoff or not. In [6], authors have proposed a new handoff algorithm for data service. A new handoff initiation criterion for heavy traffic load is developed. When current traffic load exceeds a specific level, both signal strength and traffic load are used to make a decision on handoff initiation. It is mainly used to balance traffic load of access points (AP).

In [7] the architecture of a multi-mode terminal is presented that employs fuzzy logic for initiation and decision of vertical handovers among its radio interfaces. In [8] authors have proposed an agent-based architecture that determines the timing and target network of handovers with respect to user, application and terminal constraints. In [9] presented an Optimal Network selection mechanism for multi-homed mobile terminals that enable users to dynamically choose the right access network based on a set of QOS parameters. Since the algorithm was based on AHP, it gave both qualitative and quantitative evaluation of the alternatives which means that it determines the optimal target network and also evaluates how best the target network was suitable for a specific traffic class. Author in [19] has also used MADM approach to assign weights to the parameters for handoff decision making in heterogeneous environment. Authors in [10] showed the capability of the mobile users to communicate either they belong to any wireless network. In fourth generation integration of network technologies for better services to mobile users is done.

In [11] authors presented an analytical framework to evaluate VHO algorithms. This framework can be used to provide guidelines for the optimization of handoff in heterogeneous wireless networks. Subsequently, they extended the traditional hysteresis-based and dwelling-timer-based algorithms to support both VHO and HHO decisions and apply them to complex heterogeneous wireless environment. Author in [12] have reduced handoff latency by reducing the number of APs to be scanned which is accomplished by cell sectoring and distance measurement with help of GPS. In [13] authors have designed and implemented a Fuzzy Logic based Handoff controller on an FPGA. The proposed system can be reconfigured and additional features can be incorporated with increasing need of the end users and providing better quality of service. Many algorithms exist today which make use of different methods and strategies as in [14]- [22] and aim at giving a better solution for handoff.

Many conventional algorithms do not consider the dynamic behaviour of the cellular environment and hence cannot adapt the handoff parameters to the dynamic cellular environment. After a thorough literature review the following objectives were set for the proposed adaptive handoff initiation algorithm:

- ✓ Invoking a new handoff initiation protocol based on fuzzy logic for integrated heterogeneous networks so that the handoff can be carried out successfully before the mobile node moves out of the coverage area of the current base station.
- ✓ Reducing the ping pong effect
- ✓ Reducing corner effect and thus raising the QoS of HWN.
- ✓ Reducing the unnecessary load on the system that arises because of false handoff initiation.

An initiative was taken in [23] to introduce the concept of adaptive threshold and hysteresis to remove unnecessary handoffs. But author just explained the superficial layer of the strategy. Later on, in [24], author calculates the RSSI using path loss models and calculates threshold and hysteresis on the basis of the calculated value of RSSI, SINR and data rate and concludes that even these values can change by changing transmitter and receiver characteristics.

III. System Model

This paper develops a new fuzzy based algorithm named adaptive fuzzy handoff (AHF)algorithm to handle handoff initiation. Handoff initiation is one the most critical phase of mobility management. If a handoff is triggered at the right time then it may provide seamless connectivity to numerous services running on the internet but if it is triggered at the wrong time then it may lead to congestion, call drop or wastage of network resources. Hence the primary focus is to understand the need of handoff and initiate it as and when required. The received signal strength (RSS) measurement is considered as the key metric to initiate handoff. Previous models considered comparing the value of RSSI with fixed minimum threshold and fixed hysteresis to initiate handoff as explained in [14]. But AFH model considers adaptive value of threshold and hysteresis to initate handoff. This adaptive value is dependent on RSSI, network load, bit error rate(BER) and application running on the mobile node. The hysteresis value is difference between two signal strengths from different routers and this can be used to reduce ping-pong effect. Figure 1 explains hysteresis margin of RSSI being received from two different access points.

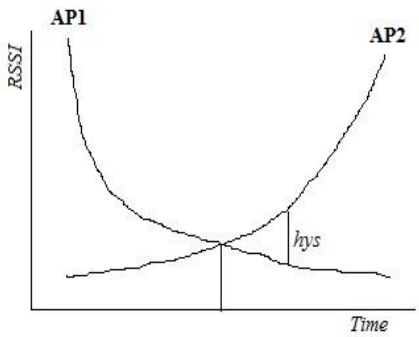

Figure 1: Hysteresis Margin

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IV. ADAPTIVE FUZZY BASED HANDOFF STRATEGY

An initiative was taken in [25] to develop an algorithm based on adaptive threshold and hysteresis but the approach was limited to horizontal handoff. So, this is an extension to this work by extending it to vertical handoff. The proposed fuzzy logic based adaptive threshold and adaptive hysteresis method would be superior to fixed threshold and fixed hysteresis method thus reducing leading to better quality of service. The proposed system initiates handoff using fuzzy logic and considers three fuzzy controllers as given in Figure 2. There are many reasons to consider three fuzzy controllers for initiating handoff. Different scenarios initate handoff due to following reasons

a. When a user is not getting sufficient signals from the serving base station for running the application
b. Signal strength is good but application running on the mobile requires more bandwidth than available.
c. Other network related parameters such as network load or bit error rate is high on the serving network.
d. Power consumption is high on the current network
e. Sometimes handoff takes place even when not required due to change of location but user is not running any application or does not require any service at that time so user controlled must be incorporated for handoff initiation.

Incorporating all reasons and metrics in one fuzzy controller is not possible so an effort has been made to design three different fuzzy controllers. Three controllers are:

1. Network Initiation fuzzy controller
2. Mobile initiation Fuzzy controller
3. User initiation fuzzy controller

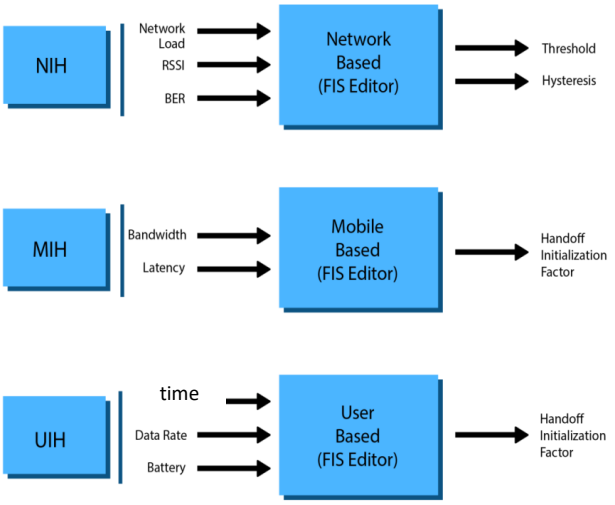

Figure 2: Three fuzzy controllers

V. FUZZY CONTROLLERS

Three fuzzy controllers have been designed to cater to the need of the coming era. Users on internet are increasing and their demand for high bandwidth is increasing day by day. Today along with smart technology, a user has also become smart and interacts with the vendor for speed and bandwidth. Therefore, seeing to the changing scenario, there is a need of different fuzzy controllers which can solve different issues regarding handoff.

1. **Network Initiated Fuzzy Controller:** It takes three input parameters and gives two outputs as follows:
   a. Received signal Strength Indicator
   b. Bit-error-rate
   c. Network Load
   d. Adaptive Threshold
   e. Adaptive Hysteresis

   INPUT
   OUTPUT

   This module aids in solving the problem of ping-pong and corner effect by incorporating changing value of threshold and hysteresis. Network based parameters are considered in this controller. When RSSI decreases or network load increases, this module will execute and check the requirement of handoff on the basis of application running on the mobile. Handoff is initiated only if it is required and avoided if application is running on the current state of network.

2. **Mobile Initiated Fuzzy controller:** It considers two input parameters **-latency and bandwidth** and gives **handoff initiation factor** as an output. This module initiates handoff on the basis of the performance metrics of the mobile. If the application is not getting sufficient bandwidth or it is taking too long to get executed, then in that case mobile based handoff is initiated which checks the current state for bandwidth and latency. If bandwidth is not available and latency is too high, then the mobile is switched to optimal available base station.

3. **User initiation fuzzy controller:** It takes three input parameters and gives handoff initialization factor as the input. The metrics for this controller are:
   a. Estimated time of stay in cell
   b. Data rate
   c. Battery consumption

   This fuzzy controller is initiated when user initiates handoff as per his needs. Suppose a user moves from one location A to another new location B. It its stay in new cell location B is in hours and application running is urgent, then user can initiate handoff explicitly. and if stay time is few minutes or very less and application can be postponed, then the need for handoff can be avoided. This controller initiates handoff on the basis of user demand and considers battery power also as one of the important criteria. A user can initiate handoff if the battery consumption is very high on the current network and user can switch to a network which consumes less power consumption.

Hence it is seen that three controllers have different task to perform which solves the need of handoff on the basis of network, performance and user. Even the results show that these controllers initiate handoff only when required. Hence solving the problem of unnecessary handoffs.

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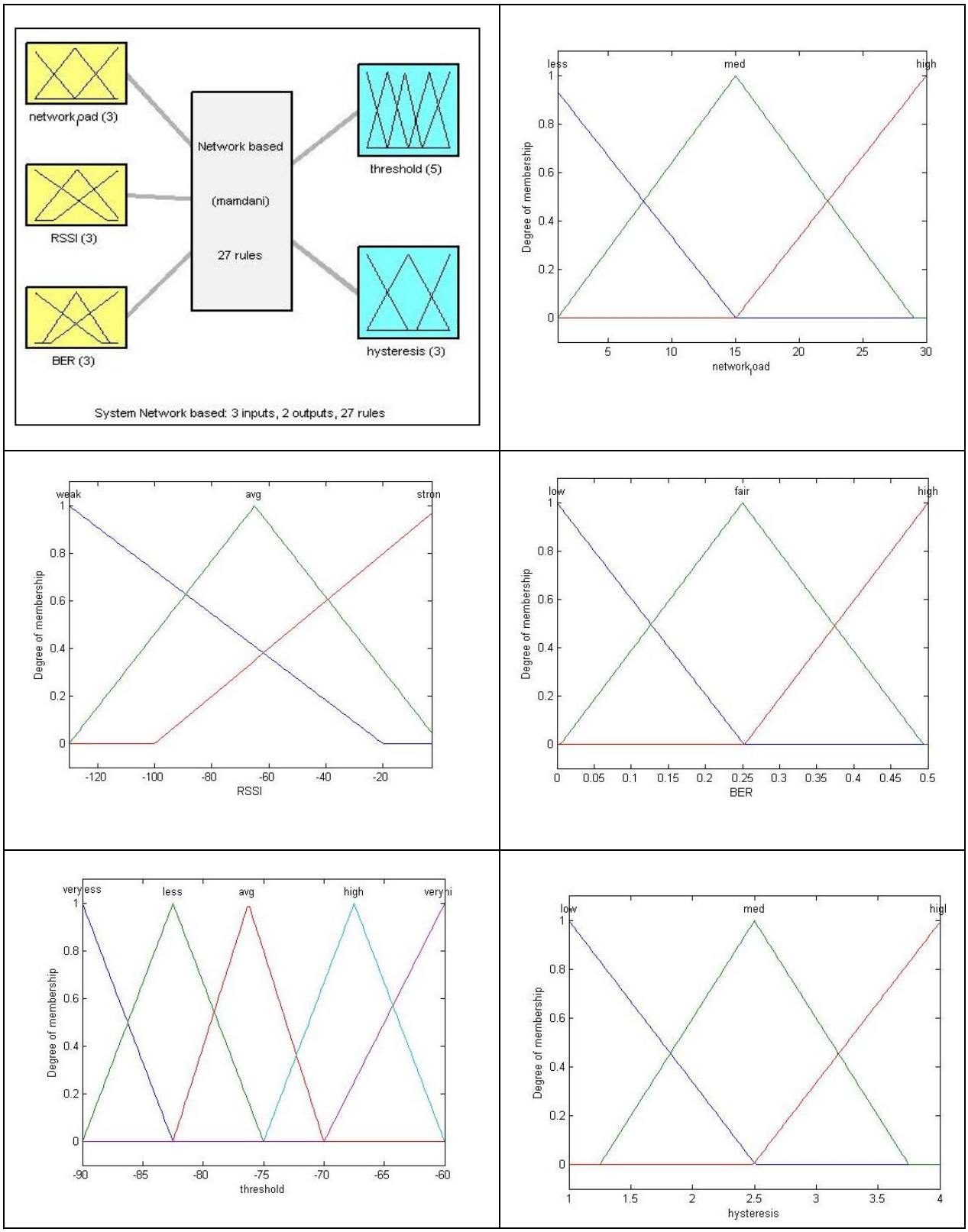

Figure 3: Fuzzy Controller for Network Initiation Handoff with RSSI, Network Load and BER Membership Functions

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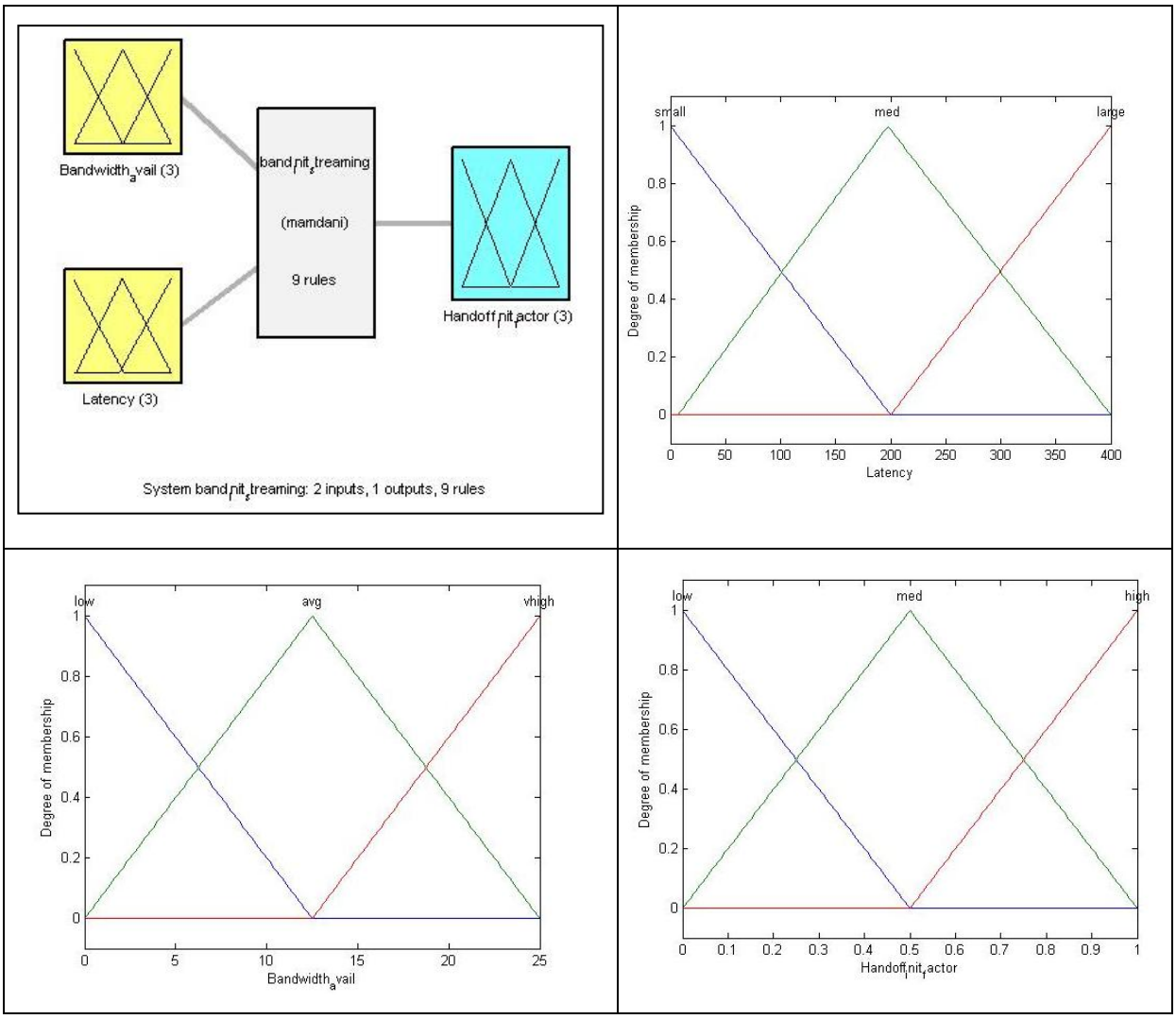
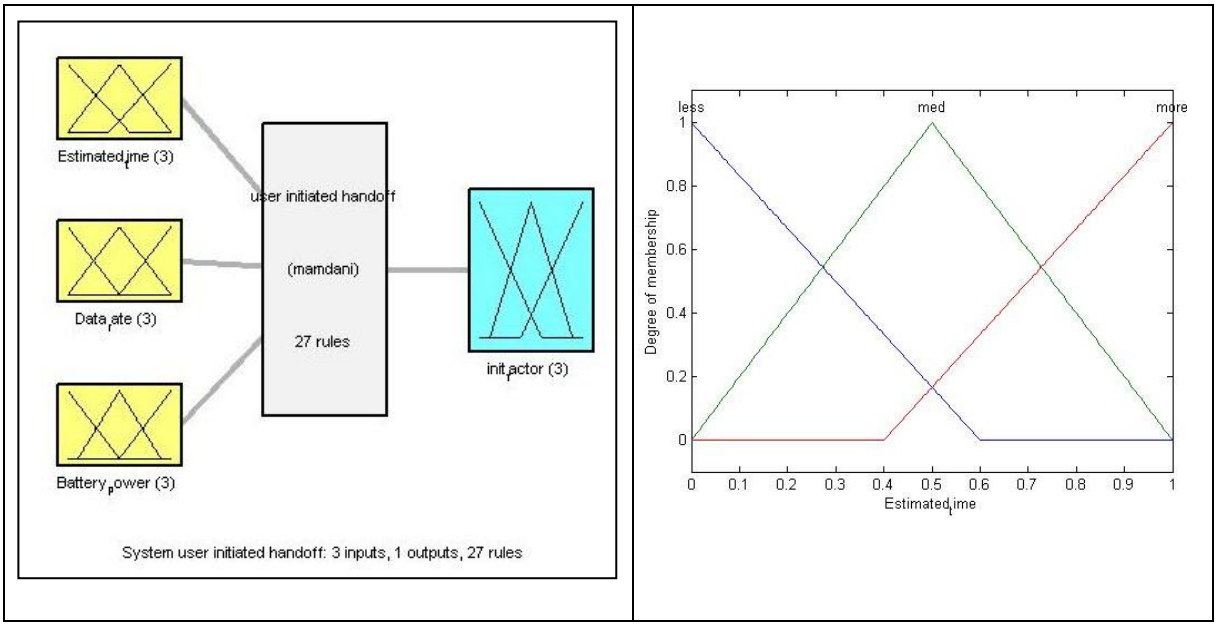


Figure 4: Fuzzy Controller for Network Initiation Handoff with RSSI, Network Load and BER Membership Functions



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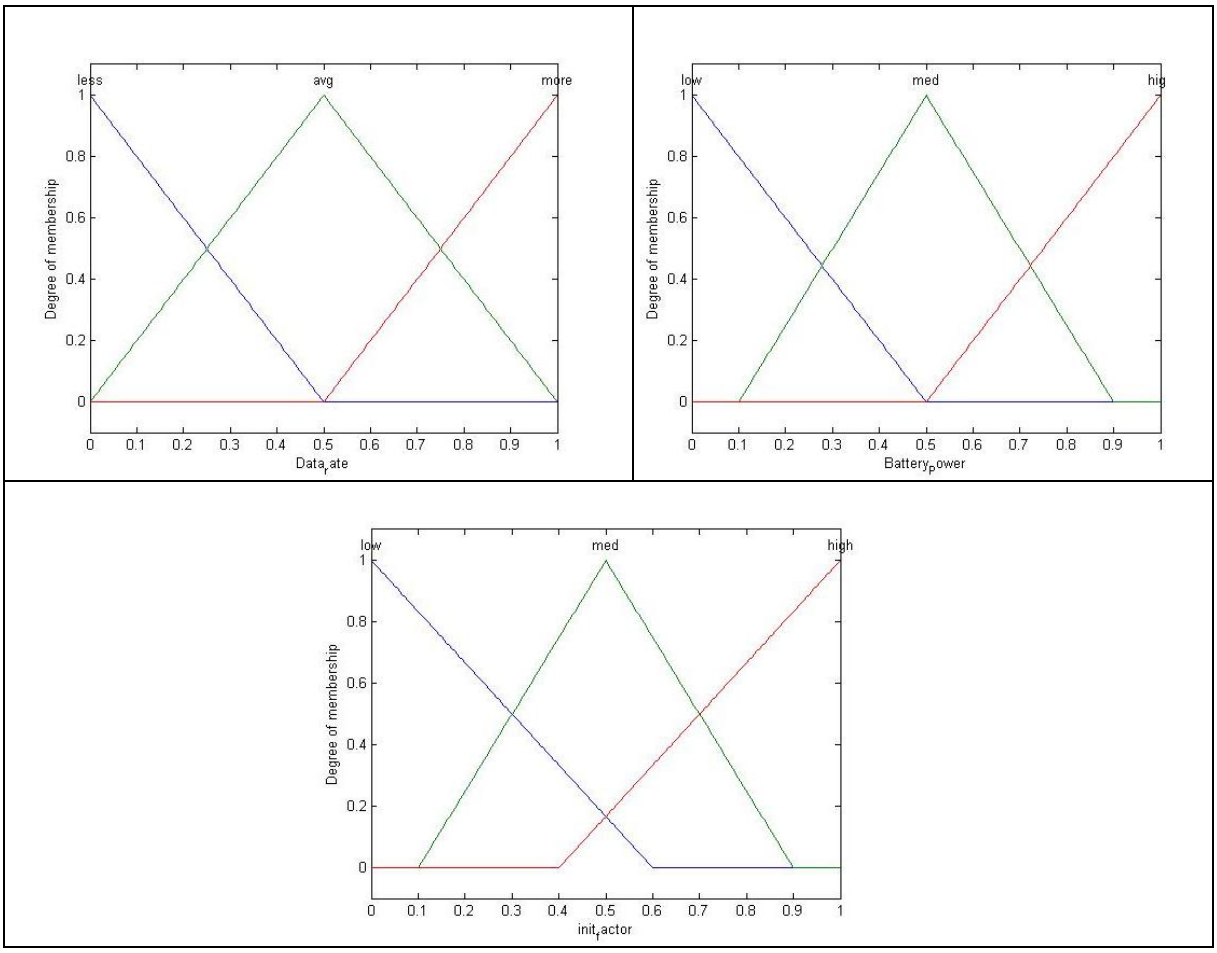
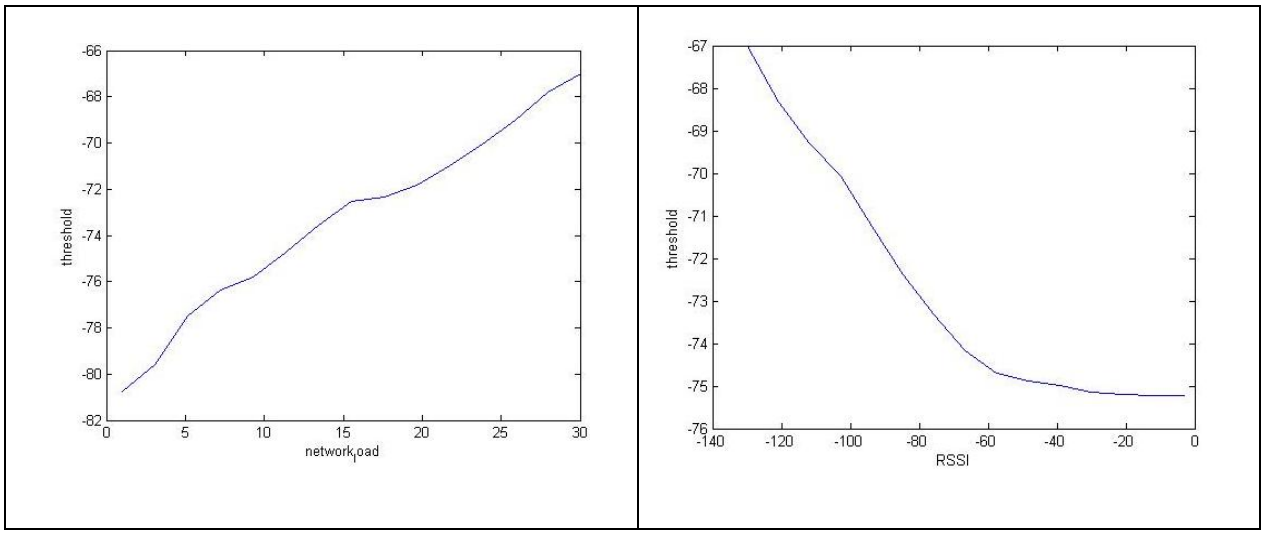


Figure 5: Fuzzy Controller for Network Initiation Handoff with RSSI, Network Load and BER Membership Functions

VI. PERFORMANCE ANALYSIS



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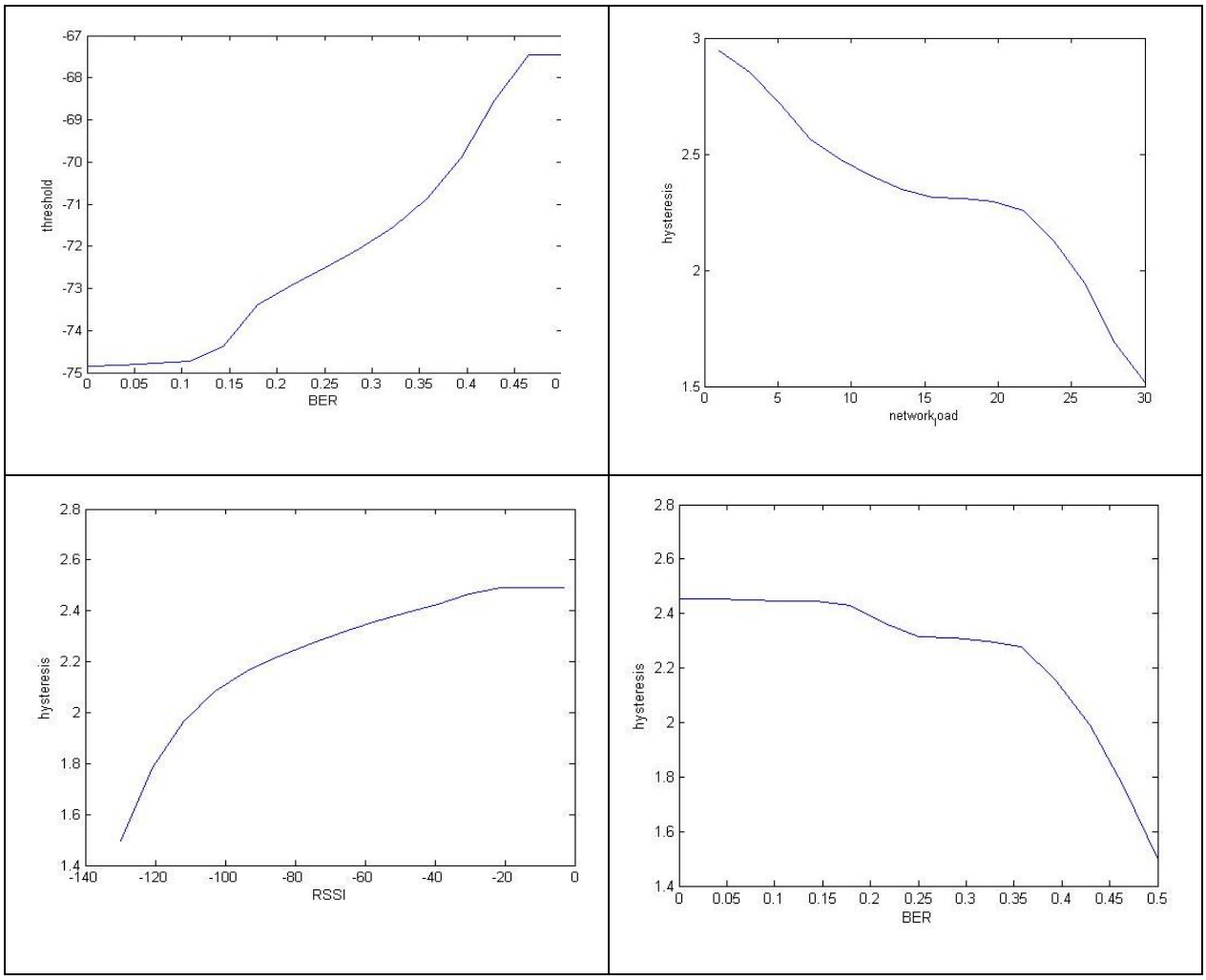

Figure 6: Relationship between different network related parameters with adaptive threshold and hysteresis.

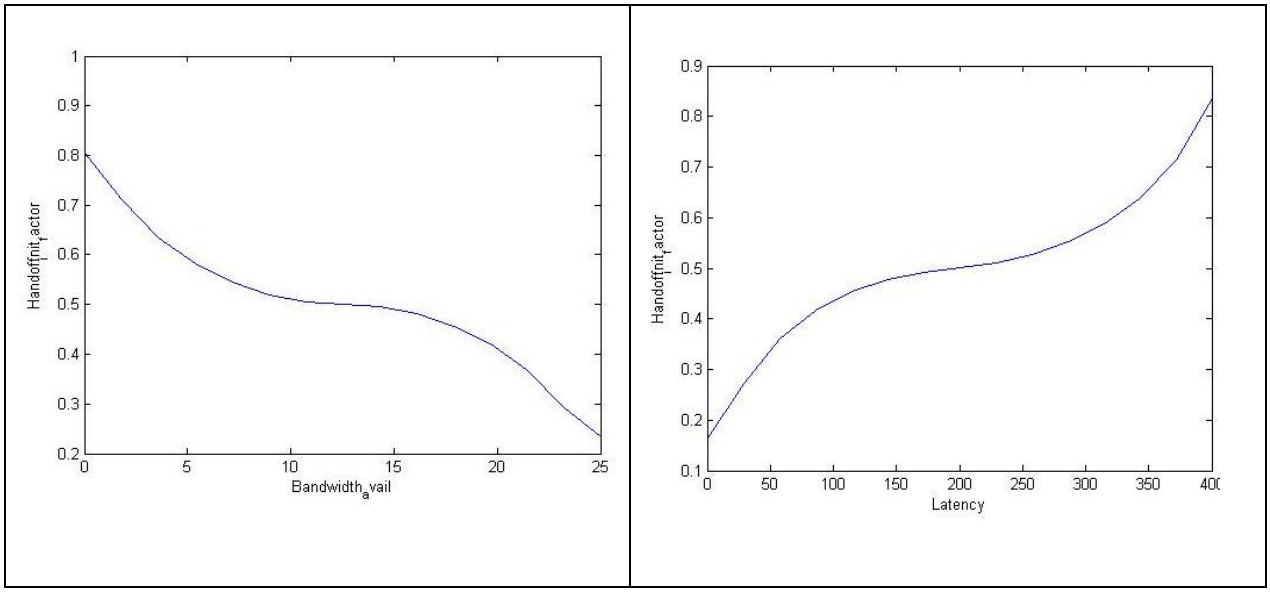

Figure 7: Relationship between different mobile or performance related parameters with handoff initiation factor

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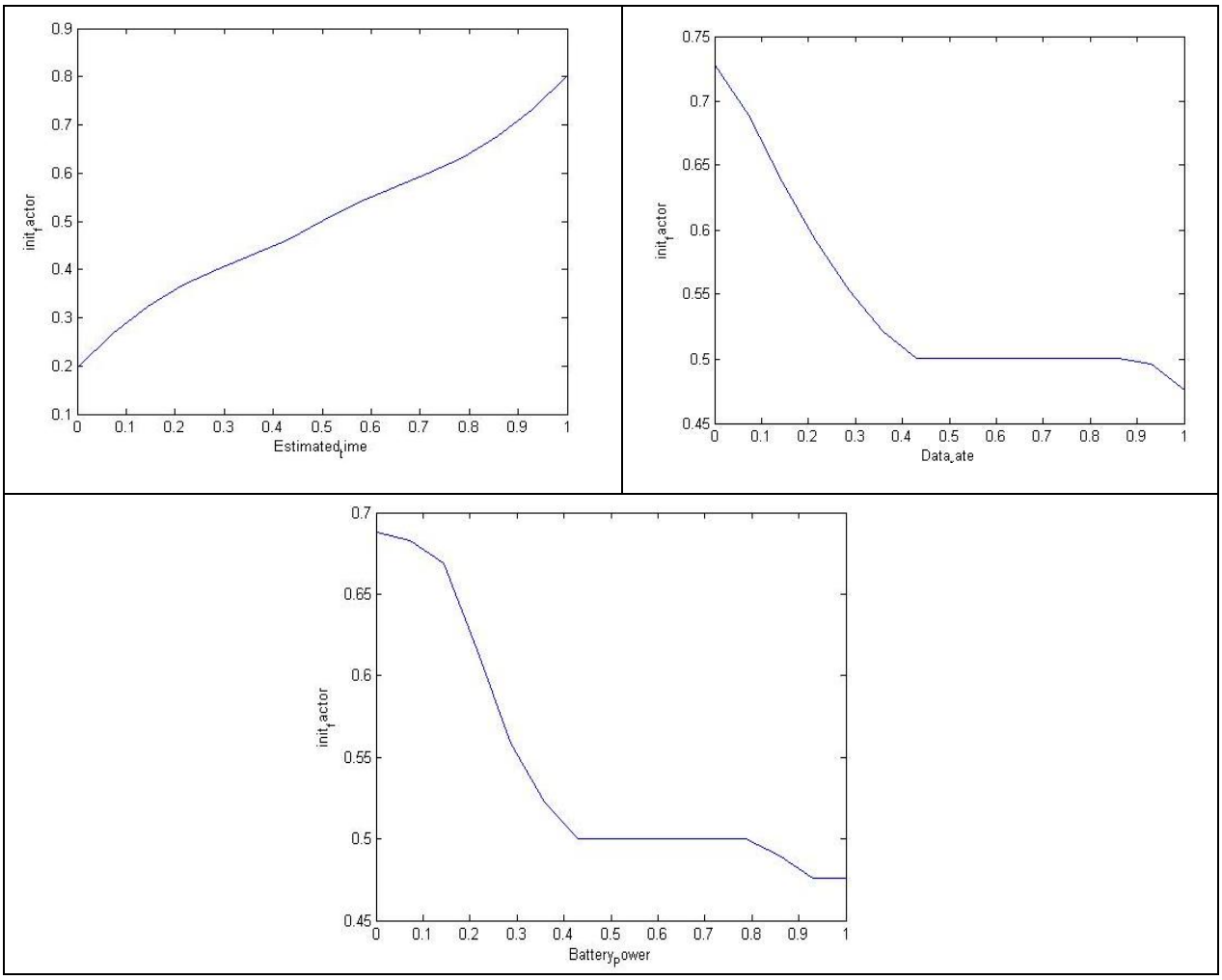

Figure 8: Relationship between different user preferences related parameters with adaptive threshold and hysteresis.

VII. CONCLUSION

This paper focuses on a handoff initiation algorithm by dynamically determining the RSSI threshold and RSSI hysteresis value from network load, RSSI and bit error rate using fuzzy logic. Many issues still exist in handoff management which are left for future consideration. There will be an escalating drift in future large-scale roaming and more attention will be focused on mechanisms which are applicable in heterogeneous networks. Finally, some open future works in this direction are:

1. Movement aware metrics can be incorporated.
2. More intelligent tools like ANFIS can be used to get more precise results.
3. Metrics can be prioritized.

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