Fuzzy Controlled Multi-metric Strategy for Flow Mobility in Heterogeneous Wireless Networks

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***Abstract*—**An unprecedented growth of Smartphone based internet and mobile services has resulted in astonishing growth in data traffic over cellular networks. This has led to foster new ideas and alternatives to alleviate the problem of congestion to deliver best Quality of Experience (QoE) to users. Different types of applications cause a different level of traffic. Hence, there is a need of smarter traffic steering schemes to manage the flow rate depending upon the availability of bandwidth. This paper presents two fuzzy controllers- low bandwidth and high bandwidth. The algorithm imbibes network intelligence in the proposed method to allow flow mobility by making use of fuzzy logic and considering the bandwidth requirement of different applications such as high throughput, low bandwidth, high bandwidth, best effort etc. The method takes three input parameters -bandwidth, data change rate, response time during signaling and data transfer, finally generating flow rate. Depending on the value of flow rate and application type, decision is taken for network switching for offloading of packets onto better QoS based network for seamless data flow. Results prove that this adaptive approach aids in reducing unnecessary handovers and packet loss.

Keywords*-mobility;flowrate; fuzzy;congestion;multi-metric.*

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I. INTRODUCTION

Tremendous data traffic growth has been witnessed by cellular industry over last decade with 5G roll ut around 2020 as surveyed in [1] and is continuously growing massively every year. Thus, posing challenges to the existing cellular networks motivating the integration and cooperation among the existing networks. The upcoming fifth generation networks are expected to overcome presnt challenges like end-to-end performance, higher capacity and coverage with reduced latency, cost and energy consumption [2][3].To meet these demands multi-tier framework is being adopted comprising of varied cell like macro, micro, Femto, Pico etc. this kind of setup will contribute in achieving required Quality of Sevice(QoS) and Quality of experience(QoE) to the users. Integration of various Radio Access Technologies (RAT) belonging to 802 family or non 802 family will offer seamless roaming in the above said multi-tier framework. A multi-modal device can connect to any of these networks by switching from its current PoA to new Point of Attachment (PoA)[4]. Conventional algorithms were based on single or few prominent metric like Received Signal Strength(RSS) or Signal to Noise Ratio(SINR), did not considered QoS , mobile node's mobility or end user's preference also the applications required level of QoS. Handoff initiation is being studied and new creative proposals are being put forward by researchers to make the process of Vertical Handoff (VHO) efficient and also reducing the unnecessary handovers. The ultimate objective of these wireless networks providing global connectivity and ubiquitous computing to the mobile nodes supporting the principle of Always Best Connected. The latest developments [5] in wireless technology helps in uninterrupted service provision supporting real-time application like video or gaming. The user's expectation is quality along with normal cost [6].

II. RELATED WORK

Node mobility and its management has become the major challenging area in current scenario [7]. Many new models and mobility frameworks are being proposed to overcome the challenge being posed by the exiting wireless networks [8]. Various layers of protocol stack are being cooperatively performing for effective decision making during mobility and new protocols are being designed for better mobility management especially in the dynamic wireless environment [9].

In [10] an exhaustive survey has been carried out to study the interference in shared spectrum being accessed by heterogeneous networks at various tiers in multi-tier framework. The existing schemes will not yield the desired level of QoS as users have varied priorities in various tiers for random channel access. Efficient traffic load balancing, minimizing SINR for prioritized users have been suggested for better throughput.

Vertical handoff has been emphasized as the most significant challenge faced during mobility and traffic offloading has again been discussed critical issue to resolve in heterogeneous environment. Networks need to operate in a cooperative fashion synchronizing efficiency in terms of capacity and coverage [12].

Researchers in [13] have emphasized multi attribute technique for network selection during vertical handoff. The existing MADM approach has been extended as Simplified-Improved Multi-Attribute Ranking Method (SI-MAAR) to expel normalization of attribute and calculation of weight. The proposed method has resolved the problem of rank reversal. MATLAB has been effectively used to implement the proposed algorithm. Use of Fuzzy logic in many such logic implementations has been extensively covered in [14].

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Serving the similar objective another VHO algorithm is proposed Vertical Handoff Necessity-Estimation(VHONE) which computes precise time for VHO ensuring quality and continuity of the existing service being utilized [15]. Many VHO have been proposed using multi-objective functions utilizing fuzzy inference system which help in computing cost functions after associating all the parameters of the available networks. Though multiple controllers have been designed but complex and massive rules increased the complexity of the algorithm and significant parameter like mobile speed was not considered leading to unfair algorithm performance. Artificial intelligence, genetic algorithms along with multi-criteria decision making gives an adaptable and scalable solution [16]. Cross layer model for interlayer cooperation and flow of information has been proposed which makes the handoff decision making efficient by involving information from various layer of protocol stack [17]. In the proposed paper fuzzy logic has been employed for designing two fuzzy controllers. The two fuzzy controllers are categorized on the basis of high and low bandwidth-based application. The proposed algorithm is application centric. It has integrated a congestion parameter and QoS parameter for handoff initialization.

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III. PROPOSED WORK

In order to alleviate congestion and better utilization of network resources, complementary network technologies and new techniques for data delivery and offloading need to be devised. Application like multimedia files, videos, gaming are commonly supported by almost all devices and being used commonly by almost all the users. The proposed solution employs two fuzzy controllers which are segregated on the type of application currently being executed.

A. *Need for bandwidth restricted controllers*

Exhaustive survey of work conducted by scholars gave an understanding about various service classes and network needs of these classes for optimal performance. Different applications consider varied attributes to measure their QoS satisfaction. The application's QoS requirement is briefly summarized in Table 1.

Table 1: Minimum QoS need of service class

Category	Delay (ms)	Jitter (ms)	Packet Loss	Bandwidth (bps)
Web browsing	< 400	N/A	Zero	<40K
VoIP-Low bandwidth	<150	<400	<1%	<64 K
Video-High Bandwidth	<100	<400	<0.01%	<3 M
FTP	Med	N/A	Zero	High

From Table1 bandwidth can be observed as one of the prime measure to satisfy an applications requirement in terms of QoS. The Initialization of VHO begins with applications request for flow rate. If the required flow rate is high in comparison to existing bandwidth new flow rate is computed and application transmit as per the newly compute flow rate.
Figure 1 summarizes the steps involved in flow rate computation where the parameters involved are network bandwidth, computation of RTT, data change rate and response from end system. Since the logic is being implemented through MATLAB's fuzzy logic toolbox the considered range for various parameters is normalized.

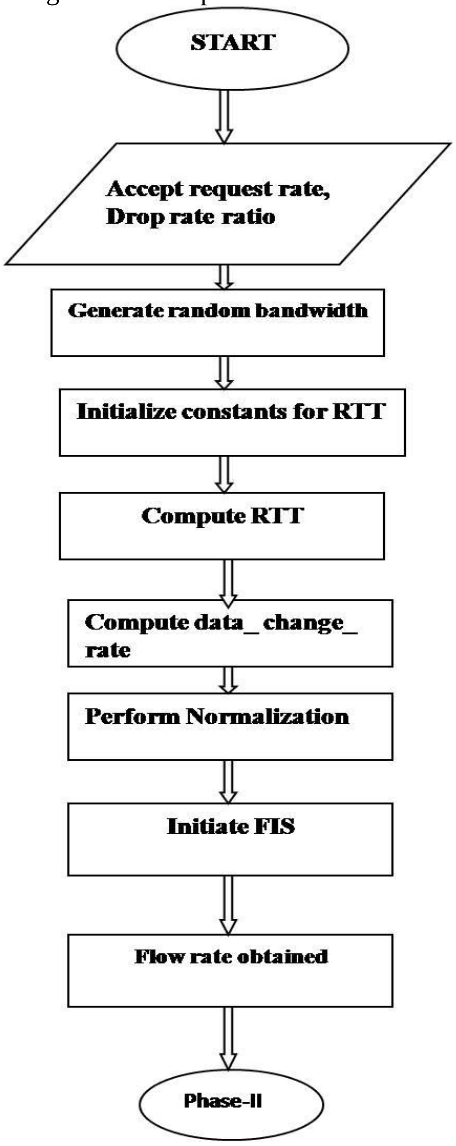

Figure 1: Flow Chart for Flow Rate Computation

Based on the requirement of application proposed model is categorized into two modules:

- Fuzzy controller for application with low bandwidth requirement
- Fuzzy controller for application with high bandwidth requirement

B. *Low Bandwidth Application fuzzy controller*

For flow rate computation, two independent fuzzy controllers have been proposed. Controller as shown in Figure 2 is meant for application desirous of low bandwidth i.e 1Mbps to 15Mbps.

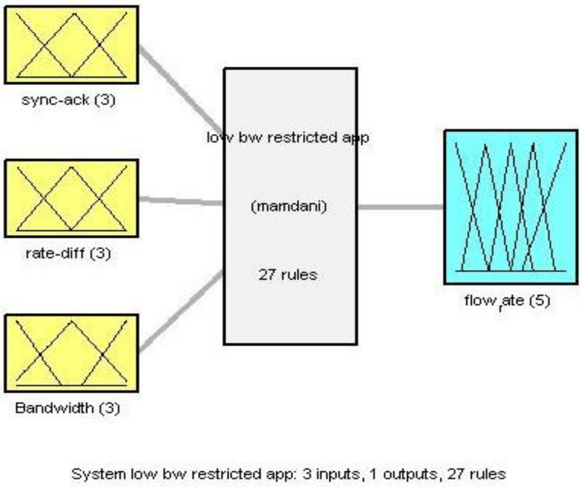

Figure 2: Low Bandwidth Model

Sync_ack, bandwidth and rate_diff are the prime inputs to the controller. Sync_ack refers to end to end response time and its value is normalized. It is computed as following [18].

Sync_ack=(sqrt(3/2)*packetSize)/(RTT*sqrt(T_PacketDropRate))

Round trip time is obtained from the following expression [19].

RTT =(1-alpa)*rtts+alpa*rttm

Rate_diff represents the varying data rate at two time intervals and is computed with the following expression [18].

Rate_diff=(T_lastSendRate-T_lastTimeRate2)/elapsedTimeLong

Bandwidth varies from application to application and is randomly generated. Once the input parameters are normalized, processed and ready for FIS, controller triggers fuzzy inference system with the input parameters as already discussed. The output parameter, flow rate (normalized value) is preserved as last rate. In order to acquire the actual value of flow rate, the normalized value is multiplied as a percentage of bandwidth.
The membership function depicts the range of input and output values Figure 4(a) exhibits bandwidth from 0-1, showing weak and healthy link status. Figure 4(b) exhibit sync_ack , an input parameter indicating response from end system. The membership acquires range from 0 to 1. If the response is weak the link is underutilized 0) and higher range of sync_sck reveals best link utilization. Another significant input to the controller is rate_diff as in Figure 4(c) indicating data rate variation over the link. Low range signifies restricted data rate also acquires -1. When, rate_diff is less governed it acquires positive range (1). Flow_rate is an output parameter acquiring five different ranges. '0' marks congested link and '1' non congested link as seen in Figure 4(d).

Framing of rules have been done with the given objectives; a sample of it is as shown in Table 2

Table 2: Sample rule sample-low bandwidth controller

	Sync_ack	Bandwidth	Rate_diff	Flow_Rate
1	Low	Low	Decreasing	Low
2	Low	Mid	Decreasing	Low
⋮	⋮			
26	High	Mid	Increasing	High
27	High	High	Increasing	High

- With low sync_ack , reduced rate_diff and low bandwidth, the flow_rate acquires low range
- With low sync_ack , fair rate_diff and low bandwidth, the flow_rate acquires mid range
- If sync_ack is mid, rate_diff is increasing and bandwidth is low, the flow_ rate is set to mid.

Rule viewer helps in monitoring the behavior of each rule and a defuzzified output value can be observed vertical bold line.

27 rules are framed which generates an optimal flow_rate as can be seen through Figure 3.

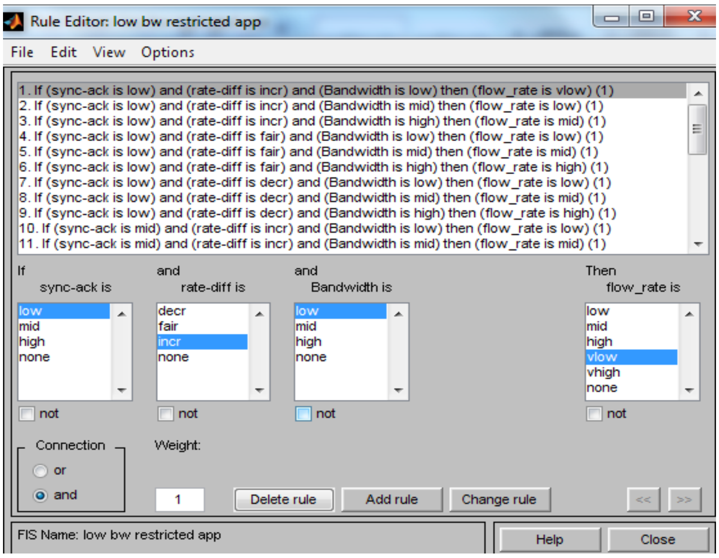

Figure 3: Rule Editor

Table 3 shows the possible range for formulating the rules.

Table 3 : Possible range combination

Rate_diff	Sync_ack	bandwidth	Flow_rate
Decr	low	Low	Vlow
Fair	mid	Mid	Low
Incr	high	high	Mid
			high
			vhigh

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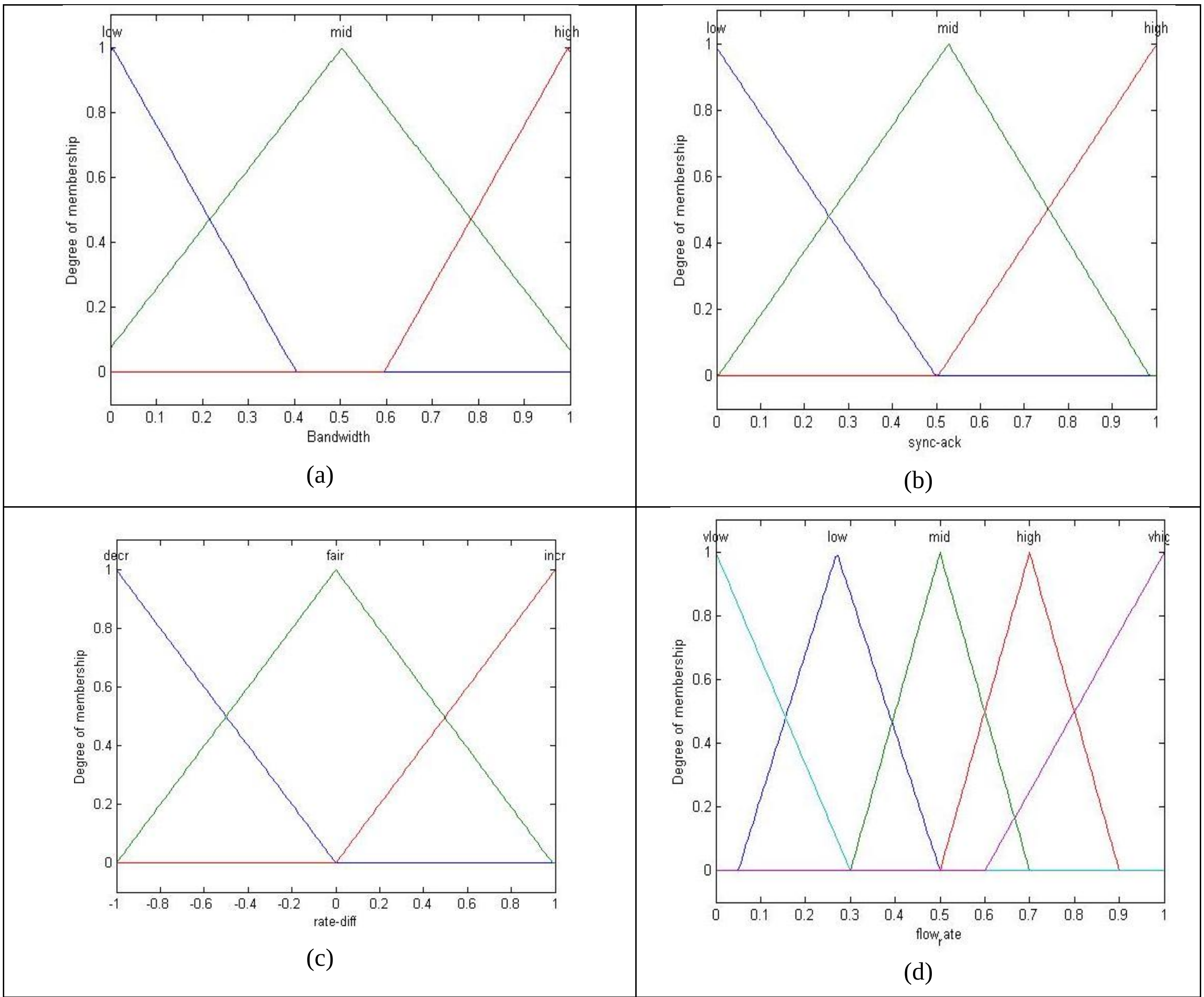

Figure 4: Input Membership functions a)bandwidth b) sync_ack c) rate_diff Output membership function d) flow rate

The surface view exhibit the effect of input parameters on the output. Figure 5(a) indicates the variation in flow_rate based on rate_diff and sync_ack. Figure 5(b) indicates the variation in flow_rate based on bandwidth and sync_ack. Figure 5(c) indicates variation in flow_rate based on rate_diff and bandwidth

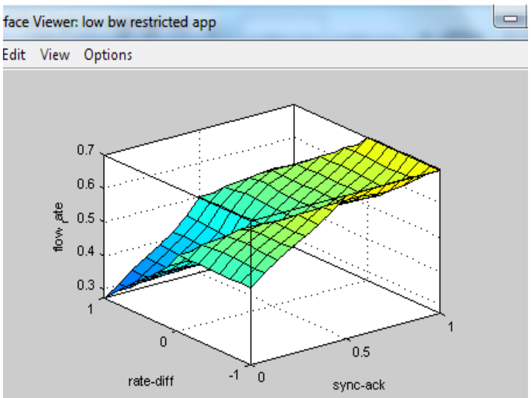

Figure 5: (a)

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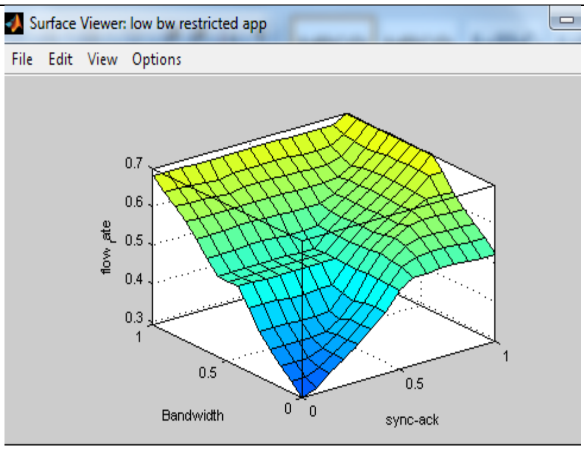
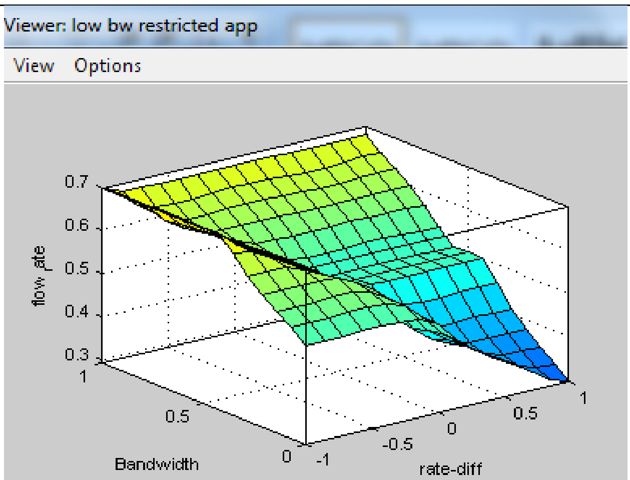


(b)



(c)

Figure 5

(a) **indicates the variation in flow_rate based on rate_diff and sync_ack**

(b) **variation in flow_rate with sync_ack and Bandwidth**

(c) **variation in flow_rate with rate_diff and bandwidth**

Varying range of sync_ack in multiple repeats shows consistent rise in flowrate with increased Sync_ack. Bandwidth and flow_rate have been proportionately changing.

C. High bandwidth application controller

Similar to low bandwidth fuzzy controller a high bandwidth controller is designed in which similar input parameters exists but range and membership function differs according to high bandwidth desirous application i.e 15Mbps to 30Mbps as shown in Figure 6. The three input parameters are sync_ack, rate_diff and bandwidth. Output parameter is flow rate.

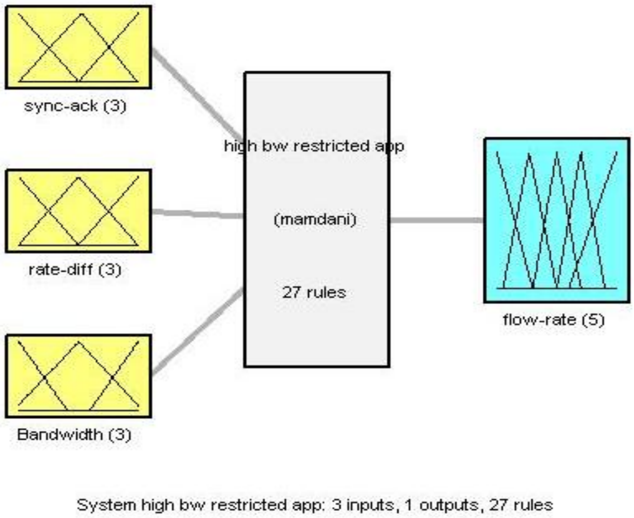


Figure 6: High Bandwidth Controller

Sample rules for the high bandwidth controller can be observed through the following Table 4.

Table 4: high bandwidth controller-sample rules

	rate_diff	sync_ack	bandwidth	Flow_rate
1	Decreasing	Low	Low	Low
2	Decreasing	Low	Mid	Low
		: : :		
26	Increasing	Mid	High	Mid
27	Decreasing	High	Low	Low

Figure 7(a)(b)(c) exhibits effect of bandwidth and end system response on flow rate which increases with the rise in the two input parameters. The surface view shows a very clear fall and rise of flow_rate with the varying input range of rate_diff and bandwidth.

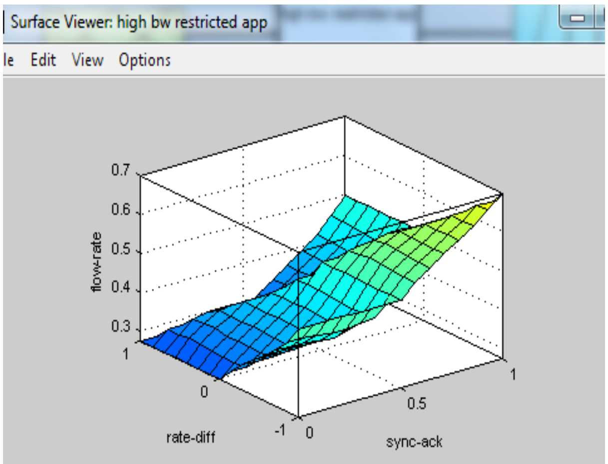
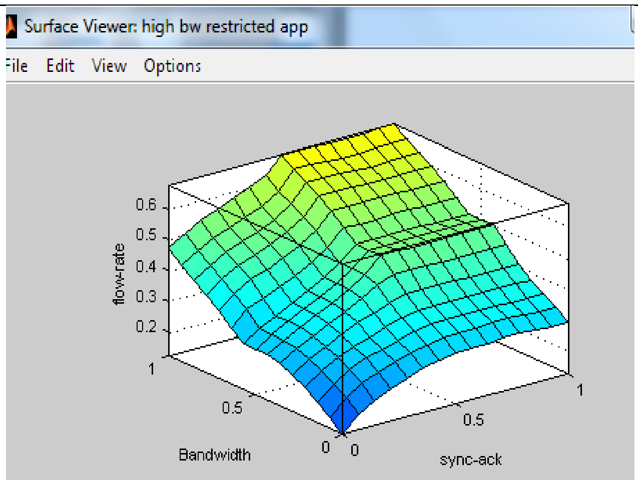
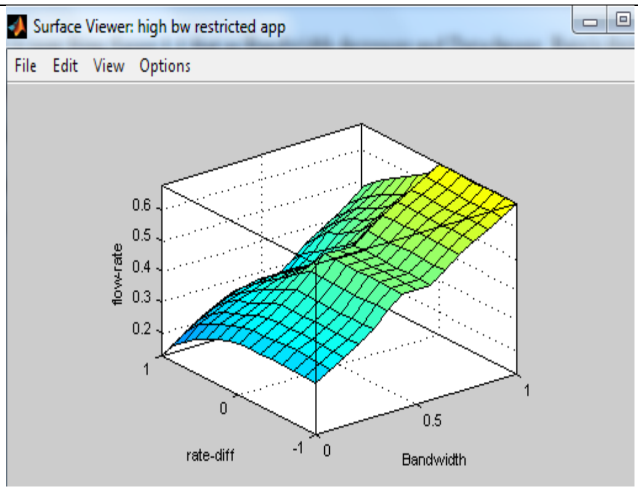


Figure 7(a): variation in flow_rate with sync_ack and rate_diff and sync_ack



(b)



(c)

Figure 7: (b) variation in flow_rate based on Bandwidth and sync_ack
(c)variation in flow_rate with rate_diff and bandwidth

IV. Conclusion

The two controllers have satisfactorily fulfilled the computation of flow rate which will be a significant factor for handoff initiation. If the existing network posses a normalized flow_rate of 0.4 or higher the application will continue to execute on the current network. But if the flow_rate falls below 0.4 the proposed logic will further check QoS parameter of the existing and neighbour networks. The computed flow_rate can further serve as an input parameter to network simulator to make the algorithm more adaptive and handle the real time scenario during network switching and vertical handoff

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