Handover Detection of WAN Using Fuzzy Inference System

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Abstract— **In Wide Area Network (WAN) users experience frequent handover while on a high-speed vehicle. In 4G and 5G mobile communication, the coverage area of cells is reduced compared to 3G systems therefore handover occurs frequently. An intelligent handover decision is essential to protect unnecessary handover to reduce network overhead on control plane i.e. the activities of control channels. Again, handover failure or forced termination deteriorates the QoS of the network on user plane i.e. the data flow of traffic channels. In this paper a Fuzzy Inference System (FIS) is developed to make the correct decision of handover. Here four fuzzy variables: velocity of mobile station (MS), SNR of received signal, SINR of received signal and acceleration of MS are used, where each of the variables possess 3 to 5 linguistic values. Around 200 Fuzzy rules are applied to link crisp and fuzzy values. Finally, four defuzzification methods: Centroid, Bisection, MOM and LOM are used to take the decision of handover and a comparison is made among them in both tabular form and using surface plot. All of the four methods ensure correct decision of above 92%.**

Index Terms— **Syntax of fuzzy variables, surface plot, MOM, LOM and SINR.**

I. Introduction

In wireless networks, handover plays a crucial role in maintaining seamless connectivity for mobile devices. This paper proposes a Fuzzy Inference System-based approach for handover detection using four parameters: SNR, SINR, velocity, and acceleration. Additionally, we have shown a comparison of the performance of four different defuzzification methods to determine the most effective approach. A lot of research paper is found regarding detection of appropriate handover decision. Only few of them, relevant to the concept of the paper are discussed here to find out the research gap with the proposed methodology of the paper.

Taking of appropriate handover decision and to reduce the ping-pong affect in mobile communication is a vital issue for 5G network because of adverse effect of mm wave and small coverage area of outdoor gNB. Above two problems under high mobility of users and frequent handover is discussed in [1-3]. A fuzzy logic-based handover technique was used by the authors of [4] to calculate the speed and direction of the user equipment (UE) relative to the base station as a single metric to prevent the ping-pong effect. The authors of [5] proposed an adaptive neuro-fuzzy controller for 5G heterogeneous networks considering three variables: the user's speed (S), distance (D), and received signal strength indicator (RSSI). The similar analysis is found in [6], which used another three parameters: the fuzzy logic-based handover system presented by the authors considered distance, change in signal strength, and the signal strength of the neighbor. In order to avoid the ping-pong effect, they decided to use the RW model. In [7], the authors introduced a new fuzzy logic technique to determine the best handover margin (HOM) and the right time-to-trigger (TTT). The bandwidth, load, and velocity are combined with other parameters in [8] to improve handover performance. In [9], An adaptive system ANFIS was proposed with parameters: data rate, cost and RSSI for minimizing the handover failure. This adaptive neuro-fuzzy algorithm optimizes the performance of handover. Authors proposed a speed-aware handover system in [10] based on fuzzy logic which consists of three FLCs (Fuzzy Logic Controllers). The FLC1 determines the speed of MN, FLC2 makes handover decision for slow speed users and FLC3 makes decision for high speed users. A new concept of handover decision is found in [11], where authors described a fuzzy inference scheme that will help to make the decision for handover in heterogenous network wireless WAN and wireless LAN. Here the input data is taken from both user and the system to evaluate three parameters: Bandwidth, RSSI and network for evaluating the values and make a decision if handover is performed or not. In [12-13] authors proposed a vertical handover algorithm that takes predicted RSS as parameter along with velocity, current RSS and available bandwidth. They used forward differential algorithm for calculating predictive RSS and applied pre-decision method for filtering out unnecessary data. The fuzzy logic principle is applied on the decision algorithm FNDQ for both UMTS and WLAN handover decision. In [14], authors proposed a hybrid ANFIS for minimizing the handover failure that combines two methods: Fuzzy Logic System (FLS) and Artificial Neural Network (ANN). The three input parameters taken for ANFIS structure are: signal to inference ratio (SIR), traffic difference (TR) and speed of mobile (VEL). The performance of this adaptive network-based system is done through evaluation of MSE, the rate of handover failure and QoS. Finally, three ML algorithms: intelligent Intersystem Handover (IH), Fuzzy Logic Based vertical handover (FLBVH) and ANFIS are found in [15] to measure handover delay and throughput of the Heterogeneous Wireless Networks.

All of the above papers, worked on different parameters for fuzzy inference systems of handover detection but the parameter 'acceleration of an MS' is found unexplored. None of above papers deal with the combination of SNR, SINR, Velocity and Acceleration as the input parameters of FIS. Therefore, the proposed model used highest possible linguistic variables hence highest possible fuzzy rules are used in this paper to acquire accurate decision of handover. For the defuzzification, four methods were used: Centroid, Bisection, MOM, and LOM and the outcomes of all the four techniques are compared with the real decision.

The rest of the paper is organized as: section 2 presents the basic theory for fuzzy inference systems and the process of handover, section 3 presents the methodology of the proposed solution, section 4 provides the result of entire work and section 5 concludes the analysis of the paper with few future recommendations.

II. Theoretical Analysis

This section deals with theoretical analysis of FIS, handover mechanism of WAN and incorporation of handover variables with the FIS.

A. Fuzzy Inference System

The fuzzy inference system consists of three components: fuzzification, inference engine and defuzzification as shown in fig.1. The fuzzification converts the crisp input or numerical values (against a crisp variable) to fuzzy values using MFs. The inference system converts fuzzy input values to fuzzy output values using several fuzzy rules based on 'if-then statements' and logical operators. The defuzzification block again converts the fuzzy output values to crisp values are found in [16-17].

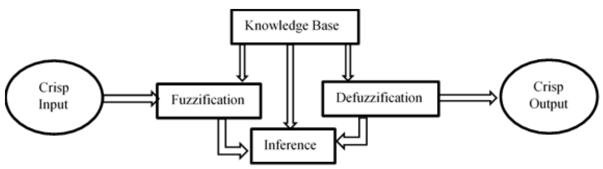


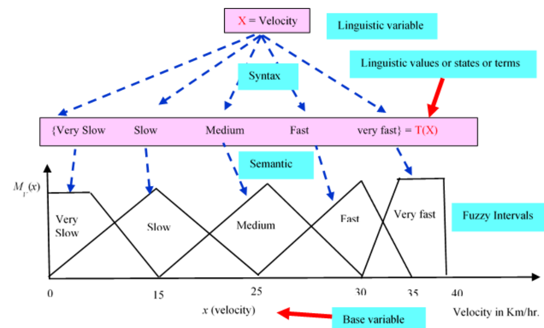
Fig.1. Fuzzy Inference System

B. Handover Procedure

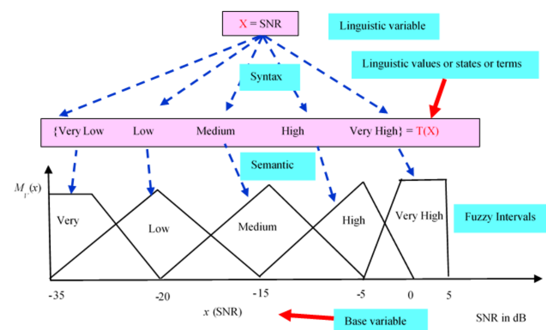
In mobile cellular network, when a user crosses the cell boundary while in conversation needs handover. In this case a new traffic channel is allocated for the user against the base station (BS) of new cell and the old traffic channel of the previous cell is released by the user. The operation is done by BSC in 2G, RNC by 3G, S-GW by 4G and AMF by 5G respectively. A large number of factors are considered to take the final decision of handover. If the decision is taken with some delay then the received signal strength of the user will fall below the threshold and handover will be failed, called forced termination. In mobile cellular network the received signal strength (in SNR or SINR) of mobile station (MS) decreases with increase in distance between MS and BS. When a user arrives at the cell boundary its signal strength reaches closed to the threshold value to keep the call in-service. The base station controller (BSC) in 2G, radio network controller (RNC) in 3G, serving gateway (S-GW) in 4G and Access and Mobility Management Function (AMF) in 5G takes the decision about handover. An intelligent decision is essential to take the handover at the right time and at the right position of MS. Otherwise unnecessary handover will take place several times, which makes the control channels of the system overloaded; even handover failure due to delayed decision will make mental pressure on the users due to drop of call in the midst of communication. The rapid reduction of SNR, SINR or strength of received signal indicates that the MS is moving out of the coverage of the cell, therefore handover need to be initiated by the control channels. In this paper velocity, acceleration, SNR and SINR of MS is monitored by the FIS to take the decision of handover.

III. Methodology

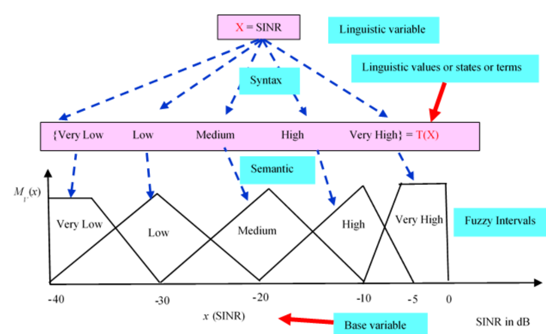
In a fuzzy system, the linguistic variable and corresponding values are related by some syntax rules. Again, semantic in FIS provides the numerical range of fuzzy values through its MFs. The syntax and semantics of the four fuzzy variables used in this paper are shown in the fig. 2(a)-(d) based on the concept of [18-19].



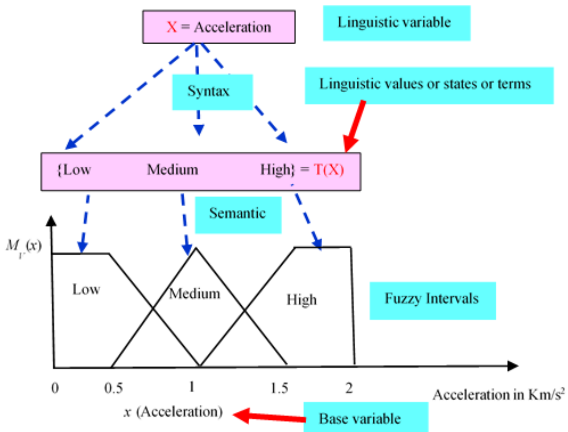
(a) Syntax and semantics of fuzzy variable Velocity



(b) Syntax and semantics of fuzzy variable SNR



(c) Syntax and semantics of fuzzy variable SINR



(d) Syntax and semantics of fuzzy variable Acceleration

Fig.2. Syntax and semantics of fuzzy variables

A. Design steps

a) Choose the fuzzy variables: Velocity, Signal to Noise Ratio (SNR), Signal to Interference and Noise Ratio (SINR) and Acceleration.

b) Select input fuzzy values against each fuzzy variable as: Velocity → Very High (*VH*), High (*H*), Medium (*M*), Low (*L*) and Very Low (*VL*).
Signal to Noise Ratio (SNR) → Very High (*VH*), High (*H*), Medium (*M*), Low (*L*) and Very Low (VL).
Signal to Interference Ratio (SINR) → Very High (*VH*), High (*H*), Medium (*M*), Low (*L*) and Very Low (*VL*).
Acceleration → High, Medium, Low.

c) Select output fuzzy values against the fuzzy variable: Handover → Handover (*H*), No Handover (*NH*).

d) Choose the Membership Function (MF) and numerical range of the base variable against each fuzzy variable.

e) Choose fuzzy rules to relate input and output fuzzy variable/value.

f) Select defuzzification methods.

g) Apply test datasets to Fuzzy Inference System (FIS).

h) Evaluate % of error from the test data set.

i) Compare % of error for Centroid, Bisection, LOM and MOM methods.

j) Show the surface plot relating input and output fuzzy variables.

The outcomes of this subsection are shown in result part of the paper.

IV. Result

The complete FIS of the paper is shown in fig. 3 and the MFs of corresponding input and output fuzzy variables are shown in fig. 4(a)-(e). About 300 fuzzy rules are used in this paper and few of them are shown in fig. 5. Verification of Fuzzy rules for four cases of defuzzification is shown in fig. 6(a)-(d) and fig. 7(a)-(d) taking two test input vectors: [5; -5; -6; 1] and [15; -25; -36; 2]. In this paper four de-fuzzification methods (i) centroid (ii) Bisection (iii) MOM (iv) LOM are considered, where LOM gives the best results i.e. makes sharp division between HO and NHO.

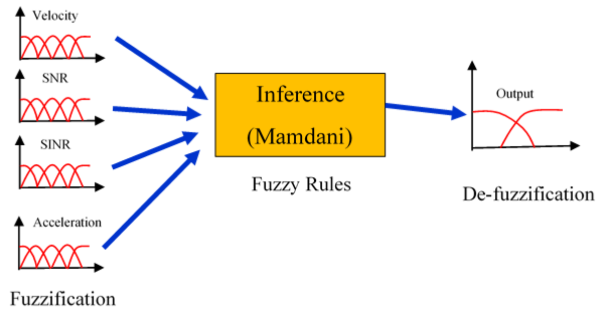
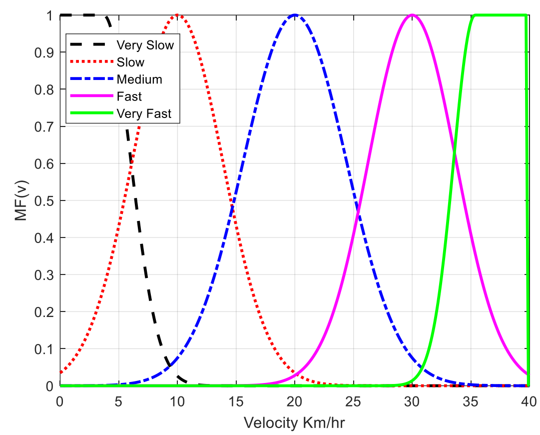
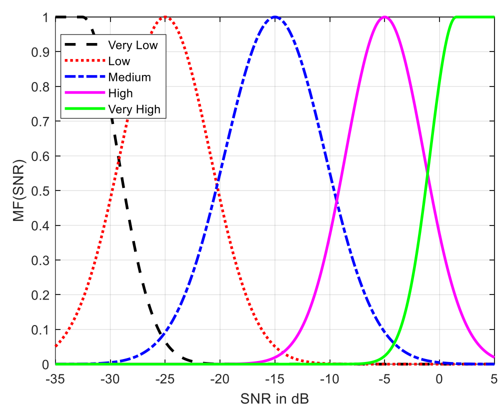


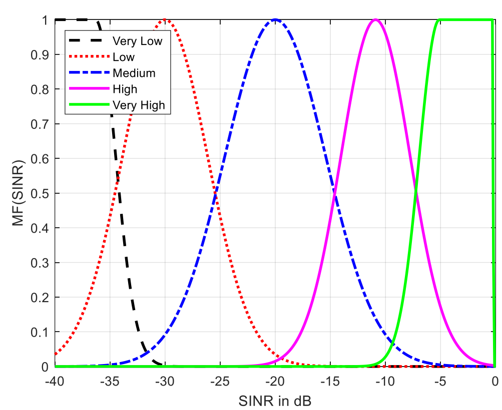
Fig.3. FIS of handover under WAN



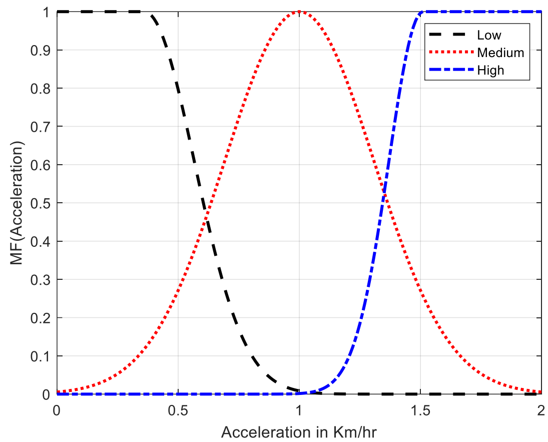
(a) MF of velocity



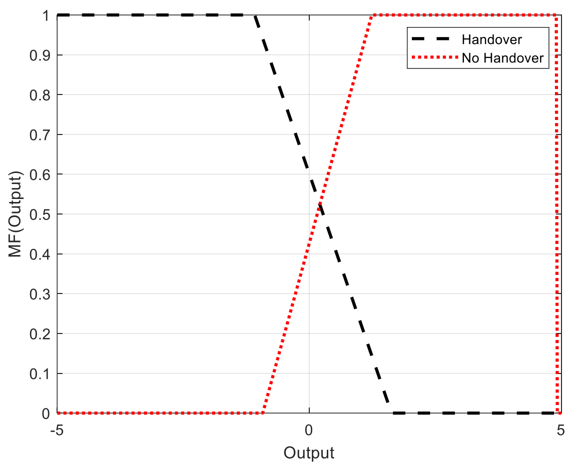
(b) MF of SNR



(c) MF of SINR



(d) MF of Acceleration

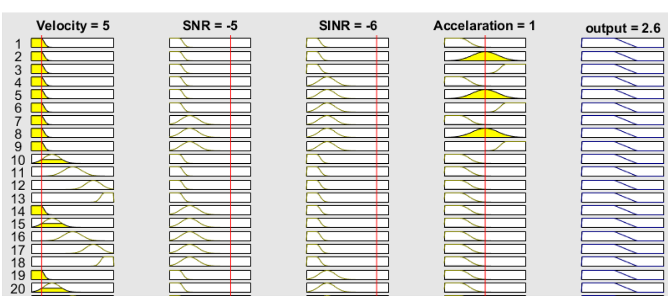


(e) MF of output

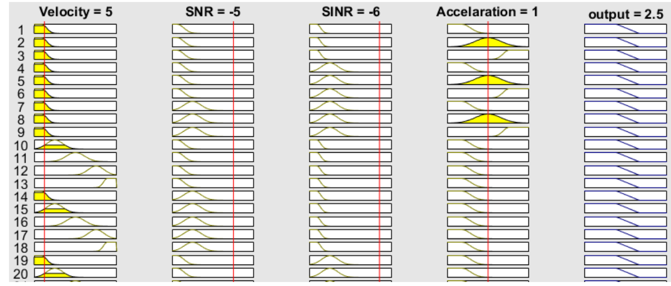
Fig.4. MFs of Fuzzy input and output variables

1. If (Velocity is VerySlow) and (SNR is VeryLow) and (SINR is VeryLow) and (Accelaration is Low) then (output is Handover) (1)
2. If (Velocity is VerySlow) and (SNR is VeryLow) and (SINR is VeryLow) and (Accelaration is Medium) then (output is Handover) (1)
3. If (Velocity is VerySlow) and (SNR is VeryLow) and (SINR is VeryLow) and (Accelaration is High) then (output is Handover) (1)
4. If (Velocity is VerySlow) and (SNR is VeryLow) and (SINR is Low) and (Accelaration is Low) then (output is Handover) (1)
5. If (Velocity is VerySlow) and (SNR is VeryLow) and (SINR is Low) and (Accelaration is Medium) then (output is Handover) (1)
6. If (Velocity is VerySlow) and (SNR is VeryLow) and (SINR is Low) and (Accelaration is High) then (output is Handover) (1)
7. If (Velocity is VerySlow) and (SNR is Low) and (SINR is Low) and (Accelaration is Low) then (output is Handover) (1)
8. If (Velocity is VerySlow) and (SNR is Low) and (SINR is Low) and (Accelaration is Medium) then (output is Handover) (1)
9. If (Velocity is VerySlow) and (SNR is Low) and (SINR is Low) and (Accelaration is High) then (output is Handover) (1)
10. If (Velocity is Slow) and (SNR is VeryLow) and (SINR is VeryLow) and (Accelaration is Low) then (output is Handover) (1)
11. If (Velocity is Medium) and (SNR is VeryLow) and (SINR is VeryLow) and (Accelaration is Low) then (output is Handover) (1)
12. If (Velocity is Fast) and (SNR is VeryLow) and (SINR is VeryLow) and (Accelaration is Low) then (output is Handover) (1)
13. If (Velocity is VeryFast) and (SNR is VeryLow) and (SINR is VeryLow) and (Accelaration is Low) then (output is Handover) (1)
14. If (Velocity is VerySlow) and (SNR is Low) and (SINR is VeryLow) and (Accelaration is Low) then (output is Handover) (1)
15. If (Velocity is Slow) and (SNR is Low) and (SINR is VeryLow) and (Accelaration is Low) then (output is Handover) (1)

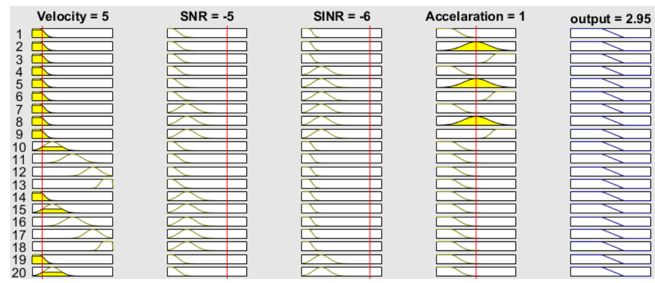
Fig.5. Few Fuzzy rules of the FIS



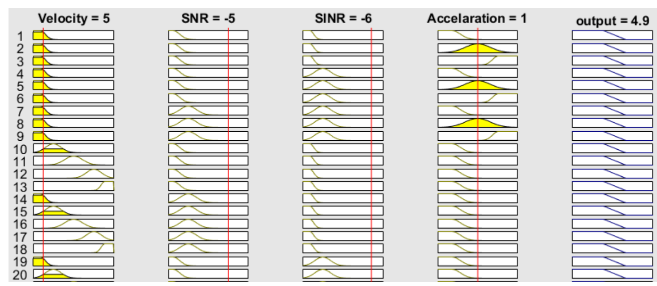
(a) Centroid



(b) Bisection

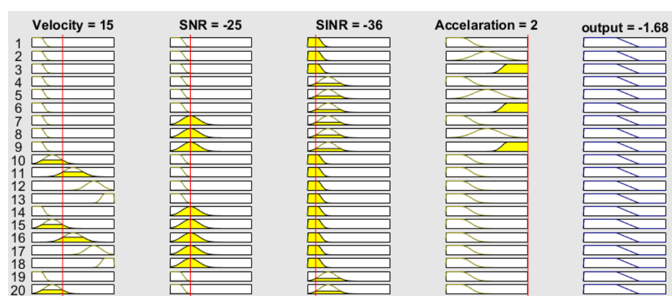


(c) MOM

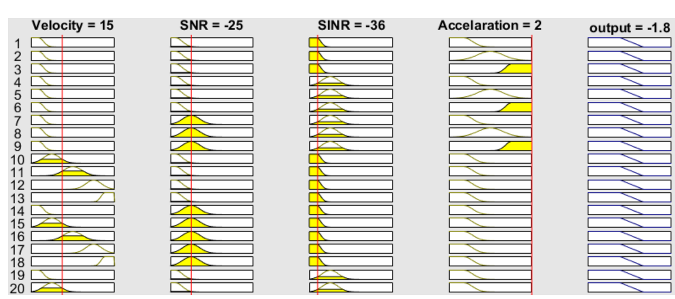


(d) LOM

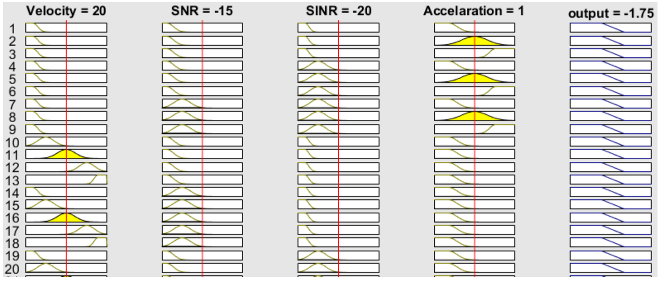
Fig.6. Output of FIS for the test vector [5; -5; -6; 1]



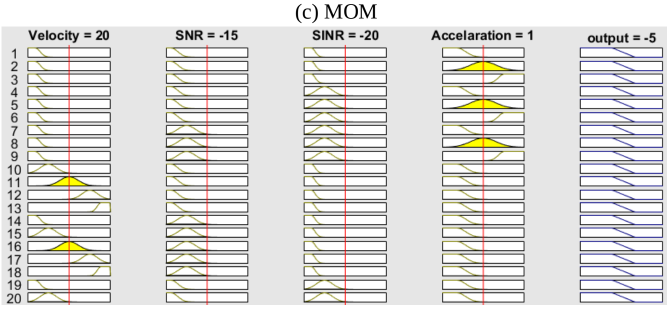
(a) Centroid



(b) Bisection



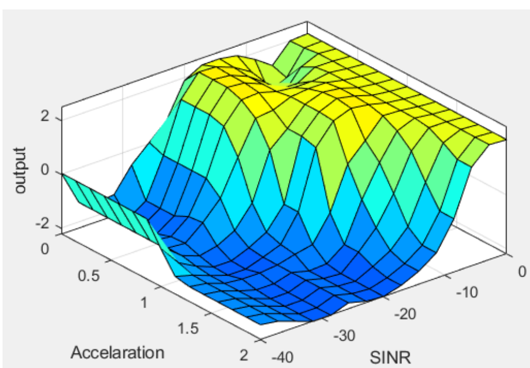
(c) MOM



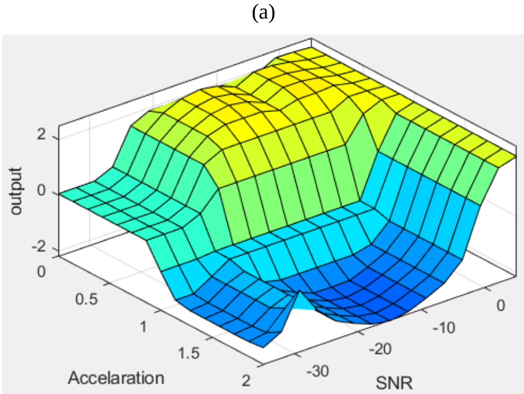
(d) LOM

Fig.7. Output of FIS for the test vector [15; -25; -36; 2]

The variation of Fuzzy output variables (HO and NHO) against input variables are visualized from surface plot of the centroid method as shown in fig. 8(a)-(f). A similar result of the LOM method is shown in fig. 9(a)-(f). The centroid method provides smooth variation of output against input variables. The sharp variation of Fuzzy output is found from LOM, from the comparison fig. 8 and 9.



(a)



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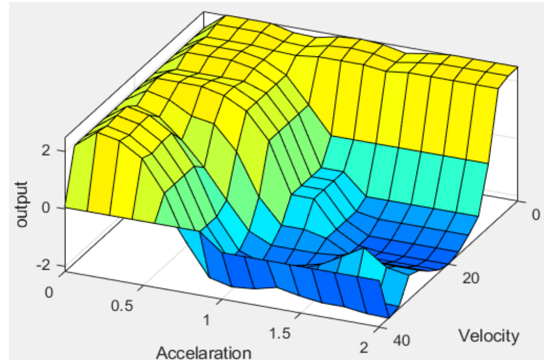

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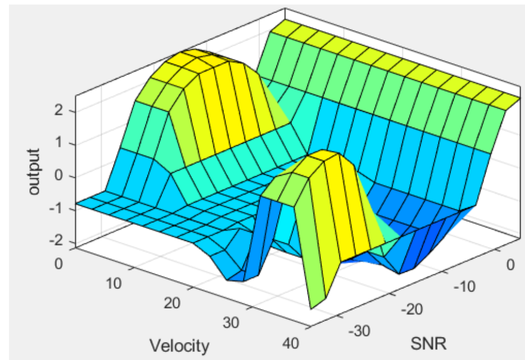

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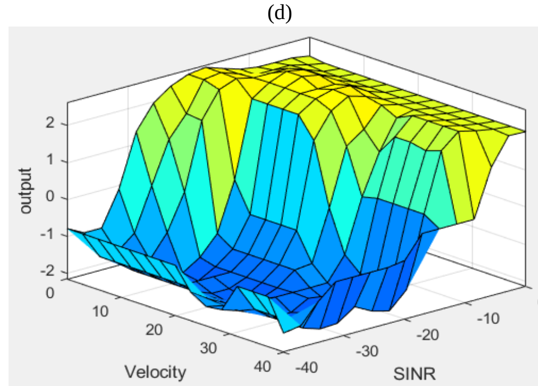
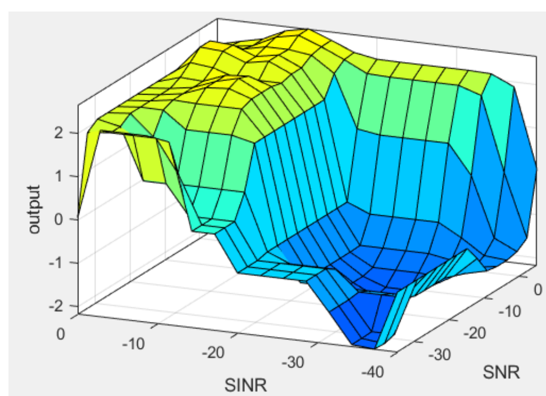
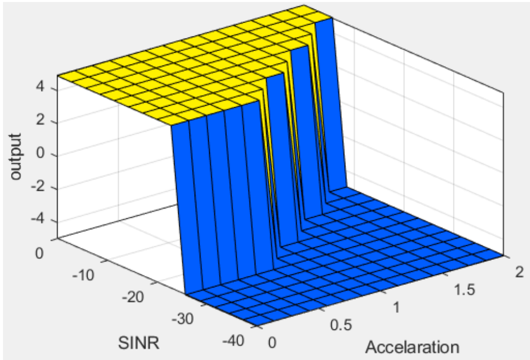


(e)

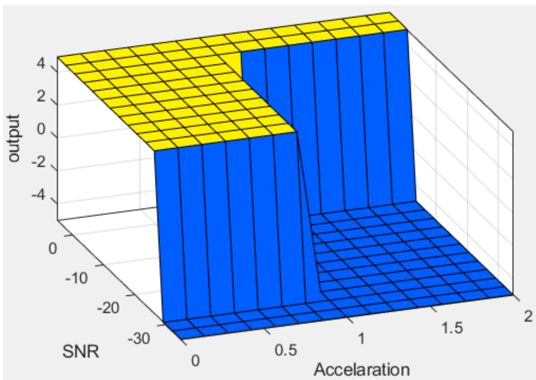


(f)

Fig.8. Surface plot of Fuzzy variable under Centroid method of De-fuzzification



(a)



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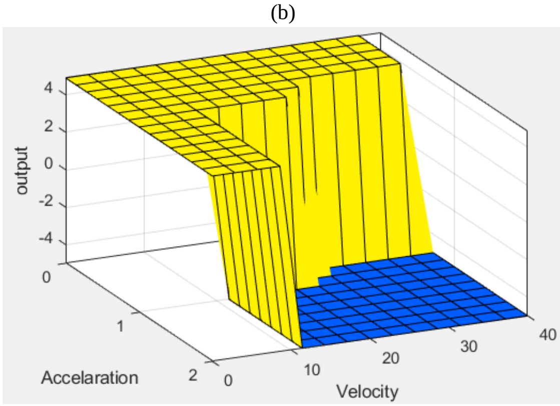

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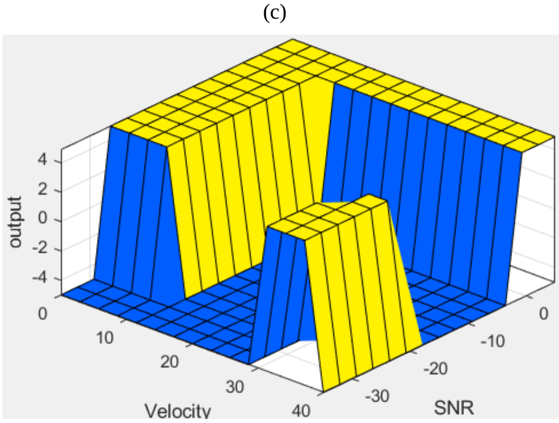

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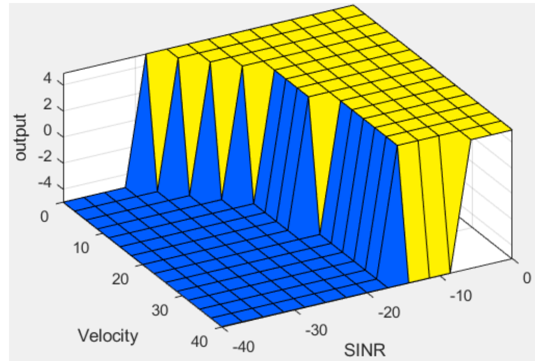

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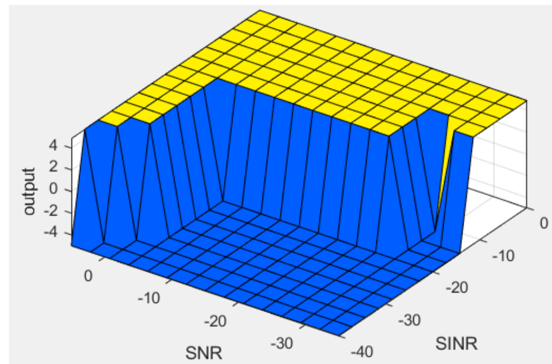

(f)

Fig.9. Surface plot of Fuzzy variable under LOM method of De-fuzzification

Table I
Comparison of Fuzzy Output

Vectors	Centroid	Bisector	MOM	LOM
[25; -20; -25; 02]	-2.05 (HO)	-01 (HO)	-1.75 (HO)	-05 (HO)
[5; -10; -15; 0.75]	2.3 (NHO)	2.3 (NHO)	2.60 (NHO)	4.9 (NHO)
[02; -08; -10; 0.5]	2.37 (NHO)	2.4 (NHO)	2.75 (NHO)	4.9 (NHO)
[01; 02; -03; 0.15]	2.51 (NHO)	2.6 (NHO)	3.10 (NHO)	4.9 (NHO)
[18; -22; -30; 1.5]	-1.91 (HO)	-1.9 (HO)	-2.15 (HO)	-05 (HO)

We run the FIS rule 100 times and get the accuracy of a decision as 100% for LOM, 95% for centroid, 92% for MOM and 93% for the Bisection method. Few results are shown in Table I, where both numerical and Fuzzy values are shown.

V. Conclusion

In this paper, a fuzzy inference system is designed to solve the handover problem of wide area network. Four fuzzy variables and four defuzzification techniques are used to take the decision of handover. Comparing the results of four defuzzification methods, it is found that the LOM method performs the best in acquiring correct handover decision. The paper used only FIS to take the decision of handover but to enhance the accuracy of decision several machine learning algorithms are used and combined in fusion center. In the future, we will design chromosome and its fitness functions incorporating possible variables of handover under a genetic algorithm. A deep learning method can be designed and it will be trained with different range of handover variables. Finally, all the methods can be combined in reaching the optimum performance.

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