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Performance Analysis of Fuzzy Logic Based Vertical Handoff Decision Algorithm for Heterogeneous Networks

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ABSTRACT

The heterogeneous networks are consist of integration of various access technologies such as WI-FI, WI-MAX, 3G/B3G, cellular networks and other services like *ad hoc* networks etc. and are expected to provide seamless roaming across the networks. When the MN switch to one network to other networks, the inter-domain handoff (VHO) involves. The requirements for VHO are power conception, bandwidth, user preferences, velocity, network cost and network latency etc. To obtain overall QoS of the heterogeneous networks we need to feed these input to an efficient system based on fuzzy logic theory to choose best networks among various access networks. This study mainly focused on the fuzzy logic algorithms with different aspects to choose best networks and discuss its input factors that taken into consideration for Network Selection Function (NSF). Finally, we evaluated handoff delay performance using NS-2 simulation environment.

Key words: Hetrogeneous networks, mobility management, vertical handoff, fuzzy logic theory

INTRODUCTION

The next generation of wireless networks are expected to provide seamless roaming across various access networks such as wireless LAN, UMTS, WI-MAX and *ad hoc* network etc. the purpose of an integration among such technologies are expected to provide diverse range of high data rate multimedia service to end users since the WLAN and UMTS interfaces are have the characteristics of complement to each other. Since, it has these unique characteristics, these are coupling to combine them to provide ubiquitous roaming for users with contemporary mobile devices that are equipped with multiple network interfaces (Makaya and Pierre, 2008). For example, given the complementary characteristics of 802.1x WLAN offer faster, high BW, lowered cost, short distance access and 3G cellular WWAN such as universal mobile telecommunication (UMTS) which offers slower, high cost, long range always connected access, it is combined to provide ABC (always best connected) for the end users. There are many papers had focused to combine these networks (Lampropoulos *et al*., 2005) as shown in Fig. 9 in an architecture point of view such as loose coupling, tight coupling, very tight coupling and peer to peer networking architecture for the desired application to provide ubiquitous roaming for heterogeneous networks. Thus, the integration and interoperation of these heterogeneous networks requires the design of intelligent vertical handoff decision algorithms (VHDAs) to enable seamless terminal, personal and network mobility. Thus to offer for continuity and transfer of an existing session for IMS networks or IP packets for an all IP networks, need to design an efficient system for vertical handoff decision.

For any heterogeneous wireless communication system the user prefer to move from one network to other network to offer high data rate services and then it is termed as vertical handoff.

The need for vertical handoff depends on various parameters(Bosoanca and Vargan, 2011) like RSS, bandwidth, velocity, network cost, QoS, metrics such as handoff delay, network cost, network latency and packet lost, signaling overhead/cost, jitter and throughput etc.

This study mainly focused on an existing works (Nkansah-Gyekye and Agbinya, 2007) on vertical handoff decision making algorithms to choose best access technology and how they considered and classify input parameter for the fuzzy logic inference systems.

CLASSIFICATION OF VHO CRITERIA

The main process of vertical handoff involves are:

- Handoff initiation process
- Network discovery process
- Handoff execution process

The vertical handoff requirements are depends on various metrics such as power conception, RSS, velocity, network latency, user preferences etc. The vertical handoff decision algorithm had been proposed in the literature (Kassar *et al.*, 2008) in to a three main categories as detailed in Fig. 1.

Handover criterias are measured to calculate whether or not to take handoff. This can be further classified as follows:

- Network related parameters in Fig. 2
- Terminal related parameters in Fig. 3
- User related parameters in Fig. 4
- Service related parameters in Fig. 5

These parameter are further classified as static or dynamic as shown in Fig. 6 and 7, respectively.

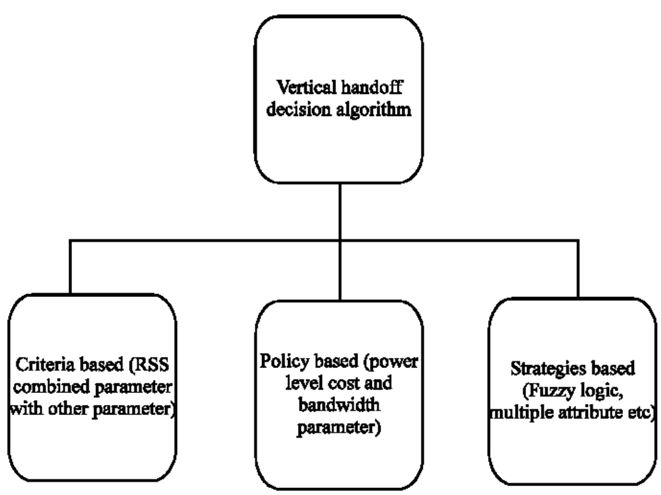

Fig. 1: VHDA classification

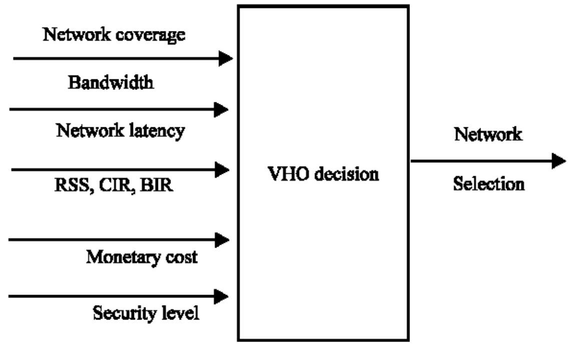

Fig. 2: Networks related parameters

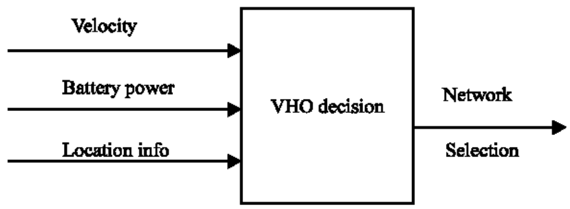

Fig. 3: Terminal related parameters

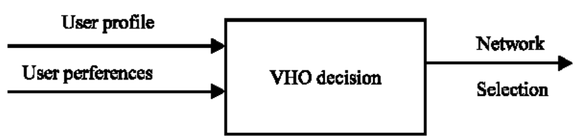

Fig. 4: User related parameters

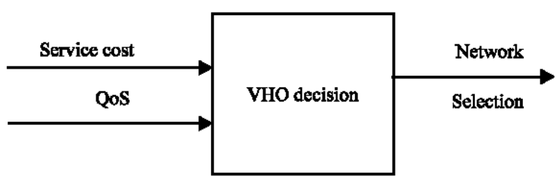

Fig. 5: Service related parameters

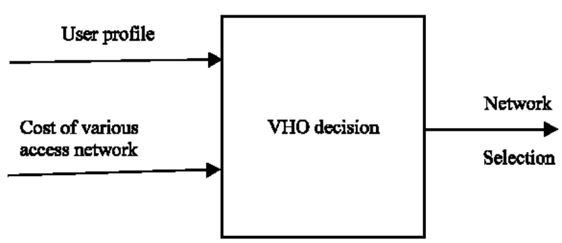

Fig. 6: Static parameter

FUZZY LOGIC THEORY

Inference is known as the process that draws conclusions from a set of facts using a collection of rules (Chan *et al.*, 2001). The fuzzy inference system is a computing framework based on the

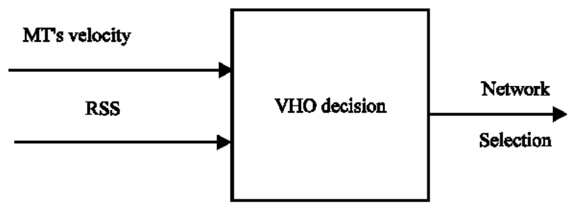

Fig. 7: Dynamic parameter

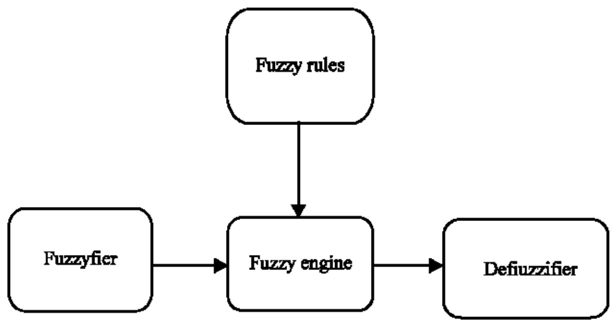

Fig. 8: Fuzzy inference engine

concepts of fuzzy set theory, fuzzy if-then rules and fuzzy reasoning. The differences between these fuzzy inference systems lie in the consequents of their fuzzy rules and therefore their aggregation and defuzzification processes differ accordingly. A fuzzy inference system is composed of the functional blocks as shown in Fig. 8.

A fuzzy inference system is composed of the functional blocks. This study uses a Mamdani FIS that is composed of the functional blocks (J-S. R. Jang and C-T) as shown in Fig. 9. The fuzzifier transforms the crisp inputs into degrees of match with linguistic values. Fuzzy rule base contains a no.of fuzzy IF-THEN rule. Fuzzy system has n inputs and a single output. A defuzzifier transforms the fuzzy results of the inference into a crisp output. The crisp handoff factor computed after defuzzification is used to determine when a handoff is required as follows:

- If handoff factor>0.85, then initiate handoff

Here discuss about handoff from WLAN to WMAN and vice versa. As we mentioned earlier (Nkansah-Gyekye and Agbinya, 2007) the authors had designed and implemented multi criteria vertical handoff decision algorithm in a heterogeneous network environment and presented the use of fuzzy logic concept to obtain useful handoff decision using MATLAB. There are no performance evaluation results of the vertical handoff algorithm and so we have simulated fuzzy inference system in order to evaluate performance of the algorithm by using NS2.

Fuzzy logic handoff decision algorithms: A handoff algorithm must be capable of making a decision based on incomplete information and in a region of uncertainty. An adaptive multi-criteria handoff decision algorithm that incorporates fuzzy logic because of the inherent strength of fuzzy logic in solving problems exhibiting imprecision and the fact that many of the terms used for

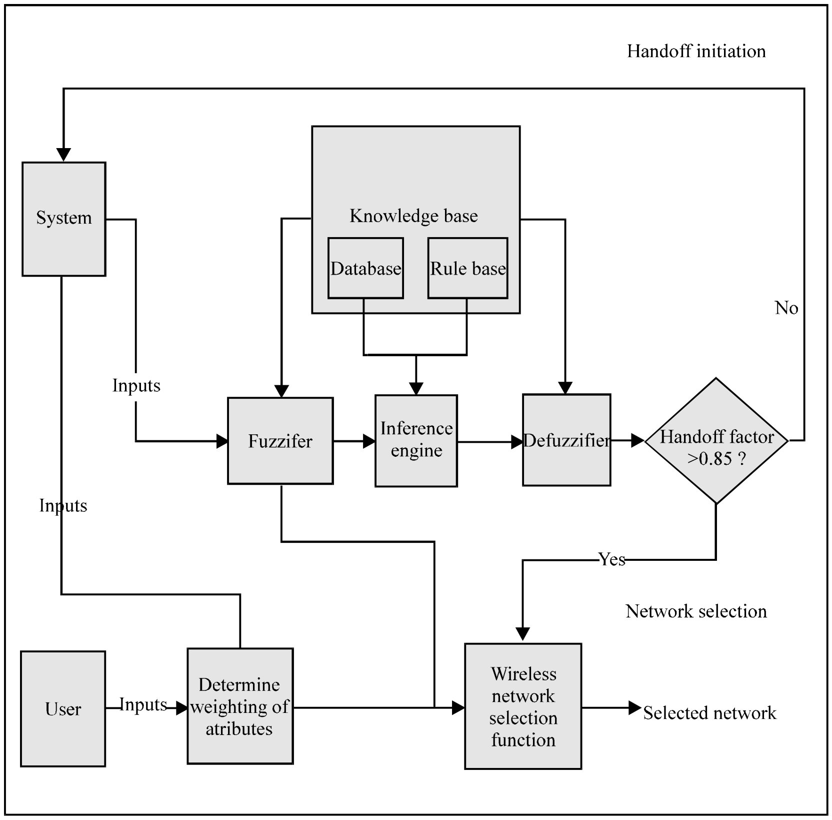

Fig. 9: Block diagram for vertical handoff decision

describing radio signals are fuzzy in nature. The algorithm gives users the option to influence the handoff result by specifying user preferences such as the preferred user wireless network and the QoS required. Fuzzy logic can be exploited to develop approximate solutions that are both cost-effective and useful. Fuzzy logic algorithms can be implemented in the MN as a Handoff Decision Engine to provide rules for decision making. The input parameters (preferred user wireless network, RSSI, available bandwidth and network coverage area of the target WLAN network) are fed into a fuzzifier, which transforms them into fuzzy sets by determining the degree to which they belong to each of the appropriate fuzzy sets via membership functions. Next, the fuzzy sets are fed into a fuzzy inference engine where a set of fuzzy IF-THEN rules is applied to obtain fuzzy decision sets. The output fuzzy decision sets are aggregated into a single fuzzy set and passed to the defuzzifier to be converted into a precise quantity during the final stage of the handoff decision. We consider two handoff scenarios as shown in Fig. 10.

Handoff from WMAN 802.16 to WLAN802.11 and handoff from WLAN 802.11 to WMAN802.16.

Handoff from WMAN 802.16 to WLAN 802.11: Each of the input parameters is assigned to one of three fuzzy sets as shown in Table 1. For example, the fuzzy set values for the RSSI consist of the linguistic terms: Strong (S), Medium (M) and Weak (W). These sets are mapped to corresponding Gaussian membership functions. The universe of discourse for the fuzzy variable RSSI is defined from -78 dBm to -66 dBm. The fuzzy set “Strong” is defined from -72 to -66 dBm

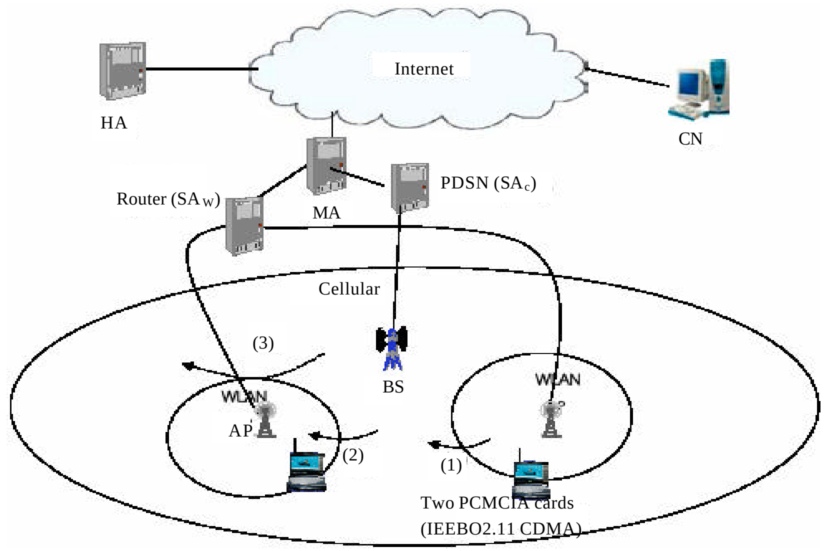

Fig. 10: WLAN interconnection architecture

Table 1: Fuzzy rules

RSSI	Available bandwidth	Network coverage	Wireless network	Handoff
Weak	Low	Bad	Public WLAN	No
Weak	Low	Medium	Residential WLAN	Probably No
Strong	High	Good	Office WLAN	Yes
Strong	Medium	Medium	Residential WLAN	Probably Yes
Medium	High	Good	Office WLAN	Yes
Medium	Low	Medium	Public WLAN	Uncertain

with the maximum membership at -66 dBm. Similarly, the fuzzy set "Medium" for the RSSI is defined from -78 to -66 dBm with the maximum membership at -72 dBm and the fuzzy set "Weak" for the RSSI is defined from -78 to -72 dBm with the maximum membership at -78 dBm. The universe of discourse for the variable available bandwidth is defined from 0 to 56 Mbps, the universe of discourse for the variable network coverage is defined from 0 to 300 m and the universe of discourse for the variable preferred user wireless network is defined from 0 to 10. The fuzzy set values for the output decision variable Handoff are {Yes (Y), Probably Yes (PY), Uncertain (U), Probably No (PN) and No (N)}. The universe of discourse for the variable Handoff is defined from 0 to 4, with the maximum membership of the sets "No" and "Yes" at 0 and 4, respectively. Membership Functions for Fuzzy Variables (a) RSSI, (b) Bandwidth, (c) Network Coverage, (d) Preferred Network and (e) Handoff. Since there are four fuzzy input variables and three fuzzy sets for each fuzzy variable, the maximum possible number of rules in our rule base is 34 = 81. The fuzzy rule base contains IF-THEN rules such as:

- IF RSSI is weak and available bandwidth is low and network coverage area is bad and preferred user wireless network is public WLAN, THEN handoff is N
- IF RSSI is weak and available bandwidth is low and network coverage area is medium and preferred user wireless network is residential WLAN, THEN handoff is PN
- IF RSSI is strong and available bandwidth is high and network coverage area is good and preferred user wireless network is office WLAN, THEN handoff is Y

- IF RSSI is strong and available bandwidth is medium and network coverage area is medium and preferred user wireless network is residential WLAN, THEN handoff is PY
- IF RSSI is medium and available bandwidth is high and network coverage area is good and preferred user wireless network is office WLAN, THEN handoff is Y
- IF RSSI is medium and available bandwidth is low and network coverage area is medium and preferred user wireless network is public WLAN, THEN handoff is U

Handoff from WLAN 802.11 to WMAN 802.16: Since WLAN 802.11 has a smaller coverage range, when the mobile user is moving out of a WMAN 802.16 area, we need to have an accurate and timely handoff decision to maintain the connectivity before the loss of WLAN 802.11access. The parameters that we are using in this directional handoff include RSSI(received signal strength indication), available bandwidth, network coverage area and perceived QoS of the current WLAN network.

The design of the fuzzy inference system for this handoff scenario is similar to the design of the fuzzy inference system for the WMAN 802.16-to-WLAN 802.11 handoff. We are using three fuzzy sets for each of the input variables (preferred user wireless network, RSSI, network coverage and available bandwidth) and five fuzzy sets for the output variable. The fuzzy sets are mapped to corresponding Gaussian membership functions. The fuzzy set values for the output decision variable Handoff are {Yes (Y), Probably Yes (PY), Uncertain (U), Probably No (PN) and No (N)}. The fuzzy rule base contains IF-THEN rules such as:

- IF RSSI is weak and available bandwidth is low and network coverage area is bad and perceived QoS is undesirable, THEN handoff is Y
- IF RSSI is weak and available bandwidth is low and network coverage area is medium and perceived QoS is undesirable, THEN handoff is PY
- IF RSSI is strong and available bandwidth is high and network coverage area is good and perceived QoS is desirable, THEN handoff is N
- IF RSSI is strong and available bandwidth is medium and network coverage area is medium and perceived QoS is undesirable, THEN handoff is PN

Handoff algorithm analysis: There are many differences between the radio link characteristics of the 802.16 WMAN and the 802.11 networks. Hot spot areas, such as campuses, hotels and restaurants are covered by 802.16 WLAN at low cost and high data rate. However, 802.11 networks serve a wider area than 802.16 WMAN at a higher cost and lower data rate. Table 1 shows the coverage, cost and data rate of WMAN 802.16 and 802.11.Depending on the delay sensitivity characteristics application traffics are further classified into two groups. Conversation and streaming classes that are sensitive to delay are classified as real-time services. The loads in both the networks are assumed to be nominal. In such case, there is a tradeoff between the handoff delay and throughput during those handoff operations, which occur between networks whose radio links have different characteristics. In the case of delay sensitive real-time services, handoff should be performed as rapid as possible in order to minimize the delay due to frequent handoffs. For non-Real-time service, the amount of transmission data is more important than the delay and therefore, the connection to the WLAN should be maintained as long as possible.

SIMULATION RESULTS

It has been tested the performance of the fuzzy logic handoff initiation algorithm over a varied range of simulation parameters.

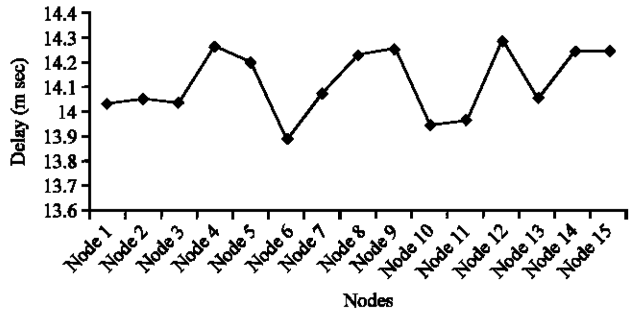

Fig. 11: Delay analysis

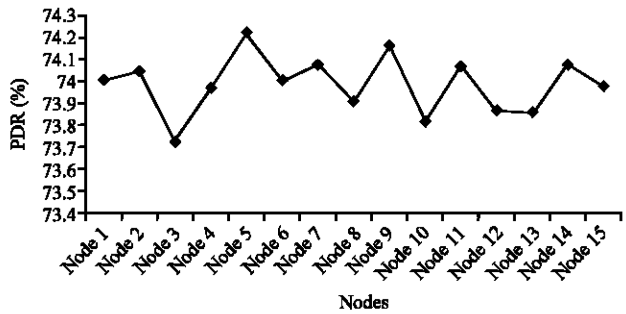

Fig. 12: Packet delivery ratio analysis

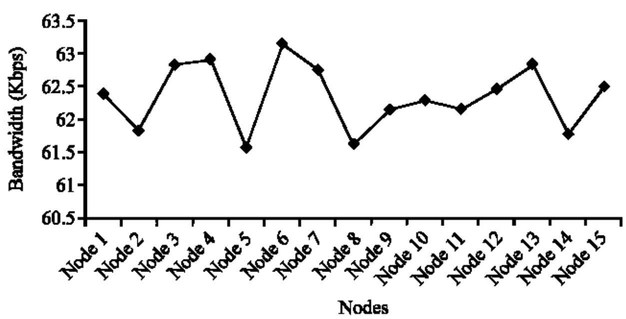

Fig. 13: Bandwidth usage analysis

Figure 11 shows the graph plotted between the nodes and delay occur in each node. By analyzing the graph, the delay time is varied node to node. In Fig. 12, the packet delivery ratio is analysed by plotting the graph between the nodes and packet delivery ratio in terms of percentage. That graph shows that Node5 has the highest PDR value (74.2%) and the Node3 has lowest PDR value (73.7%). Figure 13 shows the graph which is used to analyse the Bandwidth usage of each and every node in the network. The maximum bandwidth usage of our proposed scheme is 63 Kbps. The packet loss ratio is analysed in the Fig.14. The maximum packet loss rate in our system is 11.55%. From Fig. 11-13 plotted threshold value of the signal strength against the time spent in WLAN networks. It shows that as the threshold value increases the time spent in 802.11 decreases. This is because the user/device criterion for a strong signal increases, forcing most of the signal strength measurements to be weak and hence the user hand over the another network. When the

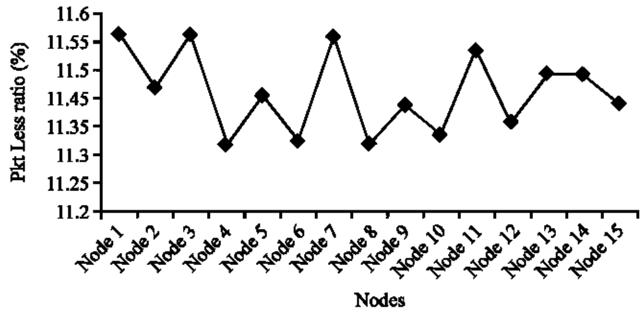

Fig. 14: Packet loss rate analysis

node value is 15, found an anomaly and this is because of simulation is multi parameter based and affects other parameters. If the threshold value had been low then the user would be forced to switch a number of times between WLAN to WMAN networks. Thus the simulation results shows that less packet loss ratio, handover delay and higher packet successive transmission range.

CONCLUSION

This study had presented the vertical handoff requirements. Vertical handoff initiation algorithm based on simple fuzzy rule has been applied to the mobility scenario. The algorithm, as shown by the simulation results, does not result in too many switches between the WLAN networks and hence would provide quite a useful tool for the device in real time functioning. In the handoff algorithm number of continuous beacon signals are used whose signal strength from the WMAN 802.16 falls below the predefined threshold value. The assumption that the load of the WLAN networks is nominal for the purpose of simplification is made in analyzing the average throughput, bandwidth usage, packet loss ratio, packet delivery ratio and handoff delay. It has been found that the delay encountered by the system is low since unnecessary handoff between WLAN. However handoff Delay can be reduced by an intelligent architecture which considers network latency as the primary parameter in decision making for the future work.

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