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Intelligent Congestion Aware Media Independent Handover for the 4G Heterogeneous Wireless Network

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Abstract: Heterogeneous 4G wireless networks are the next generation of wireless networks which connect various wireless networks of different technologies. Heterogeneous networks have to handle both horizontal and vertical handovers. Vertical handover is one of the critical issues of 4G wireless networks that has to be handled intelligently in order to maintain seamless connectivity over the 4G network. This study introduces an intelligent, congestion aware and media independent handover mechanism for the 4G heterogeneous wireless network. The algorithm makes direct handover in less congested situations and uses fuzzy logic and neural network based approach to take the handover decision when there is congestion in the network. The algorithm performs better with reduced latency and increased bandwidth in all situations and also performs with gain in terms of load, power and cost.

Key words: 4G heterogeneous networks, vertical handover, media independent handover, handover decision algorithm, India

INTRODUCTION

Now a days, different wireless networks of different technologies are established everywhere. For example Wireless Lan (Deng and Yen, 2005), wimax (Wang *et al*., 2008), satellite systems (Beakley, 1984), Bluetooth (Sairam *et al*., 2002), Wi-Fi, UTRAN, etc. are some of the wireless network technologies that are established everywhere. 4G is the next generation wireless technology (Akyildiz *et al*., 2004) which targets seamless connectivity among these various networks of heterogeneous technologies. 4G networks should handle both horizontal and vertical handovers. Horizontal handover is the handover of mobile nodes from one cell to another cell; both belonging to the same technology. Vertical handover is the handover of a mobile node from one cell to another cell, each one belonging to a different technology. A handover can also be either soft handover or hard handover. In soft handover, the association of mobile node with the current cell is broken only after it is connected with the new cell. In hard handover, the connection with the current network is broken and then the node is immediately connected with the new network. A handover decision algorithm should be seamless (Mohr and Konhauser, 2000; Taniuchi *et al*., 2009) and should consider all these strategies. This study concentrates on vertical handover even though the simulation supports all the above types of handovers. Handover decisions are taken by applying fuzzy logic and neural networks based logics in appropriate places. The algorithm handles the congestion in an intelligent way that calls the fuzzy logic or neural network logic only when the congestion goes above certain level. In low congested situations, the handover decision is taken automatically by connecting the node to the next nearby network with good signal strength. The performance study of the algorithm is made using simulation for connecting 2G and 3G wireless networks through 4G. Simulation implementation and performance study is made using MATLAB tool. The proposed logic performs better in terms of latency, bandwidth, load, cost and power than its pure fuzzy logic and neural network counter parts. The proposed algorithm assures substantial gain in latency and bandwidth when heterogeneous networks are established everywhere andwhich is not far away.

RELATED WORK

Many handover decision algorithms have been developed in the recent past. Also many papers have surveyed about different vertical handover algorithms. The vertical handoff algorithms usually take handoff decisions based on network condition, battery power and user preferences. Certain proposals uses a vertical

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Table 1: Mobility management issues

Issue	Description
Connectivity	According to 4G network, a mobile node can be connected to any network of any access technology. So handover of mobile node from technology to technology will face problems such as radio interface in compatibility, network capability differences, etc.
Location management	Location management requires registering the current location of the mobile node and must also forward the calls to the mobile node. In 4G, different technologies may differ in database architecture, etc. and the differences must be resolved
Seamless mobility	Seamless mobility must ensure easy and uninterrupted service to the user even when the user switches from cell to cell belonging to different technologies
Mobility context management	The mobile node's current context must be entered in Context Information Base (CIB). Different technologies will be using different structure for context information base
Paging	4G network require radio technology independent IP layer paging solution. Earlier networks use Link layer technology which is radio dependent
Network composition	Composition of networks can be done by network integration; control sharing and network interworking
Terminal mobility	Terminal mobility is a must in 4G infrastructure networks as they consist of many heterogeneous systems
Security	Current security services are inadequate for the 4G networks as they consist of many heterogeneous networks
Migration	Migration is also an essential requirement in 4G heterogeneous networks
Personal mobility	The 4G infrastructure must ensure that the user is available with the service independent of whatever he is and whatever terminal he is using

handoff decision function (Nasser *et al*., 2006) which uses network parameters such as cost, power consumption, security and network performance in order to take handover decision. Many proposals take the handover decision according to the user requirements and preferences (Song and Jamalipour, 2006). Also, handover problems use network resources utilized by the connection and signal cost to take the handover decision as a Markova decision process. Route prediction server proposed by Kaleru and Avula (2011) uses load and round trip time to take handover decision.

Mobile agents also assist (Chander and Juneja, 2011) vertical handover decision according to a few proposals. Prioritized hard handoff (Bhowmik *et al*., 2011) ensures hard handoff at reduced rate of dropped calls. UMTS-WLAN integrated architecture proposed by Patil (2011) employs a dynamically updating database to know about network condition in order to take handoff decision. Likewise, there are many proposals towards the vertical handoff decision algorithms and the proposal in this study is a combined approach which uses fuzzy logic and neural network based approaches with respect to the handover situations to make the handover decision.

MOBILITY MANAGEMENT ISSUES

Mobility management is the key issue of 4G networks and (Hussain *et al*., 2006; Hui and Yeung, 2003) some of such challenges are listed and some of them are shown in Table 1. The earlier said mobility management issues must be taken into account while designing an algorithm. The proposed research considers all the above 4G issues while designing intelligent vertical handover decision algorithm.

MEDIA INDEPENDENT HANDOVER

Media Independent Handover (MIH) is described in IEEE802.21 standard. This study uses a media independent approach to perform vertical handover as described by Fallon *et al*. (2007). IEEE 802.21 supports a range of networks which belong to 2G and 3G networks in order to perform seamless horizontal as well as vertical handover. The handover function in IEEE 802.21 is implemented through the MIH function. The MIH function embeds three elements viz., the event service, command service and information service.

Event service: The media independent event service will identify and will indicate the necessity for a handover.

Command service: IEEE 802.21 media independent handover implements the handle of handover in the logical link layer itself. The higher layers can control these lower layers through the command service.

Information service: In order to facilitate the handover the MIH function uses the MIH information service to discover and obtain the network information within a geographical area.

INTELLIGENT, CONGESTION AWARE HANDOVER

This study proposes an intelligent, congestion aware handover mechanism in order to take handover decision in a 4G heterogeneous environment. This study proposes to use six parameters namely signal strength, bandwidth, load, cost, congestion and power consumption. If the congestion around a moving node is below a threshold

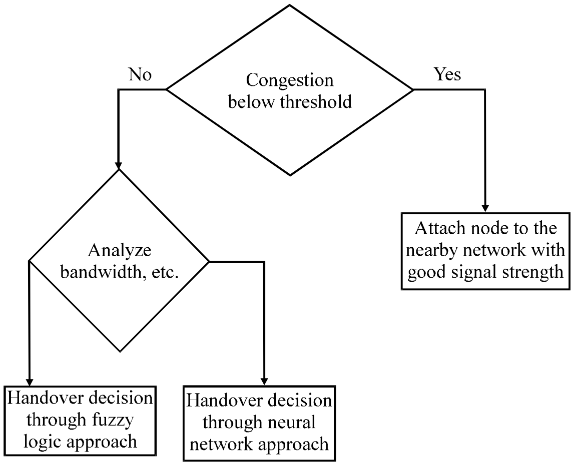

Fig. 1: Overview of intelligent, congestion aware handover

value the vertical or horizontal handover decision is taken only according to the signal strength. The node is connected to the nearby network which shows good signal strength. Only when the congestion level increases above the threshold value the algorithm chooses a fuzzy logic and neural network based function according to the other parameters such as bandwidth, cost, power and load in the network. The simulation results show that the approach performs better in terms of latency and bandwidth. Other parameters also experience lower values than their counter parts viz., fuzzy logic and neural network approaches. Figure 1 shows the overview of the intelligent, congestion aware handover.

FUZZY APPROACH

Fuzzy logic is a many valued logic which produces fixed and exact results in reasoning. The congestion aware media independent handover mechanism uses the fuzzy logic mechanism (Hou and O'Brien, 2006) to take the handover decision when the congestion goes above the threshold value. The priority is given to fuzzy logic over the neural network approach. Fuzzy approach takes the decision according to the input parameters bandwidth, power, load and cost and the output parameter connection. The structure of the fuzzy engine is shown in Fig. 2. The four input variables bandwidth, power, load and cost and the output parameter connection are individually associated with two number functions low and high. The functions are defined using the following equation:

$$F(x : a, b, c) = \max(\min((x-a)/(b-a), (c-x)/(c-b)), 0) \quad (1)$$

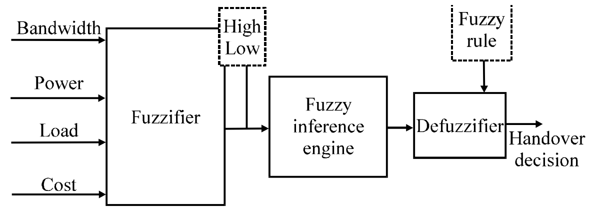

Fig. 2: Fuzzy engine

where the values of a, b and c for the member function low are 0, 0.5 and 1. The values of a, b and c for the member function high are 0.5, 1 and 1.5. And the following fuzzy rule is set to the rule base:

```
Rule = [ 1 1 1 1 1 (1) 1
         1 1 1 2 1 (1) 1
         1 1 2 1 1 (1) 1
         1 2 1 1 1 (1) 1
         1 2 1 2 2 (1) 1
         1 2 2 1 2 (1) 1
         1 2 2 2 2 (1) 1]
```

Each row in the rule matrix defines a separate rule. The first four columns represent the four input parameters. The fifth column represents the weight associated with each rule. Sixth column indicates the conjunction operation to be applied in between the input parameters. For the sixth column 1 indicates and operation and 2 indicates OR operation. For the first five columns 1 indicates that the function low has to be applied and 2 indicates that the function high has to be applied. All the variables and member functions are fed to the fuzzy inference engine. In order to perform the fuzzy test the following assumptions are made.

Bandwidth	=	wifi_bandwidth/wifi_connection
Power	=	wifi_power x wifi_connection
Load	=	wifi_load x wifi_connection
Cost	=	wifi_cost – wifi_connection
Max_bandwidth	=	wifi_bandwidth/total congestion
Max_power	=	wifi_power x total_congestion
Max_cost	=	wifi_cost x total congestion
Max_load	=	wifi_load x total congestion
Bandwidth_threshold	=	abs (wifi_bandwidth-max_bandwidth)/2
Power_threshold	=	abs (wifi_power-max_power)/2
Load_threshold	=	abs (wifi_load-max_load)/2
Cost_threshold	=	abs (wifi_cost-max_cost)/2

And a test input is set to either 0 or 1 according to the following condition checking to each input parameter and passed to the fuzzy inference calculation.

```
If bandwidth_threshold <= bandwidth
        Test_input = 1
Else
        Test_input = 0
End
If power_threshold <= power
        Test_input = 1
Else
        Test_input = 0
End
If cost_threshold<=cost
        Test_input = 1
Else
        Test_input = 0
End
```

According to the above conditions fuzzy fit are found for wifi, 3G and 4G networks. The node is associated to the network with the highest fit value.

NEURAL NETWORK APPROACH

The proposed handover uses the neural network approach (Nasser *et al*., 2007) as an alternative with the fuzzy logic approach in high congestion situations. The neural network approach is used when the fuzzy logic approach could not take a decision because of unknown values. On the other hand a neural network system can withstand even in these situations as they are trained. The system is trained for the same variables and rules as discussed in the fuzzy approach.

RESULTS AND DISCUSSION

The simulation environment is set up using the MATLAB tool. The environment can be viewed as a GUI as shown in Fig. 3 and 4. Researchers can give input for number of nodes, number of moving nodes, travelling time in terms of number of moves the density as capacity and the speed of the moving nodes in seconds per move in order to change these parameters. The network environment is assumed as having many 2G (wifi) cells inside one 3G cell and many 3G cells altogether constitute the 4G network. In the GUI, red points represent nodes, blue lines represent nodes connected to the wifi, green lines represent nodes connected to the 3G network and yellow lines represent nodes connected directly to the 4G access point. It is set that if the congestion is below 5 (No. of nodes together) then the further nodes are connected to the best wifi network neighbouring them according to the signal strength.

If the congestion is above 5 and below 5×9 then the further nodes are connected to the 3G network. If the congestion is above 5×9 then the further nodes are connected directly to the 4G network. The same thing happens during handover situations also. The Fig. 3 shows a situation in which the network is lightly loaded and less congested and hence most of the nodes are connected to the wifi cells. The Fig. 4 shows a situation in

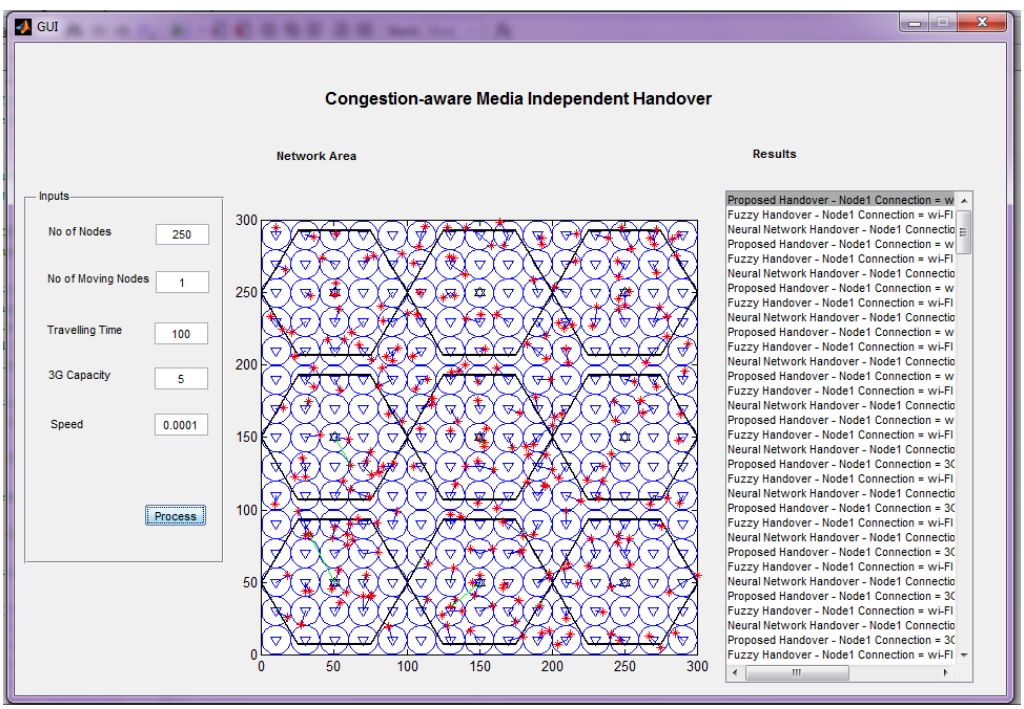

Fig. 3: Simulated GUI shows congestion free network

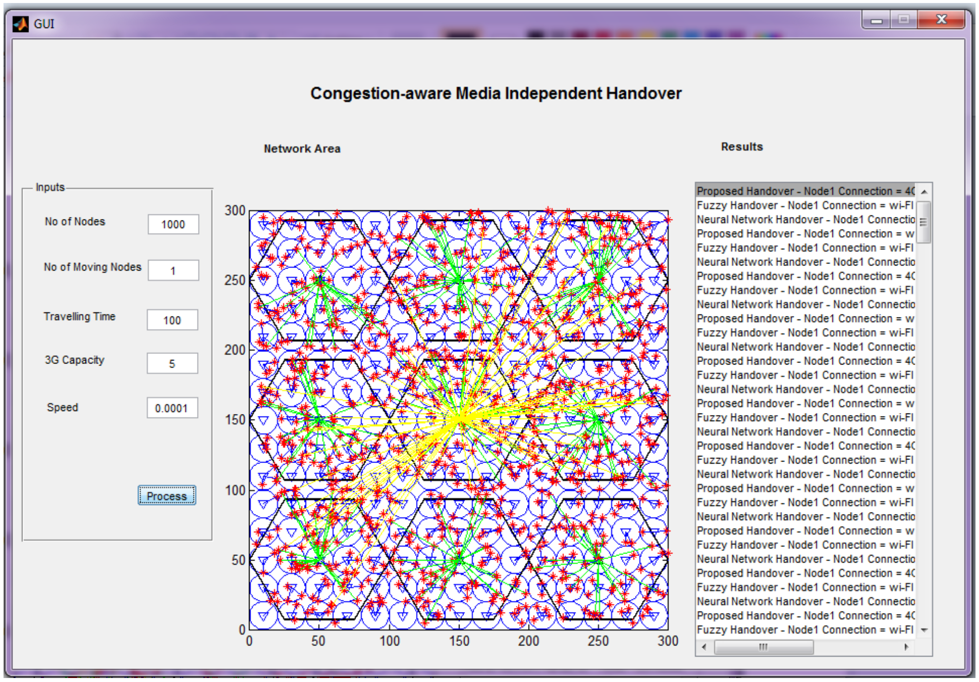

Fig. 4: Simulated GUI shows congested network

Table 2: Simulation parameters

Network condition	No. of nodes	No. of moving nodes	Travelling time (No. of moves)	3G capacity	Speed (sec/move)
Congestion free	250	1	100	5	0.0001
Congested	1000	1	100	5	0.0001

Table 3: Sample latency table

Logic	Access point	Time taken (sec)
Proposed	wi-FI : 182	0.0016241
Fuzzy	wi-FI : 182	0.0378110
Neural	wi-FI : 182	0.1121200
Proposed	wi-FI : 182	0.0021777
Fuzzy	wi-FI : 182	0.0344210
Neural	wi-FI : 182	0.1077400
Proposed	wi-FI : 182	0.0021638
Fuzzy	wi-FI : 182	0.0350370
Neural	wi-FI : 182	0.1079200
Proposed	wi-FI : 182	0.0021654
Fuzzy	wi-FI : 182	0.0351150
Neural	wi-FI : 182	0.1083100
Proposed	wi-FI : 182	0.0024375
Fuzzy	wi-FI : 182	0.0335640
Neural	wi-FI : 182	0.1083500

which the network is heavily loaded and in congestion and hence many nodes are also connected to 3G and 4G networks. This is because of simulation setup connects the further nodes to high order networks when lower networks become congested. The values assumed for creating congestion free network in Fig. 3 and congested network in Fig. 4 are tabulated in Table 2. And the proposed logic results in low latency in milliseconds

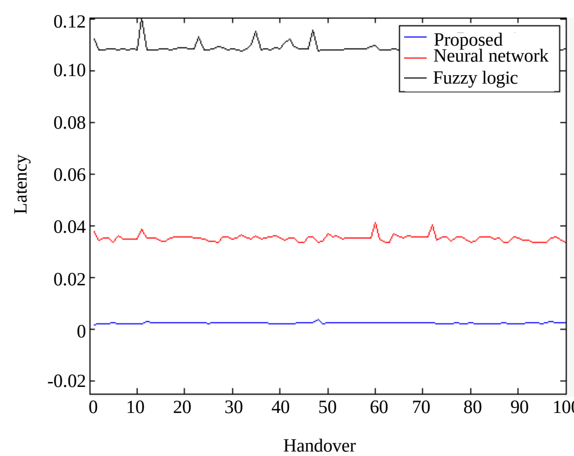

Fig. 5: Proposed logic with low handover latency

neural network approach. This is shown in Fig. 5. The proposed, fuzzy and neural network approaches are run seperately for 100 moves of the node. The access point associated after every move and the time taken for performing the handover in the congestion free network for the first 5 moves are tabulated as sample in Table 3.

This congestion aware approach consumes less control messages and hence gets more bandwidth measured in mbps for the proposed logic than the pure neural network and fuzzy logic counterparts. This is

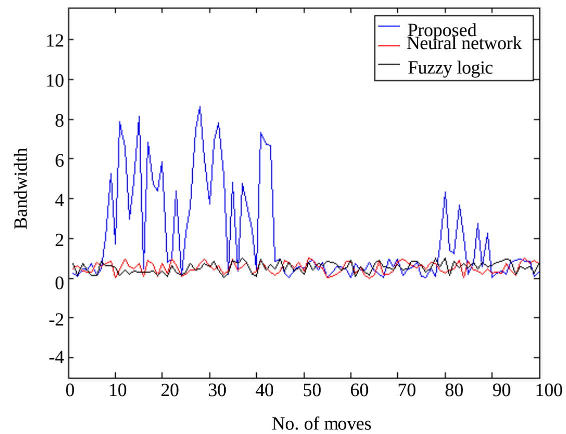

Fig. 6: Proposed logic with better bandwidth history

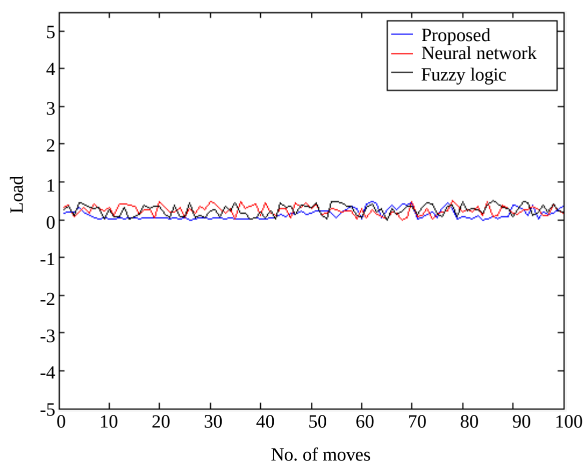

Fig. 7: Load vs. No. of moves

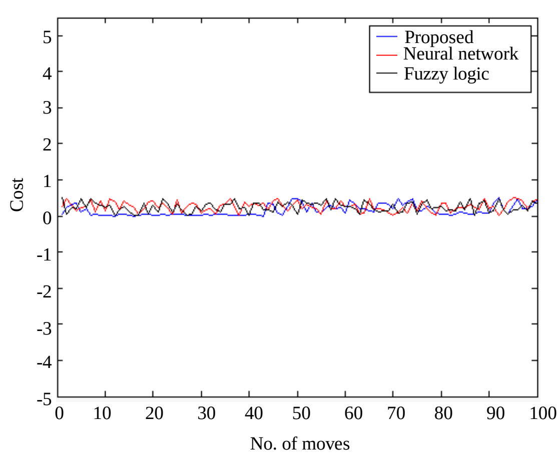

Fig. 8: Cost vs. No. of moves

shown in Fig. 6. Also, researchers experience only gain in terms of power, load and cost due to the fact that the intelligent, congestion aware approach save the

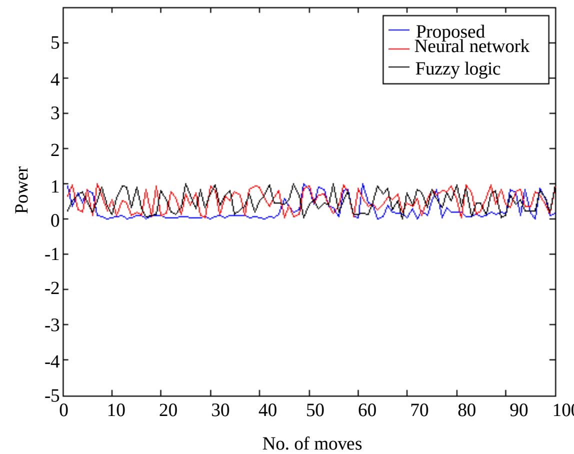

Fig. 9: Power vs. No. of moves

processing requirements. Graphs plotted with number of moves against power, load and cost (normalized between 0 and 1) are shown in viz (Fig. 7-9).

CONCLUSION

In this study, researchers have proposed a new intelligent congestion aware approach towards vertical handover decision algorithm in 4G wireless networks. The algorithm makes direct handover in less congested situations and uses fuzzy logic and neural network based approach to take the handover decision when there is congestion in the network. The algorithm performs better with reduced latency and increased bandwidth in all situations and also performs with gain in terms of load, power and cost. The future research of this study will be simulating the 4G handover with different approaches such as artificial intelligence, Markova process and comparing the performance with the new approaches.

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