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SAR BASED VERTICAL HANDOVER ALGORITHM

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Abstract -L**ot of research is carried out in the field of wireless networks specifically next generation networks. As the research is moving towards integration and interoperability of various wireless networks, this will lead to number of challenges. One of the challenges is the handovers across various/ heterogeneous wireless networks, reduction of call drop probability and reducing biological effects on human body. Number of solutions has been proposed for this challenge. A method is propose in this paperto solve this problem for enhancement of end-to-end Quality of Service, also the user will be able to get high data rates, real time transmission over wide area and users can also specify their personal preferences using Markov Decision Process (MDP) and also solution to reduce the effect of electromagnetic radiations. The proposed method uses delay and SAR (specific absorption rate) value as its basic parameters to select a network during handovers. The selection of the network amongst the existing wireless network considers the ongoing application of the user during the handover. Also we have taken into consideration SAR value to reduce the biological effects on human body.**

Keywords— Markov Decision process, Reinforcement Learning, Reward, SAR value, Vertical Handover.

I. INTRODUCTION

The growing demand of services in mobile communication is leading to a revolution in the field of mobile communication. Various wireless networks can be utilized which can provide the demand of services of the users anytime, anywhere. As a result, the users in next generation networks (NGN) should be able to roam between whichever wireless network they want to use at any time or which satisfies their requirements to the maximum at that time, in a seamless manner. In NGN all the wireless networks are integrated to support users' communications. Services in one particular access network should be delivered to other networks seamlessly. This needs the user to move from one wireless network to the desired one during which vertical handover takes place. Three main research directions have been identified in the area of vertical handovers,

- interworking between access networks
- minimization of handover delay
- maintaining QoS parameters values during/after handover as they were before the handover[1]

In addition to the above stated research directions, one more important aspect that is to be taken into consideration is the effect of rapid increase in number of mobile users as well as base stations. The electromagnetic radiations which are radiated by the mobile equipments as well as base stations can cause adverse effects on the human body. It is broadly accepted that mobile phones cause heating of the human organ when they are exposed to the radiation. When exposed to the radiation, the human body absorbs the energy radiated and the absorbed energy is measured using Specific Absorption rate (SAR).

Vertical handover is responsible for the continuity of service when a mobile user needs to roam across heterogeneous wireless access networks. It consists three steps [2], [3] system discovery, decision for handover, and execution of handover. The issue of enhancement of the performance of vertical handover has gained considerable attention in recent years [4]. Most related research work mainly focus on decreasing handover delay through the design of various vertical handover or access network selection algorithms.

We now mention some of the recent work on vertical handover decision (VHD) algorithms in NGN.
The author of paper [6] proposes Artificial Neural Networks (ANNs) to solve this problem. The proposed method distinguishes the best existing wireless network that matches predefines user when performing a vertical handoff.
Paper [9] proposes a network selection method which is based on predictive RSS and Fuzzy Logic. The RSS (Received Signal Strength) predicted is beneficial to avoid dropping calls. For non-real time service the policy here uses services of WiMax/ WLAN as long as possible. Final decision to select the target network is made by Fuzzy logic using Quantitative decision function.

In paper [7] the author addresses the problems related to improvement of user's QoS and system performance in heterogeneous integrated system of WLAN and UMTS using Neural Network based system modeling. Applying a novel

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algorithm, which allows user to adjust the input parameters according to required QoS in the heterogeneous networks, despite of the dynamic traffic load in handover source network wherein seamless and stable QoS supports for the users can be guaranteed.
Paper [8] discusses Constraint Markov Decision Process (MDP) based vertical handover decision algorithm for 4G heterogeneous wireless networks. Here the work considers the connection duration, the available bandwidth and delay of the candidate networks, Mobile terminals velocity and location information, signaling load incurred on the network, network cost, user's choice, and user's monetary budget for the vertical handover decision. MDP was used wherein a decision of the optimal policy was done which is a threshold policy in the available bandwidth, delay, and velocity. The proposed CMDP-based vertical handover decision algorithm outperforms other decision schemes in a wide range of conditions.

Although much of the work is carried out in reducing the handover delay, none of these studies consider the history of delay for a particular network during vertical handover between heterogeneous wireless networks. We are trying to reduce this delay much more by considering the history of handover delay of the target network considered for a specified time.

After the analysis of the various methods it was found that MDP can be thought of as appropriate method to deal with a discrete time stochastic control process. Reinforcement learning (RL) can solve Markov decision processes without distinct specification of the transition probabilities [11].

RL is learning process which interacts with an environment. An RL agent learns from the outcomes of its actions, rather than from being taught and it selects its actions on basis of its past experiences and also by new possibilities, which is essentially trial and error learning. RL that satisfies the Markov property is called MDP. MDPs provide a mathematical framework for modeling decision making in situations where outcomes are partially random and partially under the decision maker's control. MDPs are useful for studying a wide range of optimization problems which are solved via dynamic programming and reinforcement learning.
More precisely, a MDP is a discrete time stochastic control process. At any time step, the process is in some state *S*, and the decision maker may choose any action *a*, available in state *S*. The process responds at the next time step by randomly moving into a new state *S'*, and providing the decision maker a corresponding reward $R_a(S, S')$.

The probability that the process moves into its new state *S'* is decided by the chosen action. Specifically, it is given by the state transition function $P_a(S, S')$. Thus, the next state S' depends on the current state S and the decision maker's action a. But given S and a, it is conditionally independent of all previous states and actions, the state transitions of an MDP possess the Markov property [11].

A MDP has 4 parameters (*S ,a, P(s,s'), R(s,s'*)), where

- *S* is a finite set of states, which is type of network such as WiMAX, UMTS,GSM etc.
- *a* is finite set of actions, such as handover from WiMAX to UMTS.
- *P(s,s')* is the probability of transition from state S to S' when MN performs action *a* such as handover from WiMAX to UMTS.
- *R(s,s'*) is a reward function which is associated with every action.

In our work, the vertical handover decision algorithm takes into consideration the following aspects:
1. The state of the user and Mobile Node (MN). This includes the coverage area of the existing network.
2. The state of the wireless access networks consists of the available bandwidth, delay, current cost, and access cost information of the adjacent networks.
3. The current application of the user.
4. The current status of the target networks as well as the history of its previous handover delay.

The rest of the paper is arranged as follows. In section 2 the system model is described. Reward calculation is presented in section 3. The policy formulation is presented in Section 4. Section 5 presents the simulation and results. Conclusions are given in Section 6.

II. SYSTEM MODEL

Elements needed in the RL will be agent, environment along with four main sub-elements of the system: a policy, a reward function, a value function, and, a model of the environment.
In this paper, it is assumed that the system model is heterogeneous integrated system of various networks like, Wi-Fi, Wi-Max, GSM, UMTS, LTE represented by Network 1, Network 2, Network 3, Network 4 and Network 5.

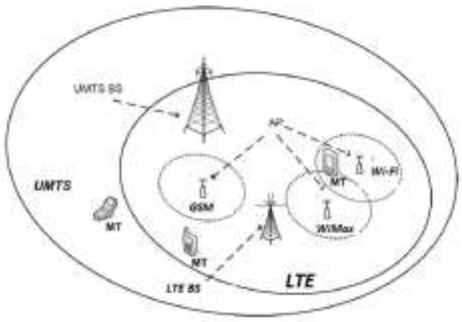

Fig.1 System Scenario

MDP has following 4 tuples-

- S is the set of networks which define states {Net1, Net2, Net3, Net4, Net5}.
- A is the set of actions

  {a_{1-1}, a_{1-2}, a_{1-3}, a_{1-4}, a_{1-5},
  a_{2-1}, a_{2-2}, a_{2-3}, a_{2-4}, a_{2-5},
  a_{3-1}, a_{3-2}, a_{3-3}, a_{3-4}, a_{3-5},
  a_{4-1}, a_{4-2}, a_{4-3}, a_{4-4}, a_{4-5},
  a_{5-1}, a_{5-2}, a_{5-3}, a_{5-4}, a_{5-5}}
  during handovers to various networks.

TABLE I
SET OF ACTIONS

	Net 1	Net 2	Net 3	Net 4	Net 5
Net 1	a_{1-1}	a_{1-2}	a_{1-3}	a_{1-4}	a_{1-5}
Net 2	a_{2-1}	a_{2-2}	a_{2-3}	a_{2-4}	a_{2-5}
Net 3	a_{3-1}	a_{3-2}	a_{3-3}	a_{3-4}	a_{3-5}
Net 4	a_{4-1}	a_{4-2}	a_{4-3}	a_{4-4}	a_{4-5}
Net 5	a_{5-1}	a_{5-2}	a_{5-3}	a_{5-4}	a_{5-5}

here action a_{ij} indicates the MN's transition from i^{th} network to j^{th} network.

- Transition probability depends on the users current application is considered during the handover to the appropriate target network

TABLE II
TRANSITION PROBABILITY

Application		Eco		BW		HBW	
		HN	VN	HN	VN	HN	VN
Audio	Eco	1	0.95	X	0.80	X	0.70
	BW	X	0.80	1	0.95	X	0.85
	HBW	X	0.60	X	0.8	1	0.95
Video (Non real-time)	Eco	0.7	0.65	X	0.95	X	0.85
	BW	X	0.75	1	0.95	X	0.85
	HBW	X	0.60	X	0.95	1	0.95
Video real-time)	Eco	0.6	0.50	X	0.7	X	0.95
	BW	X	0.70	0.80	0.75	X	0.95
	HBW	X	0.50	X	0.65	1	0.95

Table 2 defines the transition probability. The transition probability is decided depending upon the users' current application and type of network. Table 3 represents the category of networks.

TABLE III
NETWORK STATES AND REWARD

State	Category
Net 1	Bandwidth
Net 2	Higher Bandwidth
Net 3	Economical
Net4	Economical
Net 5	Economical

These networks are categorized in terms of cost of network and bandwidth of networks. Networks with lower cost are considered as economical networks, networks with medium bandwidth and medium cost are termed as bandwidth type networks and networks having higher bandwidth and higher cost is considered as higher bandwidth type networks.

III. REWARD CALCULATIONS:

Reward is a parameter which is bonus to the user if he switches from one network to other network having a common factor link. The reward is calculated using factors like Cost (C), Power consumption (PC), available bandwidth (BW), SAR value (SV).
As the mobile moves across various networks, the algorithm performs calculations for the reward of each available network based on the specified parameters. The reward of each network can be calculated via the following function.

$$\mathrm{Ri} = \mathrm{f}\left(\frac{1}{\mathrm{Ci}} + \frac{1}{\mathrm{PCi}} + \mathrm{BWi} + \frac{1}{\mathrm{SVi}}\right)$$

Where, Ri is the Reward getting from the ith network, Ci, PCi, BWi and SVi are the Cost, Power Consumption, Available Bandwidth, and SAR Value of the ith network respectively. In order to allow for different conditions, different weights can be assigned for different parameters. The equation becomes,

$$\mathrm{Ri} = \mathrm{f}\left(W_C \frac{1}{\mathrm{Ci}} + W_{PC} \frac{1}{\mathrm{PCi}} + W_{BW}\mathrm{BWi} + W_{SV} \frac{1}{\mathrm{SVi}}\right) \quad ..... \quad (1)$$

Where, WC,WPC,WBW, and WSV are the weights (values from 0 to 1) assigned to the parameters Cost, Power Consumption, Available Bandwidth, and SAR Value respectively. Each weight is proportional to the significance of the parameter to the VHD. The users can register their preferences in order to assign weights for the factors via user interfaces. The parameter which is more important to the user should have larger weight (Maximum 1.0) and which is least important should have lower weight (Minimum 0.0). Each network parameter has different unit and to normalize it the below mentioned equation is necessary

$$\mathrm{Ri} = \mathrm{f}\left(\frac{W_C \frac{1}{\mathrm{Ci}}}{\mathrm{Cmax}} + \frac{W_{PC} \frac{1}{\mathrm{PCi}}}{\mathrm{PCmax}} + \frac{W_{BW}\mathrm{BWi}}{\mathrm{BWmax}} + \frac{W_{SV} \frac{1}{\mathrm{SVi}}}{\mathrm{SVmax}}\right) \ldots\ldots\ldots\ldots(2)$$

Where

$C_{max} = \max\left(\frac{1}{C_1}, \frac{1}{C_2}, \ldots, \frac{1}{C_n}\right)$,

$PC_{max} = \max\left(\frac{1}{PC_1}, \frac{1}{PC_2}, \ldots, \frac{1}{PC_n}\right)$,

$BWC_{max} = \max\left(BW_{1,} BW_{2,\ldots,} BW_n\right)$,

$SV_{max} = \max\left(\frac{1}{SV_1}, \frac{1}{SV2}, \ldots, \frac{1}{SVn}\right)$.

Another important parameter is discount factor which is defined as weight given to the reward function. The assumption done here for discount factor lies between 0-1.

IV. POLICY FORMULATION

During the time of connection the MN will continuously scan the Received signal strength (RSS) of the current network. As it is observed that the value of a urrent network's RSS is less than a threshold value, it will scan for the adjacent networks.
During each handover decision, the mobile terminal will choose an action (i.e., select a network) based on the current application and previous history of delay of the target networks.

With this state (existing network) and action (handover to target network), the system then moves to a new state (target network) based on a transition probability function. Mobile Node will remain in the new state for a period of time until the next handover decision comes, and then new decision is made by the Mobile Node (i.e., selects a network again). For any action that the Mobile Terminal chooses at each state, a reward and a discount factor is associated with it.
Each MN is having a goal that the expected total reward that it can obtain during the handover to the target network should be maximized.
The goal of the MDP is to choose a policy that will optimize the return at any start state.

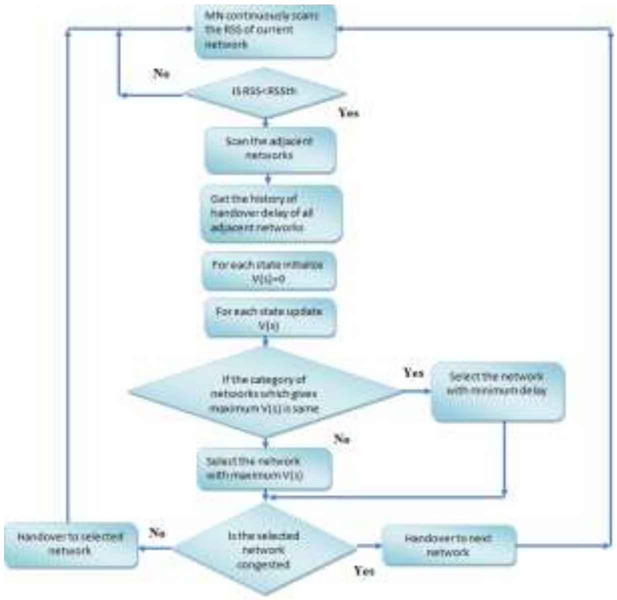

Fig.2 System Flowchart

With a policy π: S→A, we can obtain the discounted reward function as[13],

$$V(S) = \max_{\alpha \epsilon A} [Ra(s, s') + \gamma \sum Pa(s, s')H(S)] \quad ..(3)$$

Where,

V(s) – Expected maximum return
Pa(s, s') – is the probability of transitioning from state s to s' when action a is taken
H(s) – History of handover delay

Equation used here considers various parameters which helps in selecting a target network having less handover delay and which can simultaneously satisfy the user's requirement for the current application in other words this equation helps to optimize the handover process and maintain the quality of service (QoS).

V. SIMULATION AND RESULTS

Data used in this paper is used in a way to suit the purpose of this method. Assumption related to the actuals is used to represent a set of delays, user applications, its related rewards and discount factor defined in Table 4. These are used as weights for calculating the return function of each available network.

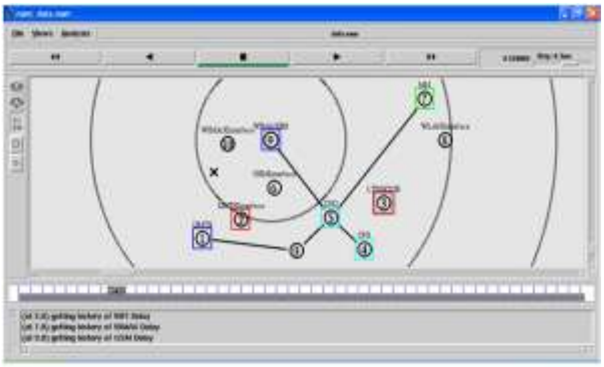

Fig. 3 Simulation Scenario

In this scenario MN is in the network coverage of WLAN. As it approaches the coverage area less than the threshold it approaches the adjacent networks Net 1, Net 2 Net 3, Net 4 & N5. The optimal policy decided here will help the MT to select one network amongst the available target networks.

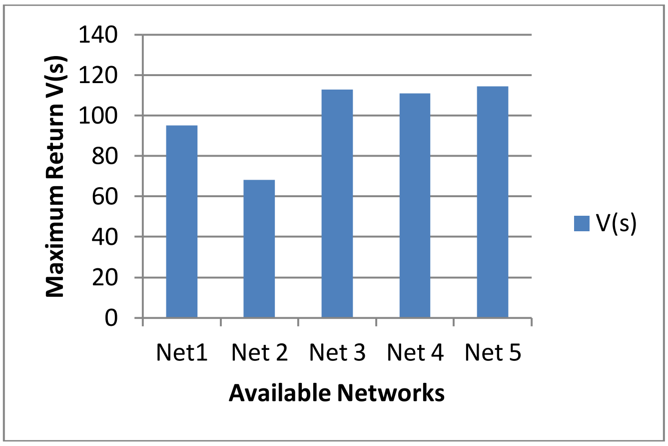

Fig.4 Network selection during Audio call

Figure 4 shows the network selection when the user's ongoing application is audio call. Here the MT previously was in economical type of network and here Net 3, 4 & 5 give max V(s) so the delay of these three networks are compared and Net 4 with minimum delay is selected which is also economical.

Similarly figure 5 and figure 6 shows the network selection when the users ongoing application is Video (non real-time) and video (real time) respectively. Our simulation here selects the Network 2 for video application as it is higher bandwidth type of network.

The simulation here helps to select the appropriate network for the current application.

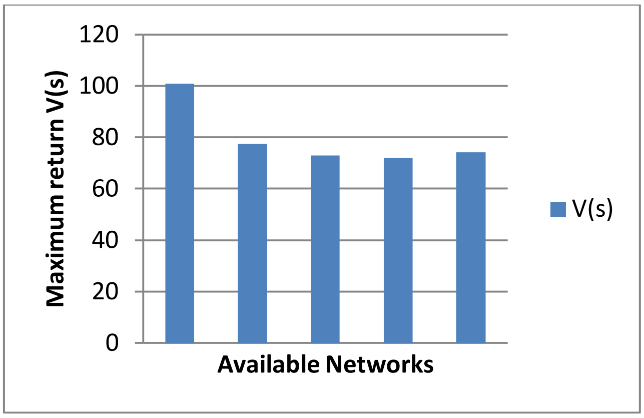

Fig.5 Network selection during Video (non real-time) application

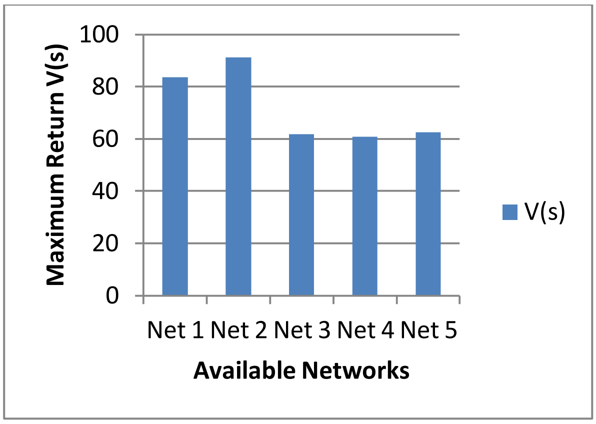

Fig.6 Network selection during Video (real-time) application

Call drop probability:

As the MN continuously scans the NN it collects the data of the status of congestion of a network. If the selected network does not have a free channel to assign for the call, the MN is forwarded to the next network with maximum return. This process takes care of congested network and reduces the chances of call drop during handover.

Bandwidth of the network is divided into number of channels and these channels can be allocated to the users as per the demand. Let tc be the total number of channels of the selected network, oc denote the ongoing calls in the network, ic denote the incoming calls at tk instant and dc be the departing calls at that moment. To calculate the call drop probability

$$tc \geq oc + ic - dc$$

has to be true before handover. If this expression does not stand true then handover is done to the next selected network.

If confirmation of the selected network for handover is done within 2ms then the call is continued else it will be dropped.
When a call during handover does not get a channel in the selected network with maximum reward then handover request is forwarded to the second network having maximum reward.

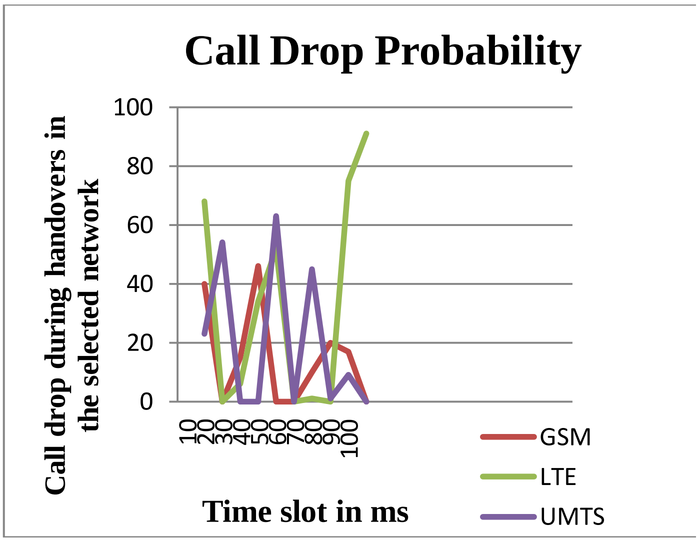

Fig. 7 Call drop in various networks during handover

VI. CONCLUSION

Calculations from above case scenarios successfully demonstrate that the algorithm assigns a suitable network considering the application and cost during handover. It also considers the SAR value. MDP makes proper utilization of information which is available on network coverage along with the available QoS on each interface to intelligently manage the allocation of network to requesting application. This process prevents both delays in handover and call drop during vertical handovers.
These results prove the basic point that coverage information as well as SAR value can play a crucial role in improving the QoS parameters when a MN roams freely inside heterogeneous network. This algorithm also reduces biological effects on human body.
Also, the decision to check the congestion status of the selected network before handover reduces the call drop probability.

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