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An Energy Efficient Protocol For Vertical Handoff In Mobile Networksusing Q-Learning

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ABSTRACT

Due to the fact that a mobile device can transmit different types of data ranging from text, audio, streaming multimedia video e.t.c., it becomes imperative that today's mobile device be able to perform a seamless transition when moving from one cell site to another especially when such transition involves mobile network of different technology (Vertical handoff). The requirement that different typebils of data has its unique QoS necessitates the need fora mobile terminal to connect to different types of networks best suited for the required QoS. There is need that today's moe devices be configured to be compatible with different networks technologies, such as 3G, 4G LTE, wifi , Wimax and 5G. These myriads of network also provide for the availability of more users to communicate simultaneously on wireless networks as evident in the increased use of the wireless communication media due to online learning occasioned by COVID-19. Cognitive radio has been used to opportunistically check for free channels within the range of channels allotted to primary users. This concept is borne out of the need to efficiently improve data throughput especially when mobile terminals (MT) move from one cell site to another and therefore need to make efficient handoff decision. The focus of this paper is two folds, first a mobile terminal must be capable of selecting appropriate network for optimum delivery, both in terms of QoS and user experience, and secondlythe design of an energy efficient protocol for channel allocation,as a mobile device moves between different mobile network technology, in a densely populated region using Q-learning. Most especially Q-learning will be used to search for multiple backup channels on an intending network for vertical handoff in a mobile network. This is an improvement over the single backup channel used in previous work as evident in the simulation results in this paper.

Keywords— Q-learning, Mobile Terminal, Quality of Service, Energy-Efficient.

I. INTRODUCTION

In today's mobile networking world there is a need for a mobile network to select a suitable network for an effective vertical handoff. This sometimes becomes necessary when a mobile terminal needs to select an appropriate network before considering the need for an energy efficient vertical handover when moving from BS to macro station. This is necessary in order to have a seamless and optimal handover with minimal delay and packet loss while also satisfying the user requirements of being cost effective.Hence it becomes imperative that a mobile device be configured so as to be compatible to different types of network, i.e. 3G, 4G, Wifi, Wimax and 5G.

Researchers has devoted attention in using cognitive radio in handling vertical handover in mobile networks through improving data throughput and minimizing collisions between primary and secondary users during mobile communication. As stated in (Jiang et al 2017),the primary users are expected to have uninterrupted communication within a channel, it is then imperative for cognitive radio to give access for secondary users to use these channels whenever they are not been used by the primary users,so as to give optimum use of the channel. However this is not as easy as it seems because there are no definitestatistics on how the primary users access the channels. In fact primary user's access to the channels are random and hence an intelligent protocol must be designed to efficiently access the channels so as to have optimum results.According to (Saravnan and Prithivra 2019), it is a known fact that channelsensing is as much energy consuming as transmission. Therefore, a protocol used for the cognitive radio for handoff decision must be capable of optimizing for high data throughput, minimal loss of data and minimal energy expenditure in sensing the primary user's channel.However, energy consumption cannot be considered as theonly metric of efficiency in wireless mobile networks, in general and inCRNs in particular. Other parameters must be taken into consideration when deciding on an efficient vertical handover decision, this includes spectral efficiency, Quality of service (QoS), cost of transmission and transmission delay. The motivation for this paper is as follows: (i) investigating the tradeoff between the spectrum utilization and the energyspent for transmission and reception in spectrum sensing andhandoff and (ii) Configuring a mobile terminal (MT) to select appropriate mobile network for vertical handoff in order to satisfy the user's requirement of minimizing cost of download. In this paper, a critical analysis between spectrum utilization and energy efficient vertical handoff is investigated. A new performance metric defined as bit persec per Hertz, namely the number of bits that can be transmitted perunit of energy is proposed.It is assumed that a cognitive radio is embedded in the mobile terminal (MT).The paper is outlined as follows: (i) in the second section, the spectrum sensing and spectrumhandoff strategies proposed in the literature are reviewed with a view to evaluate thedesign parameters of CRNs affecting the energy efficiencymetric.(ii) In the third section, the methodology for the Q-learning model is described, (iii) the fourth section shows the results and analysis from the simulation experiments performed and finally the fifth section gives the conclusion and future works.

II. RELATED WORK

In (Shuhui et al 2013),a model for the vertical handoff mobility in a two hierarchy network was designed. It was based on RSSI and signal to interference noise ratio. The shortcoming here is that (1) there are other parameters that is needed to model an optimal vertical handover, this was not considered here. (2) No mention of energy efficiency of the vertical handover scheme was mentioned in the comparison. (3) Errors resulting from faulty sensor readings of the cognitive radio embedded in the mobile terminal to determine the status of a channel was not also considered. For an optimal vertical handover scheme other parameters such as cost of services, network conditions and user satisfaction (user experience) must be included in the performance metrics. In the proposed Q-learning algorithm a value function, estimates the service quality for available channelsusing the parameters outlined above, and progressively updates the reward with higher values until the Q-value converges to the optimal. Whereas, traditional VHO schemes cannot achieve the optimization because they don't consider the influence of the other handoff UE (User equipment) requirements when implementing the vertical handoff decision (VHD) for a certain UE. In the work of (Vahid 2016), it was observed that many mobile devices may try to handoff to the same femto-cell or macro-cell, this is because the researcher's work only consider the individual UEs RSSI and SINR irrespective of the other handoff requirements. This may result in the collision among these UEs which eventually leads to more power consumption and a high block rate at the mobile devices resulting from increased congestion delays and dropped call probability. Hence the goal of this scheme is to facilitate the optimization of the various QoS for the different mobile networks.

In (Jung-Minand Dong-Ho2011)a model for a hierarchical macro/femto cell networks was developed. It serves as a realistic way of providing better quality of service to indoor mobile users. In these emerging networks, many low-power femto base stations (f-BSs) are implemented within the coverage of macro BSs (m-BSs) that typically use large transmit power for covering a wide geographic area. The shortcoming here is lack of support for the successful inbound mobility that corresponds to the handoff from the m-BS to the f-BS. In order to achieve this, an energy efficient handoff algorithm to be used in the hierarchical macro/femto cell networks is developed. A variety of handoff algorithms based on received signal strength (RSS) with hysteresis and threshold have been studied. In (Kyungkoo and Sijung 2017)the threshold sets a minimum RSS from a dealing BS and the hysteresis adds a margin to the RSS from the dealing BS over that from a target BS. However the energy efficiency of the macro/femto cell networks handover was not evaluated. Thereforein this paper, a new RSS- based handoff algorithm that is suitable for the hierarchical macro/femto cell networks is proposed. The handoff scenario considered in this paper is the inbound mobility from the m-BS to the f-BS capable of taking cognizance of other service requirements as opposed to the singular criteria used above.

III. METHODOLOGY FOR ENERGY EFFICIENT VERTICAL HANDOVER

A configuration of five mobile network is considered, namely 3G, 4G LTE, Wifi, Wimax and 5G. A Mobile device UE, is expected to be configured be able to use any of this mobile network. However only one of this network will be assigned primary responsibility on the mobile device, while the other mobile network will be assumed to be as secondary user.A mobile device in its primary network may decide to switch (handover) to a secondary network using the handover protocol described in the next paragraph. The following consists of the list of important parameters required for the handover.

(a) **Fitness for handover**: A mobile device may handover to an intending primary mobile network based on the following fitness requirements:residual battery energy of the mobile device, availability of free channels on the primary network, cost requirements, Received signal strength, and signal to interference noise ratio(SINR).

Residual energy: re_k Є (good, bad): This defines the ability of a mobile device to perform handover based on the fraction of the battery's remaining energy. A mobile device will perform the required handover if it has atleast 40% of the remaining energy remaining before performing the intended operation, otherwise the operation will be disabled and no handover will be done.

Availability of free channel: af_k Є (idle, busy) this defines the ability of a mobile device to perform handover based on the availability of free channel on the intending primary network. A network handover will be performed only if there exists free channels on the intending network to be switched. Otherwise the handover operation will be disabled resulting in nVHO.

Received Signal strength:rs_k Є (high low): This defines the power of the signal received from the intending mobile network. The received signal is high if the signal power in the channel of the intending network is higher than that of the current channel by at least -20dB and handover operation will be done, otherwise the signal received power is low and the handover will be disabled,

Signal to interference noise ratio:si_k Є (high, low): This denotes the levelof noise in the channel of the intending network. If the noise is below a certain threshold value of -22 dB, then the handover will be performed, otherwise the handover will be disabled.

Overall goal: The aim of the Q-learning model is to enable vertical handover if all the requirements for the parameters stated above is satisfied. The values of the parameters determine the Q-values which in turn determines the suitability for handover or otherwise.

3.1 The Vertical Handover Model

The main goal of the vertical handover model is to determine a fit channelfrom within the intending network to be switched to. The states, actions, observations and rewards for the vertical handover are described in Table 1. The transition model maintains a belief over the overall fitnessf_k of a mobile terminal's having enough remaining energy to perform the handover to an appropriate channel. , i.e.,re_k = good(g), if k (mobile terminal) has enough remaining energy to perform the handover and re_k = bad(b), if k is unfit.

It should be noted here that two parameters are required to perform this energy computation. (i) the fraction of the remaining energy of the mobile terminal and (ii) the availability of free channels in the secondary network. To determine fe_k, the evaluate action $\sim eval_k$ is used which determines a mobile terminal's capacity to perform a handover. This is a given by a weighted value of the following parameters: (i) Received signal strength (RSS) (ii) Signal to

Table 1: The Vertical handover $\sim eval_k$ function table.

VHO model	States	Observation	Action	Reward
Handover procedure	$F_k ε$ {f,u}	$O_{fit} ε$ {f,u}	$\sim eval_k$ cost Handover $success_j$ Handover failure Channel idle	$C(\sim eval_k) = -20$ $C(f_k'=f, transit_k) = 200$ $C(f_k'=u, transit) = -200$ C(idle) = -5
Danger	$F_k ε$ {f,u} Dangersent ε {1…….m} Dangerreceived ε {1…….m} $DangerDSent_j ε$ {T,F}	$O_{fit} ε$ {f,u} $O_{rec} ε$ {1…….m} $O_{trans} ε$ {1…….m}	$\sim eval_k$ Calculate vho_j Idle	$C(\sim eval_k) = -15$ C(f'transit=f/u,vho) =100/-200 C(f'transit=u/f,vho = 100/-200 C(idle) = -5

RSS	$si_k\varepsilon$ {good, bad} $rs_k\varepsilon$ {high, low} $af_k\varepsilon$ {VHO, no VHO} $t_j\varepsilon$ {good,,bad,}idle }	$T_{power}\varepsilon$ {good, bad} $T_{rb}\varepsilon$ {transmit, no transmit} $T_r\varepsilon$ {good, bad}	$Seek_{jj'}$ VHO_fit No VHO_unfit	$C(seek_{jj'}) = 20$ $C(f'_{mode} = f, sendfit) = 200$ $C(f_{mode} = u, sendunfit) = -300$ $C(f'_{mode} = u, sendunfit) = 200$ $C(f'_{mode} = f, sendunfit) = -300$ $C(lazy) = -5$

M = number of channels in the intending network, f = fit u = unfit

interference noise ratio (SINR), (iii) Probability that a channel is free P(F), (iv) cost per megabyte of transmission (C). The following types of data are transmitted in the mobile terminal: (i) Text, (ii) Audio, (iii) Animation (iv) Graphics, (v) Video, (vi) HDD video, (vii) Streaming video. The nVHO (disable handover) action is taken when the mobile terminal does not have enough remaining energy for the vertical handover or when no free channel is available on the intending channel. Table 2 lists the different network technology and the preferred data type for transmission.

Table 2 Data types with the corresponding intending network

Types of data	Network type applicable
Text	3G
Audio	Wifi
Animation	4G LTE
HDD Animation	5G
Graphics	Wimax
HDD graphics	5G
Video	4G LTE
HDD video	5G
Streaming video	5G

There is a cost associated with the ~$eval_k$ action. Here it is assumed that whenever the mobile terminal does not have enough remaining battery energy or no free channel is available in the intending channel for the vertical handover, the handover operation will not be possible and thus a penalty $C(f'_k = u, transit_k)$ is levied. Similarly, a reward $C(f'_k = f, transit_k)$is given for selecting a secondary mobile network with adequate free channels to enable the handover It should be noted that~$eval_k$ is an abstract action which in turn calls the transition action. The transition action will only be called when the intending network has a free channel for vertical handover. The simulation environment is shown in figure 1.

An example of the ~$eval_k$ action is now explained for a VHO that has two channels that can be transited to within the intending mobile device , as shown in table 2 i.e. here a decision will be made to perform vertical handover among the two alternatives. Initially equal observation is given to different combination (channels) possible under this scenario. This includes: (i) the first and the second channels are free, this is denoted as ff i.e. (fit fit), (ii) the first channel is free, but the second one is busy. This is denoted as fu i.e. (fit, unfit) (iii) the first channel is busy while the second channel is free. This is denoted as uf and (iv) the first and second channels are busy,this is denoted as uu. In order to describe this operation the four different combinations possible from the permutation of the actions are initially assigned the value 0.25. However after the POMDP model is applied and the mobile terminal perform the vertical handover (VHO) for the cases involved, the actual observation probability is then obtained. This is explained as follows: after the ~$eval_k$ sub-function is activated actions uu has observation probability of 0.15, fu has observation probability of 0.02, ff has observation probability of 0.47, and uf has observation probability of 0.03. These are the probability from the simulation in the environment scenario shown in figure 1.

Environment	
Field size	1km X 1.8 km
Number of base-stations	6
Number of access beams	[4 4 4 4 4 4]
Number of link beams	[4 10 10 10 10 4]
Transmit Power (dB)	45 42 42 42 42 45]
Mobility Model	Semi-deterministic

Fig 1 Simulation Environment

3.2**The Q-learning Model**

The Q-learning model consists of the following:

(1) **States**: This consists of the different mobile network a mobile device can switch to i.e. 3G, 4G Wifi, Wimax, and 4G LTE or 5G.

(2) **Actions:** This consists of the transitions that is accepted between the various networks. For example a mobile device can switch (transition/VHO) from a primary location of 3G to an primary location of 4G LTE (The primary network for the simulation is fixed as 3G while the transition is fixed apriori as shown in table 2).

(3) **Transition function:** This is modeled using Partially Observable Markov decision process. It describes an iterative procedure that enables the mobile device makes the optimal decision in choosing an appropriate mobile network for handover. It learns of the most probable free channels in the intending network and assigns Q-value to them. It gives higher reward (Q-value) to the channel that has the most-likelihood of being free. This defines the transition function that is able to optimize all the parameters used in making the handover decision. This replaces the old reward. Hence the reward is progressively updated with higher rewards until the value converges to the optimal value.

(4) **Reward:** This allocates reward for any particular transition. Initially the reward is 0 showing that the agent has learnt nothing about the environment i.e. channels in the intending network. However as the agent continues to make transition from one channel to another with the intending mobile network, it learns about the probability of a channel being idle and otherwise and thus assigns appropriate Q-value to it.

(5) **Value Function:** This describes the mathematical model that describes the convergence of the algorithm. The algorithm converges when the agent learns on the appropriate channel on the intending mobile network to switch to from its primary location which in this instance is the 3G network.

3.2NOVHO / VHO

This sub-function is responsible for triggering the unfit signal procedure when the battery level of the mobile terminal (MT) is low, or all the primary channels stored in the channel table for the required VHO is busy.Alternatively, when the MT battery level is high, the cognitive radio embedded in the MT search for free channels from the appropriate intending primary network as described in section 3.1:

However instead of searching for a backup channel as in (Saravanan and Prithiviraj 2019), the Q- learning protocol is used to progressively update and store the best three free channels from the list of available channels. This is needed so that in case the first backup channel is found to be busy, the mobile agent can use alternate channels using the POMDP transition model. The number of searched channels is limited to three so that the size of the channel table does not grow far above the capacity of the energy constrained MT and also to make the protocol converge in finite time. An alternate channel is scanned using the $C(seek_j)$ action. Here the Q-learning model is used to scan for 3 channels with the highest Q-values, using a weighted Quantized value of the formula given below:

$$RSS + SINR + P(F) - C \qquad (1)$$

Where RSS is the received signal strength, SINR is the signal to interference noise rate percentage, P(F) is the probability that the given channel is free and C is the cost of transmission per megabyte.The flowchart for the Q-learning protocol is shown in figure 2.

As said earlier this scenario can happen in two ways: (i) when a MT battery energy is low and hence the VHO routine will be disabled. This will translate to nVHO_unfit. In this case the alarm sub-function will be triggered which displays on the MT “Battery down please recharge. (ii) When a MTsearch for free channels in the primary network spectrum using the C_{seek} function, described in section 3.1.

The aim of the cognitive radio (mobile agent) is to select a channel with the highest Q-value. It stores the three free channels with the highest Q-value. This is an improvement over the technique used in literature by other researchers where a backup channel is reserved as a secondary network channel for a VHO. The shortcoming with the previous researcher’s work is that in the event the backup channel is busy, the handover will not be performed which will lead to packet loss.

The other use of this sub-function is to use the POMDP model to identify when false information is given about a channel i.e. when a free channel is erroneously identified as busy or when a busy channel is erroneously identified as free. This is performed by the rating procedure r_k. When the $\sim comp_k$ sub-function is activated it assigns probability to the free channels. Q-values are assigned for this observation. This includes (i) good recommendation, which shows that a secondary channel is good and fit for VHO, (ii) probabilistic recommendation, which shows that a secondary channel may or may not be able to perform the vertical handover routine.

Equations 2 – 4 below show the conditional probability for the rating sub-function used for P(F)in equation 2. In the equation, N_{good} denotes that a free channel is identified as free. i.e., number of times re_k=good, rs_k = high, t_j= VHO, si_k = high while N_{bad} denotes that a free cannel is denoted as busy and vice-versa. i.e., number of times re_k= bad, rs_k = low, t_k= no VHO, si_k = low.

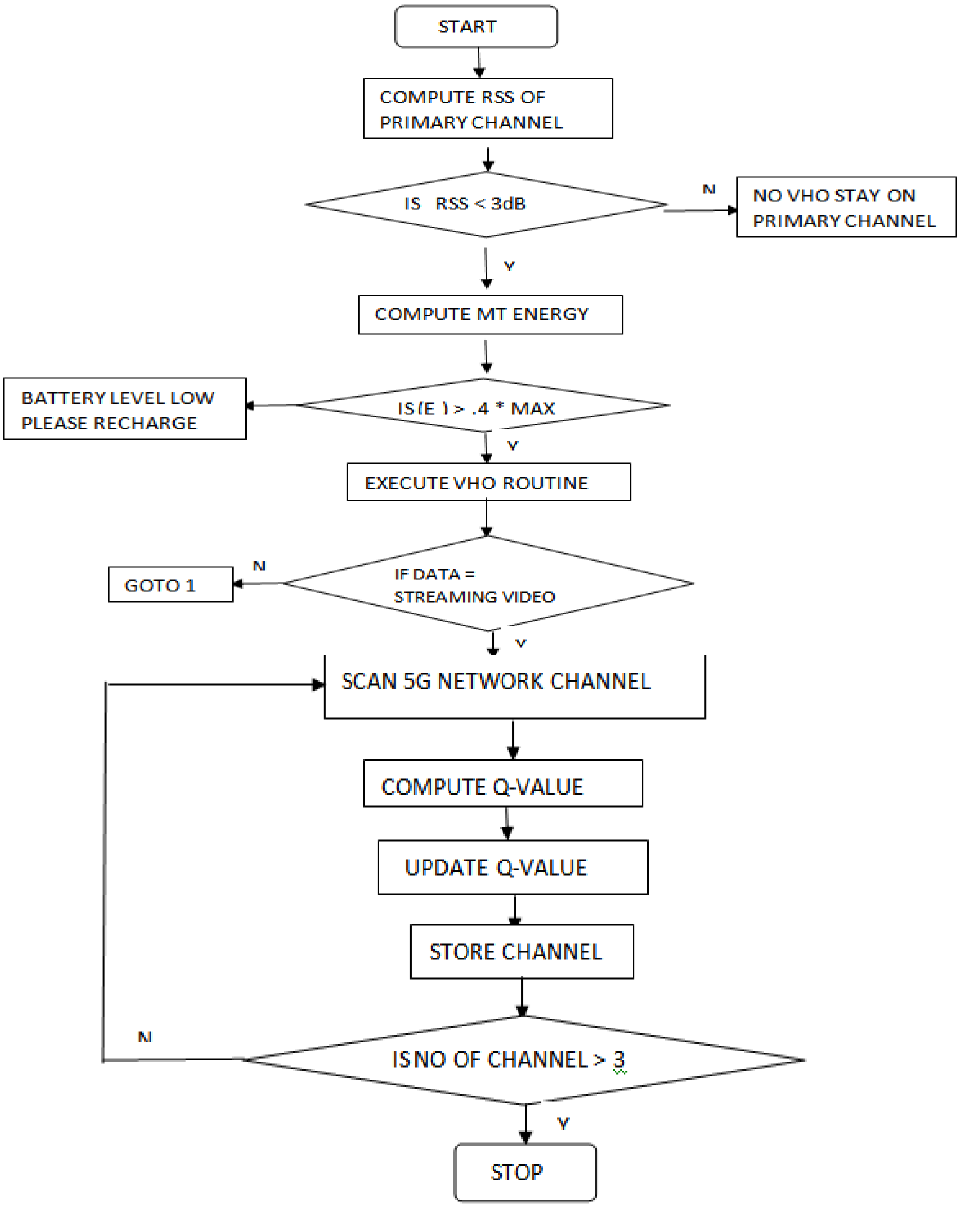

Figure 3 Flowchart for Q-learning Vertical handover protocol

NB In the flowchart GOTO 1 will scan the other mobile network depending on the type of data to be transmitted.

$$b^0(s) = b^0(f_1|re_1,rs_1,si_1)\, b^0(f.re_1)\, b^0(f.rs_1) \text{ -------------} \quad (2)$$

$$b^0(f_1 = g \mid re_1,rs_1,si_1) = \frac{N_{good}}{N_{good} + N_{bad}} \quad (3)$$

$$b^0(f_1 = b \mid re_1,rs_1,si_1) = \frac{N_{bad}}{N_{good} + N_{bad}} \quad (4)$$

IV. RESULTS AND ANALYSIS

The performance of the proposed vertical handoff scheme, is evaluated in terms of collision probability and throughput. Thiswas performed through extensive simulations and the results analyzed with two other protocols “POMDP–backup” (Muhammad et al 2017), and “POMDP–no backup (Sultan. 2014), schemes. The POMDP–no backup scheme makes an optimal decision to stay idle or sense/transmit based on POMDP, but considers only the operating channel for transmission, whereas POMDP-backup searches a backup channel in addition to the optimal channel in the intending mobile network when the received signal strength of the current channel falls below a threshold value.

The POMDP-based scheme considers the entire future horizon to maximize the value function.The parameters used for simulations, unless otherwise specified, are summarized in Table 3. Thesimulation is executed for 200 iterations (slots).

Table 3 Simulation Parameters

Description	Symbol	Value
Number of sensor nodes	MT	1
Number of channels	C	16
Operating (backup) channel idle probability	$P(H_0)$	0.5
Transition probability from state F to itself	$P_0^{FF} = P_B^{FF}$	0.6
Transition probability from backup to free	$P_0^{BF} = P_B^{BF}$	0.4
Signal to noise ratio for intending network for 3 channels	Xc	-12dB
Signal to noise ratio at primary network	X_p	-22dB to -7 dB
Slot duration	T	25ms
Sensing duration	T_s	1ms
Battery maximum capacity	E_{max}	4W
Transmission energy	E_{tx}	2W
Energy consumed in sensing	E_s	1W
Energy consumed in switching	E_{sw}	0.5W

Figure 3 shows the average throughput of the Q-learning VHO scheme in comparison with POMDP–nobackup, and POMDP-backup schemes for different values of the target detection probability.Here a high value of (P_d),indicates more protection for the Primary network i.e.there will be no transition to an intending channel except it has a high RSS value, and its prior probability of being free is high. This translates to fewer transmission opportunities for the secondary user (SU), which translate into reduced throughput of the intending mobilenetwork. This relationship can be analyzed from the figure as the value for throughput is inversely proportional to the target detection probability. For all values of the detection probability, the Q-learning VHO scheme performs better in terms of achieving higher average throughput compared with the other two schemes. This is because by having more alternate backup channels to switch to there is less likelihood of all backup channels being busy, unlike the POMDP-backup that has only one backup channel where in the event of the backup channel being busy will lead to packet loss and low data throughput..

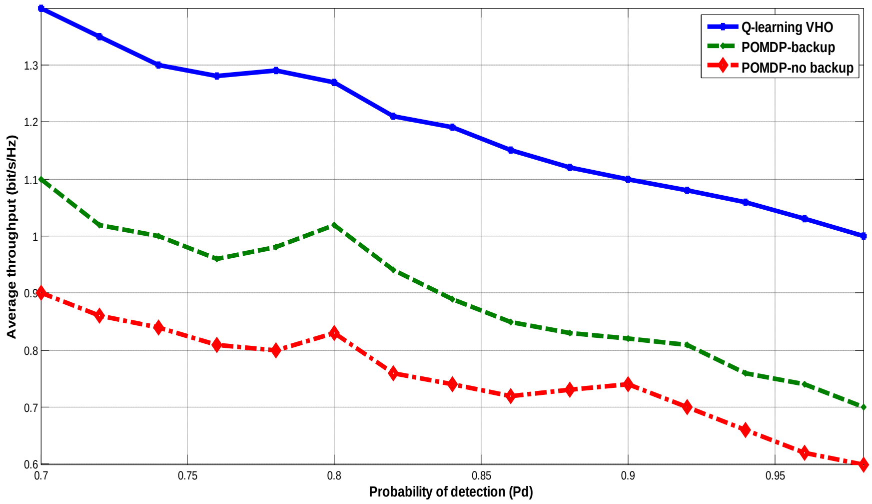

Figure 3 Graph of Average throughput with varying values of P_d

Secondly the fact that the channels are regularly updated means that an optimum channel will always be chosen for handover such that the probability of call drop is reduced, thereby increasing the throughput of the data transmission as evident in figure 3. The Q-learning improves the throughput in comparison to POMDP-backup by 27% and the POMDP-no backup by 55%

The simulation results for the analysis of the maximum average throughput for different battery capacitiesare shown in Figure 4a and figure 4b. P_d was kept constant at 0.9. As expected the maximum throughput for the three protocols increase with an increase in battery capacity. This can be seen from figure 4a, this is because a higher value for E_{max} signifies higher remaining battery energy which ultimately translates to more energy for vertical handover to the intending mobile network. The Q-learning VHO improves the maximum throughput by 20% compared with POMDP-backup and by 38% compared with POMDP-no backup as can be seen in figure 4a. Figure 4b shows that the average throughput decreases with increase in transmission energy, this is because as more energy is expended for data transmission it drains the mobile terminal battery more leading to less energy remaining to partake in vertical handover. This signifies that the transmission requirement for data transmission should employ an energy efficient vertical handover protocol so as to prolong the active time of the MT.

From the figure it can be realized that for E_{tx}= 1, E_{tx} = 2, and E_{tx} = 4, there is no throughput for E_{max}less than 2, 3, and 5, respectively. This is due to the fact that the energy required for sensing, transmission, and switching exceedsthe maximum capacity.

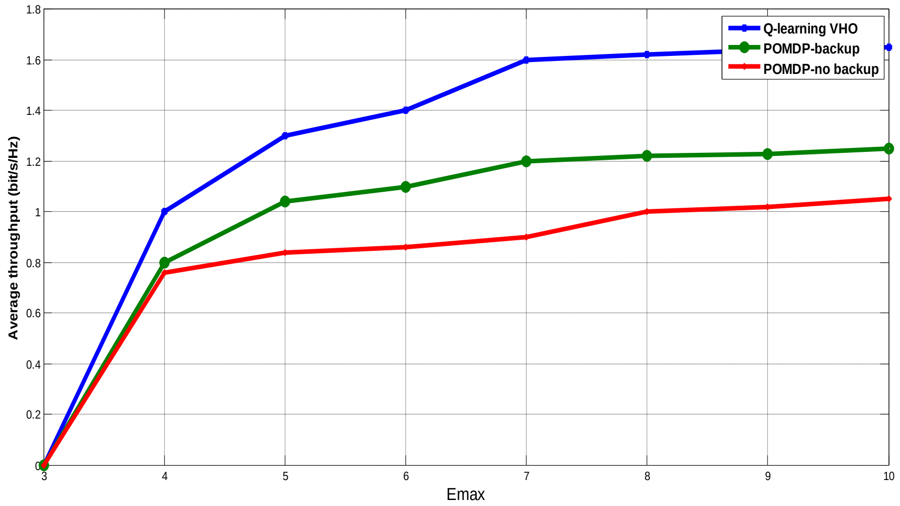

Figure 4a Graph of battery capacity on average throughput

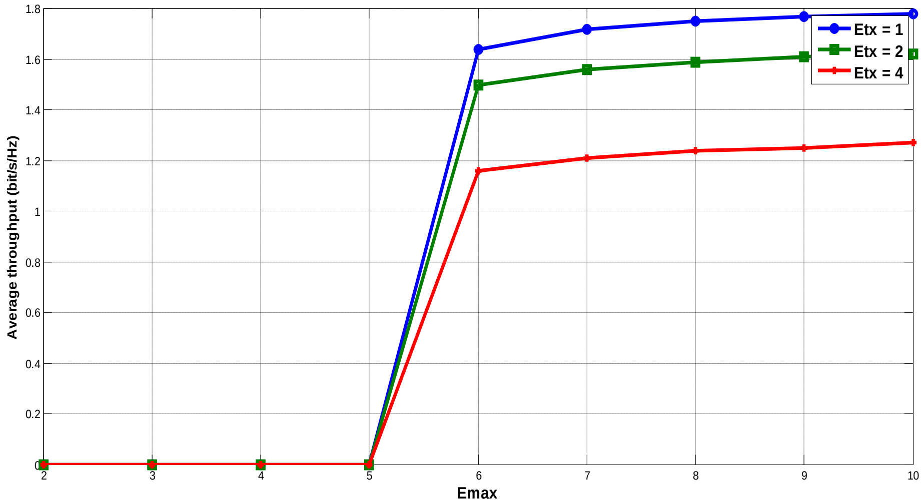

Figure 4b Graph of transmission energy on average throughput at varying values of E_{max}(battery energy)

In Figure 5 the effect of transmission energy on average throughput is analyzed. It can be seen from the figure that Q-learning VHO outperforms POMDP-backup scheme by 14% and the POMDP-no backup scheme by 58%. The proposed scheme's ability to regularly update information concerning the backup channels gives it an edge over the other two protocols as the probability of all backup channels being busy is quite slim.

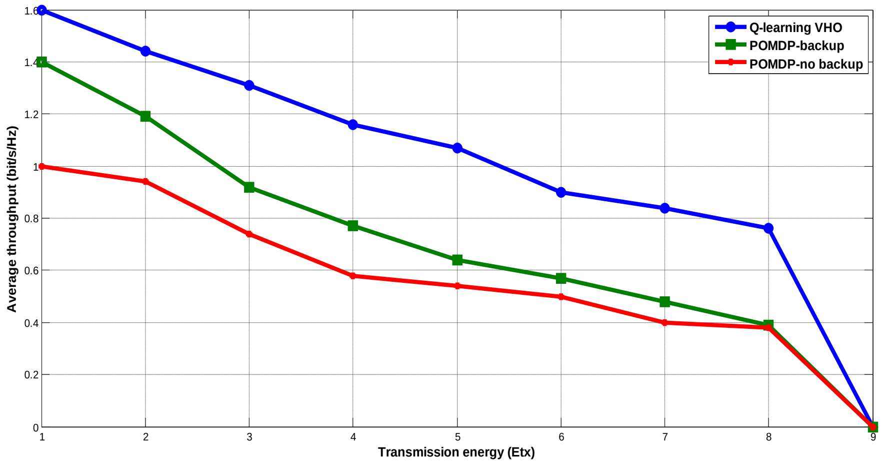

Figure 5 Graph of throughput with varying transmission energy

The transmission energy is increased while the value of $E_{max}$is fixed at 10. For E_{tx} = 9, the throughput drops to zerobecause both transmission and sensing energy become equal to E_{max}, which is the condition for no transmission.

Figure 6 shows the analysis of varying the idle probability (belief) of the operating channel on average throughput. Here the idle probability of the operating channel is varied, while keeping the idle probability of the backup channels fixed at 0.5. For $P(H_0) < 0.5$, the MT searches for free channels on the intending network because the continuous transmission on the operating channel results in significantly lower throughput. When $P(H_0)$) is increased from 0.5 to 0.8, the throughput for the Q-learning VHO outperforms that of POMDP-backup by 33% and the POMDP-no backup scheme by 68%. This is due to the proposed scheme availability of more free backup channels and its regular updating of this backup channels for optimum data transmission i.e. it updates its channel table with channels with high probability for successful transmission. This is responsible for its improvement over the POMDP-backup scheme, for in the event that the backup channel is busy data will be dropped. In comparison with the POMDP-no backup scheme, a huge improvement was realized because of the absence of backup channel. Here data will be dropped as soon operating

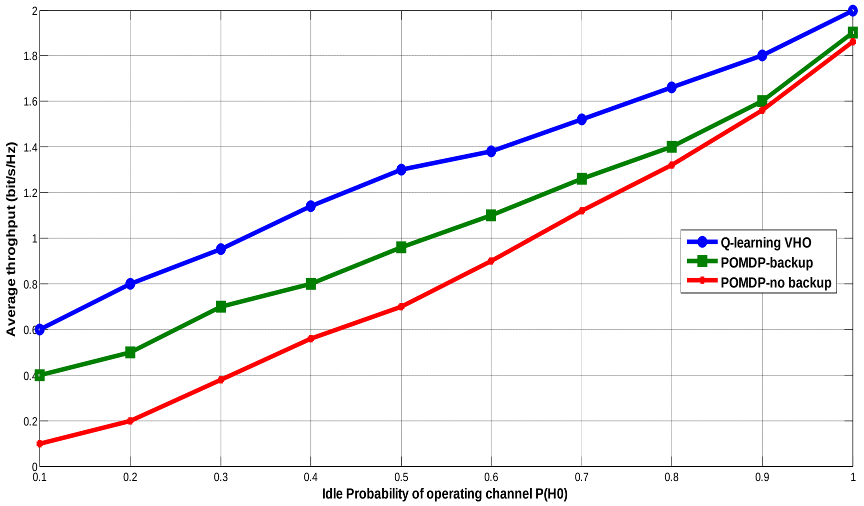

Figure 6 Graph of average throughput at varying idle probability of operating channel while idle probability of backup channels are fixed.

channel is busy i.e. probability of operating channel is low.

Figure 7, shows the analysis where the average throughput of the intending network(backup channels) idle probability $P(H_b)$ is varied while that of theoperating channel ($P(H_0)$) is fixed at 0.5. Since the value of $P(H_0)$) does not change, throughput of the other schemes remains constant.On the other hand, when $P(H_0) < 0.5$, the MT searches the intending mobile network for free channels using the Q-learning protocol for data transmission thereby switching to the backup channel for data transmission. Now since the Q-learning VHO regularly updates its channel table,it will always have available free channels for transmission thereby leading to an increased throughput of the proposed scheme. For $P(H_b) > 0.5$, the probability of having free channels on the intending mobile network's is high. This translates to data transmission being on the backup channels.Analysis of figures 6 and7show similar trend in average throughput (i.e., increasing the idle probabilities of operating of operating or backup channels increases the average throughput. However, it can be seen that the average throughputcorresponding to the highest value of $P(H_0)$ is higher than that of the highest value of $P(H_b)$. In fact increasing the idle probability of the operating channel results in an increase of the average throughput of the Q-learning VHO by 12% compared to that of POMDP-backup, and by 23% compared to POMDP-no backup. (This is less than the comparative increase in figure 6). Thisis because a higher value of $P(H_b)$ causes the MT channels on the intending network. This results in extra energy and delay, which translates to a slightly lower throughput.

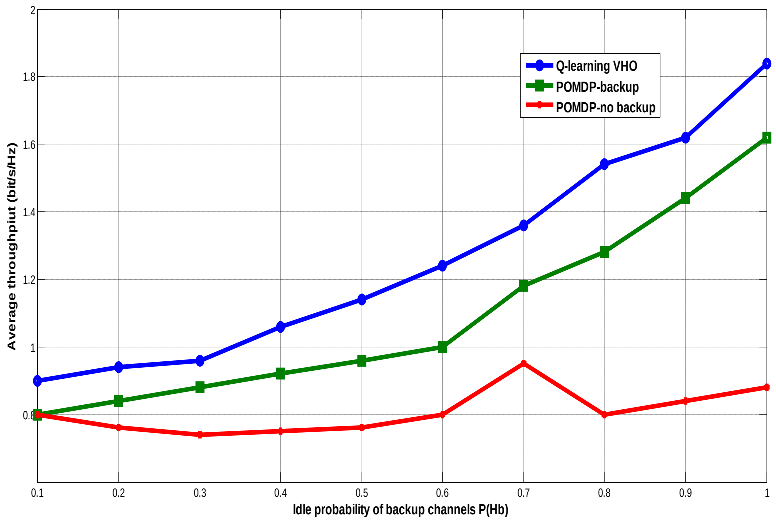

Figure 7. Graph of average throughput on varying idle probability of backup channel while idle probability of operating channel is fixed.

V. CONCLUSIONS AND FUTURE WORK

Channel handover involving multiple networks is inevitable due to the differing QoS (Quality of Service) requirements of the different types of data types being transmitted online. This is the reason behind this paper, A protocol was proffered for an energy efficient techniques for vertical handover that satisfies both QoS and the user experience. The previous researcher's method of having an extra backup channel among the intending network cannot fully guarantee high throughput in all conditions, considering the high volume and rate of mobile data transmission in recent time. Subsequently the present Corona virus pandemic(COVID 19), we are currently experiencing in the world has almost doubled the volume and rate of mobile data communication. Hence this paper is a highly welcomed idea in this period as the availability of more up to date backup channels with high throughput capability will help to reduce the frustrations of users especially as it concerns online streaming multimedia applications.

Future work will be concentrated on how to develop an optimal protocol totransmit data on a high streaming multimedia platform. This will require dedicated channels primarily for this purpose as this type of applications has increased considerably worldwide.

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