A Bayesian-Based Vertical Handover Management Algorithm for Heterogeneous Networks

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Abstract

One of the key challenges for providing services over Heterogeneous wireless networks is the design of Handover Management strategy to guide the decision for a mobile terminal (MT) handoff between different types of networks. Handover process is a necessity in order to cope with various multimedia services QoS settings. The traditional handover decision algorithm is usually based only on Received Signal Strength (RSS) or focused on the network-physical level parameters. The aim of this paper is to present a novel intelligent vertical handover management algorithm that can achieve seamless connectivity and Always Best Connected (ABC) call status for group mobility, while considering user satisfaction and/or to meet application or device related contexts. The proposed algorithm strategy is based on Bayesian classifier, which is one of the advanced tool and proven concept for knowledge representation and inference under uncertainty.

The proposed Bayesian-based vertical handover management strategy (BBVHO) evaluates and create relationships between different decision attributes, related to heterogeneous networks conditions, terminal capabilities, application requirements, and user preferences. Afterward, the estimates of each attribute value are forwarded to a Bayesian classifier to select the optimal access network.

For evaluation of the proposed Bayesian algorithm performance, it is simulated in a heterogeneous network's environment, offering both real time services (voice over IP services), and data Services (packet data traffic). The performance results show that the use of the Bayesian based management strategy to carry out the Handover process can enhance the QoS perceived by both types of voice and data service, while fulfilling to great extent the user preference. The simulation study also showed that the proposed BBVHO algorithm outperforms the Received Signal Strength (RSS) traditional scheme in all performance measures. Besides, It allows solving the complexity of the handover decision process resulting from the multitude dimensions of the VHO decision criteria and the dynamicity of many of its components.

Keywords: Vertical Handoff (VHO) Scheme, Bayesian Classifier Application In Networking, Bayesian Network Algorithms, QoS Over Heterogeneous Networks.

1. INTRODUCTION

The wireless network sector specifies radio interface systems are focused towards integration of different wireless access technologies. The next generation (NG) of mobile networks will result in in a converged network of different wireless access technologies because of the growing demand of the mobile users to access various services anywhere and anytime [1]. In wireless network environment a call vertical handoff VHO (across heterogeneous networks) and a horizontal handoff HHO (within a same network type) are challenging issues. VHO and HHO must be frequently activated to reduce call drop probability for achieving Always Best Connected call status. Due to the different characteristics of wireless access networks, vertical handovers can also result in modification of service quality provisioning. Hence, networks with limited resources, needs to implement different handovers schemes to enhance QoS, reduce connection cost, reduce power consumption, improve network utilization, fulfill user convenience and/or to balance traffic load.

To handle VHO tasks, mobile terminals (MTs) must be able to seamlessly reconnect to the best access network, among several candidates' heterogeneous wireless networks, without being interrupted to an ongoing call communication or any traffic discontinuity [2]. Therefore, in the case of vertical handover between two different access networks, an important measure is minimization of the data loss and interruption time during the handover. The end customer may or may will not become aware of the replacement unit of the access network, but handover should be transparent to the application. Thus, the performance of VHO techniques has a direct effect on each user's individual satisfaction and on the overall network performance.

Because of the growing popularity of cellular communications and the central role that handover strategy plays in QoS provisioning, VHO in heterogeneous cellular networks has received a great deal of attention in recent research literature. A number of researches addressed VHO decision making strategies and are summarized in [3]. The handover problem is tackled through proposing various vertical handoff algorithms that takes into account end-to-end QoS metrics (e.g. handover delay), based on a common network parameter (e.g. RSS), and aim towards enhancing connectivity across different types of networks including WLAN to WiMAX, Wi-Fi, Bluetooth and UMTS [4-14]. In general, handover management decision making algorithms in recent literature are based on either : user mobility profiles and configurations, by using utility functions for network resources, or is based on Intelligent techniques such as: fuzzy logic, back propagation neural network, and genetic algorithms[5-7,11].

Many of these previous research works, however, either concentrate on the network level parameters (e.g. RSS), or are limited to cellular and Wi-Fi or a Bluetooth networks. Furthermore, it is application for intelligent scheme limit its use for a single or few decision criteria. Our work broaden the handover decision criteria to involve various diverse parameters related to customer's satisfaction, network needs, device attributes and application and service requirements. It is also applied for vertical handover management in multi-heterogeneous networks offering both real time services and data Services.

The organization of this paper is as follow: Next Section presents the design concepts of the Bayesian Based vertices handover algorithm and its various attributes and decision criteria. Section three covers the details of the simulation Study, carried to evaluate the performance of the handover management strategy algorithm. In section four, we present the performance of the proposed Bayesian based vertical handover algorithm and its comparison to the traditional RSS based vertical handover strategy.

2. BAYESIAN-BASED VERTICAL HANDOVER MANAGEMENT STRATEGY

Bayesian classifier is one of the advanced tools for inference under uncertainty and knowledge representation [15]. Based on the beliefs of numerous descriptive attributes, that is widely used to assign a class from a predefined set to a target object under consideration. Using Bayesian Network as classifiers, have many effective applications in several domain [15, 16]. For a particular system, Bayesian Belief Network (BBN) model simulates the behavior of the system under uncertainty. It reflects the states of system that is being modeled and describes how those states are related by probabilities. Bayesian Networks can draw conclusions and does inference about the future system state.

In this paper, we considered all the vertical handover process attributes related to application requirements, user preferences, device resources and network resources. Each one of these attributes parameters are used as the input of the classifier system that we build based on a Bayesian Network classifier. A forwarding score (Bayesian classifier factor) is then computed for each call handover request as a probability of handover to a particular network. The selection of the best network is then based on various attributes instantaneous values which are measured from all available candidate networks, as well as from MT based on the attributes model. As multiple criteria for evaluating the available alternatives has wide variances in its values, the users' and/or operators' preferences is first decided. Afterword, each other attribute value is evaluated based on the relative importance of each attribute involved in selecting the candidate networks.

2.1 Bayesian-Based Handover Strategy Design Phases

Bayesian-Based handover management strategy design involves the execution of the following phases:

- Handover criteria definition:

Here various decision criteria related to handover process are defined. The relationships between different decision criteria and its attributes related to heterogeneous networks conditions, terminal capabilities, application requirements, and user preferences are created.

- Handover attribute information gathering:

The information required to identify the need for handover are collected. Estimates of each attribute are determined. Handover will be initiated on the basis of this information. This stage can also be called handover initiation phase.

- Bayesian-Based handover decision

In this stage which also can be called handover decision phase. The belief of each criteria attribute is forwarded to a Bayesian network to select the optimal access wireless network. Handover will be initiated on the basis of Bayesian network outcomes. In this stage, the VHO decision will be determined to select the most suitable access network (taking into account defined criteria attributes). Instructions to the execution phase are the output of this phase.

- Handover execution

In this stage, the result of the decision phase is executed.

2.2 Bayesian-Based Handover Strategy Decision Criteria Attributes

The strategy presented in this paper included various handover attributes related to several decision criteria to perform the VHO decision. These attributes are the qualities measured or estimated to give an indication of whether or not a handover is needed. We can regroup these attributes as follows:

- Network-related

Coverage area, bandwidth offered, latency, network availability (RSS (Received Signal Strength), CIR (Carrier-to-Interferences Ratio), SIR (Signal-to-Interferences Ratio), BER (Bit Error Rate), network traffic load, and security level.

- Terminal-related

Device mobility speed, battery power, location information, etc.

- User-related

User profile and preferences (data rate/bandwidth required), affordable cost for the service.

- Service-related

Monetary cost of service, service capabilities, QoS, etc.

The buildup of the BBN involves three steps. The first step is identifying all attributes of the model. Second step is to build the Influence Diagrams (ID) in which random variables of interest and the directed arcs represent causal or influential probabilistic relationship between the nodes is defined. Once the ID's identifications as shown in Figure 1 is completed, the probabilities are entered into the network, through a Conditional Probability Table (CPT) for each node in the network. These tables are constructed by subjective estimate from the experts. For variables with no parents, this task is simple; its CPT is reduced to its prior probability.

In this research, the probability tables have been set up based on subjective estimate for the illustration purposes as stated above. In practice, other criteria can be also identified. Most of the synthetic criteria assume three values, which are low, medium and high. These values are deterministic and are set according to the attribute value combination. For example, the user preferences are normally set to high, medium or low depending on the cost and the quality of service values. The probability is then read directly from the Conditional Probability table.

The implementation of the Conditional Probability Tables (CPT) parameters depend on the problem domain. In some domains, the knowledge of the attributes can be specified as a mathematical formula. In other domains, information on the relationship is available as a database of cases in which case parameter estimation is used. If the knowledge is not available as a mathematical formula or data, then subjective estimates have to be used as what had been done in as input to Bayesian network to give us a result of the best wireless network that MT should move to.

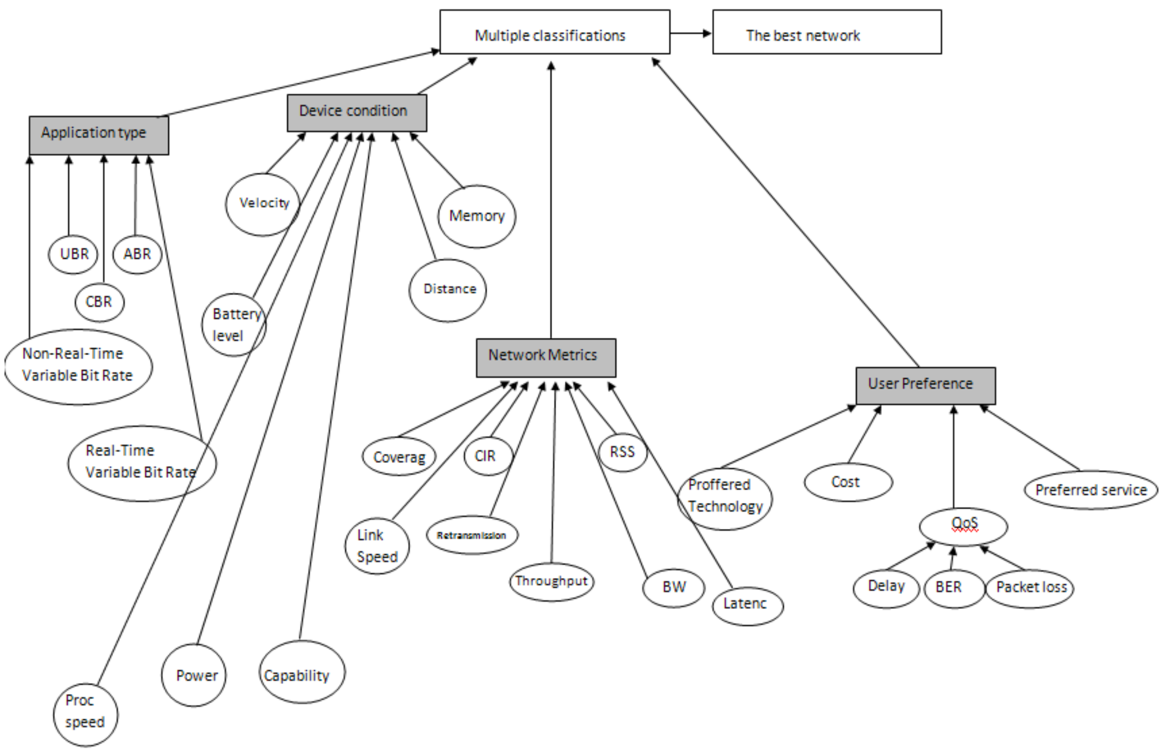

FIGURE 1: Influence Diagrams.

3. HANDOVER MANAGEMENT STRATEGY SIMULATION STUDY

To show relative improvement in performance by the proposed handover strategy as compared to traditional handover strategy, a detailed simulation experiment were developed for performance evaluation of our proposed BBVHO. The simulation software was developed using C++ and was linked with MATLAB.

As discussed in section two, the BBVHO starts by defining all required attributes and relations. The attributes parameters were presented earlier under four categories: network, user preference, device condition, and application type. Afterwards, the actual process of timely vertical handover is broadly divided into three phases: handover initiation phase, handover decision phase to select target network and handover execution phase. All three phases are collectively responsible for a handover decision. In our simulation experiment, all required attributes and relations are predefined according to Influence Diagram (ID), discussed previously. We took the following attributes into consideration, to select the optimum wireless access network:

- Received Signal Strength (RSS)
- Mobility (Speed of the MT)
- Data rate/bandwidth
- The cost for the service
- QoS (Packet Delay, BER, and Packet loss)
- Preferred Technology
- Preferred service
- Throughput
- Area Coverage
- Battery Level
- Distance between MT and BS
- Application Type (Real Time and non-Real time)

During handover initiation phase, various instantaneous estimation of these attributes are given to the classifier network and keep continuously collected. According to traditional handover algorithm, the handover is triggered at a point where MT within area is covered by two or more wireless networks. Traditionally, the wireless network with high RSS is always recommended. The proposed handover strategy will consider not only RSS but all attributes parameters to select best network. At the beginning in the simulation experiment, the signal strength of serving cell as well as neighbor cells are continuously monitored. if MT is determined to be located in overlapping coverage area, the handover decision process will be initiated to find the best wireless network. At the decision phase, the Bayesian controller is executed to evaluate all wireless networks within MT coverage area. Using various estimates of attributes as inputs, the classifier will decide on the optimum network that MT should switch to, which balance the user and service provider expectation level with QoS requirement. All parameters values is updated when MT is triggered to move to another wireless network or is going to stay in the current network.

3.1 Network and Traffic Model

In the simulation experiment, we included multi-heterogeneous networks in the vertical handoff decision phase including: a single LTE, WiMAX and WLAN network with network coverage as shown in Figure 2.

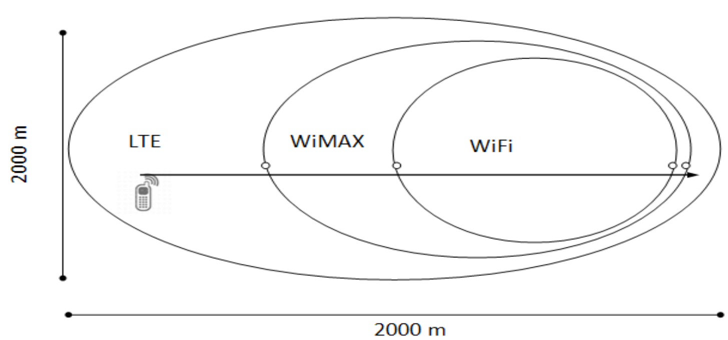

FIGURE 2: Network Coverage Model.

Each mobile connection may experience a number of vertical handoffs during its connection lifetime. The MT is assumed to periodically receive information from the collocated networks within its receiving range. The mobile user is assumed to travel in a straight line with constant speed from serving cell to neighboring cell. The network model includes an LTE BS covering all area and that the network setup covers different combination of overlapping regions between various wireless network technologies. Table.1, shows the simulation parameters for each wireless network.

Factors	LTE	WiMax	WiFi
Bit Rate	35 Mbps	70 Mbps	54 Mbps
Coverage	Wider	16 Km	300 m
Mobility	High	Medium	Low
Bit Error Rate (per 10^8)	100	150	200
Cost	High	Medium	Low
Packet Process	25 ms	12 ms	3 ms

TABLE 1: Wireless Network Parameters.

The main objective of the overlay network is to provide access to different traffic types and the traffic model has to reflect the characteristics of the Internet traffic. In this paper, we consider a mix of voice and data traffic. The packet source is assumed at the IP level. The packet traffic per user is generated by an Interrupted Poisson Process (IPP) [17]. The voice traffic is characterized by an on/off model, where the on and off periods are exponentially distributed with mean values $1/\alpha$ and $1/\beta$, respectively. Data and voice calls bandwidth is shared equally with data flows are permanent TCP flows.

To simulate VOIP traffic, exponential ON/OFF traffic generators were used over the UDP agents. G.711 codec is used with 64 Kbps coding rate, 20 ms interval, 200 bytes packet. On the other hand, the data traffic is generated with 4 Mb/s data rate and 1024 bytes packet as summarized in Table.2.

Traffic	**Average ON duration**	**Average OFF duration**	**Packet size**	**Sending rate**
Voice	1.00 s	1.35 s	200 bytes	64 Kb/s
Data	NA	NA	1024 bytes	4 Mb/s

TABLE 2: Traffic Parameters.

3.2 Simulation Experiment Performance Measures

To measure the performance of the proposed algorithm, various parameters were considered in this paper. These parameters are basically a function of: the number of users, Voice/Data traffic Arrival rate and MT speed. We defined a set of performance measures to evaluate network performance. These measures normally represent special challenge for the design of handover strategies at various network conditions. The performance measures considered are: the packet delay, the mean delay jitter, system throughput, available bandwidth, and revenue return. These are defined in what follow:

Mean Packet Delay: for a successfully transmitted packet, is defined as the mean for time intervals from the moment the packet is leaving the MT until the packet is received at the destination. The mean packet delay is the therefore the sum of the Transmission Delay, Propagation delay and Handover latency.

The Network Bandwidth: refers to the data rate supported by a network connection or interface. It measures how much data can be sent over a specific connection in a given amount of time. In our study, Available bandwidth is defined as the amount of residual bandwidth that service provider can provide for admitted calls.

The effective Throughput represents amount of data packets received within a given period of time at the node physical layer and afterwards sent to the higher layers if they are addressed to the node

The Revenue, from the service provider's perspective, is considered to be one of the performance measures that shows how handover strategy is effective in increasing provider operational income from his network investment. To evaluate provider net monthly revenue, we first estimate the expenditure of the wireless network which consists of two parts:

- Capital Expenditure: This is the setup cost for each wireless network. This amount includes equipment and devices installed, the licenses of frequency, etc.

- Operational Expenditure: This is the monthly amount that the service provider is paying to operate and maintain the service, as well as the power being consumed to run the system. The manpower and marketing cost is represented here as a percentage of capital expenditure.

The Capital Expenditure afterwards is converted into a monthly cost and is added to the monthly operation expenditure; this sum is the total cost per month.

In Table 3, a sample estimate of both expenditures is presented. From these, the cost per Mbit is calculated. This is how much a service provider should gain for each Mbits communicated by its customers to get back its network investments.

The service provider monthly revenue is estimated based on the total amount of bits received per call, the network nominal data rate, the estimated cost per Mbit and calls duration. The service provider net revenue profit is then difference between the monthly estimated provider revenue and the total cost per month.

Capital Expenditures (K$)				
Network	Equip	Core & Edge Equipment	License	Installation and Civil work
LTE	110	600	1200	100
WiMax	35	400	280	50
WiFi	5	100	0.0	20
Operational Expenditures (k$)				Cost/MB ($)
Network	O&M	Power	Sales And marketing	
LTE	4.5	2.7	10%	24
WiMax	1.2	0.0	10%	7.1
WiFi	0.55	0.0	10%	0.36

TABLE 3: Wireless Network Parameters.

4. PERFORMANCE RESULTS AND ANALYSIS

In this section, we present the performance for the proposed Bayesian based vertical handover scheme (BBVHO) and its comparison to the traditional RSS based vertical handover strategy.

4.1 Mean Delay Performance

To evaluate the end-to-end delay performance, each MT will send the server either FTP or VoIP traffics. Each traffic follows a different route depending on the location of BS and the way it is connected to the routers and to the server. Figure 3 illustrates BBVHO scheme mean delay as a function of MT speed. The arrival rate in this figure was fixed at 40 calls/sec. Figure 4 shows the delay performance as a function of network call arrival rate.

In general, the average of end-to-end delay for all simulation environments (LTE, WiMAX and Wi-Fi) increases whenever the moving speed of MT or call arrival rate increase. This is expected in wireless environments due to queuing delays at every hop node (BS or AP). However, as shown in Figure 3 and Figure 4, the average end-to-end delay for BBVHO is lower than VHO RSS based scheme.

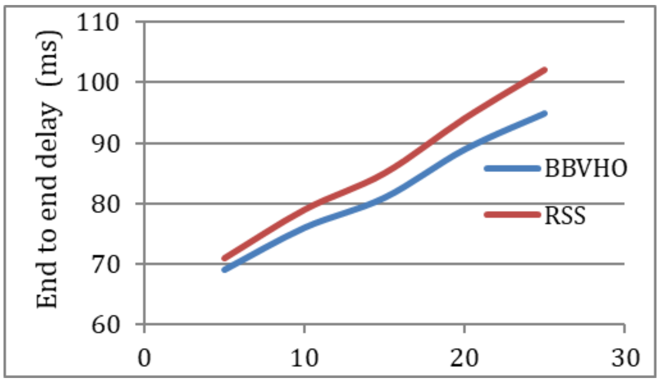

FIGURE 3: Packet Delay vs MT Speed.

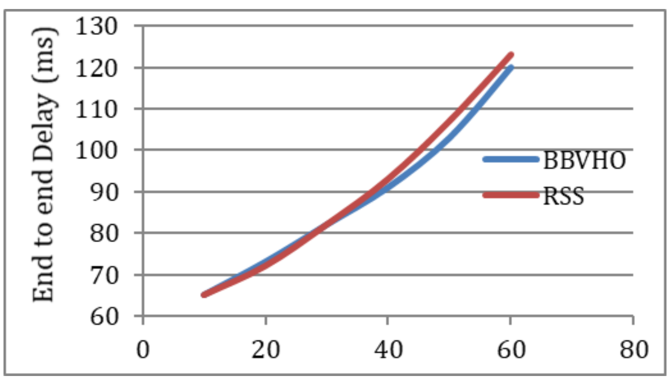

FIGURE 4: End-to-End Delay vs Call Arrival Rate.

4.2 Jitter Delay Performance

Jitter is an important metrics to measure VoIP performance. The simulation result of the overall packets Jitter performance as a function of MTs speed is shown in Figure 5. According to this figure, jitter metric increases as MT speed increases. This is due to more handovers occurrence with a higher MT speed. As shown, the BBVHO offers improved performance compared to RSS scheme.

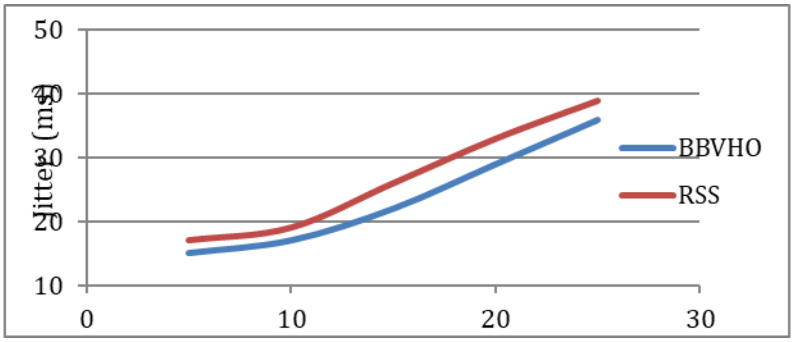

FIGURE 5: Average Jitter of BBVHO and RSS vs MT Speed.

The jitter performance with varying arrival rate is shown in Figure 6. Again, BBVHO has in general less jitter delay compared to RSS algorithm.

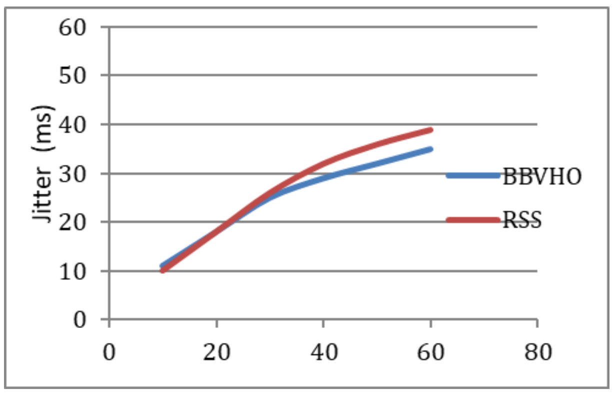

FIGURE 6: Average Jitter of BBVHO and RSS vs Call Arrival Rate.

4.3 Available Bandwidth

Available bandwidth is one of the main parameters linked to the use of vertical handover schemes. The available bandwidth affects several decisions, including the number of traffic calls accommodated within the MT.

Figure 7 and Figure 8 highlight the performance of BBVHO available bandwidth. In general, and as expected, with high MT speed or at higher arrival rate, the available bandwidth is reduced. The RSS algorithm shows lower performance when compared to BBVHO.

From these figures, it can be concluded that BBVHO allows a better solution from service provider point of view, for provider load balancing among BSs.

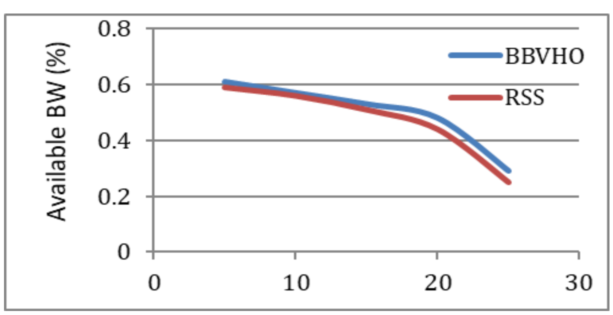

FIGURE 7: Available bandwidth performance of the BBVHO and RSS algorithms.

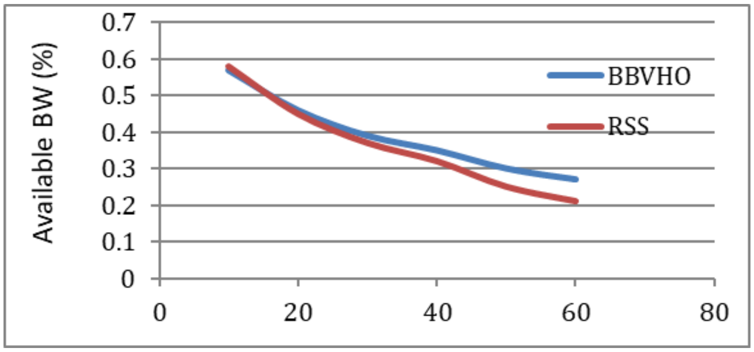

FIGURE 8: Available bandwidth performance of the BBVHO and RSS algorithms.

4.4 Effective Throughput

Figure 9 indicate how the BBVHO and RRS based algorithms have performed, in terms of throughput with different MT speeds. As shown in Figure 9, throughput does change slightly by increasing the MT speed. Again, the BBVHO yields better performance results when MTs are moving with high speed.

Furthermore, Figure 10 indicates the performance of the effective throughput with different arrival rate. As shown, with high arrival rates the effective throughput is dramatically reduced. This is in turn a result of a higher packet loss with high call arrival rate. The proposed BBVHO algorithm is more effective than RSS based scheme in selecting the right network path from source to destination.

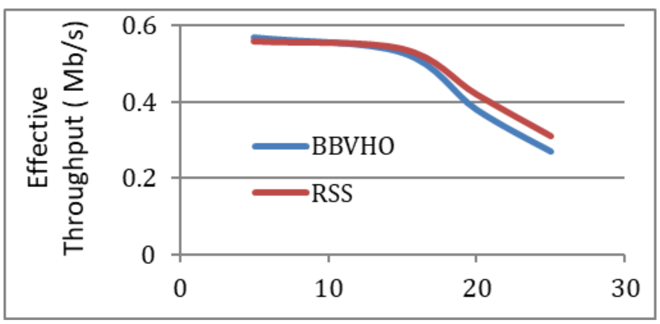

FIGURE 9: Effective Throughput performance of BBVHO and RSS algorithm vs MT speed.

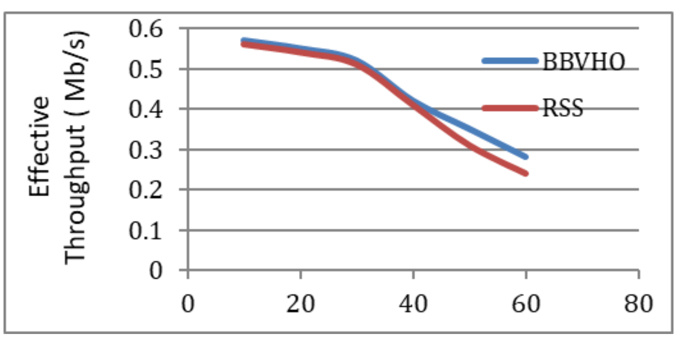

FIGURE 10: Effective Throughput performance of BBVHO and RSS algorithm vs call arrival rate.

4.5 Revenue

Income revenue, from the service provider's perspective, is considered one of the important performance measures. Figure 11 indicates the net revenue profit of BBVHO and RSS schemes. Again, the BBVHO shows better revenue over the RSS traditional algorithm.

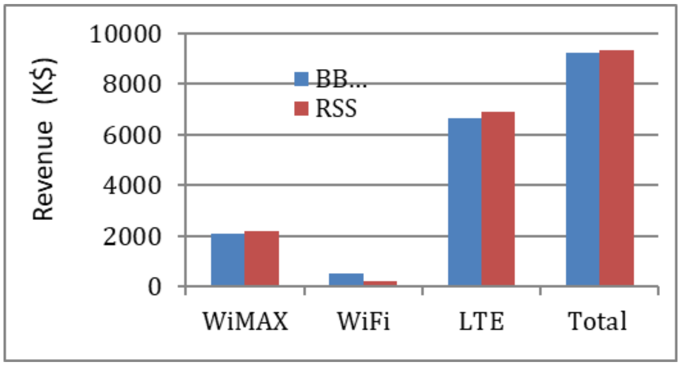

FIGURE 11: Revenue of the BBVHO and RSS algorithms.

5. CONCLUSION

In this work, a Bayesian network based vertical handover strategy was proposed. Our study evaluates the strategy performance for a combination of three wireless networks including LTE, WIMAX, and Wi-Fi. VoIP traffic over wireless was assumed to study the Bayesian algorithm where QoS of VoIP can be identified and monitored over the selected wireless networks. The traditional RSS algorithm performance was compared to the proposed BBVHO scheme. The performance results show that the proposed strategy outperforms the RSS traditional scheme in all performance measures. It also allows solving the complexity of the handover decision process resulting from the multitude dimensions of the VHO decision criteria and the dynamicity of many of its components.

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