Vertical Handover Decision Algorithm from WWAN to WMAN or WLAN Environments

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Abstract

Decisions for vertical handovers from WWAN to WMAN or WLAN access technologies are very challenging issue because it needs to deal with different radio access networks and make smart decisions for vertical handover calls between them. Especially the decisions for vertical handovers from WWAN to WLAN hotspots in heterogeneous mobile and wireless networks are very important because they impact the QoS of the mobile users, especially when they are using real-time services. In this paper we propose vertical handover decision algorithm from WWAN to WMAN or WLAN networks based on the load of the networks, speed of the mobile users, bandwidth and priority of the sessions of the mobile nodes. We use the IEEE 802.21 standard as a layout for implementing the algorithm. The results show that the proposed algorithm reduces unnecessary vertical handovers from WWAN to WMAN or WLAN access technologies and optimizes the load of the networks, improves the distribution of the call arrival rates and blocking probability of the vertical handovers from WWAN to WMAN or WLAN.

Keywords: *Blocking probability, call arrival rate, heterogeneous mobile and wireless networks, vertical handover decision algorithm*

1. Introduction

Heterogeneous mobile and wireless networks will enable the service providers to manage more efficiently with the radio resource management and to supply more efficiently the mobile users with their traffic demands. A key role when the users switch from one network to another in mixed wireless environment has the mobility management. One of the most important components of the mobility management is the handover management. It is responsible for changing the attachment of the mobile terminals while crossing from one wireless technology to another. The vertical handover decision strategy is a key factor in the handover management of the heterogeneous wireless networks. The decision for vertical handover depends on many factors (cost, load, network bandwidth, coverage, security speed, power consumption *etc.*) that need to be considered together with the signal strength in the complex heterogeneous wireless environment.

As a result of the above facts, sophisticated vertical handover decision algorithms are more than needed in order to increase the efficiency of the resource management for the next generation of the heterogeneous mobile and wireless networks. Network selection in heterogeneous scenarios is a key issue to optimize the system performances in accordance with the defined heterogeneous networks.

There are many research papers that propose various vertical handover decision algorithms based on different aspects. In [1] the authors develop a vertical handover decision algorithm that enables wireless access network to balance the overall load among attachment points and maximize battery lifetime of mobile nodes. In [2] the authors propose a new user centric algorithm for vertical handovers, with a combination to continuously maintain the connection and to maximize the user throughput, implemented in existing standard technologies like 802.16 and 802.11. In [3] the authors propose a new user centric algorithm for vertical handovers, with a combination to continuously maintain the connection and to maximize the user throughput, implemented in existing standard technologies like 802.16 and 802.11. In [4] the authors developed a mathematical model for vertical handoff decision problem between the WLAN and the cellular network and proposed a multi-objective optimization immune algorithm-based vertical handoff decision scheme.

In the beginning of the scientific researches of the VHO only RSS was used as the main condition for the process of the handover decision making [5]. But, in the recent years a few more factor are included in order to trigger VHO [6]. In [7] authors proposed a VHO algorithm based on a assumption that the are as soon as possible vertically handed over in order to avoid handover delay and a data call as long as possible is kept in the higher bandwidth network. Authors in [8] present a network selection strategy based on the power consumption of the mobile users. In [9] authors present a network selection strategy based on a policy, combining price, power consumption, bandwidth provision.

When there is an option to make a vertical handover from WWAN to WLAN, the vertical handover decision criteria are not the same as those in the vertical handover from WLAN to WWAN. In this particular case, since WLAN has drastically lower coverage area than WWAN, the mobile node can keep the connection to the WWAN network while it moves into the WLAN coverage. None of the aforementioned and so far published contributions for vertical handover decision criteria in heterogeneous networks, including the IEEE 802.21 standard, have deeply researched the effect of the load of the network, speed of the mobile users, session's priority, and bandwidth to decide upon vertical handover from WWAN to WMAN or WLAN networks. When the mobile nodes move with higher speed, there is no need to process the vertical handovers to small cells like a WLAN, because the user will be covered in a short time period [10]. Furthermore, the WLAN network is more sensitive to higher speeds of the mobile terminals comparing with WMAN or WWAN, hence it is very important to consider the speed when deciding whether to trigger a vertical handover to WLAN network. A problem that arises in the practical implementation of this kind of algorithms is how to measure the speed of the mobile terminal. There are research papers that deal with this kind of problem. In [11] information for the mobile node's speed can be detected from the Doppler spread in the received signal envelope. In [12] the traveling speed of the mobile terminal is measured by an accelerometer embedded in the mobile terminal.

The above mentioned facts were our challenges to design a vertical handover decision algorithm that will decide upon the load of the network, speed of the mobile terminal nodes, priority of their sessions (high priority – real-time traffic or low priority – non-real-time traffic), bandwidth of the sessions (high or low) whether to trigger or no vertical handovers when approaching the coverage of WMAN or WLAN network.

The structure of this paper is as follows. Section 2 proposes vertical handover decision algorithm from WWAN to WMAN or WLAN in heterogeneous networks. Section 3 describes the analytical framework of the proposed algorithm. Then, Section 4 presents the results from the performance evaluation of the proposed solution. Finally, Section 5 concludes the paper.

2. Vertical Handover Decision Algorithm from WWAN to WMAN or WLAN Access Technologies

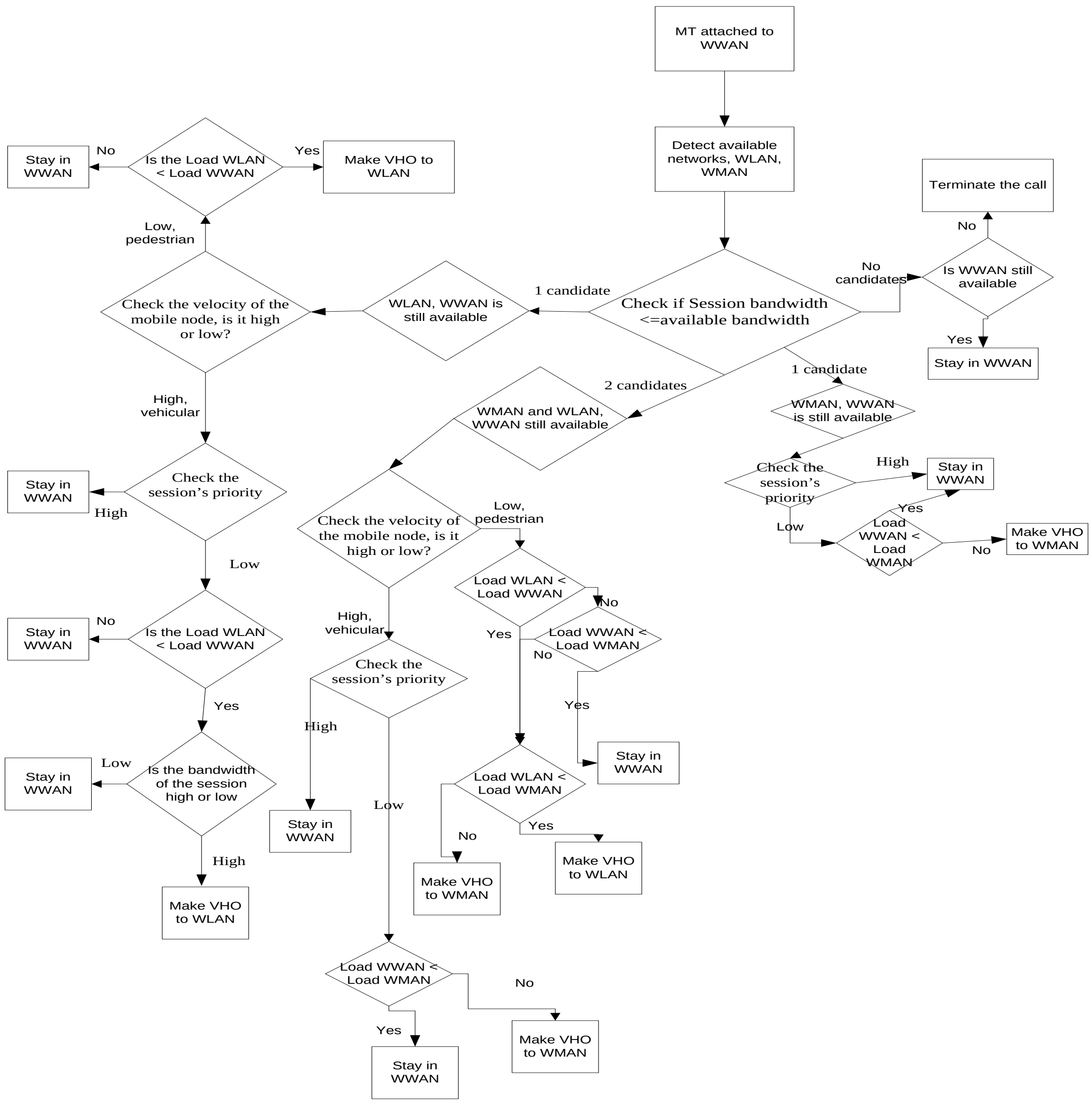

Figure 1. Vertical Handover Decision Algorithm from WWAN to WLAN/WMAN

The vertical handovers are very important part in the field of heterogeneous networks. When a mobile node is moving between different technologies, like WWAN, WMAN and WLAN, the connection between different base stations also has to move. WWAN, WMAN and WLAN networks are complementing each other in terms of data rates, coverage area, QoS support, installation cost. In real life scenarios mobile users might prefer to perform vertical handovers from one wireless network to another based on various factors as quality, service cost, speed and availability. WLAN networks are cheap for installation and operation but they have limited coverage and minimal mobility support. WMAN networks, like WiMAX (Worldwide Interoperability for Microwave Access), offer wireless access in metropolitan area network. Vertical handovers are supported by the Mobile IP. Mobile IPv6 (Internet protocol version 6) is composed of three functional entities, MN (mobile node), HA

(Home Agent) and FA (Foreign Agent). When a mobile node moves to a foreign network with different technology, COA (care-of-address) is acquired in order the mobile node to be uniquely identified in the foreign network. Home Agent of the mobile node registers this care-of-address in the home network of the mobile node. Then, the traffic is tunneled to the COA of the mobile node by the Home Agent.

Figure 1 presents the VHO decision algorithm from WWAN to WMAN/WLAN networks. When mobile user is attached to WWAN vertical handover decision algorithm can occur if the conditions according our proposed algorithm are fulfilled.

Our proposed algorithm is aimed for vertical handovers from WWAN to WMAN or WLAN networks. It makes vertical handover decision from WWAN to WLAN or WMAN network considering the load of the network, speed of the mobile node, the priority of the traffic class, the bandwidth of the session. It determines whether the incoming requests for vertical handovers from WWAN to WMAN or WLAN network will be rejected or accepted. Per example, if we analyze one segment of the algorithm showed in Fig. 1, we can conclude the following. If the speed of the mobile node while approaching the WLAN network from WWAN network is above the acceptable threshold for the WLAN technology and there is no detection of WMAN technology, the incoming request for handover will be accepted to WLAN only if the session's priority is low, load of WLAN is lower than WWAN access technology and bandwidth of the session is high.

Applying the algorithm we achieve better channel utilization when using WWAN, WMAN or WLAN networks while still satisfying the QoS requirements of the users. It is applied also for the vertical handovers to the WLAN networks. Access Points (AP) of the WLAN networks has lower coverage radius (from 50 to 100 meters depending on the type of 802.11 standards). When the radius of the AP is lower and the speed of the mobile node is higher it is better not to trigger a vertical handover to that AP. Furthermore, when there are mobile users with various types of traffic – real-time or non-real-time, it is better mobile users that use real-time traffic, which has high priority not to trigger vertical handover to the AP, because they are more sensitive to delays and handover latencies. We consider real-time traffic as high priority session like conversational or streaming. Non-real-time traffic, like web or background is regarded as low priority session in the algorithm.

We have implemented and tested our designed algorithm in the IEEE 802.21 standard for Media Independent Handover (MIH) [13]. Simulations has been done using the handover module in the network simulator (ns) [14], and our added vertical handover decision algorithm in the module, explained in Figure 1. The IEEE 802.21 add-on module is based on the signal strength and the type of interface for the interface selection. Adding our developed algorithm we are enhancing the module with the information about the mobile terminal's speed, session's priority, bandwidth of the session and load of the network when deciding for a vertical handover session from WWAN to WMAN or WLAN.

3. Vertical Handover Probabilities from WWAN to WMAN/WLAN

For each scenario equations for transition probability of vertical handovers between states must be calculated separately. Vertical handover criteria (load of the networks, estimated velocity, session's priority and bandwidth call) are prepared according the Figure 1, and they are independent. Event when the user that could be in state 3 in WWAN, could make vertical handover to WLAN in state 1 at the *m*-th moment can be expressed as:

$$
\begin{aligned}
&\{S_1[m]S_3[m-1]\} = \\
&= \{RSS_{WLAN}[m] > RSS_{th-WLAN}, RSS_{WMAN}[m] \le RSS_{th-WMAN}, \\
&RSS_{WWAN}[m] > RSS_{th-WWAN}, V[m] > V_{th}, Traffic[m] = low, \\
&Load_{WLAN}[m] < Load_{WWAN}, Bandwidth[m] = high \mid S_3[m-1]\} + \\
&+\{RSS_{WLAN}[m] > RSS_{th-WLAN}, RSS_{WMAN}[m] \le RSS_{th-WMAN}, \\
&RSS_{WWAN}[m] > RSS_{th-WWAN}, V[m] \le V_{th}, Load_{WLAN}[m] < Load_{WWAN} \mid S_3[m-1]\} + \\
&+\{RSS_{WLAN}[m] > RSS_{th-WLAN}, RSS_{WMAN}[m] > RSS_{th-WMAN}, \\
&RSS_{WWAN}[m] > RSS_{th-WWAN}, V[m] \le V_{th}, Load_{WLAN} < Load_{WWAN}, \\
&Load_{WLAN} < Load_{WMAN} \mid S_3[m-1]\}
\end{aligned} \tag{1}
$$

Probability for the vertical handover from WWAN to WLAN, which is from state 3 to state 1 can be calculated with the following equation:

$$
\begin{aligned}
&P_{31}[m] = P\{S_1[m] \mid S_3[m-1]\} = \\
&= \frac{P\{RSS_{WLAN}[m] > RSS_{th-WLAN} \mid S_3[m-1]\}}{P\{S_3[m-1]\}} \times P\{RSS_{WMAN}[m] \le RSS_{th-WMAN}\} \times \\
&\times P\{RSS_{WWAN}[m] > RSS_{th-WWAN}\} \times P\{V[m] > V_{th}\} \times P\{Traffic[m] = low\} \times \\
&\times P\{Load_{WLAN}[m] < Load_{WWAN}\} \times P\{Bandwidth[m] = high\} + \\
&+ \frac{P\{RSS_{WLAN}[m] > RSS_{th-WLAN} \mid S_3[m-1]\}}{P\{S_3[m-1]\}} \times P\{RSS_{WMAN}[m] \le RSS_{th-WMAN}\} \times \\
&\times P\{RSS_{WWAN}[m] > RSS_{th-WWAN}\} \times P\{V[m] \le V_{th}\} \times P\{Load_{WLAN}[m] < Load_{WWAN}\} + \\
&+ \frac{P\{RSS_{WLAN}[m] > RSS_{th-WLAN} \mid S_3[m-1]\}}{P\{S_3[m-1]\}} \times P\{RSS_{WMAN}[m] > RSS_{th-WMAN}\} \times \\
&\times P\{RSS_{WWAN}[m] > RSS_{th-WWAN}\} \times P\{V[m] \le V_{th}\} \times P\{Load_{WLAN} < Load_{WWAN}\} \times \\
&\times P\{Load_{WLAN} < Load_{WMAN}\}
\end{aligned} \tag{2}
$$

The event when the mobile terminal that is in the state 3 (attached to WWAN network), makes vertical handover to state 2 (which is WMAN access network), at the *m*-th moment can be expressed with the next equation:

$$
\begin{aligned}
&\{S_2[m]S_3[m-1]\} = \\
&= \{RSS_{WMAN}[m] > RSS_{th-WMAN}, RSS_{WLAN}[m] \le RSS_{th-WLAN}, \\
&RSS_{WWAN}[m] > RSS_{th-WWAN}, Traffic[m] = low, Load_{WMAN} < Load_{WWAN} \mid S_3[m-1]\} + \\
&+\{RSS_{WMAN}[m] > RSS_{th-WMAN}, RSS_{WLAN}[m] > RSS_{th-WLAN}, \\
&RSS_{WWAN}[m] > RSS_{th-WWAN}, V[m] \le V_{th}, Load_{WMAN} < Load_{WWAN}, \\
&Load_{WMAN} < Load_{WLAN} \mid S_3[m-1]\} + \\
&+\{RSS_{WMAN}[m] > RSS_{th-WMAN}, RSS_{WLAN}[m] > RSS_{th-WLAN}, \\
&RSS_{WWAN}[m] > RSS_{th-WWAN}, V[m] > V_{th}, Traffic[m] = low, \\
&Load_{WMAN} < Load_{WWAN} \mid S_3[m-1]\}
\end{aligned} \tag{3}
$$

Probability of the corresponding state transition for the vertical handover between WWAN and WMAN is:

$$
\begin{aligned}
&P_{32}[m] = P\{S_2[m] \mid S_3[m-1]\} = \\
&= \frac{P\{RSS_{WMAN}[m] > RSS_{th-WMAN} \mid S_3[m-1]\}}{P\{S_3[m-1]\}} \times P\{RSS_{WLAN}[m] \le RSS_{th-WLAN}\} \times \\
&\times P\{RSS_{WWAN}[m] > RSS_{th-WWAN}\} \times P\{Traffic[m] = low\} \times P\{Load_{WMAN} < Load_{WWAN}\} + \\
&+ \frac{P\{RSS_{WMAN}[m] > RSS_{th-WMAN} \mid S_3[m-1]\}}{P\{S_3[m-1]\}} \times P\{RSS_{WLAN}[m] > RSS_{th-WLAN}\} \times \\
&\times P\{RSS_{WWAN}[m] > RSS_{th-WWAN}\} \times P\{V[m] \le V_{th}\} \times P\{Load_{WMAN} < Load_{WWAN}\} \times \\
&\times P\{Load_{WMAN} < Load_{WLAN}\} + \\
&+ \frac{P\{RSS_{WMAN}[m] > RSS_{th-WMAN} \mid S_3[m-1]\}}{P\{S_3[m-1]\}} \times P\{RSS_{WLAN}[m] > RSS_{th-WLAN}\} \times \\
&\times P\{RSS_{WWAN}[m] > RSS_{th-WWAN}\} \times P\{V[m] > V_{th}\} \times P\{Traffic[m] = low\} \times \\
&\times P\{Load_{WMAN} < Load_{WWAN}\}
\end{aligned} \tag{4}
$$

4. Performance Evaluation

In our simulations, for the purpose of testing the above proposed vertical handover decision algorithm, we use heterogeneous mobile and wireless network structure that is composed of WWAN, WMAN and WLAN access networks. The scenario considered for the simulation results consists of one WLAN cell located inside WMAN cell, both of them located inside WWAN cell (Figure 2). Detailed characteristics of the simulation parameters are explained in Table 1. Mobile node terminals that are moving in WWAN, WMAN and WLAN coverage require VoIP, MPEG-4, FTP and web traffic. In the beginning of the simulation runs all mobile node terminals are attached to WWAN base station. They are performing vertical handovers to WMAN or WLAN network.

VoIP G.711 traffic is simulated with a packet size of 160 bytes at the application layer and inter-arrival packet time of 20 ms. VoIP G.711 and MPEG-4 are considered in the study as sessions with high priority, because they are real-time traffic types. Web and FTP are considered as sessions with low priority, and they are non-real-time traffic types. The propagation model is *TwoRayGround*, considering both the direct path and a ground reflection path. The total simulation time is 200 seconds.

Table 1. Simulation Parameters

Name of the parameter	Value of the parameter
Simulation range	2000 m x 2000 m
Simulation duration	200 seconds
Transmission radiuses of WiMAX (IEEE 802.16)	500 meters
802.16 BS Transmission power	0.025 W
MAC/802.16 scan interval	50 seconds
MAC/802.16 UCD interval	5 seconds
MAC/802.16 DCD interval	5 seconds
802.16 RXThresh	2.025e-12 W
802.16 CSThresh	0.9 x RXThresh
Transmission radiuses of WLAN (IEEE 802.11)	50 meters
Frequency of WLAN	2.412 GHz
Bit rate of WLAN	11 Mbps
802.11 AP Transmission power	0.0134 W
802.11 RXThresh	5.25089e-10 W
802.11 CSThresh	0.9 x RXThresh
Antenna	Omni Antenna
Propagation model	TwoRayGround

Firstly, the simulations are done without applying our designed algorithm using provided IEEE 802.21 add-on module [14] for vertical handovers. After analysis of the results we applied our vertical handover decision algorithm and made simulations using the same simulation scenario.

The scenario consists of 30 mobile terminals, 15 of them are using VoIP, 5 - MPEG-4, 5 – Web and 5 FTP traffic. They are all firstly attached to WWAN technology, *i.e.*, UMTS and move as it is shown in Figure 2. Example of the moving pattern for all 30 mobile terminals is presented in Figure 2. In the moments when mobile terminals are approaching WMAN coverage and WLAN hotspot, the load of the WLAN technology is 60%, the load of the WMAN is 70% and of WWAN is 80%. 5 VoIP mobile users are moving with low speed (3 kmph) in those moments and 10 of them with high speed (60 kmph). 3 mobile users in that moments with MPEG-4 and FTP are moving with low speed and 2 with high speed, 2 mobile users with Web traffic are moving with low speed and 3 with high speed in the moments of making decisions for vertical handovers to WLAN or WMAN, *i.e.*, Wifi or WiMAX. Without applying the proposed algorithm we have noticed that all 30 mobile terminals are making VHOs.

After applying the proposed vertical handover decision algorithm and repeating the above explained simulation scenario, we have obtained the following results. When all 30 mobile terminals firstly approach WMAN coverage area (WiMAX), 20 mobile terminals that use real time traffic (VoIP and MPEG-4 and they are also high priority traffic classes in our simulations) are staying in WWAN (UMTS) according the proposed algorithm in Figure 1. The other 10 mobile terminals that use FTP and Web traffic (non-real time or low priority traffic classes) are making VHOs to WMAN according the proposed algorithm, because load of the WMAN is lower than the load of the WWAN. 20 mobile terminals with real time traffic that have stayed in WWAN after some time approach to WLAN according the simulation scenario in Figure 2. 5 of the mobile terminals that use VoIP and move with low speed and 3 of them that use MPEG-4 and move also with low speed will make VHOs to WLAN according the implemented algorithm shown in Figure 1. The other 10 mobile terminals that use VoIP and move with high speed and 2 of them that use MPEG-4 and move also with high speed will stay in WWAN (UMTS in our simulated case) according the implemented VHO decision algorithm. We can conclude from these results that this is optimized solution for vertical handover decisions in this supposed scenario, because the load of WLAN has the lowest value and the load of WWAN has the highest value. The proposed algorithm optimizes the load of the three different radio access technologies and improves the QoS, especially for the users that use real time traffic and move with high velocities.

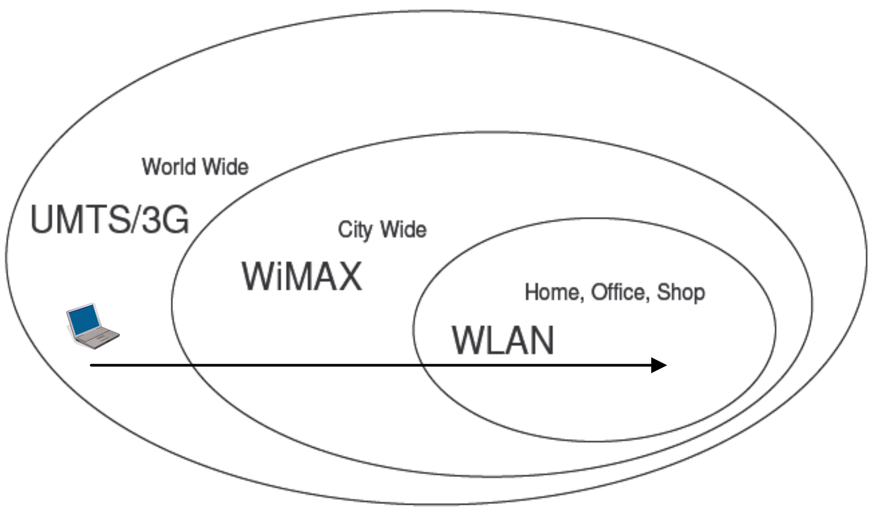

Figure 2. Simulation Scenario

Second part of the performance evaluation will be based on a topological coverage and geometric assumptions (inclusion of coverage areas). We will utilize also our proposed analytical model in the Section 3 for heterogeneous mobile and wireless networks developed according the proposed vertical handover decision algorithm in Figure 1 for vertical handover calls. Performance metrics that we will use here will be call arrival rate of the vertical handovers and probability of vertical handover call blockage in WWAN, WMAN and WLAN networks.

The total call arrival rate can be written as:

$$\lambda_t = \lambda_n + \lambda_{vh} \tag{5}$$

λ_n is the total call arrival rate of the new calls and λ_{vh} is the total call arrival rates of the vertical handover calls between WLAN, WMAN and WWAN.

Call arrival rates of the vertical handovers from WWAN to WMAN or WLAN can be written with the following equations, where P_{hv} is the probability (percentage) of the users that move with high velocity (vehicular users), P_{lv} is the probability (percentage) of the users that move with low velocity (pedestrian users), P_{hp} is the probability (percentage) of the users that has high priority (users with real time traffic), P_{lp} is the probability (percentage) of the users that has low priority (users with non-real time traffic), P_{hb} is the probability (percentage) of the users that has high bandwidth sessions and P_{lb} is the probability (percentage) of the users that has low bandwidth sessions, $P_{loadwlan<loadwwan}$ is the probability that the load of the WLAN access technology is lower than the load of the WWAN access technology and $P_{RSSwlan>th\text{-}RSSwlan}$ is the probability that the received signal strength of the WLAN technology is above the acceptable threshold level.

$$\begin{aligned}\lambda_{wwan2wman} &= (\gamma \cdot P_{RSSwman>th-RSSwman} + \beta \cdot P_{hp} \cdot P_{hb}) \cdot P_{lp} \cdot P_{loadwman<loadwwan} \cdot \lambda_t + \\ &+(\gamma \cdot P_{RSSwlan>th-RSSwlan} \cdot P_{RSSwman>th-RSSwman} + \beta \cdot P_{hp} \cdot P_{hb} \cdot P_{RSSwlan>th-RSSwlan}) \cdot \\ &\cdot(P_{lv} \cdot P_{loadwlan<loadwwan} \cdot P_{loadwman<loadwlan} + P_{hv} \cdot P_{lp} \cdot P_{loadwman<loadwwan}) \cdot \lambda_t\end{aligned} \tag{6}$$

$$\begin{aligned}\lambda_{wwan2wlan} &= \gamma \cdot P_{RSSwlan>th-RSSwlan} \cdot P_{lv} \cdot P_{loadwlan<loadwwan} \cdot \lambda_t + \\ &+\gamma \cdot P_{RSSwlan>th-RSSwlan} \cdot P_{hv} \cdot P_{lp} \cdot P_{loadwlan<loadwwan} \cdot P_{hb} \cdot \lambda_t + \\ &+(\gamma \cdot P_{RSSwlan>th-RSSwlan} \cdot P_{RSSwman>th-RSSwman} + \beta \cdot P_{hp} \cdot P_{hb} \cdot P_{RSSwlan>th-RSSwlan}) \cdot \\ &\cdot P_{lv} \cdot P_{loadwlan<loadwwan} \cdot P_{loadwlan<loadwman} \cdot \lambda_t\end{aligned} \tag{7}$$

Let the total call arrival rate is λ_t=0.1 call per second (that is 360 calls per hour). The mean duration of the call 1/μ is 200 seconds. We will suppose that WWAN technology can have 17 connections in the same time, WMAN – 12 and WLAN – 18 connections in the same time.

Now, we'll analyze the performances of the call arrival rates using the vertical handover probabilities according the proposed vertical handover decision algorithm. α denotes the probability of the users that are located in the WLAN coverage. They are also in the coverage of WMAN and WWAN technologies because WLAN networks are overlapping with WMAN and WWAN networks. β denotes the probability of the users located in WMAN coverage. They are in the same time in the WWAN coverage also, but we don't consider here the users that are in the same time in the WLAN coverage. Let us suppose that γ presents the probability of the users that are located only in the WWAN coverage, without taking into consideration the users that are also in the WMAN and WLAN coverage, because some of WLAN coverage areas and WMAN coverage area are overlapping with WWAN coverage area. Probability α_{wwan} denotes the probability of the users that are located in WLANs that are only inside WWAN coverage area, and α_{wman} denotes the probability of the users located in WLANs inside WMAN coverage area. If we try to evaluate the call arrival rates for vertical handovers between WWAN/WMAN and WWAN/WLAN supposing the following values: α = 0.2, β = 0.3, γ = 0.5, α_{wwan} = 0.14, and α_{wman} = 0.06, $P_{lv} = P_{hv} = P_{lp} = P_{hp} = P_{lb} = P_{hb} = 0.5$, $P_{loadwman<loadwwan}$ = 0.7, $P_{loadwman<loadwlan}$ = 0.3, $P_{loadwwan<loadwman}$ = 0.3, $P_{loadwwan<loadwlan}$ = 0.1, $P_{loadwlan<loadwwan}$ = 0.9, $P_{loadwlan<loadwman}$ = 0.7, and changing the values of the radio signal strengths of the three technologies, we will get the following graph in Figure 3.

Blocking probability values for the call arrival rates of the vertical handovers between the three technologies taking in account the same assumptions as for the previous graph are presented in the following graph in Figure 4. We have evaluated the blocking probability of the vertical handovers changing the probability that the mobile terminals have received RSS of WLAN above the acceptable threshold between the values of 0.1 and 0.3.

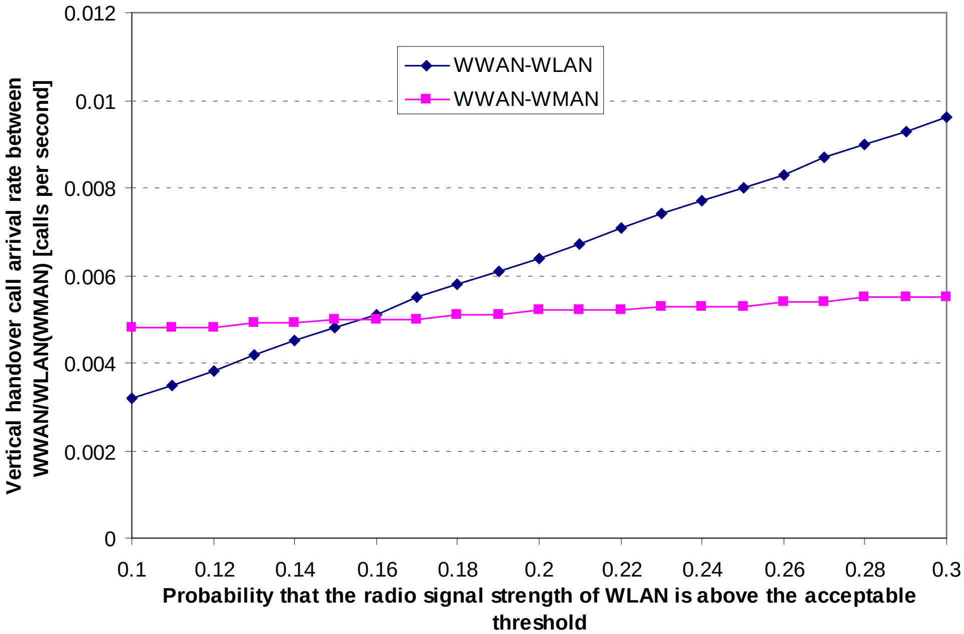

Figure 3. Call Arrival Rates for the Vertical Handovers between WWAN and WMAN(WLAN) changing the Probability that RSS of the WLAN is above the Threshold

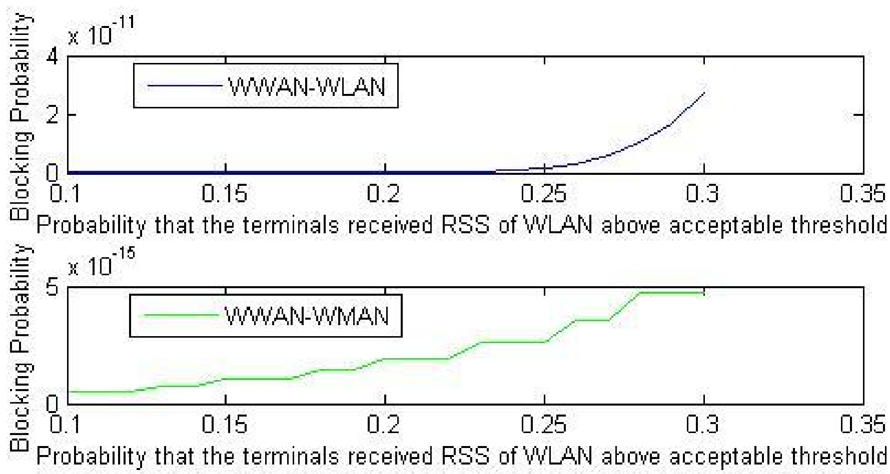

Figure 4. Blocking Probability of the Vertical Handovers between WWAN and WLAN(WMAN) when the Total Call Arrival Rate is 0.1 Calls per Second

5. Conclusion

Effective and optimized vertical handover decision strategies are essential part of the heterogeneous mobile and wireless networks which can combine their advantages on data rates and coverage, offering the best QoS for the mobile users. WLAN is designed for low mobility, high-medium data rate access, low range and therefore can be used as a complement to the larger WMAN or WWAN network. In this paper, we have proposed a vertical handover decision algorithm that uses many important parameters (velocity of the mobile terminals, bandwidth - low or high, priority of the users - real-time or non-real-time traffic, load of the technology) and not only the radio signal strength of the technologies, when making decision for vertical handover from WWAN to WMAN or WLAN network. The algorithm is integrated with the IEEE 802.21 standard modifying the NIST simulation package [14]. By testing the proposed algorithm in a supposed simulation scenario with mixed traffic and different moving speed of the mobile users we have optimized the load of the networks and improved the QoS of the users, especially for the mobile users that use real time traffic and move with high velocities. Proposed vertical handover decision algorithm also reduces unnecessary vertical handover procedures from WWAN to WLAN or WMAN network compared with the module for VHOs in [14] when we have complex simulation scenarios with different moving speeds and types of traffic of the mobile users.

The contribution of this paper is in improving the QoS results when trial mode WWAN/WMAN/WLAN terminals are performing vertical handovers from WWAN to WLAN hotspots or WMAN environments. Our main goal was to improve the QoS of the mobile terminals that utilize complementary WWAN/WMAN/WLAN coverage, with the design of the vertical handover decision algorithm that can be easily implemented in the resource management for heterogeneous networks. We practically applied the algorithm in the already existing NIST simulation tool for IEEE 802.21 standard and practically tested it with many mobile terminals that use mixed traffic. We proved that with the implementation of this vertical handover decision algorithm we can avoid unnecessary vertical handovers to WMAN or WLAN network, balance the load of these three technologies and improve the call arrival rate distribution and blocking probability of the mobile users which are very important metrics.

Furthermore, numerical analysis is conducted presenting the vertical handovers probabilities from WWAN to WMAN or WLAN in heterogeneous mobile and wireless networks. Results show that the proposed algorithm for vertical handovers optimizes the performances of the mobile terminals.

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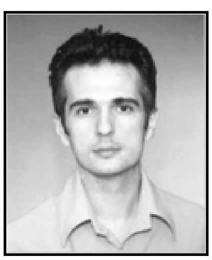

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