Vertical Handover between LTE and Wireless LAN Systems based on Common Resource Management (CRRM) and Generic Link Layer (GLL)

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ABSTRACT
It is expected that many heterogeneous wireless networking systems such as 3GPP Long-term Evolution (LTE) systems, WiMAX/WiBro systems and WLAN systems will be exist in next generation wireless communication environment. Under such environment, various communication services will be introduced by integrating heterogeneous wireless networking technologies, especially at the radio access networks. In order to provide such integrated communication services, integrated radio resource management and seamless vertical handover across such heterogeneous access networks should be supported. In this paper, to tackle these problems, we propose a Generic Link Layer (GLL) based common radio resource management (CRRM). In particular, we propose the network architecture and functions of each network element for integrated radio resource management among heterogeneous access networks. Then, we propose policy-based and multi criteria decision making (MCDM) based seamless vertical handover schemes between LTE and next generation WLAN systems. Performance of the proposed vertical handover schemes are evaluated via extensive simulation studies. Simulation results show that the proposed VHO schemes outperform other VHO schemes such as received signal strength (RSS) based VHO scheme in terms of throughput, handover success rate and the service cost.

Keywords
Vertical Handover, Common Radio Resource Management, Generic Link Layer, LTE, WLAN.

1. INTRODUCTION
All in next generation communication environment, a mixture of heterogeneous radio technologies will be available. This multi-radio access technologies (RAT) situation could give simultaneous access to any networks in an "Always Best Connected" fashion [1].

There have been many research efforts on how to combine multiple RATs not only within a single operator's service domain but also between many operators' service domains. In particular, many EU Information Society Technology (IST) and Framework Program (FP) projects such as Ambient Networks (AN) [2], EVEREST [3], AROMA [4] and GANDALF [5] have been conducted with focusing on this research topic.

The Ambient Networks (AN) project aims at a new network vision based on dynamic coordination and integration between networks. This will provide access to any network, possibly even without subscription through instant establishment of internetwork agreements. The AN project suggested multi-access system architecture which is composed of the multi-radio resource management (MRRM) and the generic link layer (GLL). IST-EVEREST suggested a set of specific strategies and algorithms for access and core networks to lead an optimized utilization of available radio resource for the support of mixed services within heterogeneous networks beyond 3G. IST-AROMA project concentrated on development of a set of specific strategies and algorithms for access and core network parts where end-to-end Quality of Service (QoS) can be guaranteed in the context of an all-IP heterogeneous network. Celtic-GANDALF project aimed at introducing and developing new techniques and approaches such as Fuzzy control based VHO and joint radio resource management (JRRM) for performing complex resource management tasks.

Under the Multi RATs environment, the vertical handover (VHO) between different radio access technologies are one of the key factor in leading optimal utilization of available radio resources. Handover decisions are usually based on the evaluation of received signal strength (RSS) for horizontal handover (HHO). However, RSS evaluation is not sufficient to make a vertical handover decision due to the asymmetrical nature of different networks. Therefore, many VHO algorithms are developed to take such nature of multi RATs situation into account for making VHO decisions.

An advanced neural-network-based VHO algorithm was developed in [6] to satisfy user bandwidth requirements. A policy-enabled VHO algorithm was proposed in [7] along with a cost function that considers several of the factors mentioned above. An adaptive multi-criteria VHO algorithm for heterogeneous radio access networks were proposed in [8]. In order to provide QoS and AAA information with minimum signaling overhead, a handover decision strategy in mobile All-IP networks was introduced in [9]. A VHO algorithm between WLAN and UMTS were proposed in [10] based both on RSS and the distance between BS and the mobile node to avoid performing handover to a wrong destination. In [11], a VHO algorithm was developed by considering both RSS and bandwidth as two
ARCHITECTURE AND GLL FUNCTIONS supports seamless services over multi-RATs environment. Based on the CRRM structure, we proposed an policy and MCDM based VHO algorithm to support seamless services efficiently and cost-effectively.

The rest of the paper is organized as follows. In section II, we propose the CRRM network architecture and functions these are designed to support the vertical handover and multi-radio resource management between the 3GPP Long-term Evolution (LTE) system and the next generation WLAN system. Then, we propose a policy and MCDM based vertical handover algorithm between LTE and next generation WLAN systems under the CRRM network architecture. In order to develop efficient VHO algorithm for such multi-RATs environment with considering different characteristics of each RAT, we use the GLL approach introduced in the Ambient Networks (AN). Simulation study shows that the proposed VHO algorithm outperforms other VHO algorithms in terms of the data throughput, the handover success rate and the system service cost.

In this paper, we propose a common radio resource management (CRRM) strategy for next generation multi-RATs environment. We first present the CRRM network architecture and functions these are designed to support the vertical handover and multi-radio resource management between the 3GPP Long-term Evolution (LTE) system and the next generation WLAN system. Then, we propose a policy and MCDM based vertical handover algorithm between LTE and next generation WLAN systems under the CRRM network architecture. In order to develop efficient VHO algorithm for such multi-RATs environment with considering different characteristics of each RAT, we use the GLL approach introduced in the Ambient Networks (AN). Simulation study shows that the proposed VHO algorithm outperforms other VHO algorithms in terms of the data throughput, the handover success rate and the system service cost.

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In this section, we propose the concept, the structure and functions of the common radio resource management (CRRM). The CRRM is devised to enable effective service provisioning in interlocking structure with 3GPP radio access (LTE) and non-3GPP radio access (WLAN) as shown in figure 1. In order to support seamless mobile service across heterogeneous radio access technologies, radio resources of many heterogeneous radio networks should be managed together in an unified and coordinated way, and the VHO algorithm is one of the most important function for optimal utilization of available radio resources. To address this problem, we proposed the CRRM structure and functions as an underlying infrastructure that supports seamless services over multi-RATs environment. Based on the CRRM structure, we proposed an policy and MCDM based VHO algorithm to support seamless services efficiently and cost-effectively.

2. THE PROPOSED CRRM ARCHITECTURE AND GLL FUNCTIONS

In this section, we propose the concept, the structure and functions of the common radio resource management (CRRM). The CRRM is devised to enable effective service provisioning in interlocking structure with 3GPP radio access (LTE) and non-3GPP radio access (WLAN) as shown in figure 1. In order to support seamless mobile service across heterogeneous radio access technologies, radio resources of many heterogeneous radio networks should be managed together in an unified and coordinated way, and the VHO algorithm is one of the most important function for optimal utilization of available radio resources. To address this problem, we proposed the CRRM structure and functions as an underlying infrastructure that supports seamless services over multi-RATs environment. Based
Therefore figure 2 shows interlocking structure of LTE which is 3GPP access system and WLAN which is Non-3GPP access system as CRRM server format. It provides Common Radio Resource Management (CRRM) with gathered information from LTE network and WLAN network by locating CRRMS into P-GW that exist in Core Network. In addition let it control each network area locally by assigning location of LRRM (Local RRM) that controls LTE and WLAN network as MME(Mobility Management Entity) and ePDG(evolved Packet Data Gateway), MME and ePDG control location information of mobile node in local and control regional mobility for Handover of 3GPP radio access network and Untrusted non-3GPP radio access network.

Properties of CRRM are option module to connect to initial RAT, network option module in VHO, NSMM (Network State Monitoring Module) and TSMM (Terminal State Monitoring Module) that collects the information about mobile node and network condition. Also it is comprised of Congestion Control Manager, Admission Control Manager and Packet Scheduling property and each RAT access network, LRRM is in charge of HHO function. Figure 3 shows CRRM and LRRM functions this study suggests.

For this, in LTE and WLAN system, when you calculate [12][13] Path loss and signal strength in cell radius of 1000m and 250m as of an assumption in simulation, difference is showing by dividing level value that was defined in each system as equal ratio by signal value like shown in table 1. Therefore it could restructure signal value about each network environment into one unified signal value and divide into 1–7 grade level, and it utilize as numerical value of weight which is used in suggested algorithm by transferring this value to CRRM server.

![Diagram of CRRM Functions to support the vertical handover](image)

**Figure 3. CRRM Functions to support the vertical handover**

### 2.2 The Proposed GLL Functions

GLL function this study suggests play a role in restructuring individually different quality network signal value from physical layer into one unified format to transfer to CRRM server in different heterogeneous network. GLL that are physical layer and abstract layer which is located in data link layer works located in CRRM server, in each LRRM and in mobile node. Figure 4 shows GLL concept diagram.

![Diagram of GLL Functions](image)

**Figure 4. GLL Functions**

**Table 1. Metric (level, weight) of LTE and WLAN**

<table>
<thead>
<tr>
<th>LTE Path loss (dB)</th>
<th>WLAN Path loss (dB)</th>
<th>Level</th>
<th>Weight</th>
<th>LTE Path loss (dB)</th>
<th>WLAN Path loss (dB)</th>
<th>Receive level (dBm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>-92.5</td>
<td>1</td>
<td>1/7</td>
<td>75</td>
<td>-94.0</td>
<td>0</td>
</tr>
<tr>
<td>500</td>
<td>-90.0</td>
<td>5</td>
<td>1/3</td>
<td>500</td>
<td>-90.0</td>
<td>15</td>
</tr>
<tr>
<td>250</td>
<td>-87.5</td>
<td>4</td>
<td>2/6</td>
<td>75</td>
<td>-96.0</td>
<td>10</td>
</tr>
<tr>
<td>125</td>
<td>-85.0</td>
<td>3</td>
<td>3/5</td>
<td>125</td>
<td>-86.0</td>
<td>12</td>
</tr>
<tr>
<td>100</td>
<td>-80.0</td>
<td>2</td>
<td>4/4</td>
<td>100</td>
<td>-81.0</td>
<td>12</td>
</tr>
<tr>
<td>75</td>
<td>-75.0</td>
<td>1</td>
<td>5/3</td>
<td>75</td>
<td>-75.0</td>
<td>10</td>
</tr>
<tr>
<td>50</td>
<td>-70.0</td>
<td>0</td>
<td>6/2</td>
<td>50</td>
<td>-70.0</td>
<td>0</td>
</tr>
<tr>
<td>25</td>
<td>-65.0</td>
<td>-1</td>
<td>7/1</td>
<td>25</td>
<td>-65.0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>-60.0</td>
<td>-2</td>
<td>8/1</td>
<td>0</td>
<td>-60.0</td>
<td>0</td>
</tr>
</tbody>
</table>

**3. THE PROPOSED VHO ALGORITHM OF WHICH POLICY_BASED AND MCDM**

Before Unlike VHO algorithm that considers only signal strength in 3GPP standard method [14], this study suggests algorithm that parallels policy with since Network (LTE, WLAN) this study suggests to have big quality difference and to have many handover decision factor. In other words, it is decided by policy when the choice of network by factors is definite (when comparison is possible by service type and speed) or it is decided by multi criterion decision making (MCDM) when the choice of network is indistinct.

First, as shown on figure 5, CRRM server clarifies the type of service first when VHO request comes in during the WLAN service. In the case of the voice data and high speed service type, if there is a leftover available bandwidth after verifying network service first when VHO request comes in during the WLAN network and if there are none left VHO fails. Also when service type is voice and low speed but is Web data it fails if there is no possible application available bandwidth or it chooses the network by using MCDM algorithm if there is possible application available bandwidth in LTE network.

Secondly, as shown on figure 6, it first verifies the mobile node speed when VHO request comes into CRRM server during LTE service. When mobile node speed is high politically LTE service continues since handover (L to W, W to L) occurs often.

In addition, when mobile node speed is low, it is live service if the type is Web and there is WLAN possible available bandwidth,
VHO occurs as low cost and as bigger available bandwidth as possible WLAN since data size is larger compared with voice and it is considered as VHO failure on simulation code when there is no capacity but it does not mean Call drop and LTE connection is continued. At last, it chooses network as MCDM algorithm considering signal strength, cost, and possible available bandwidth if the speed is low and service type is voice.

To select network in VHO, Use of MADM method that is based on several factors when political decision in mobile node speed and service type are indistinct helps better to choose the most appropriate network. For example, each factors are mapping as Cost, Bandwidth, RSSI when it is assumed that there are A1, A2, A3, A4 in candidate cell for present VHO, presently connected cell is A1 using LTE and rest A2, A3, A4 are candidate cells from WLAN 1–3 region. SAW method can be used to regulate mapped decision procession and proportion (Bandwidth, RSSI) factors to bigger value are regulated as formula (1), reverse proportion factor (cost) to bigger value is regulated as formula (2).

\[
\begin{align*}
\text{max} & \quad 1, \ldots, 4 \\
\text{min} & \quad 1, \ldots, 3 \\
\end{align*}
\]

Figure 8 describes several factors and values in network types as decision procession (D) and displays regulated decision procession (D') by using SAW method.

Such regulated decision procession and weight value are needed in order to select network and this weight classified by factors are gained through AHP method. AHP method in MCDM technique is to classify evaluation standard and to decide weigh by class if the decision making is comprised of several evaluation standards. Therefore, classified problem sets priority in lowest class alternative by finding the value of relative weight through pair comparison of factors from upper class viewpoint to lower class.

For example, it processes step by step by approximate calculation method in assumption of deciding the relative importance classified by factors about voice as shown on figure 9. First of all, make procession (B) based on pair comparison decision and find the total in each rows. As a second step make the total in each rows of each factor 1 by dividing total numbers of row. Last thing

Figure 9. An example of weight gained through AHP method

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MCDM method calculates the weight with pre selected score in each elements by using most well known simple additive weighting(SAW)[15][16] in MCDM to formalize information contained form network and mobile node and to choose suitable network through AHP method that is Analytic Hierarchy Process(AHP)[17]. This study did scoring for weight calculation as Cost, Bandwidth, RSSI according to network feature and service type, '1', '4', '7' if Voice and '4', '7', '1' if Web data as shown below on figure 7 [18]. This scoring is according to network property and user friendly that puts priority weight on RSSI and Bandwidth if voice to give more service in LTE and that puts priority weight on Bandwidth and Cost if Web data to give more service in WLAN.
is to get the average value by adding each procession and this average values become priority vector of weight.

Through previous steps, network selection priorities can be decided by regulated decision procession value and weight value classified by factors as shown on figure 8 and 9. WLAN2 which is A3 access network will be chosen if you calculate each network's priority(A1-0.513, A2-0.570, A3-0.736, A4-0.500) by using weight of procession(D') and procession(B') about voice in the example above.

4. SIMULATION ENVIRONMENT

If you observe the system model, mobility model uses Gauss Markov model [19], traffic model uses Voice and Web traffic. Voice service uses On/Off modeling [20] and transmit SID(Silence Insertion Descriptor)[21] during Off time that is to say Silence in addition. Web service uses theses [22][23] as reference that proposes its composition with session that are comprised of several web pages including multi packets and datagrams.

In System model, mobile node is generated equally as LTE is one cell which is radius 1000m, 100Mbps WLAN is three cells which are radius 250m and 1Gbps (assuming as next generation WLAN) [24] as shown on figure 10 and low speed(5km/h) and high speed(60km/h) mobile node exist mixed by differentiating the speed of mobile node. Also WLAN is designed to give affect of RSSI by locating closely or afar from LTE in order to make MCDM algorithm properly affect substantially.

Performance is measured by increasing concurrent users from 25 to 250 as continue moving in 180o reverse direction if mobile node reaches LTE boundary that is 1000m cell. In addition, Trigger and Threshold line are arranged and if mobile node reaches Trigger line, CRRM server requests handover, and then Threshold line practice handover effectively with the network chosen by algorithm.

LTE system is multiple access method that downlink is based on OFDM (Orthogonal Frequency Division Multiplexing), uplink is based on SC-FDMA (Single Carrier Frequency Division Multiple Access) and this study considers uplink [25]. LTE and simulation parameter of next generation WLAN are comprised based on LTE standard as shown on table 1 and 2 and even though next generation WLAN is considered WLAN is performed in 1/100 times reduction for effectiveness of simulation as shown table 3.

This study measures efficiency of VHO when different service type or data type exist with avg.throughput and handover success rate and (measures) mobile node service cost in an assumption of 6:1 ratio cost rate between LTE and WLAN.

Table 2. LTE Frame Simulation Parameters

<table>
<thead>
<tr>
<th>Simulation parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>SC-FDMA(uplink)</td>
</tr>
<tr>
<td>Bandwidth per resource block</td>
<td>20MHz</td>
</tr>
<tr>
<td>Bandwidth of resource block</td>
<td>180KHz</td>
</tr>
<tr>
<td>Subcarrier bandwidth</td>
<td>15KHz</td>
</tr>
<tr>
<td>Frame duration</td>
<td>10ms</td>
</tr>
<tr>
<td>Slot duration</td>
<td>0.5ms</td>
</tr>
<tr>
<td>Number of subcarriers per resource block</td>
<td>12</td>
</tr>
<tr>
<td>Number of resource blocks per slot</td>
<td>100</td>
</tr>
<tr>
<td>Number of subcarriers per slot</td>
<td>120</td>
</tr>
</tbody>
</table>

Table 3. Real simulation parameters (performed in 1/100 times reduction)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LTE</th>
<th>WLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>100Mbps</td>
<td>1Gbps</td>
</tr>
<tr>
<td>Number of block / Frame per 10ms</td>
<td>2000</td>
<td>500</td>
</tr>
<tr>
<td>Simulation capacity</td>
<td>1Mbps (100Mbps/100)</td>
<td>10Mbps (1Gbps/100)</td>
</tr>
<tr>
<td>Simulation number of resource block / frame per 10ms</td>
<td>20(2000/100)</td>
<td>5(500/100)</td>
</tr>
<tr>
<td>Block / frame size</td>
<td>63.5bytes</td>
<td>2500bytes</td>
</tr>
</tbody>
</table>

Figure 10 and 11 compares average throughput and service cost of proposed algorithm according to speed and ratio and RSSI algorithm that considers only signal strength with fixed ratio of Voice and Web users. Proposed algorithm and RSSI algorithm both show higher throughput and low service cost as high speed concurrent users increase. RSSI algorithm by signal strength has lower throughput and higher service cost for its character (AP1 does not occur handover since WLAN signal strength is weaker than LTE when handover is requested). In addition, proposed algorithm cost lower than RSSI algorithm in general. MCDM algorithm receives service with relatively lower cost WLAN since cost weight is higher as Web data.

Figure 12 and 13 compares handover success rate of proposed algorithm according to the ratio of service type and RSSI algorithm that considers only signal strength with fixed ratio of low and high speed users. When proposed algorithm and RSSI algorithm are compared, the success rate of proposed algorithm shows higher regardless of service type for the character of RSSI algorithm (AP1 does not occur handover since WLAN signal strength is weaker than LTE when handover is requested).

5. CONCLUSIONS AND FUTURE WORKS

This thesis performs the study about VHO plan that is applied with GLL and CRRM method in LTE/WLAN heterogeneous network system. The result shows exceeded performance in data throughput, handover success rate and service cost than conventional RSSI based algorithm by providing effective network selection with political VHO decision based on mobile
node speed and service type and with multiple criterion decision making (MCDM).

This thesis mentions standard application plan for CRRM and GLL but more concrete application plan needed to be studied for practical system application in the future and Single-Cell LTE that this study was performed needs to be extended to Multi-Cell. Also additional process to find the most appropriate score and weight of MCDM is needed through proposed algorithm tuning process and HHO/VHO interlocking study considering both L2/L3 in extended heterogeneous networks (IEEE 802.16, Mesh, femto cell, etc) system. At last, this study compares with simple RSSI algorithm by approaching to simulation considering both L1/L2 but VHO should speak well of its performance when compared with other conventional plans.

6. ACKNOWLEDGMENTS
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7. REFERENCES