Vertical Handoff Decision System based on Support Vector Machine

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ABSTRACT

It is expected that many heterogeneous wireless systems, such as 3GPP LTE systems, WiMAX systems and WLAN systems, will coexist in the next generation wireless communication environments. Integrated radio resource management and seamless vertical handoff (VHO) should be supported to provide integrated communication services over multi-radio access networks. A new class of adaptive VHO system that views the handoff problem as a pattern recognition problem is proposed. In this paper, we propose a unified radio resource management (URRM) architecture and Support Vector Machine (SVM) based vertical handoff decision system. Extensive simulation studies show the proposed VHO algorithm outperforms RSS based VHO algorithms in terms of throughput and service cost.

Key Words : Vertical Handoff Decision, Heterogeneous Wireless Networks, Pattern Recognition, Support Vector Machine

Ⅰ. Introduction

It is expected that many heterogeneous wireless networking (HWN) systems, such as 3GPP LTE systems, WiMAX systems and WLAN systems, will coexist in the next generation wireless communication environments. This networking environment, the so called multi-radio access technologies (RAT) environment, could give a mobile user access to networks simultaneously in an Always Best Connected fashion[1]. Vertical handoff (VHO) between different RATs is a key factor to support seamless mobility for real-time applications when a mobile node (MN) crosses the overlay multi-RAT networks. The IMT-Advanced system is expected to provide seamless service across many heterogeneous wireless networks through VHO. The handoff process in the packet-switched 4G wireless system is apparently a more critically challenging task than in traditional wireless networks due to the existence of more bandwidth intensive multimedia applications, client mobility and other metrics such as monetary cost.

Related works on VHO have been presented in recent research literature but still much more works needs to be done. The VHO decision is an involved issue in HWNs and takes on a substantial role in RRM frameworks[2]. Most approaches, e.g. [3] to network selection resort to a form of "network score function" where the different networks are rated through normalizing and weighing different criteria such as network properties, available interfaces and user preferences. However, some of the works have taken the received signal strength as the sole element of network choice in HWNs. While signal strength is mandatory in determining a network's availability, it remains only a single factor in determining the most appropriate network.

※ This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2010-0025125)
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논문번호 : KICS2011-02-115, 접수일자 : 2011년 2월 16일, 최종논문접수일자 : 2011년 3월 24일

Notwithstanding, general complexity of network selection have lead researchers to propose heuristics, the use of logical, rule-based and policy-based frameworks and neural networks[4-7].

The handoff problem is formulated as a pattern recognition problem in [8] to solve the complexity problem. Pattern recognition identifies meaningful regularities in noisy or complex environments. These techniques are based on the idea that the points that are close to each other in a mathematically defined feature space represent the same class of objects or variables. Previous work on using pattern recognition techniques for handoff-related purposes includes[9]. Reference[9] uses hidden Markov models for pattern recognition of signal strength patterns for user location. It also mentions that the proposed pattern recognition techniques could possibly be used for various system functions like handoff. More recent work on pattern recognition for handoff algorithms is described in [10], which uses probabilistic neural networks and attempts much more extensive tracking of user location than do the algorithms in this paper.

Support Vector Machine (SVM) is a new well-founded and largely used valid machine learning algorithm[11]. They have been well used for pattern recognition, regression estimation, prediction, etc. and proved to be very effective on several real-world problems such as Internet traffic classification and Intrusion detection system[12]. SVM poses great potential and superior performance as appeared in many previous researches. SVM is a convenient and compact way of implementing a multiple criteria handoff decision algorithm. We thus employ SVM to the VHO decision. The main contributions of our paper are as follows:

URRM architecture and a SVM-based handoff decision system are proposed to support both accurate and real time decision making which can result in higher capacity and better overall link quality than what is available with today's systems, in which the dynamics of the future multi-RAT environment are very complex.

VHO message flow and procedures are presented at the L3 level between two heterogeneous wireless networks under the proposed URRM internetworking architecture.

The SVM-based VHO decision system supports the adaptive feedback system to cope with the complex environment.

Extensive simulations are performed to evaluate performance of the proposed VHO algorithm. Performance of the proposed algorithm is evaluated in terms of data throughput and service cost with various scenarios including a variety of mixed traffic types and MN velocities.

The remainder of this paper is organized as follows. The fundamentals of SVM classification are discussed in section 2. In section 3, we propose the URRM architecture, L3 level VHO procedure and SVM-based VHO decision system. In section 4, we describe our simulation model and analyze performance of the proposed VHO algorithm compared to RSS based VHO algorithms. In section 5, we conclude our paper, presenting further research issues.

Ⅱ. SVM Classification

SVM has recently been introduced as a new technique for solving a variety of learning, classification and prediction problems. SVM originated as an implementation of Vapnik's structural risk minimization (SRM) principle, which minimizes the generalization error, i.e., true error on unseen examples[13].

In this section, we briefly review some basic work on SVMs for classification problems that will be used in the proposed system. To explain the principles of SVMs, we first examine the simplest case, a two-class problem, where the classes are linearly separable. In this problem, the goal is to separate the two classes via a function that is induced from the available examples. Consider the example in Fig. 1. Many possible linear classifiers could separate the data, but only one can maximize the margin. This linear classifier is termed the optimal separating hyperplane.

Consider the problem of separating the set of training vectors belonging to two separate classes,

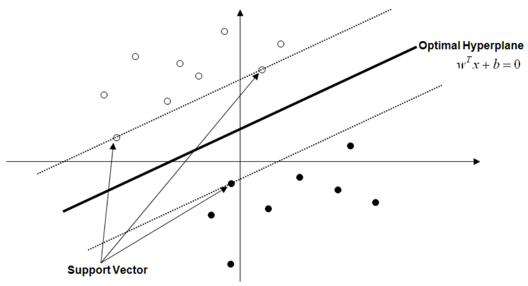

Fig. 1. Optimal separating hyperplane and support vectors

$$D=\{(x^1,y^1),\cdots,(x^l,y^l)\}, x\in R^n, y\in\{-1,1\}, \tag{1}$$

With a hyperplane,

$$w^T x+b=0. \tag{2}$$

If the set of vectors is separated without error and the distance between the closest vectors to the hyperplane is maximal, then this set is defined as optimally separated by the hyperplane. A separating hyperplane in canonical form must satisfy the following constraints,

$$y^i\left[\langle w,x^i\rangle+b\right]\geq 1, i=1,\cdots,l. \tag{3}$$

The distance $d(w,b;x)$ of a point x from the hyperplane (w,b) is,

$$d(w,b;x)=\frac{|\langle w,x^i\rangle+b|}{\| w\|}. \tag{4}$$

Hence, the hyperplane that optimally separates the data is the one that minimizes the following:

$$\begin{aligned}&\min\Phi(w)=\frac{1}{2}\| w\|^2\\&s.t.\, d_i(w^T x_i+b)\geq 1 \text{ for } i=1,\cdots,l.\end{aligned} \tag{5}$$

The solution to the optimization problem of equation (5) is given by the saddle point of the Lagrange function:

$$\Phi(w,b,\alpha)=\frac{1}{2}\| w\|^2-\sum_{i=1}^{l}\alpha_i\left(y^i\left[\langle w,x^i+b\rangle\right]-1\right), \tag{6}$$

Where α are the Lagrange multipliers. The Lagrangian has to be minimized with respect to w, b and maximized with respect to $\alpha\geq 0$. Classical Lagrangian duality enables the primal problem, given by equation (6), to be transformed to its dual problem, which is easier to solve. The dual problem is given by:

$$\begin{aligned}&\max\Phi(\alpha)=\sum_{i=1}^{l}\alpha_i-\frac{1}{2}\sum_{i=1}^{l}\sum_{j=1}^{l}\alpha_i\alpha_j d_i d_j\langle x_i x_j\rangle\\&s.t.\,\alpha_i\geq 0, i=1,\cdots,l \text{ and } \sum_{i=1}^{l}\alpha_i d_i=0.\end{aligned} \tag{7}$$

The hard classifier is then given by:

$$f(x)=sgn\left\{\sum_{i=1}^{N}\alpha_i d_i K(x_i,x)+b\right\}. \tag{8}$$

Ⅲ. Proposed VHO Decision System

In this section, we propose the URRM architecture, L3 level VHO procedure and the SVM-based VHO decision system. URRM is devised to enable effective service provisioning in interworking architecture with 3GPP radio access and non-3GPP radio access.

3.1 URRM Architecture

We designed the URRM architecture by applying the CRRM server based centralized approach [14] to the 3GPP interworking specification[15], where the evolved packet core (EPC) provides interworking

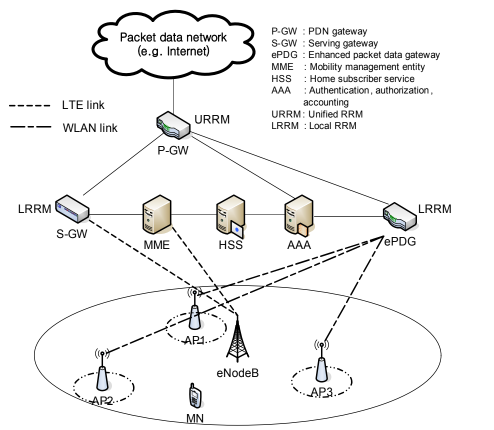

Fig. 2. URRM Interworking Architecture for LTE and WLAN access

function between 3GPP and non-3GPP access networks.

We consider the LTE and the WLAN access systems, as 3GPP and non-3GPP accesses, respectively. As shown in Fig. 2, the LTE and the WLAN accesses are integrated through the PDN gateway (P-GW) in the EPC. The URRM entity is integrated into the P-GW, as a centralized resource managing entity. The LRRM entities of the LTE and the WLAN accesses are integrated into the serving gateway (S-GW) and the enhanced packet data gateway (ePDG), respectively.

3.2 VHO Procedure

Figure 3 shows the VHO procedure performed among URRM interworking elements in the case of VHO from WLAN to LTE. The reverse direction VHO procedure, i.e., VHO from LTE to WLAN, is not presented in this paper, because the overall procedure is similar to the procedure from WLAN to LTE.

Procedure 1 in Fig. 3 shows that each network element, a MN that has dual radio interfaces for WLAN and LTE system and local RRM entities, such as eNodeB and Access Point, needs to be registered to the URRM entity through its GLL. After registration, the LinkAttach message is sent from the URRM entity to the GLL of each element to set up a radio link. After reception of this message, the GLL initiates the setup of a L2 radio connection that leads to actual attachment. In this example procedure, a MN is assumed to be connected to the WLAN access networks. In such a scenario the MN is initially served by the WLAN network, but frequently requests Link quality information and listens to its interfaces to probe other connectivity opportunities in Fig. 4 Handoff Information Gathering. The MN reports the link measurements to the URRM entity either periodically or event triggered.

Procedure 2 shows a VHO initiation procedure. A MN periodically measures the signal strength sent from the eNodeB of the LTE system, as well as the current serving AP. When the measured received signal strength from the AP falls below a predefined trigger level, the MN initiates the handover procedure by sending the handover preparation message to the ePDG and the URRM entity. Upon receiving the handover request message from the MN, the URRM entity executes the SVM Pattern Classifier to find a possible access network (e.g., a LTE cell) that can support the connection to the MN in Fig.4 Handoff Decision. Then the URRM entity responds to the MN about the new access network discovery result whether or not it is successful.

When it is successful, procedure 3 is executed in Fig. 4 Handoff Execution. In this procedure, the mobility management entity (MME) contacts the home subscriber service (HSS) entity and the authentication, authorization and accounting (AAA) entity to authenticate the MN to the new access network (e.g., the LTE system). After successful

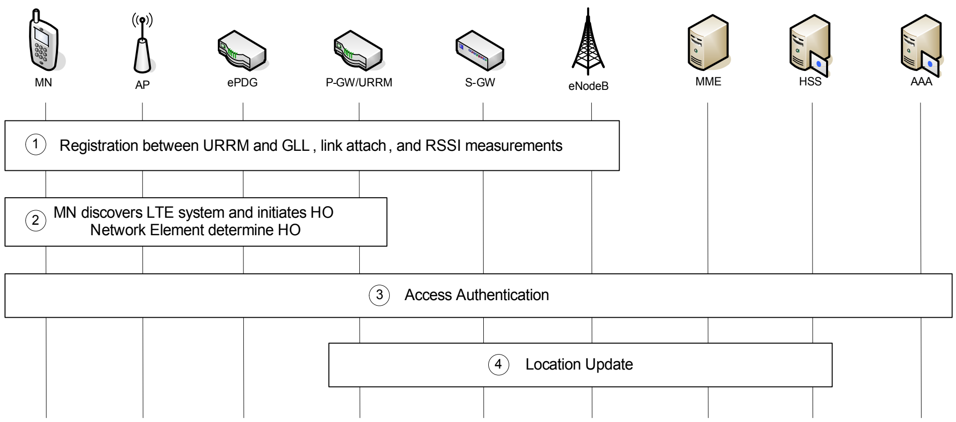

Fig. 3. A brief VHO Procedure from WLAN to LTE

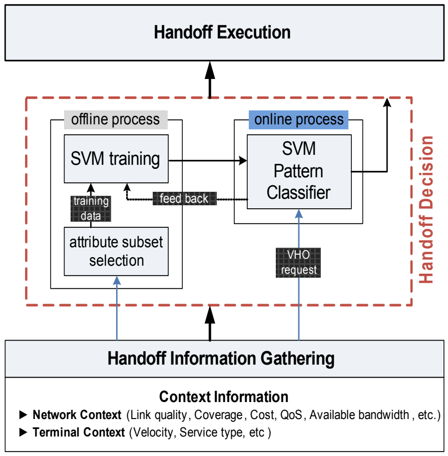

Fig. 4. Block diagram of the proposed SVM-based VHO decision system

authentication, the MME entity performs the location update procedure.

3.3 SVM-based VHO decision system

The proposed SVM-based VHO decision system is described in Fig. 4. As shown in Fig. 2, it is located in the URRM entity. The main phases of the handoff management process are shown in Fig. 4. : 1) Handoff Information Gathering; 2) Handoff Decision; and 3) Handoff Execution.

1) Handoff Information Gathering collects all the contextual information required to apply SVM training and to apply the VHO request, through monitoring and measurements. In our experiment, data training samples are obtained from our early work[16]. Suggested context parameters that may be considered are:

- Terminal's context: velocity, service type
- Network context: link quality, coverage, cost, QoS, available bandwidth, etc.

2) Handoff Decision decides if a handoff is requested, it chooses the best target access network. The proposed VHO decision system is composed of three modules: The SVM Pattern Classifier module of one online process module, and the attribute subset selection and SVM training module of two offline process modules. a) The attribute subset selection module selects the optimal data attribute subset for SVM training that improves the accuracy and the classification speed of the entire SVM Pattern Classifier. After that, data sets are used in the SVM training module. b) The SVM training module performs training based on the attribute selection of the data for binary SVM classification, as mentioned in Section 2. SVM performs supervised learning on the training data set. c) The SVM Pattern Classifier module classifies the handoff request data by SVM training. They are applied on scenarios as follows: when a MN is moving out of the serving access network and will enter another access network shortly; or when a MN is connected to a particular network, but chooses to be handed over to another available access network for its future service needs. The proposed VHO decision system is a feedback system from the earlier result through principal component analysis to cope adaptively with the dynamic and complex future network environment.

3) Handoff Execution performs the Access Authenticate procedure. In this procedure, the mobility management entity (MME) contacts the home subscriber service (HSS) entity and the authentication, authorization and accounting (AAA) entity to authenticate the MN to the new access network as shown in Fig. 2. After successful authentication, the MME entity performs the location update procedure. Then, MN establishes the IP connectivity to ensure service continuity through the chosen access network.

Ⅳ. Performance Evaluation

4.1 Simulation Model

Performance of the proposed VHO decision system is exploited under the URRM interworking architecture via extensive simulation analysis. As shown in Fig. 2, three WLAN hot spots are assumed to be located in a single LTE cell coverage. The cell radius of LTE and WLAN are assumed to be 1000m and 250m, respectively. We assume the Gaussian Markov model[17], where MNs moving toward the outside of the LTE cell are assumed to bounce back into the same cell for the mobility of MNs[18]. We also assume that the WLANs are IEEE802.11n standard based systems capable of supporting up to 1 Gbps of data rate and that the LTE standard based cellular system is able to support up to 100 Mbps of data rate. Two service types, voice over IP (VoIP) and web traffic, are assumed to be used. Three different velocity models are assumed for MNs; a stationary model (0 km/h), a pedestrian model (below 5 km/h), and a vehicular model (above 60 km/h). Performance of the proposed VHO algorithm is examined with a number of mixes of service types and velocity models.

Simulation parameters of the LTE system are summarized in Table 1. In order to reduce simulation time, we scale down the simulation parameters of both of LTE and WLAN systems, as shown in Table 2. Although this may leave the applicability of the analysis to a more realistic network environment in doubt, we believe the general trends obtained through scaled down simulation still remains valid.

Table 1. LTE frame simulation parameters

Parameters	Value
System	SC-FDMA (uplink)
Bandwidth per Resource Block (RB)	20 MHz
Frame duration	10 ms
Slot duration	0.5 ms
Number of subcarriers per RB	12
Number of RB per slot	100
Number of subcarriers per slot	1200

Table 2. Summary of simulation parameters

Parameters	LTE	WLAN
Capacity	100 Mbps	1 Gbps
Number of block / frame per 10 ms	2000	500
Simulation Capacity	1 Mbps	10 Mbps
Simulation number of RB / frame per 10 ms	20	5
Block / Frame size	62.5 bytes	2500 bytes

4.2 Performance Metrics

We evaluate performance of the proposed VHO decision system in terms of throughput and usage cost with respect to different numbers of concurrent users (i.e., the traffic load) via extensive simulations. We compare the performance of the proposed adaptive VHO algorithm to that of the RSS based VHO algorithm[19].

4.3 Performance Evaluation

Figure 5 compares throughput performance of the WLAN system for the proposed VHO algorithm to that of the RSS based VHO algorithm with respect to the traffic load. The percentages of voice and web users are set equal. Two types (5km/h and 60km/h) of velocity models are used, with three different mixtures: 20% vs. 80%, 50% vs. 50%, and 80% vs.20%. The simulation shows that as the traffic load increases, throughput performance of the WLAN system is enhanced. The proposed VHO algorithm outperforms the RSS based VHO algorithm for all cases of the velocity mixtures. Since the signal strength from APs is less than that from LTE, VHO from LTE to WLAN is not executed with the RSS based VHO algorithm in some WLAN coverage area, especially in the AP1 hot spot area in Fig. 2. In contrast, instead of using the measured RSS value, the proposed VHO algorithm uses the seven level abstraction value of MIVI that is equally applied to each system. In addition, the proposed VHO algorithm considers other decision factors, such as the available bandwidth and usage cost. As a result, the proposed

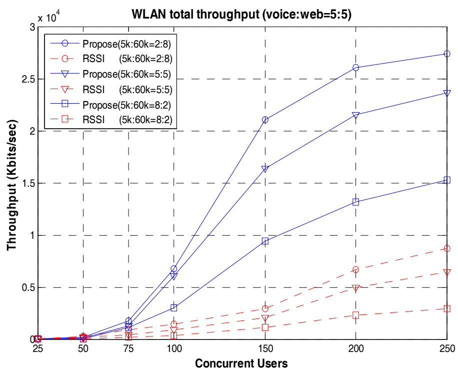

Fig. 5. WLAN total throughput

VHO algorithm outperforms the RSS based VHO algorithm.

Figure 6 compares throughput performance of the LTE system for the proposed VHO algorithm to that of the RSS based VHO algorithm under the same circumstances. The simulation shows that as the traffic load increases, throughput performance of the LTE system with the proposed algorithm is enhanced to a certain point (up to 75 concurrent users) and slowly decreases, since the LTE system is fully loaded when the number of concurrent users reaches 75; after that, more web traffic users tend to be handed over to the WLAN systems. Consequently, after 75 users throughput of the LTE system begins decreasing. In contrast, throughput performance of the LTE system with the RSS based VHO algorithm is higher than that with the proposed VHO algorithm with fewer than 75 concurrent users; due to the same reason explained in the previous paragraph (i.e., the wider coverage

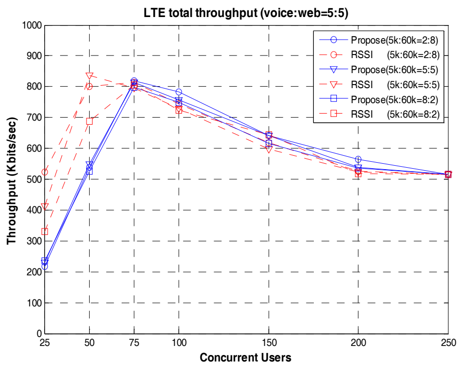

Fig. 6. LTE total throughput

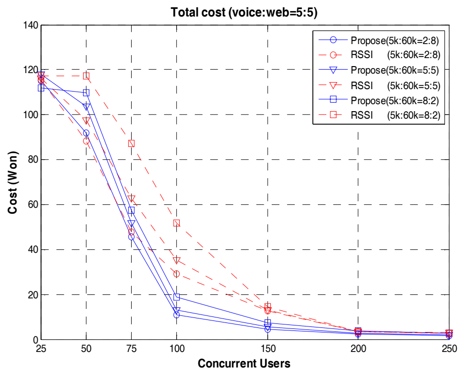

Fig. 7. Total cost

area of LTE system), the LTE system accommodates more web traffic users in this phase. Therefore, the LTE system reaches its capacity limit with the RSS based VHO algorithm faster than with the proposed VHO algorithm.

Figure 7 shows the average usage cost per user. In this case, the proposed VHO algorithm outperforms the RSS based algorithm, since the proposed algorithm takes the usage cost into account for VHO decision making, while the RSS based VHO algorithm does not.

Ⅴ. Conclusion

In this paper, we proposed the URRM architecture and a SVM-based VHO decision system which is a pattern recognition approach between the 3GPP LTE and the next generation WLAN systems. Simulations show that the proposed VHO algorithm outperforms RSS based VHO algorithms in terms of throughput and service cost.

Although the proposed decision scheme based on the SVM requires relatively long training time, it is fast in making the VHO decision. The fast VHO decision seems to be particularly advantageous in the beyond 4G (B4G) environment where cells with small coverage such as femtocells and WLANs are likely coexist with macro cells.

However, there remain further study issues. First, the approach described for a linear SVM can be extended to create a nonlinear SVM (SVDD) for classifying linearly inseparable data. Second, the handoff algorithm based on pattern recognition can be extended to other possible performance criteria. Various feature extractors, pattern classifiers, and neural network architectures will be incorporated. Finally, unsupervised learning methods can be applied to eliminate the necessity of training runs.

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