A Vertical Handoff Decision Process and Algorithm Based on Context Information in CDMA-WLAN Interworking†

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Abstract. The integration of WLANs and CDMA networks has recently evolved into a very hot issue. In order to support a vertical handoff, we propose a context based vertical handoff decision process and the corresponding algorithms from WLAN to CDMA system, and vice versa, based on wireless channel assignment. We focuses on the handoff decision which uses context information such as dropping probability, blocking probability, GoS (Grade of Service), the number of handoff attempts and velocity. As a decision criterion, velocity threshold is determined to optimize the system performance. The optimal velocity threshold is adjusted to assign available channels to the mobile stations with various handoff strategies. The proposed scheme is validated using computer simulation. Also, the overflow traffic (a vertical handoff) is evaluated and compared with non-overflow traffics in terms of GoS.

1 Introduction

There has been a huge development in wireless communication technologies: mobile technology and WLAN technology. Mobile technologies such as GSM (Global System for Mobile Communications), GPRS (General Packet Radio Service), UMTS (Universal Mobile Telecommunication System) and CDMA (IS-95 A/B and cdma2000) offer high mobility but with low rates. In contrast, WLAN technologies offer high rates but with low mobility. The integration of mobile technology and WLAN technology, which compensates the coverage, bandwidth, and mobility to each other, achieves the requirements of the increasing user demands. In order to provide a convenient access of both technologies in different environments, interworking [1] and integration [2] of the two networks are regarded as a very important work.

Recently, the 3rd generation partnership project (3GPP), a standard body that develops and maintains GSM, GPRS, and UMTS, initiates the specification of interworking architecture for WLANs and 3GPP system. In [3], six interworking scenarios have been identified under different supporting services and operational capabilities.

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The combination of WLAN and CDMA technology uses the best features of both systems. The key goal of this integration is to develop heterogeneous mobile data network, capable to support ubiquitous data services with very high data rates in hotspots. The effort to develop such heterogeneous networks, especially seamless roaming, is linked with many technical challenges including seamless vertical handoff across WLAN and CDMA technologies, security, common authentication, unified accounting & billing, WLAN sharing, consistent QoS and service provisioning, etc [4].

A handoff mechanism in an overlay CDMA and underlay WLAN should perform well so that the users attached to the CDMA just easily check the availability of the underlay WLAN. The decision criteria for vertical handoff (or network selection) can be based on the maximum link speed, reliability, power utilization, billing, cost, user preference, mobile speed, and Quality of Service like bandwidth, delay, jitter, and loss rate, etc [5]. For simplicity, we do only consider the mobile speed in this paper. A good handoff algorithm is to be derived in order to minimize unnecessary handoff attempts. An appropriate handoff control is also an important issue in system management for the sake of the benefits above with the overlaid cell structures. This paper suggests three handoff strategies : ① no-overflow, ② Overflow – From WLAN to CDMA system, ③ Overflow – From WLAN to CDMA system and vice versa.

In this paper, we deal with a vertical handoff decision process and algorithms based on context information (GoS) and we first propose a context based vertical handoff decision process and the corresponding mechanism between WLAN and CDMA system, based on wireless channel assignment. Secondly, we present a handoff control scheme for a hierarchical structured network. As a decision criterion, velocity threshold is determined to optimize the system performance. The proposed scheme is validated using computer simulation. Also, the overflow traffic (vertical handoff) is evaluated and compared with non-overflow traffics in terms of GoS. The simulation results show that overflows strategy performs as good as other handoff strategy.

The rest of the paper is organized as follows. In Section 2, the proposed vertical handoff algorithms are presented, problems are formulated, and core part of algorithmic decision procedure for the optimal velocity threshold for the WLAN and CDMA selection schemes. Section 3 explains the architecture for integrated networks, the mobility model, performance parameters (i.e. new call blocking probability and handoff call dropping probability, and Grade of Service). Simulations are performed in Section 4 to validate the proposed approach. Finally, the summary of the result and the future related research topics are presented in the conclusion section.

2 A Vertical Handoff Decision Process and Algorithm

A vertical handoff decision process decides when to invoke a vertical handoff operation. The decision process evaluates user location changes (as users may leave or enter a particular network coverage) and context information (QoS, GoS, mobile speed, network preferences, and etc.) of the current and alternative networks. The evaluation of user location changes is carried out based on the Received Signal Strength (RSS). The vertical handoff process is rule based and the rules are decide whether handoff is necessary and to which network. The latter is decided by the GoS based network selection process invoked when the GoS of a integrated network is below perceived acceptance quality, or GoS is minimized.

Decision rules are described as call initialization, moving out of networks, and entering new networks. Our proposed vertical handoff algorithm between WLAN and CDMA networks considered velocity threshold related to GoS performance and handoff rates is shown in Fig. 1.

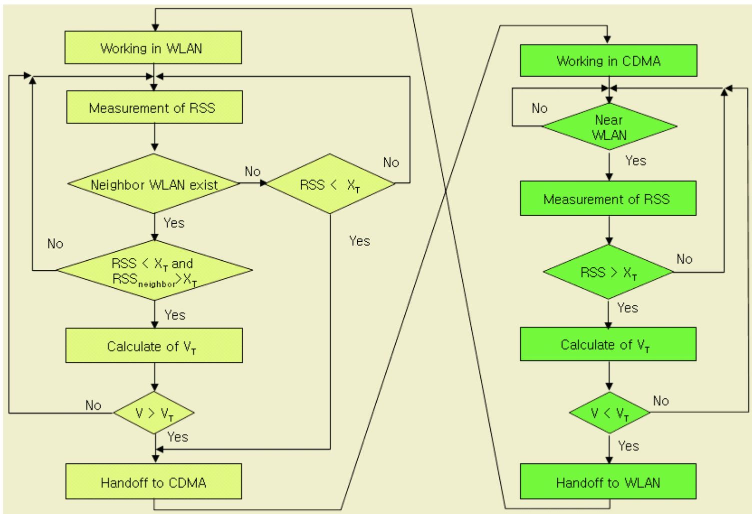

Fig. 1. A vertical handoff algorithm

We use the following variables to determine the vertical handoff:

- X_T : predefined threshold value when the handoff
- V_T : velocity threshold whether a fast mobile station (MS) or a slow MS

When the signal from the WLAN access point (AP) is strong, the MS is connected to the WLAN when the MS is larger than velocity threshold (V_T). As the MS moves away from the coverage of the access point, the signal strength falls. The MS then scans the air for other access points. If no other access point is available, or if the signal strengths from available access points are not strong enough, the handoff algorithm uses this information along with other possible information to make a decision on handing off to the CDMA network.

In a proposed vertical handoff algorithm, the estimation of the velocity threshold procedure is shown in Fig. 2. For the estimation of the mobile speed, Global Positioning System (GPS) or Differential GPS can provide adequate location information. Using GPS and Time-of-Arrival (TOA) information from the user signal, we can estimate for user's velocity. We develop the handoff algorithm based on an optimal velocity threshold. The problem here is to find V_T improving the GoS and decrease the number of handoff attempts (N_h) with the given traffic parameters and MS mobility; $f_\Lambda(\lambda)$ and $f_V(v)$. We have to find the velocity threshold satisfied the following equation.

$$\min_{V_T}\{GoS(V), N_h(V)\} \tag{1}$$

The procedure is now concerned with the GoS in which the system wide new call blocking probability PB and the handoff call dropping probability PD are weighted to be averaged as in Equation (11). The GoS can be written as a function of V_T, and hence finding the optimum value of V_T minimizing the value of GoS and N_h is a typical minimization problem.

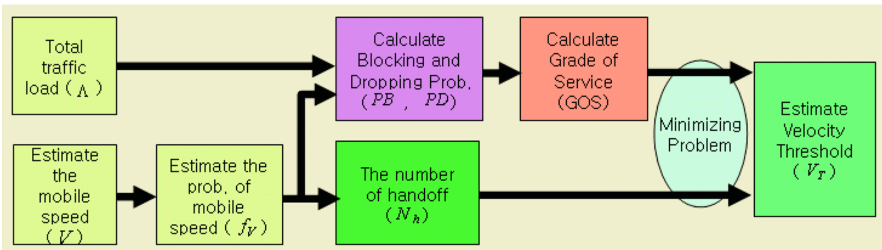

Fig. 2. The estimation of velocity threshold

3 Performance Measures and Analysis

3.1 System Description

We consider a large geographical area covered by contiguous WLANs. Figure 3 shows traffic flows between different wireless networks with related parameters. All the WLANs are overlaid by a large CDMA system. The overlaying CDMA system forms the upper cell layer. Each CDMA system is allocated c_0 traffic channels, and the number of channels allocated to the WLAN cell-i is c_i, $i = 1,2,\cdots,N$. All channels are shared among new calls and handoff calls. MSs are traversing randomly the coverage area of WLAN and CDMA system.

In this paper, all WLANs of the lower layer are treated equally to simplify the overflow. We present analytical results for the proposed system. As stated, our objective is to focus on simple and tractable mechanism for which analytical results can give an insight into handoff between different networks. According to the velocity threshold, all the mobile users are divided into two groups; slower moving users (λ^S) and fast moving users (λ^F). In order to determine the value, which is one of the main goals of this study, a few assumptions related to mobility characteristics are made in system.

The assumptions we employ in the mobility models are taken from [6] as cells are circular with radius R, mobiles are uniformly distributed in the system, mobiles making new calls in WLAN move in a straight line with a direction uniformly distributed between $[0,2\pi)$, and mobiles crossing cell boundary enter a neighbor cell with the incident angle θ of distribution: $f(\theta) = 1/2 \times \cos\theta, \quad -\pi/2 < \theta < \pi/2$.

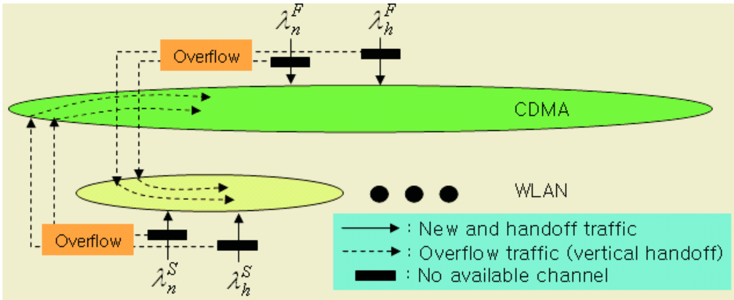

Fig. 3. Management of traffics in integrated system

WLAN cells compose of two types of new call traffics, represented by the call arrival rates λ_n^S and λ_h^S, respectively modeled by the Poisson process (To simplified simulation, voice call considered). Let random variables X and Y denote the straight mobile path for new calls and handoff calls, respectively. With the assumption of the unique WLAN cell size and the same speed of the MS, WLAN cell boundary crossing rate per call (μ_B), provided that no handoff failure occurs [6]: $\mu_B = 2E[V]/\pi R$. New calls assume to finish within the average call duration time, $1/\mu$, or the call handoffs to an adjacent cell. The proportion of the channel returned by the handoff is $P_h = \mu_B/(\mu + \mu_B)$ [7]. In other words, the rate of channel release and that of the call completion due to handoff are $\mu_B/(\mu + \mu_B)$ and $\mu/(\mu + \mu_B)$, respectively.

3.1 The New Call Blocking Probability of WLAN and CDMA System

We denote the blocking probability of calls from CDMA system and WLAN by P_{B0} and P_{B1}, respectively. And the handoff traffic from slow and fast mobiles is denoted as follows. The λ_{h0}^F and λ_{h0}^S is the rate of fast and slow mobile handoff traffic in a CDMA systems, respectively. The λ_{h1}^F and λ_{h1}^S is the rate of fast and slow mobile handoff traffic in a WLAN, respectively. And we denote the take-back traffic rate to CDMA system and WLAN by λ_{T0} and λ_{T1}, respectively. The P_{T0} and P_{T1} are the take-back probability from CDMA system and WLAN, respectively.

The aggregate traffic rate into the WLAN due to a slow MS is computed as follows:

$$\lambda_1^S = \lambda_{n1}^S + \lambda_{h1}^S \tag{2}$$

The aggregate traffic rate into the WLAN due to fast MS is expressed as

$$\lambda_1^F = 1/N \times (\lambda_{n0}^F + \lambda_{h0}^F) P_{B0} + \lambda_{h1}^F \tag{3}$$

The generation rate of the handoff traffic of a slow mobile station in a WLAN is given as follows:

$$\lambda_{h1}^S = P_{h1}^S (\lambda_{n1}^S + \lambda_{h1}^S)(1 - P_{B1}) \tag{4}$$

The generation rate of the handoff traffic of a fast moving MS in a WLAN is characterized as follows:

$$\lambda_{h1}^{F} = P_{h1}^{F}\{1/N \times (\lambda_{n0}^{F} + \lambda_{h0}^{F})P_{B0}(1-P_{B1}) + \lambda_{h1}^{F}(1-P_{B1})\} \tag{5}$$

The parameter ρ is the actual offered load to a WLAN from the new call arrival and the handoff call arrival. Invoking this important property, we can use $\rho_1 = \lambda_1^S / \mu_1^S + \lambda_1^F / \mu_1^F$ as the offered load to the WLAN, the Erlang-B formula calculates the blocking probability with the traffic ρ_1 and the number of channels c_1 [8]

$$P_{B1} = B(c_1, \rho_1) \tag{6}$$

Like as the new call blocking probability of WLAN, we can use $\rho_0 = \lambda_0^S / \mu_0^S + \lambda_0^F / \mu_0^F$ as the offered load to CDMA system, and blocking probability can be written as

$$P_{B0} = B(c_0, \rho_0) \tag{7}$$

3.2 The Handoff Call Dropping Probability of WLAN and CDMA System

Slow MSs are supposed to use WLAN channels. However, since handoff to CDMA system is also allowed, the probability of handoff call drop in WLAN can be calculated as follows. Let P_{10} denote the probability that a slow MS fails to be handoffed to a near WLAN. The probability of the calls, P_{B0}, in a WLAN denotes the probability of failed hand-up to the overlaying CDMA system due to the channel shortage. Then the handoff call dropping probability is

$$P_D^S \approx P_{10}P_{B0} + P_{10}(1-P_{B0})P_{F0}^S \tag{8}$$

Here P_{F0}^S is the probability that a slow MS handoff to CDMA system fail. The P_{10} is defined in such a way that the i th handoff request is successful but the $(i+1)$ th request is dropped:

$$P_{10} = f_1 + s_1 f_1 + s_1^2 f_1 + \cdots = f_1/(1-s_1) \tag{9}$$

where $f_1 = P_{h1}P_{B1}$ and $s_1 = P_{h1}(1-P_{B1})$. f_i describe the probability that handoff fails due to channel shortage and the s_i is the probability of successful handoff. The overall probability of either dropping or handoff failure is

$$PD = R_S P_D^S + R_F P_D^F \tag{10}$$

where R_S and R_F is fraction of slow and fast MSs , respectively

3.3 Grade of Service (GoS)

Among many system performance measures, GoS is most widely used. In fact users complain much more for call dropping than for call blocking. It is evaluated using the prespecified weights, PB and PD ,

$$GoS = (1-\alpha)PB + \alpha PD \tag{11}$$

where PB and PD represent the blocking and dropping prob. of systems, respectively. The weight α emphasizes the dropping effect with the value of larger than one half.

4 Numerical Examples

The proposed procedure is tested with a number of numerical examples for the overlaid structure. The test system consists of 10 WLANs in the CDMA system. The total traffic $\Lambda = \lambda_0 + n\lambda_1$, where λ_0 and λ_1 are the new call arrival rate for the CDMA system and the WLAN, respectively. The radius of the WLAN and the CDMA system are assumed 300m and 1000m, respectively. The average call duration is $1/\mu = 120$ sec. The number of channels in each CDMA system and WLAN is $c_0 = 30$, $c_1 = 10$ for the total $\Lambda = 60$ Erlang. Assume the traffic mobility distribution is same as [6].

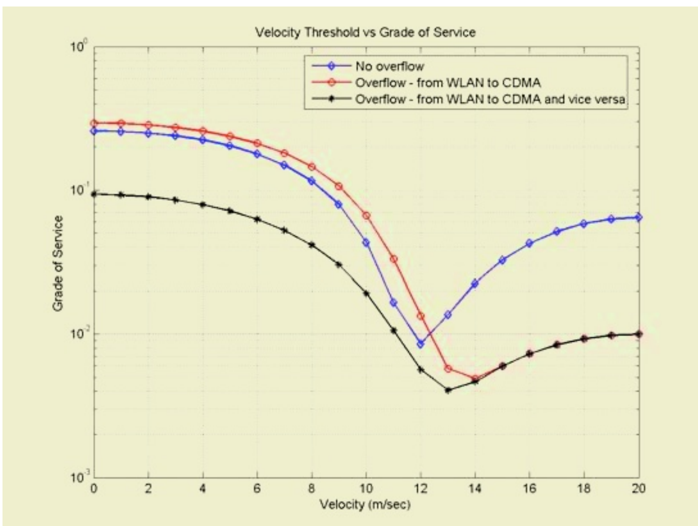

Fig. 4. Grade of Service vs. velocity threshold

In operation phase use can draw a histogram to estimate the $\hat{f}_V(v)$, and the expected value of the mobile speed can be calculated by averaging the mobile speeds monitored by the system. Analytically we can obtain $E[V]$ for such a simple hypothetical velocity distribution [7]. And we consider four handoff strategies for comparison as follows.

① No overflow : A reference system where the two layers are kept completely independent.

② Overflow – From WLAN to CDMA system : A system where only overflow of new and handoff traffic for a slow MS to the CDMA system is allowed.

③ Overflow – From WLAN to CDMA system and vice versa : A system where overflow of new and handoff traffic for both slow and fast MS is allowed.

We investigate the GoS, which is a function of both the traffic load and mobility distribution. Fig. 4 shows the plot of (11) for the mobility distributions of the MS in the system. The vertical arrows in the figure show the range of the possible velocity thresholds at a certain load level. The lowest point in the range corresponds to the maximum allowable and optimal velocity threshold. Optimal V_T is 12m/sec, 14m/sec, 13m/sec for case ①, ②, ③, respectively. Here the GoS of case ② and ③ have minimums of nearly equal values, but V_T does different cases. Case ③ is favorable (See Fig. 4) since V_T in the case ③ is smaller than that of case ② and thus more users are serviced in the CDMA system while the WLAN serves the fewer users. As a result, the WLAN will give rise to a higher number of handoff requests for high-mobility users, and the corresponding number of handoff requests of the calls in progress may cause an excessive processing load in the network. As the velocity threshold increases, the number of handoff attempts in the system also increases.

The overflow strategy, case ③, provides the value of GoS nearly equal to case ② while it has the optimal velocity threshold smaller than that of case ②. With all the observations in mind, the strategy we proposed has desirable characteristics, i.e., finding the optimal value of GoS and the number of handoff rate.

5 Conclusion

We have proposed a vertical handoff decision process with network selection deciding the optimal velocity threshold in order to improve the GoS and minimize the number of handoff attempts with the given traffic volume and three handoff strategies in WLAN and CDMA system. The simulation results show the dependency of the system performance upon the velocity threshold, V_T . The velocity threshold has shown to be an important system parameter that the system provider should determine to produce better GoS and lower handoff rate. From the simulation results we were able to validate the procedures determining the optimal V_T in which depends upon GoS as well as the number of handoff attempts. Furthermore, the overflow strategy (case ③) is more favorable than other handoff strategies in this simulation environment.

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