Adaptive Network Selection Algorithm Based on User Application Profile

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***Abstract*—In next generation network, various heterogeneous wireless access networks are expected to integrate to support user's seamless connection. In this system, efficient and reliable network selection schemes are required for users to choose a suitable network among all the available networks. In this paper, an adaptive network selection algorithm based on user profile and application profile is proposed for a cellular and WLAN integrated heterogeneous scenario. In the novel algorithm, user profile information, including user mobility, the power of user terminal, the service cost preference, etc., and the characteristics of user applications are taken into account in designing the cost function factors and the corresponding weights of the network selection algorithm. Comparing to traditional fixed-form cost function based network selection algorithms, the proposed algorithm offers better QoS guarantee and user satisfactory.**

Keywords-heterogeneous network; vertical handoff; network selection; cost function; user profile; weight-adjustable

I. Introduction

In next generation network (NGN), different access networks are integrated to support users' communication. These access networks can be cellular systems including GSM, UMTS, etc., Wireless Local Area Network (WLAN) and mobile Ad-Hoc network, etc. Services in one particular access network should be delivered to other networks seamlessly. Unlike handoff between Access Points (AP) with same technologies (called horizontal handoff), the handoff between networks with different access technologies in NGWN is referred to as vertical handoff. The vertical handoff technique design of network mobility management schemes in NGWN is of particular importance, for it can seriously affect the efficient utility of network resource and the user Quality of Service (QoS).

During the process of vertical handoff, UE/network evaluates the performance of handoff candidate networks based on network performance and user preference, and according to specific vertical handoff decision algorithm, makes the handoff decision, including the necessity of making a handoff and the determination of handoff destination network. The heterogeneity of access networks and a variety of user's profile pose difficulties in efficient and fair network performance evaluation and in turn, efficient vertical handoff design.

Current vertical handoff algorithms can be categorized into following four classes:1) Received Signal Strength (RSS) based handoff algorithm: Similar to horizontal handoff in cellular system, the vertical handoff is performed when the RSS from BS/AP of access networks satisfies some particular conditions[1-3]; 2) Fuzzy control based vertical handoff decision method: applying fuzzy logic, fuzzificating the parameters affecting handoff performance and then making the handoff decision [4,5]; 3) The characteristics of access networks and load balance based vertical handoff algorithm: In [6], it is proposed that user performs handoff from cellular system to WLAN when it arrives at the common coverage area of both WLAN and cellular system. The load balance among access networks is taken into account for the candidate handoff network selection in [7]; 4) Cost-function based method: the cost function is designed based on network characteristics and user parameters, including access bandwidth, connection delay, RSS and service costs, etc., the handoff decision is made based on the comparison of cost functions of different access networks [8-12]. Among above four methods, cost-function based method attracts considerable attention as it quantitatively evaluates both the characteristics of network and users and is thus able to provide better handoff efficiency and better QoS guarantee comparing to other methods.

In most existing cost function based network selection algorithm, a set of network and user parameters are chosen as the cost factors and fixed weights are assigned in designing the cost function. As NGWN is expected to support users with different profiles and various service applications with different QoS requirements, unique form of cost function with fixed weights can not efficiently reflect user requirements on communication service, resulting in low efficiency in network selection and vertical handoff. Moreover, in most vertical handoff algorithm design, the consideration on service application is relatively little. In some papers, user services are discussed but only limited to the classification of real time and non-real time services[13,14].

In this paper, the network selection and vertical handoff for a heterogeneous network with the integration of cellular system and WLAN is studied. It is assumed that the whole area under consideration is covered by cellular system, and some hot-spot areas are also covered by WLAN, as shown in Figure 1. For users inside the coverage area of WLAN, the network selection problem, i.e., choosing to access to WLAN or cellular system is discussed and an adaptive algorithm based on user profile and application profile is proposed. In the novel algorithm, the user profile information, including user mobility, the power of user terminal, the service cost consideration, etc. and the classes of user service applications are taken into account in designing the

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cost function factors and the corresponding weights of cost function based network selection algorithm.

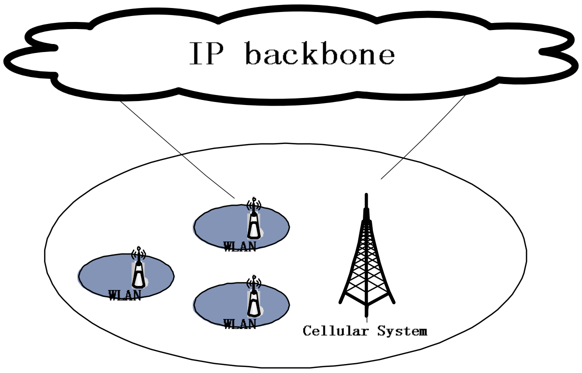

Figure 1. The integration of cellular system and WLAN

II. General Formulas of Cost Function for Network Selection

The basic idea of cost function based network selection algorithm is to choose a set of network and Mobile Terminal (MT) parameters affecting network selection performance and define a cost function based on these factors. According to the effects of each particular cost factor on the result of the cost function, cost factors can be categorized as reward factors, i.e., the larger, the better, and expense factors, i.e., the less, the better. Denoting f_{k1}^{r} and f_{k2}^{e} as the normalized reward factors and expense factors, respectively with $k1 = 1,..,M, k2 = 1,..,N$, and w_k denotes the weights corresponding to the k th factors, there are two general forms of the cost functions:

$$Q = \sum_{k1=1}^{M} w_{k1} f_{k1}^{r} + \sum_{k2=1}^{N} w_{k2} (1 - f_{k2}^{e}) \quad (1)$$

$$Q = \sum_{k1=1}^{M} w_{k1} f_{k1}^{r} + \sum_{k2=1}^{N} w_{k2} / f_{k2}^{e} \quad (2)$$

The performance of candidate networks can be evaluated based on Eq.(1) or (2), and the one with best performance, i.e., the largest Q, can then be chosen as the handoff destination network. In this paper, we choose Eq.(1) as the basic form of our proposed network selection algorithm. Unlike most existing cost function based network selection algorithms with fixed reward/expense factors and fixed weights, in this paper, an adaptive cost function with cost factors and corresponding weights varying according to user profile information and user application requirements are formulated and a novel network selection algorithm is proposed.

III. User Application Profile on Network Selection

In this section, user profile information and application profile are described, the corresponding parameters and their weights in the cost function of network selection are then discussed in detail.

A. User Profile

(1) User Mobility

NGWN is expected to support users with different mobility. In this paper, the mobility of user is classified as low, medium and high speed user, corresponding to $v \le 50km/h$, $50km/h \le v \le 100km/h$, and $v \ge 100km/h$, respectively, with v denoting user velocity.

The capability for supporting MTs with different mobility model varies for different heterogeneous access networks, for instance, a high-speed user can be better supported in cellular system than it is in WLAN. It is proposed that the next generation cellular system will be able to support users with velocity higher than several hundreds kilometers per hour [15,16], while, the QoS requirement for users with high mobility can not be guaranteed in current WLAN networks. Therefore, in the integration environment of both WLAN and cellular system, choosing of WLAN for high-speed users should be restricted, i.e., this type of users can only choose to access to cellular system even in the overlapped coverage area of WLAN. For users with medium velocity, handing off from cellular system to WLAN may lead to further handoff due to the relatively small coverage of WLAN, as a result, in this paper, the choose of WLAN for this type of users is limited unless WLAN outperforms cellular system significantly.

The affects of user mobility on the network selection algorithm can be described by users' preference on access networks. Introducing parameters P_i , with $i = 1,2$ representing MTs' preference on choosing the *i*th network, where, $i = 1$ and 2 representing cellular system and WLAN, respectively. P_i can be chosen as constants being comparable with other normalized cost factors. For MTs with low and medium mobility, different weights can be assigned for P_1 and P_2 to reflect MT's preference on access networks. Denoting $w_{i,l}^{p}$ as the weights of P_i , for $i = 1,2$, where $l = 1,2$ representing low-speed and medium-speed MT, respectively, we obtain: $w_{12}^{p} \ge w_{22}^{p}$ and $w_{11}^{p} = w_{21}^{p}$, that is medium-speed MT has preference on cellular system while low-speed MT has no preference on either network.

(2) Power Limitation of MT

MT consumes different power while transmitting data in different networks. When the battery charge of user equipment is sufficient, the factor of power consumption plays less important role in selecting the handoff target network, however, in some particular cases, for instance, the charge stored in the user terminal is relatively low, the handoff users will tend to choose the candidate network with low power consumption which can in term provide elongated usage time. In general, MT working in WLAN consumes more power comparing to that working in cellular system[17] , in this case, accessing to cellular system would be a better decision than connecting to WLAN when a MT's battery is nearly exhausted.

(3) Service Costs

The service cost or service fee is the amount of money that user needs to pay for accessing the network and using the telecommunication services. It is one of the most important factors and sometimes even the decisive factor in the choice of access network. The service fee is usually closely related to the billing plan of the service providers, the types of user service and the access networks, etc. For similar service requirements, users tend to choose service provider with lower cost. The service cost for WLAN is in general lower than that for cellular system, as the WLAN protocol, i.e., IEEE 802.11 operates over an unlicensed spectrum, whereas cellular system operates over a licensed spectrum.

In this paper, users are classified into two types depending on their priority on the service fee in network selection. Class 1 user tends to access to network with lower cost, i.e., WLAN and stay in WLAN as long as possible unless the service offered by WLAN can not be supported or the network is unavailable. Class 2 users put the priority of connection performance higher than service fee, and choose the network offering better QoS.

B. Application Profile

(1) Application Types

To manage different levels of user QoS, 3GPP has defined four QoS traffic classes based on delay, jitter, bandwidth, and reliability factors for UMTS[18]. These application traffic types include Conversational class, Streaming class, Interactive class and Background class. Conversational and Streaming classes are mainly intended to be used for real-time traffic flows while Interactive and Background classes are mainly meant to be used by non-real time traditional Internet applications.

To support user applications with different QoS requirements in WLAN, IEEE 802.11e [19] was released in 2003 as an amendment to the IEEE 802.11 standard. The traffic classes supported by UMTS can be mapped into four access categories specified in 802.11e. In this paper, the four application types specified in UMTS standard are considered and denoted as Class 1, 2, 3, 4. The various requirements of these applications on connection delays, packet loss and network bandwidth are summarized in Table 1.

TABLE I. APPLICATION TYPE AND PERFORMANCE REQUIREMENTS

Types	Conver-sational class	Streaming class	Interactive class	Backgro-und class
Connnec-tion delay	Strict	Strict on delay jittering	Not very strict	No require-ment
Packet loss rate	Not very strict	Not very strict	Low	Low
System bandwidth	Small	Small	Large	Large
Applica-tion examples	Voice, Voice over IP	Streaming video	Web browning	E-mails, file download

The characteristics of different QoS classes pose different requirements on access network performance. For MT applying Class 1 service, the strict delay requirement poses challenges for accessing to WLAN, on the other hand, the major advantage of WLAN, i.e., large system bandwidth is unnecessary for most practical applications, therefore, for this class of service application, keeping accessing to UMTS is suggested and hereafter, we do not consider Class 1 service in the network selection algorithm. In the following, the effects of system parameters, i.e., the connection delay, the system bandwidth and the packet loss rate of Class 2 to 4 applications on the network selection are discussed.

(2) Connection Delay

For most Class 2 and Class 3 applications, the maximum acceptable transmission delay, denoting as $D_2^{\max}$ and $D_3^{\max}$ are defined. That is to guarantee the normal communication of Class 2 or 3 applications, the system connection delay must meet the delay condition, i.e.,

$$D_i \le D_j^{\max}, i = 1,2, j = 2,3,$$

where, D_1 and D_2 denote the connection delay of cellular system and WLAN, respectively. To take into account the effect of connection delay in network performance evaluation, the normalized connection delay can be introduced and is defined as following in this paper:

$$D_i^{norm} = \frac{D_i}{\max(D_1, D_2)}, i = 1,2,$$

Denoting $w_{ij}^D, j = 2,3,4$ as the weights of delay factor for service classes 2 to 4 in the i th system, with $i = 1,2$ representing cellular system and WLAN, respectively, according to different connection delay requirements of application Class 2 to 4, we obtain the constraints of delay weights:

$$w_{i,2}^D > w_{i,3}^D, w_{i,4}^D = 0, i = 1,2.$$

(3) Network Bandwidth

As large available system bandwidth is desirable for most application classes, it is one of the most important factors user considers in making the network selection decision. In general, the system bandwidth required for non-real time services is much higher than that for real-time service. Denoting B_1 and

B_2 as the system available bandwidth of cellular system and WLAN, respectively, the normalized system available bandwidth can be defined as:

$$B_i^{norm} = \frac{B_i}{\max(B_1, B_2)}$$

Denoting $w_{ij}^B, j = 2,3,4$ as the weights of bandwidth factor for service classes 2 to 4 in the i th system, with $i = 1,2$ representing cellular system and WLAN, respectively, to emphasis the consideration on bandwidth factor in network selection process for non-real time applications, we apply the constraints of bandwidth weights, as following:

$$w_{i,2}^B < w_{i,3}^B = w_{i,4}^B, i = 1,2 .$$

(4) Packet Loss Rate

One of the characteristics of the Interactive and Background class is that the content of the packets shall be transferred with low error rate. The transmission of packets consists of both wireless and wired links. In this paper, we focus on the effects of access network selection on packet loss rate and only consider the packet loss/error occurs in the wireless links. In this case, the packet loss/error rate is closely related to the status of the wireless link, which can be characterized by the RSS of MT. It should be noticed that for users applying Conversational and Streaming applications, no particular requirement is posed on packet loss rate and RSS, and the only condition the RSS has to satisfy is being larger than the RSS threshold.

Denoting R_i, R_i^{th} and $R_i^{\max}$ as the RSS, RSS threshold and the maximum RSS from the ith network for $i = 1$ and 2 corresponding to cellular system and WLAN, respectively. Referring to [9], the RSS from the ith network can be normalized as: $R_i^{norm} = \frac{R_i - R_i^{th}}{R_i^{\max} - R_i^{th}}$

Denoting $w_{1,j}^R, j = 2,3,4$ and $w_{2,j}^R, j = 2,3,4$ as the weights of RSS factor for service Classes 2 to 4 in the cellular system and WLAN, respectively, according to previous discussion, we assign: $w_{i,2}^R = 0, w_{i,3}^R = w_{i,4}^R, i = 1,2.$

IV. ADAPTIVE NETWORK SELECTION ALGORITHM

In section III, different user profile and corresponding affects on network selection are discussed. The application classes and requirements posing on access network performance are studied as well, in this section, an adaptive cost function based network selection algorithm is proposed. In the proposed algorithm, for users with different profiles, the cost factors and the corresponding weights in the cost function are chosen accordingly so that the QoS and other requirement can be guaranteed adaptively, moreover, an efficient and fairness utility of network resource can be achieved.

In the proposed network selection algorithm, users applying Class 1 service or those having special characteristics, i.e., high mobility, insufficient power and cost-sensitive are particularly treated and assigned to suitable access network instead of evaluating the performance of both access networks. For other normal users, the cost function with different cost factors and corresponding weights is then chosen based on user application class.

For users with application classes 2, 3 and 4, the respective cost functions of network selection are chosen as:

$$\begin{gathered} Q_i = w_{i,j}^P P_i + w_{i,j}^D (1 - D_i^{norm}) + w_i^B B_i^{norm} + w_{i,j}^R R_i^{norm}, \\ \text{s.t. } w_{i,2}^D > w_{i,3}^D, w_{i,4}^D = 0, w_{i,2}^B < w_{i,3}^B = w_{i,4}^B, \\ w_{i,2}^R = 0, w_{i,3}^R = w_{i,4}^R, w_{i,j}^D + w_{i,j}^B + w_{i,j}^R = 1, \\ \text{for } i = 1,2, j = 2,3,4. \end{gathered}$$

For each particular application class, the analytic hierarchy process[20] can be applied to calculate the weight factors, however, the optimal weights for different application classes should be designed to potentially achieve the load balancing between access networks and the traffic fairness among different traffic classes, as will be discussed in [21].

Given particular weight factors and normalized cost parameters, the cost function of two access networks can be evaluated and the network with larger Q_i, i.e. $i^* = \arg\max_i (Q_i)$ is chosen as the destination access network. The flow chart of the proposed network selection algorithm is shown in Figure 2.

V. CONCLUSION

In this paper, an adaptive network selection and vertical handoff algorithm based on user profiles and application profiles is proposed for a cellular and WLAN integrated heterogeneous network. In the proposed algorithm, user profile information and user application class are both taken into account in designing the cost function of the network selection algorithm, more specifically, in choosing the cost factors and the corresponding weights of the cost function. Comparing to traditional fixed-form cost function based network selection algorithm, proposed algorithm offers flexibility and better user satisfactory degree. In future work, extensive performance evaluation will be conducted in verifying the efficiency of new algorithm.

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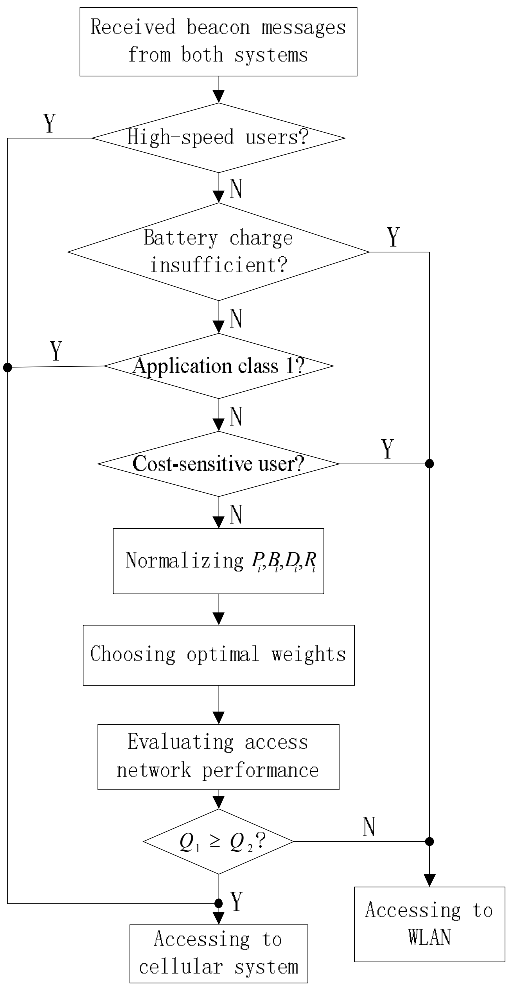

Figure 2. The flow chart of proposed network selection algorithm

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