

A priority-based dynamic load transfer algorithm for cellular/WLAN integrated networks

Chen Geng¹ Xia Weiwei¹ Xu Bo² Shen Lianfeng¹

(¹National Mobile Communications Research Laboratory, Southeast University, Nanjing 210096, China)

(² Institute of Communications Engineering, PLA University of Science and Technology, Nanjing 210016, China)

Abstract: For the integration network of a cellular network and a wireless local area network (WLAN), a priority-based dynamic load transfer (PDLT) algorithm is proposed. The dynamic vertical handoffs by call admission control are jointly determined by the network conditions and the traffic characteristics in combination with the location-condition of mobile terminals. When there is no bandwidth resource available in the cellular network or WLAN, the proposed PDLT algorithm allows an incoming voice call or data call within the overlapping area of the cellular network and the WLAN to be directed to the spare network; meanwhile, by dynamically computing the occupancy of the bandwidth resource, the proposed PDLT algorithm also allows an ongoing voice call or data communication to be transferred to the network with a sufficient bandwidth resource according to the given threshold to balance the number of voice/data calls in the two networks. The analysis results of a two-dimensional Markov model and the simulation results show that the PDLT algorithm can effectively enhance the whole integrated network's traffic, reduce the blocking probability of new calls and increase the data throughput, and thus decrease the response time for various services.

Key words: cellular network; WLAN; dynamic load transfer; blocking probability; Markov model

doi: 10.3969/j.issn.1003-7985.2012.01.003

A cellular/WLAN integrated network is a heterogeneous network that can achieve large network capacity and fine-grained quality of service (QoS). In such an integrated network, the cellular network usually employs a centralized control mechanism and a reservation-based resource allocation strategy, which provide fine-grained QoS for admitted calls, while the WLAN employs a contention-based random access protocol for call admission,

which provides a lower level of QoS. However, a WLAN can provide a higher transmission rate than a cellular network. To meet the QoS requirements of different users/calls and meanwhile efficiently make use of network resources, the traffic loads of different classes should be appropriately distributed to the cellular network and the WLAN through call admission control and vertical handoffs between the two networks. To this end, a variety of call admission control schemes have been proposed to distribute the incoming and ongoing voice/data calls in a cellular/WLAN integrated network with a two-tier overlay structure for QoS support. For example, a simple admission control scheme is proposed in Refs. [1–2], which controls the traffic loads into a WLAN based on users' bandwidth demands and the current status of the network. The numerical results given in Refs. [1–2] show that the resource utilization of the network largely depends on the admission parameters determined by user mobility and traffic characteristics. In Ref. [3], an optimal joint session admission control scheme is presented for multimedia traffic. In this work, the semi-Markov decision process (SMDP) is used to analyze the system performance. Using this control scheme, both the new session blocking probability and the handoff session blocking probability are confined to below a predetermined threshold blocking probability under several QoS constraints. In Ref. [4], a dynamic session transfer mechanism is proposed for hierarchical integrated networks. In Ref. [5], the load sharing problem is investigated by considering call distribution via admission control and load transfer via the dynamic vertical handoff.

Despite all the above work, however, little work has been done considering the dynamic vertical handoff within an overlapping area of a cellular/WLAN integrated network, which is triggered by not only the user mobility at the cell boundary but also by the network status, such as the overall blocking probability, maximum data throughput, and resource utilization of the whole network. In Refs. [6–7], an integrated service-based admission control scheme with load-balancing capability (ISACL) is proposed, in which load transfer in a cellular/WLAN overlapping area is allowed for the admission of the incoming data calls from the area with cellular access only and the admission of the vertical handoff calls from

Received 2011-11-04.

Biographies: Chen Geng (1984—), male, graduate; Shen Lianfeng (corresponding author), male, professor, lfshen@seu.edu.cn.

Foundation items: The National Science and Technology Major Project (No. 2011ZX03005-004-03), the National Natural Science Foundation of China (No. 61171081), the Research Fund of the National Mobile Communications Research Laboratory of Southeast University (No. 2011A08).

Citation: Chen Geng, Xia Weiwei, Xu Bo, et al. A priority-based dynamic load transfer algorithm for cellular/WLAN integrated networks. [J]. Journal of Southeast University (English Edition), 2012, 28(1): 14–20. [doi: 10.3969/j.issn.1003-7985.2012.01.003]

neighbor cells in the cellular network. But in this scheme, the loads are transferred with probability r_d , not dynamically based on the network status. In Ref. [8], a load sharing scheme for voice and elastic data services is proposed, which uses admission control and dynamic vertical handoff to allocate free bandwidth to elastic data traffic and improve the multiplexing gain in a cellular/WLAN integrated network. Moreover, an accurate analytical model is developed to determine a threshold value in order to appropriately distribute data calls to the cell and the WLAN. However, since the three-dimensional Markov chain is used to describe the network status, the size of the state space will explode with the increase in the number of calls, which will greatly increase the computational complexity.

In this paper, a priority-based dynamic load transfer (PDLT) algorithm is proposed to balance the voice/data calls in an overlapping area to reduce the incoming call blocking probability and increase the data throughput of a cellular/WLAN network. Unlike the existing call admission schemes, the dynamic vertical handoff in the PDLT algorithm is triggered by the network status, i. e., the overall blocking probability and network resource utilization, and the traffic type considering different characteristics of voice/data calls. Simulation results show that the proposed PDLT algorithm can effectively balance the voice/data calls to reduce the blocking probability of incoming calls and increase the data throughput of the network.

1 Network Model

We consider a network scenario with a two-tier overlay structure, in which there is only one WLAN located in a cellular network, as shown in Fig. 1. The cellular network is divided into area A and area B, and area B is an overlapping area of the cellular network and the WLAN. The resources of the cellular network are managed by the base station (BS) in the cellular network. Meanwhile, the

users/mobile nodes in the WLAN can access the Internet through the access point (AP) in the WLAN. It is assumed that the mobile nodes are dual-mode nodes, which can not only access the cellular network, but also access the WLAN based on the current network status, and the number of the mobile nodes is κ . With the two-tier overlay structure, incoming traffic should be appropriately admitted to the cellular network or the WLAN through admission control. Meanwhile, an ongoing voice/data call can be transferred to the cellular network or the WLAN based on the current network status.

For simplicity, it is assumed that the user resident time and call duration time are distributed exponentially^[9-10]. Let T_r^w denote the time that a user resides in the WLAN, which follows an exponential distribution with mean $1/\eta^w$. Let T_r^c denote the time that a user resides in a cell before it moves to a neighbor cell, which follows an exponential distribution with mean η^c . Let T_r^{bcw} denote the time that a user resides in the cellular network before it enters the cellular/WLAN overlapping area, which follows an exponential distribution with mean η^w . The average duration of a voice call is also assumed to follow an exponential distribution with mean μ_v . Therefore, the channel occupancy time of a voice call within the cellular network and the WLAN can be denoted by an exponential distribution with mean $\mu_v^c = \eta^c + \mu_v$ and $\mu_v^w = \eta^w + \mu_v$, respectively. The average duration (L_d) of a data call is assumed to follow an exponential distribution with mean $1/f_d$.

The system parameters used in this paper are explained as follows. Let n_v^c denote the number of the ongoing voice calls in the cellular network, while let n_d^c denote the number of the ongoing data calls in the cellular network. Similarly, the parameters n_v^w and n_d^w are specified by the number of the ongoing voice and data calls in the WLAN, respectively. Meanwhile, M_v^c , M_d^c , M_v^w , and M_d^w are the upper bounds of n_v^c , n_d^c , n_v^w , and n_d^w , respectively. Let λ_{ufv}^w denote the arrival rate of voice calls underflow to the WLAN from the cellular network, while the arrival rate of data calls overflow to the cellular network from WLAN is denoted by λ_{ofd}^c . Moreover, let λ_{ov}^c denote the new voice call arrival rate in the overlapping area (area B) of the cellular network and let λ_{od}^w denote the new data call arrival rate in the WLAN.

2 Priority-Based Dynamic Load Transfer Algorithm

In this section, we present the priority-based dynamic load transfer algorithm for cellular/WLAN integrated networks. We first describe the priority model used in the algorithm, which is used to decide which voice/data calls will be transferred from one network to the other based on the network status. Then we present the details of the proposed dynamic load transfer algorithm.

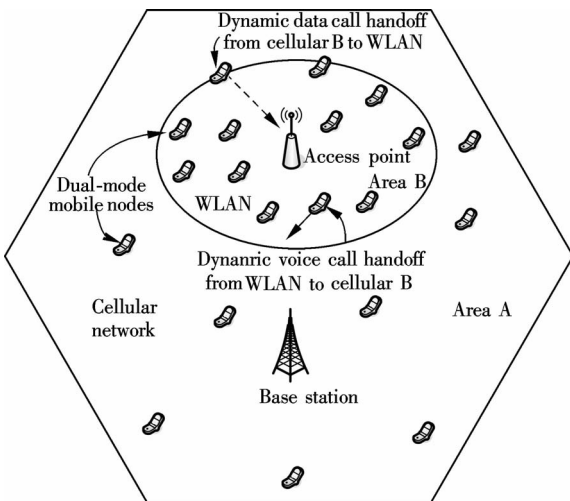


Fig. 1 Network model

2.1 Priority model

Considering that the cellular network and the WLAN provide different levels of QoS for voice/data calls, new voice calls arriving in the overlapping area are directed to the cell for fine-grained QoS, while new data calls arriving in the overlapping area are directed to the WLAN because data traffic requires more bandwidth. When the cellular network has no spare bandwidth for new voice calls, the incoming voice calls will underflow to the WLAN. When the WLAN has no free bandwidth for new data calls, the incoming data calls will overflow to the cellular network. When one of the networks is overloaded, it will result in congestion or performance degradation in the network. In this case, some ongoing sessions in the network will be returned to the other one for achieving better QoS. For example, when the cellular network is overloaded, some ongoing data calls in the network will be returned to the WLAN, and vice versa. Therefore, the next problem is the call selection problem, i. e., how to decide which calls should be returned from one network to the other network in this case.

For analytical accuracy, we take into account the QoS supporting factor p_i^Q , the moving velocity factor p_i^V and the location-dependent factor p_i^L of a call C_i , and define $\mathbf{P}_i = \{p_i^Q, p_i^V, p_i^L\}$ as a factor vector. Let r_i^C denote the network resources occupied by ongoing call i vertically handovered to the cellular network and r_i^W denote the network resource occupied by ongoing call i vertically handovered to the WLAN. Thus, the resources occupied by ongoing call i in the cellular network and the WLAN can be expressed by a vector $\mathbf{R}_i = \{r_i^C, r_i^W\}$. Assume that the number of ongoing voice/data calls in the overlapping area is m . The factor vector and the occupied resource vector for the destination network can be combined into a multi-parameter matrix \mathbf{T} , i. e.,

$$\mathbf{T} = \begin{bmatrix} \mathbf{P}_1 & \mathbf{R}_1 \\ \mathbf{P}_2 & \mathbf{R}_2 \\ \vdots & \vdots \\ \mathbf{P}_m & \mathbf{R}_m \end{bmatrix} = \begin{bmatrix} p_1^Q & p_1^V & p_1^L & r_1^C & r_1^W \\ p_2^Q & p_2^V & p_2^L & r_2^C & r_2^W \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ p_m^Q & p_m^V & p_m^L & r_m^C & r_m^W \end{bmatrix} \quad (1)$$

The weights of the above five factors affecting vertical handoffs are $\xi_Q, \xi_V, \xi_L, \xi_C, \xi_W$, respectively, where $\xi_Q + \xi_V + \xi_L + \xi_C + \xi_W = 1$. The weight vector can be denoted by $\boldsymbol{\xi} = \{\xi_Q, \xi_V, \xi_L, \xi_C, \xi_W\}$. Thus, the cost vector \mathbf{H} used for call selection can be expressed as

$$\mathbf{H} = \mathbf{T}\boldsymbol{\xi}^T = \mathbf{T}\{\xi_Q, \xi_V, \xi_L, \xi_C, \xi_W\}^T = \begin{bmatrix} h_1 \\ h_2 \\ \vdots \\ h_m \end{bmatrix} \quad (2)$$

According to Eq. (2), we can find the cost vector. Based on the cost vector, a network can decide which

calls should be selected for vertical handoff. An ongoing call in a network with the minimum cost in the cost vector will be selected and returned to the other network. In this way, the traffic loads in the two networks can be dynamically balanced to increase the resource utilization of the whole network.

Figs. 2(a) and (b) show the priority-based voice call transfer model and the priority-based data call transfer model, respectively. From Fig. 2, a voice call returned from the WLAN to the cellular network or a data call returned from the cellular network to the WLAN will be waiting in the queue for being served by its original network.

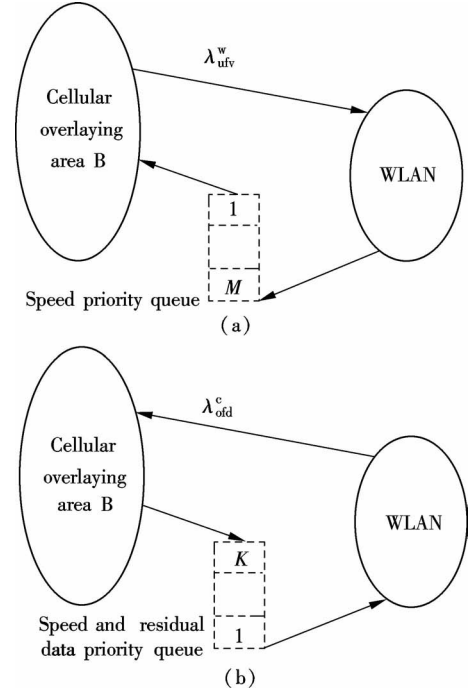


Fig. 2 Priority-based transfer model. (a) For voice calls; (b) For data calls

2.2 Algorithm description

Next, we present the PDLT algorithm. For simplicity, we only consider the moving velocity factor for voice calls, and for data calls we consider the moving velocity factor and the residual amount of data of a data call in the algorithm.

Fig. 3(a) gives the procedures of the algorithm for voice calls, which are described as follows:

1) For a new/incoming voice call to the overlapping area, if there is no bandwidth available in the cellular network, it will be rejected by the network. In this case, it will underflow to the WLAN and be accepted by the WLAN if the WLAN has spare bandwidth available. Otherwise, the voice call will be rejected by the whole network.

2) The base station monitors the bandwidth resources in the cellular network in a real-time manner.

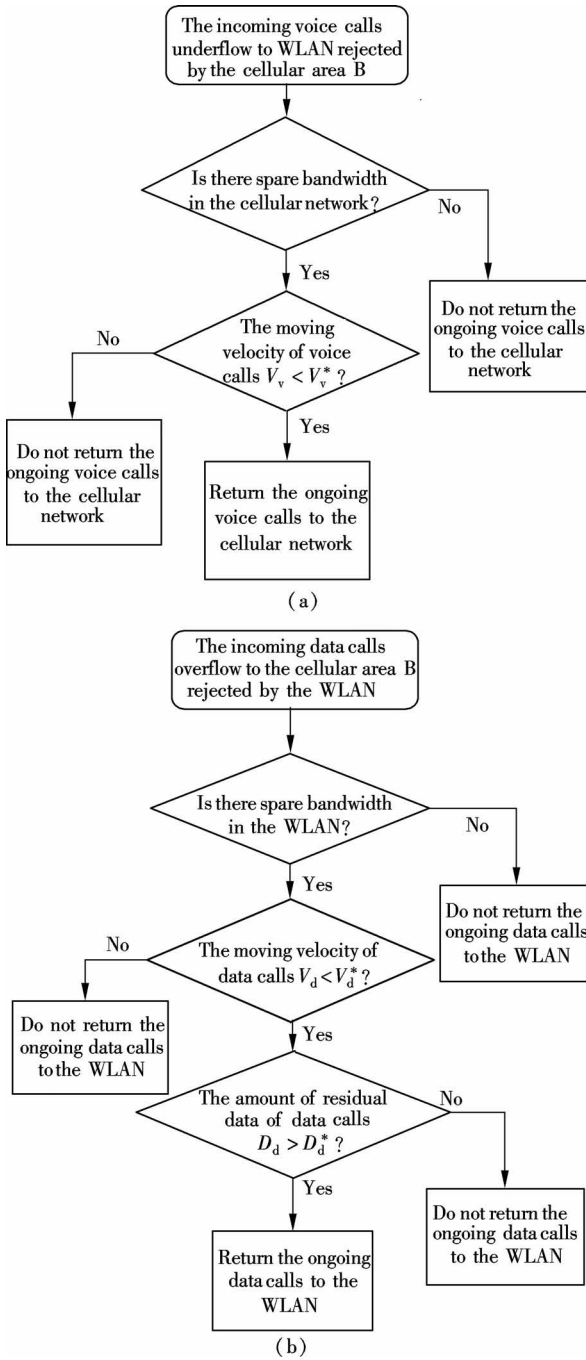


Fig. 3 Algorithm procedures. (a) For ongoing voice calls within WLAN; (b) For ongoing data calls with cellular area B

old V_v^* . Only the ongoing voice calls in the WLAN with an average velocity smaller than V_v^* and the smallest transfer cost obtained using Eqs. (1) and (2) will be selected.

Fig. 3(b) gives the procedures of the algorithm for data calls, which are described as follows:

1) For a new/incoming data call to the overlapping area, if there is no bandwidth available in the WLAN, it will be rejected by the network. In this case, it will overflow to the cellular overlapping area and be accepted by the cellular network if the cellular network has spare bandwidth available. Otherwise, the data call will be rejected by the whole network.

2) The AP monitors the bandwidth resources in the WLAN in a real-time manner.

3) If there are free bandwidth resources available, the ongoing data calls in the overlapping cellular area will be returned to the WLAN for a higher data rate and for achieving fine-grained QoS. The ongoing data calls returned to the cellular network depend on the moving velocity of the data calls and the amount of residual data in the transferred data calls. The data calls with a larger amount of residual data will have a higher priority than those with a smaller amount of residual data.

4) The ongoing data calls in the cellular overlapping area report their average velocity and amount of residual data to the BS. The BS selects data calls for return to the WLAN based on a threshold of velocity V_d^* and a threshold of the amount of residual data D_d^* . Only those ongoing data calls in the cellular network with an average velocity smaller than V_d^* and the amount of residual data larger than D_d^* , and those with the smallest transfer cost obtained using Eqs. (1) and (2) will be selected.

3 Performance Modeling and Analysis

In this section, we develop a performance model for analyzing the performance of the PDLT algorithm in terms of the voice/data call blocking probability and the data throughput in a cellular/WLAN integrated network.

3.1 Two-dimensional Markov model

Let P_v^{w-c} denote the probability of the ongoing voice calls in the WLAN returning to the cellular network. Similarly, let P_d^{c-w} denote the probability of the ongoing data calls in the cellular network returning to the WLAN. Considering there are two different networks and two types of traffic, we develop a two-dimensional Markov model to analyze the steady probability of the cellular and WLAN, respectively, with the PDLT algorithm, as shown in Fig. 4.

Let $P_{(n_v^c, n_d^c)}^c$ denote the steady probability of the cellular network. Then, the linear equilibrium equations about the steady probability in the cellular network can be expressed

3) If there are free bandwidth resources available, the ongoing voice calls in the WLAN will be returned to the cellular network for achieving fine-grained QoS. The ongoing voice calls returned to the cellular network depend on the moving velocity of the voice calls. The priority of returning an ongoing voice call depends on its moving velocity. The faster the moving velocity, the smaller the returning priority.

4) The ongoing voice calls in the WLAN report their average velocity to the AP. The AP selects voice calls for return to the cellular network based on a velocity thresh-

as

$$P_{(n_v^c, n_d^c)}^c \left[\lambda_{ov}^c + \lambda_{ufv}^w P_v^{w-c} + n_v^c \mu_v + \lambda_{ufv}^w + \lambda_{ofd}^c + \frac{n_d^c r_d^c}{f_d} + \lambda_{ofd}^c P_d^{c-w} \right] = P_{(n_v^c+1, n_d^c)}^c [(n_v^c+1)\mu_v + \lambda_{ufv}^w] + P_{(n_v^c-1, n_d^c)}^c [\lambda_{ov}^c + \lambda_{ufv}^w P_v^{w-c}] + P_{(n_v^c, n_d^c+1)}^c \left[(n_d^c+1) \frac{r_d^c}{f_d} + \lambda_{ofd}^c P_d^{c-w} \right] + P_{(n_v^c, n_d^c-1)}^c [\lambda_{ofd}^c] \quad (3)$$

where $0 \leq n_v^c \leq M_v^c$, $0 \leq n_d^c \leq M_d^c$ and

$$\sum_{n_d^c=0}^{M_d^c} \sum_{n_v^c=0}^{M_v^c} P_{(n_v^c, n_d^c)}^c = 1 \quad (4)$$

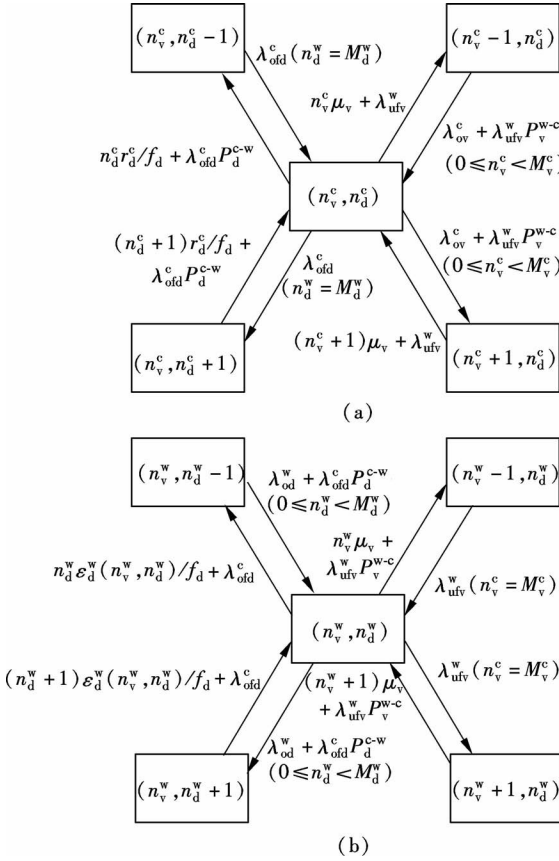


Fig. 4 Two-dimensional Markov model. (a) For cellular network; (b) For WLAN

Similarly, let $P_{(n_v^w, n_d^w)}^w$ denote the steady probability of the WLAN. Then, the linear equilibrium equations about the steady probability in the WLAN can be expressed as

$$P_{(n_v^w, n_d^w)}^w \left[\lambda_{ufv}^w + n_v^w \mu_v + \lambda_{ufv}^w P_v^{w-c} + \lambda_{od}^w + \lambda_{ofd}^c P_d^{c-w} + n_d^w \frac{\varepsilon_d^w(n_v^w, n_d^w)}{f_d} + \lambda_{ofd}^c \right] = P_{(n_v^w+1, n_d^w)}^w [(n_v^w+1)\mu_v + \lambda_{ufv}^w P_v^{w-c}] + P_{(n_v^w-1, n_d^w)}^w \lambda_{ufv}^w + P_{(n_v^w, n_d^w+1)}^w \left[(n_d^w+1) \frac{\varepsilon_d^w(n_v^w, n_d^w)}{f_d} + \lambda_{ofd}^c \right] + P_{(n_v^w, n_d^w-1)}^w [\lambda_{od}^w + \lambda_{ofd}^c P_d^{c-w}] \quad (5)$$

where $0 \leq n_v^w \leq M_v^w$, $0 \leq n_d^w \leq M_d^w$ and

$$\sum_{n_d^w=0}^{M_d^w} \sum_{n_v^w=0}^{M_v^w} P_{(n_v^w, n_d^w)}^w = 1 \quad (6)$$

To obtain the steady probabilities, the successive over-relaxation iteration algorithm^[11] is used to solve Eqs. (3) and (5). By appropriately choosing a relaxation factor between 0 and 2, and setting the original iteration vector, a more accurate solution can be found.

3.2 Performance analysis

With the steady probability $P_{(n_v^c, n_d^c)}^c$ and $P_{(n_v^w, n_d^w)}^w$ obtained using Eqs. (3) and (5), we can now analyze the voice/data call blocking probability and the data throughput.

3.2.1 Voice call blocking probability

According to the conditional probability, the set of voice call blocking states in the cellular network can be expressed as

$$B_v^c = \{ (n_v^c+1, n_d^c) \notin [(0 \leq n_v^c \leq M_v^c) \cap (0 \leq n_d^c \leq M_d^c)] \mid (n_v^c, n_d^c) \in [(0 \leq n_v^c \leq M_v^c) \cap (0 \leq n_d^c \leq M_d^c)] \} \quad (7)$$

and the voice call blocking states in the WLAN can be denoted by the set

$$B_v^w = \{ (n_v^w+1, n_d^w) \notin [(0 \leq n_v^w \leq M_v^w) \cap (0 \leq n_d^w \leq M_d^w)] \mid (n_v^w, n_d^w) \in [(0 \leq n_v^w \leq M_v^w) \cap (0 \leq n_d^w \leq M_d^w)] \} \quad (8)$$

Therefore, the overall voice call blocking probability can be derived as

$$BP_v = \sum_{(n_v^c, n_d^c) \in B_v^c} P_{(n_v^c, n_d^c)}^c \sum_{(n_v^w, n_d^w) \in B_v^w} P_{(n_v^w, n_d^w)}^w \quad (9)$$

3.2.2 Data call blocking probability

According the conditional probability, the set of data call blocking states in the cellular network can be expressed as

$$B_d^c = \{ (n_v^c, n_d^c+1) \notin [(0 \leq n_v^c \leq M_v^c) \cap (0 \leq n_d^c \leq M_d^c)] \mid (n_v^c, n_d^c) \in [(0 \leq n_v^c \leq M_v^c) \cap (0 \leq n_d^c \leq M_d^c)] \} \quad (10)$$

and the data call blocking states in the WLAN can be denoted by the set

$$B_d^w = \{ (n_v^w, n_d^w+1) \notin [(0 \leq n_v^w \leq M_v^w) \cap (0 \leq n_d^w \leq M_d^w)] \mid (n_v^w, n_d^w) \in [(0 \leq n_v^w \leq M_v^w) \cap (0 \leq n_d^w \leq M_d^w)] \} \quad (11)$$

Therefore, the data blocking probability can be derived as

$$BP_d = \sum_{(n_v^c, n_d^c) \in B_d^c} P_{(n_v^c, n_d^c)}^c \sum_{(n_v^w, n_d^w) \in B_d^w} P_{(n_v^w, n_d^w)}^w \quad (12)$$

3.2.3 Data throughput

Let R_d^c denote the data rate in the cellular network, and

R_d^w denote the data rate in the WLAN. Usually, R_d^w is greater than R_d^c because of the WLAN wider bandwidth. Therefore, the data call throughput in the whole network can be calculated as

$$T_{\text{out}} = \sum_{(n_v^c, n_d^c) \in \{(0 \leq n_v^c \leq M_v^c) \cap (0 \leq n_d^c \leq M_d^c)\}} n_d^c R_d^c P_{(n_v^c, n_d^c)}^c \cdot \sum_{(n_v^w, n_d^w) \in \{(0 \leq n_v^w \leq M_v^w) \cap (0 \leq n_d^w \leq M_d^w)\}} n_d^w R_d^w P_{(n_v^w, n_d^w)}^w \quad (13)$$

3.3 Performance evaluation

In this section, we evaluate the performance of the PDLT algorithm through simulation experiments using OPNET Modeler 16.0. We compare the PDLT algorithm with the first call access control scheme (WFAC) [10] and the service-differentiated admission control scheme (SDAC) [12–13] in terms of new voice call blocking probability and new data call blocking probability. In the simulations, we assume that $\kappa = 20$ call, $\eta^w = 0.001$ call/s, $\eta^c = 0.01$ call/s, $\eta_v^w = 0.005$ call/s, $\mu_v = 0.01$ call/s, $f_d = 2$ MB, $M_v^c = 12$ call, $M_d^c = 5$ call, $M_v^w = 10$ call, $M_d^w = 12$ call, $\lambda_{ov}^c = 0.12$ call/s, $\lambda_{od}^w = 0.8$ call/s, $V_v^* = 10$ m/s, $V_d^* = 5$ m/s, and $D_d^* = 1.5$ MB. The WLAN capacity and the cellular capacity are set to 11 and 2 Mbit/s, respectively.

Fig. 5(a) shows the new voice call blocking probability under different voice call arrival rates with the PDLT, WFAC, and SDAC algorithms, respectively. It is seen that the PDLT algorithm results in a smaller new voice call blocking probability than both the SDAC and WFAC algorithms. This is because the proposed PDLT algorithm can transfer a voice call dynamically to the WLAN when there are not sufficient bandwidth resources in the cellular network. The bandwidth resources of the cellular network and the WLAN can be shared by new voice calls efficiently, thus reducing the new voice call blocking probability.

Fig. 5(b) shows the new data call blocking probability under different data call arrival rates with the PDLT, WFAC, and SDAC algorithms, respectively. It is seen that the proposed PDLT algorithm can achieve the smallest new data call blocking probability among the three algorithms. It can be explained that the PDLT algorithm can not only transfer the data calls rejected by the WLAN to the cellular network, but also return the ongoing data calls dynamically to the WLAN based on the network status.

4 Conclusion

This paper proposes a PDLT algorithm for cellular/WLAN integrated networks. To reduce the call blocking probability, the proposed PDLT algorithm allows a voice call (or data call) to be directed to the WLAN (or cellular network) when there is no bandwidth resource available in the cellular network (or WLAN). Meanwhile, it

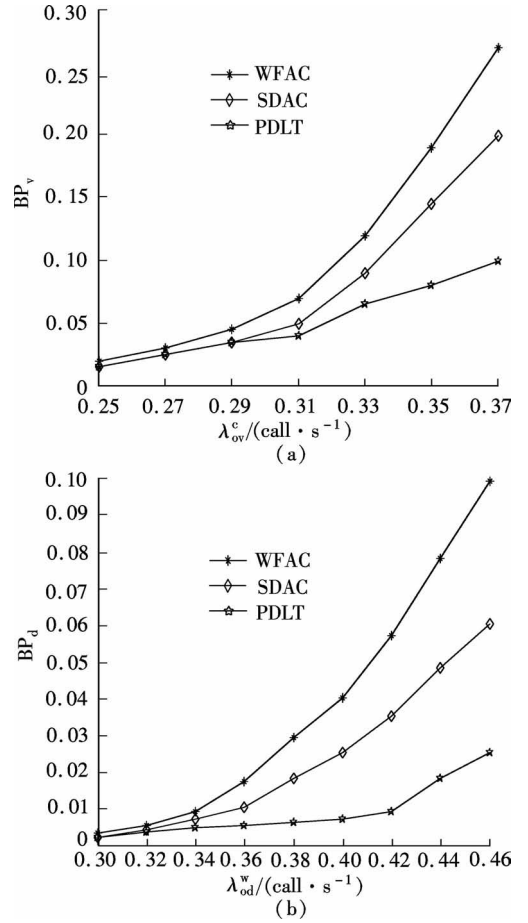


Fig. 5 New call blocking probability. (a) For new voice call; (b) For new data call

allows an ongoing voice call (or data call) in the WLAN (or cellular network) to be returned to the cellular network (or WLAN) when the bandwidth resource in the cellular network (or WLAN) becomes available. To analyze the performance of the PDLT algorithm, a two-dimensional Markov model is developed to calculate the voice call blocking probability and the data call blocking probability. Simulation results show that the PDLT algorithm can effectively reduce both the voice call blocking probability and the data call blocking probability as compared with the existing WFAC and SDAC algorithms, and thus increase the data throughput of the whole network.

References

- [1] Falowo O E. Joint call admission control algorithm for reducing call blocking/dropping probability in heterogeneous wireless networks supporting multihoming [C]//2010 *IEEE Globecom Workshops*. Miami, FL, USA, 2010: 611–615.
- [2] Klein T E, Han S J. Assignment strategies for mobile data users in hierarchical overlay networks: performance of optimal and adaptive strategies[J]. *IEEE Journal on Selected Areas in Communications*, 2004, 22(5): 849–861.

[3] Yu F, Krishnamurthy V. Optimal joint session admission control in integrated WLAN and CDMA cellular networks with vertical handoff[J]. *IEEE Transactions on Mobile Computing*, 2007, **6**(1): 126 – 139.

[4] Lincke-Salecke S. Load shared integrated networks[C]// *Proc of the 5th European Personal Mobile Communications Conference*. Glasgow, UK, 2003: 225 – 229.

[5] Son H, Lee S, Kim S C, et al. Soft load balancing over heterogeneous wireless networks[J]. *IEEE Transactions on Vehicular Technology*, 2008, **57**(4): 2632 – 2638.

[6] Xia W W, Shen L F. Call admission control with load-balancing capability in integrated cellular/WLAN networks [J]. *IEICE Transactions on Communications*, 2010, **E93-B**(5): 1190 – 1204.

[7] Xia W W, Shen L F. Modeling and analysis of hybrid cellular/WLAN systems with integrated service-based vertical handoff schemes[J]. *IEICE Transactions on Communications*, 2009, **E92-B**(6): 2032 – 2043.

[8] Song W, Zhuang W H. Multi-service load sharing for resource management in the cellular/WLAN integrated network[J]. *IEEE Transactions on Wireless Communications*, 2009, **8**(2): 725 – 735.

[9] Kuo Y L, Lu C H, Wu E H K, et al. An admission control strategy for differentiated services in IEEE 802.11 [C]// *GLOBECOM' 03: IEEE Global Telecommunications Conference*. San Francisco, CA, USA, 2003: 707 – 712.

[10] Song W, Jiang H, Zhuang W H. Performance analysis of the WLAN-first scheme in cellular/WLAN interworking[J]. *IEEE Transactions on Wireless Communications*, 2007, **6**(5): 1932 – 1943.

[11] Stewart W J. *Introduction to the numerical solution of Markov chain* [M]. Princeton: Princeton University Press, 1995.

[12] Ning Y, Hui T, Ping Z. A service-differentiated access algorithm for future cooperative networks[C]// *The 66th Vehicular IEEE Technology Conference*. Baltimore, MD, USA, 2007: 1466 – 1469.

[13] Yeow W L, Tham C K. Service differentiation and load balancing in grid architecture[C]// *The 12th IEEE International Conference on Networks Proceedings*. Singapore, 2004: 387 – 391.

Cellular/WLAN 融合网络中基于优先级的动态负载传递算法

陈 赓¹ 夏玮玮¹ 许 波² 沈连丰¹

(¹ 东南大学移动通信国家重点实验室, 南京 210096)

(² 中国人民解放军理工大学通信工程学院, 南京 210016)

摘要:针对蜂窝网和无线局域网(WLAN)的融合网络,提出一种基于优先级的动态负载传递(PDLT)算法. 呼叫接入控制的动态垂直切换由整个网络状态和业务特性以及终端位置信息联合触发. 当蜂窝网络或WLAN中无可用带宽资源时,该算法能够将重叠覆盖区域中新的语音或者数据呼叫传递到尚有带宽资源的网络;同时,动态计算网络带宽资源占用情况,根据设定的门限值将正在进行的语音或数据通信切换到带宽资源宽裕的网络,平衡网络中的语音/数据呼叫数目. 二维马尔科夫模型分析和仿真结果表明,PDLT算法能有效地提高整个网络中的业务接入量,减小新呼叫的阻塞概率,增加数据吞吐量并降低服务的响应时间.

关键词:蜂窝网络;WLAN;动态负载传递;阻塞概率;马尔科夫模型

中图分类号:TN915