Network Selection Based on Context-Awareness Services

LUO Lijuan, LV Tingjie, CHEN Xia

School of Economics and Management, Beijing University of Posts and Telecommunications, Beijing 100876, China

Abstract: In this paper, we propose a systemic architecture of network selection based on context-awareness services, which gathers contextual information that includes such network information, user information and local information. This network selection strategy considers the Quality of Service (QoS) and user preferences. Also, it perceives contexts such as speed, coverage percentage and location, etc., and it eventually performs network selection decision making and network execution based on multiple factors. From the perspective of network decision, it presents two network selection algorithms, namely the fuzzy mathematics evaluation method and multiple attribute decision making using the TOPSIS evaluation method. System simulations suggest that network selection based on the mathematics evaluation method is much faster than the TOPSIS evaluation method. However, the TOPSIS evaluation method is practically more efficient. The network selection method based on context-awareness provides an effective and flexible network vertical handover strategy, and ensures a good accuracy and efficiency.

Key words: network selection; context-awareness; fuzzy mathematics; multiple attribute decision making; TOPSIS

I. INTRODUCTION

When a mobile terminal user moves away from the service area of one network, and enters the coverage area of another network, or when a mobile terminal user has been already connected to a specific network and chooses to handover to a network available for service requirement, a network-control handover strategy will result in a serious signalling overhead. Also it consequently will make a long time delay and an increased complexity. If a terminal-control handover strategy is employed, the operability is poor. Therefore, we need to design a network selection strategy based on context-awareness service, which can not only receive messages from each network, but also can detect behaviours of the terminal user. Simultaneously the context information of user's location will be considered. Network handover decision is made on the basis of those three kinds of information.

There are three stages of vertical handover under the wireless heterogeneous network environment: system identification stage, decision making stage, and execution stage. On the system identification stage of network handover, the main task of mobile terminal is to discover the new available network. The decision making stage is to make decisions after the mobile terminal determines to execute handover. Decisions are made based on time delay, network load, service rate, price, user preference, etc., for selection of network target. Certainly network handover process may be different under different handover circumstances.

This paper investigates the system construction of network selection, especially the context-awareness information gathering. It also proposes network selection algorithms, and presents decision making method based on time delay, network load, service rate, price and user preference.

II. LITERATURE REVIEWS

Lots of researchers have studied network sele-

Received: 2013-06-01
Revised: 2013-08-16
Editor: PAN Yu

ction by using multiple attribute decision making method. SONG Qinqyang and Jamalipour A [1] weighed user preferences, service application, network condition, and proposed a network selection mechanism, which has high work efficiency under UMTS/WLAN network environment, and reduces the complexity of implementation. Khan M A et al. [2] introduced a network selection decision strategy based on auction strategy. With user oriented they considered the service capability, usability, user preference, Quality of Service (QoS) and the price offered by network operators. They also simulated the interaction between user and network operator by using multiple attribute auction theory, and defined utility function between user and network operator. Sgora A et al. [3] summarised selection methods of heterogeneous network on the basis of Analytic Hierarchy Process (AHP) (HU Hao et al. [4]) and TOPSIS method (Bari F and Leung V C M [5]; Sgora A et al. [6]). WANG Lusheng and KUO G S [7] designed a unified framework, proposing an integration mechanism in which multiple attribute decision making is regarded as the core selection procedure.

In the early studies of network selection algorithms based on fuzzy mathematics, system values are transformed into a fuzzy set, where multiple objectives are integrated for decision making to select the most suitable network at the right moment. But this method mainly processes non-real-time and non-precise data (Chan P M L, et al. [8]; Chan P M L. [9]). GUO Qiang et al. [10] introduced fuzzy inference system and modified neural network into vertical handover algorithm. They proposed an adaptive vertical handover algorithm, which improves the accuracy of vertical handover for heterogeneous networks. Charilas D E et al. [11] studied a network selection manner of fuzzy multiple attribute decision making. They also set weights for different attributes, and released a network selection ranking for candidate networks. HE Qing [12] evaluated the performance of networks to choose the optimal network based on the handover decision making algorithm in fuzzy logic.

Network selection method based on context-awareness is adopted gradually. Balasubramaniam S and Indulska J [13] smoothly carried out handover for network by gathering, managing and evaluating environment information. However, collecting environment information together will frequently make message exchanged between terminal and network, which may result in over-connection. WEI Qing et al. [14] improved this method by establishing multiple environment bases to retrieve network handover decision making time information by the aid of software agents. New network decision making system (Kassar M, et al. [15]) can be constructed based on the local information by modifying the weights of multiple parameters according to each target user's preference. This is called user preference evaluation decision making principle.

However, context information of some heterogeneous wireless networks is uncertain, which needs more advanced network selection decision making algorithm to process the inaccurate context-awareness information. Meanwhile it is necessary to compare and evaluate this information of different networks. Therefore this paper constructs a flexible system which includes network selection algorithm and vertical handover method.

This paper presents two network selection algorithms, fuzzy mathematics evaluation method and multiple attribute decision making with TOPSIS evaluation method. System simulations suggest that network selection based on mathematics evaluation method is much faster that on TOPSIS evaluation method. The former method can ensure an effective and flexible network handover strategy, as well as the accuracy and flexibility of system.

III. SYSTEM CONSTRUCTION

Vertical handover strategy: handover information gathering, network selection decision making, handover execution. Through detecting and measuring handover information collects context information demanded by all handover strategies through detecting and measuring, including the local information such as coverage and location. The knowledge base is needed to be updated in real time. A series of strategies, which represent the decision making rule of controlling selection in the whole process, is stored in this knowledge base.

Network selection decision making determines whether handover should be operated by user terminal. In handover starting stage, fuzzy logic (including fuzzy mechanism and defuzzy mechanism) or multiple attribute decision

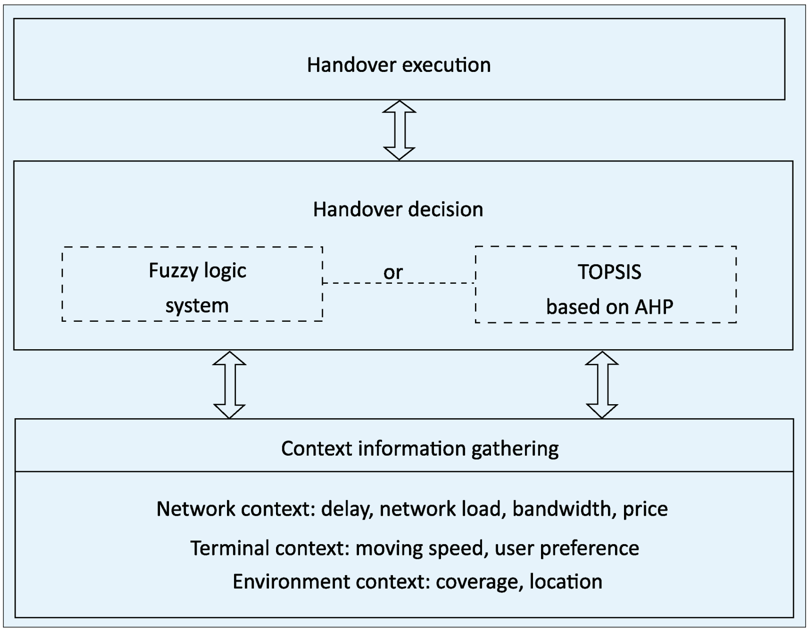

Fig.1 *Network selection based on context-awareness*

making with TOPSIS evaluation method can determine the optimal target network, ensuring that vertical handover is started at the right moment to reduce the following handover and the communication overhead.

At last, based on the handover information gathering and handover decision making procedures, mobile terminal selects the optimal network for handover. This advanced multiple targets and context-awareness decision making and strategy integrate the network information, user information, context information in the whole handover decision process. Construction of network selection system based on context-awareness is as shown in Figure 1.

IV. ALGORITHM DESIGN

4.1 Fuzzy mathematics evaluation method

When a mobile terminal enters an area covered by multiple wireless networks, it must select the optimal network connection to use services. However, it is a vague concept of optimum. Selection will become difficult when there exists multiple different selection criterions, because different networks may have different performance evaluations under different criterions. On this condition user needs to regard the overall priority-degree of networks as the performance criterion of network selection.

After widely investigating the network selection in heterogeneous wireless environment, we can choose the following criterions as evaluation parameters: delay (d_i), network load (α_i), service rate (β_i), price (p_i), user preference (δ_i) etc., where $i = 1, 2, \cdots, n$, characterising the network to be evaluated. In order to determine the priority degree of each network, we employ the fuzzy mathematics method to find the optimal criterion to evaluate different networks.

Denote $U_i = \{d_i, \alpha_i, \beta_i, p_i, \delta_i\}$ the *i*-th network priority degree. Values of those parameters represent the situation of a network. Based on the evaluation parameters we can construct the fuzzy evaluation matrix for relative membership degree. Denote $A^{(2)}$ the fuzzy set of a network priority degree to be selected. The membership of elements in U to $A^{(2)}$ is different. We can define the membership of different criterions to network priority membership according to the II-type fuzzy set theory in fuzzy mathematics. A II-type fuzzy set $A^{(2)}$ in U is a mapping: $A^{(2)} : U \to F : ([0,1])$, where $F : ([0,1])$ is all the fuzzy set in field $[0,1]$.

Assume that weights of those five evaluation criterions are $W = (W_1, W_2, \cdots, W_5)$. According to the fuzzy set we have $A = \frac{W_1}{u_1} + \frac{W_2}{u_2} + \cdots + \frac{W_5}{u_5}$. Therefore, the overall priority degree of each network is $H_i = \sum_{j=1}^{5} u_{ij} \times \beta_{ij}$ where u_{ij} is the *j*-th parameter value in *i*-th network, β_{ij} is the membership degree of the *j*-th parameter value in *i*-th network.

4.2 Multiple attribute decision making TOPSIS evaluation method

The basic principle of TOPSIS evaluation method is to establish decision making matrix, set weights and calculate the Euclidean distance between network priority degree to positive ideal solution and to negative ideal solution. Furthermore, we rank the performance of networks on the principle of negative ideal solution.

Still we choose the following evaluation parameters: delay (d_i), network load (α_i), service rate (β_i), price (p_i), user preference (δ_i) etc., where $i=1,2,\cdots,n$, characterising the network to be evaluated. In order to determine the priority degree of each network, we employ the multiple attribute decision making with TOPSIS evaluation method to find the optimal criterion to evaluate different networks.

Let $A_1,A_2,\cdots,A_n$, denote the networks to be selected, and let $\boldsymbol{D}$ denote the decision making matrix. As to the network-relevant attributes such as delay, network load and prices, the lower their values are, the better performance network in the decision making matrix will have, since they are cost-relevant attributes. As to the service speed and user preference attribute, the higher their values are, the better performance network in the decision making matrix will have, since they are efficiency-relevant parameters. The decision making matrix is shown as follow:

$$\boldsymbol{D}\left(x_{ij}\right)=\begin{array}{c} \begin{array}{ccccc} f_1 & f_2 & f_3 & f_4 & f_5 \end{array} \\ \left[\begin{array}{ccccc} d_1 & \alpha_1 & \beta_1 & p_1 & \delta_1 \\ d_2 & \alpha_2 & \beta_2 & p_2 & \delta_2 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ d_m & \alpha_m & \beta_m & p_m & \delta_m \end{array}\right] \end{array} \begin{array}{c} \\ A_1 \\ A_2 \\ \cdots \\ A_m \end{array} \tag{1}$$

Define $f_j^*=\max\limits_{1\leqslant i\leqslant m}\left(x_{ij}\right)$ as the maximal value and $f_j^\nabla=\min\limits_{1\leqslant i\leqslant m}\left(x_{ij}\right)$ as the minimal value in which j=1, 2, 3, 4, 5.

Normalise the decision making matrix by linear scaling to preserve the relative order. R denotes the matrix after scaling:

1) As to efficiency-relevant criterion, define $r_{ij}=x_{ij}\big/f_j^*$.

2) As to cost-relevant criterion, define $r_{ij}=f_j^\nabla\big/x_{ij}$, in which $0\leqslant r_{ij}\leqslant 1$, ($1\leqslant i\leqslant m$, $1\leqslant j\leqslant 5$).

Then we can get matrix $\boldsymbol{R}=\left(r_{ij}\right)_{m\times 5}$ as follows,

$$\boldsymbol{R}\left(r_{ij}\right)=\begin{array}{c} \begin{array}{ccccc} f_1 & f_2 & f_3 & f_4 & f_5 \end{array} \\ \left[\begin{array}{ccccc} d_1^* & \alpha_1^* & \beta_1^* & p_1^* & \delta_1^* \\ d_2^* & \alpha_2^* & \beta_2^* & p_2^* & \delta_2^* \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ d_m^* & \alpha_m^* & \beta_m^* & p_m^* & \delta_m^* \end{array}\right] \end{array} \begin{array}{c} \\ A_1 \\ A_2 \\ \cdots \\ A_m \end{array} \tag{2}$$

where the superscript represents data after normalization, f_1, f_2 and f_4 are the cost-relevant criterions of networks, f_3 and f_5 are the efficiency-relevant criterions of networks.

Let each weight matrix of each network performance criterion be

$$W=\begin{bmatrix} W_1 & & & & \\ & W_2 & & & \\ & & W_3 & & \\ & & & W_4 & \\ & & & & W_5 \end{bmatrix} \tag{3}$$

We construct the weighted normalised matrix as

$$\boldsymbol{V}=\boldsymbol{R}\times\boldsymbol{W}=\begin{bmatrix} W_1d_1^* & W_1\alpha_1^* & \cdots & \cdots & W_1\delta_1^* \\ W_2d_2^* & W_2\alpha_2^* & \cdots & \cdots & W_2\delta_2^* \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ W_5d_5^* & W_5\alpha_5^* & \cdots & \cdots & W_5\delta_5^* \end{bmatrix} \tag{4}$$

The way to determine the positive ideal solution A^* and negative ideal solution A^- in network selection is described as follows.

The positive ideal solution of network efficiency-relevant criterion (e.g. service speed and user preference) is the maximum value in each column of $\boldsymbol{V}$; the negative ideal solution is the minimum value in each column. The positive ideal solution of network cost-relevant criterion (e.g. delay, network load and price) is the minimum value in each column of $\boldsymbol{V}$; the negative ideal solution is the maximum value in each column. The solutions can be written as:

$$\begin{aligned} A^* &= \left[\left(\max_i v_{ij}\,\middle|\, j\in J\right),\left(\min_i v_{ij}\,\middle|\, j\in J^\#\right)\right] \\ &= \left[v_1^*, v_2^*, v_3^*, \cdots, v_5^*\right] \end{aligned} \tag{5}$$

where

$$J=\left(j=1,\cdots,5 \mid j \text{ is the efficiency-relevant target attribute}\right)$$

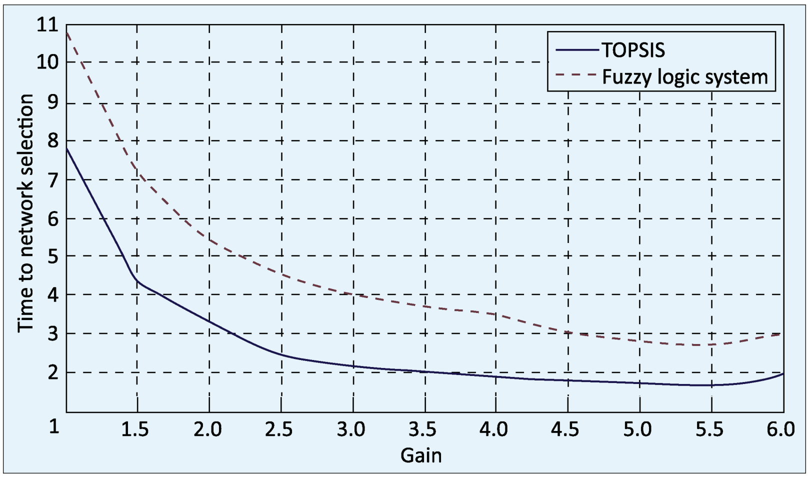

Fig.2 *Processing speed comparison of two network selection algorithms*

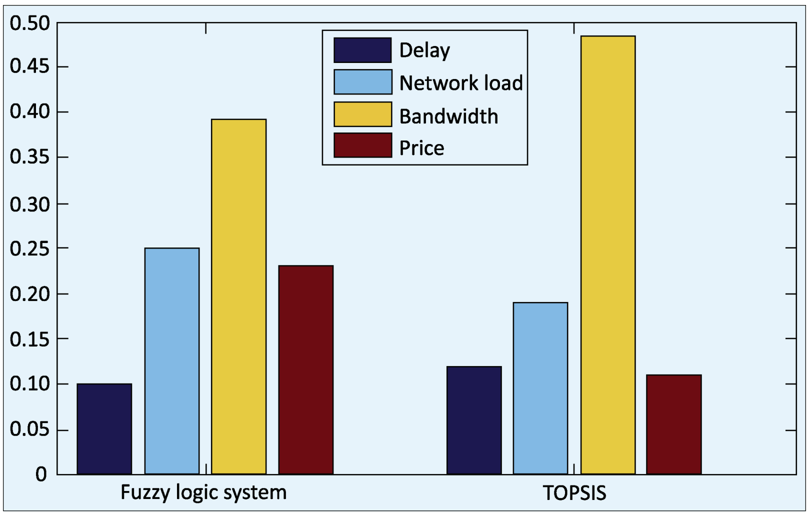

Fig.3 *Utility performance comparison of two network selection algorithms*

and

$$A^{-} = \left[\left(\min_i v_{ij} \middle| j \in J\right), \left(\max_i v_{ij} \middle| j \in J^{\#}\right)\right] = \left[v_1^-, v_2^-, v_3^-, \cdots, v_5^-\right] \quad (6)$$

where

$J = (j = 1, \cdots, 5 \mid j$ is the cost-relevant target attribute$)$

Calculate the distance between the value of parameter in each network and positive ideal solution point S_i^* as well as the negative ideal solution point S_i^-:

$$S_i^* = \sqrt{\sum_{j=1}^{5} \left(v_{ij} - v_j^*\right)^2}, i = 1, 2, \cdots, m \quad (7)$$

$$S_i^{\nabla} = \sqrt{\sum_{j=1}^{5} \left(v_{ij} - v_j^{\nabla}\right)^2}, i = 1, 2, \cdots, m \quad (8)$$

At last we can calculate the relative approach degree:

$$C_i^* = \frac{S_i^{\nabla}}{S_i^* + S_i^{\nabla}} \quad (9)$$

If $A_i = A^*$, then $S_i^* = 0$, $C_i^* = 1$; if $A_i = A\nabla$, then $S_i^{\nabla} = 0$, $C_i^* = 0$; if $A_i \to A^*$, then $S_i^* = 0$, $C_i^* \to 1$; so $0 \leqslant C_i^* \leqslant 1$. We can sort the order of A_i dependent on C_i^*. The one on the first place is the optimal network.

4.3 Algorithm comparison

Simulations are implemented under the same scenario, attribute and reserve utility curve circumstances. We select 20 mobile terminals, and each terminal is assigned to the same tasks. We carry out the network selection by using fuzzy mathematics evaluation method and multiple attribute decision making with TOPSIS evaluation method.

Because of the effect of network context-awareness, when the network gain is increased, the time to networks selection is decreased therewith, as is shown in Figure 2. The fuzzy mathematics evaluation method outperforms multiple attribute decision making with TOPSIS evaluation method in the perspective of network selection speed. However, the later method is better than the former on the criterion of utility performance, as is shown in Figure 3.

Referring to the attribute of "delay", fuzzy logic system method is better since its delay is less; however, with respect to network load, bandwidth as well as price, the above conclusion is without problem. In short, TOPSIS method is better while considering the criterions of utility performance.

V. Conclusion

In this paper, we proposed two network selection algorithms on network decision making: fuzzy mathematics evaluation method and multiple attribute decision making with TOPSIS evaluation method. System simulations showed that fuzzy mathematics theory was particularly suitable for terminals with dynamic attribute information, though the gathered information may not be accurate. Membership function in fuzzy mathematics can adjust attributes. For instance, it can increase or decrease some attributes' value in different networks. However, this kind of adjustment may reduce the accuracy. Multiple attribute decision making with TOPSIS evaluation can be used to evaluate utility values of each network attribute. For example, when the value of certain attributes was changed slightly, modifying threshold value of QoS will result in great changes in utility. Multiple attribute decision making theory provided a decision theory with comprehensive consideration of multiple attributes. Both methods have their own advantages. We can choose the appropriate algorithm according to the specific environment characteristics.

This study presents network selection system architecture based on context-awareness services, establishes multiple information knowledge bases, including network database, user database and local information base. This method can ensure an effective and flexible network handover strategy, as well as the accuracy and flexibility of system. Further study will concentrate on the model's adaptability, intensively investigate context-aware module, and realise the selection of heterogeneous wireless networks on a more general condition.

ACKNOWLEDGEMENT

This study was supported by the National Basic Research Program of China (973 Program) under Grant No. 2012CB315805; project supported by the National Natural Science Foundation of China under Grants No. 71172135, No. 71231002, No. 71201011, No. 71271099; and the Ministry of Education of the People's Republic of China under Grant No. 201200-05120001.

References

[1] SONG Qinqyang, JAMALIPOUR A. A Network Selection Mechanism for Next Generation Networks[C]// Proceedings of IEEE International Conference of Communications 2005 (ICC 2005): May 16-20, 2005. Seoul, Korea, 2005, 2: 1418-1422.

[2] KHAN M A, TOSEEFY U, MARX S, *et al*. Auction Based Interface Selection with Media Independent Handover Services and Flow Management[C]// Proceedings of 2010 European Wireless Conference (EW): April 12-15, 2010. Lucca, Italy, 2010: 429-436.

[3] SGORA A, GIZELIS C A, VERGADOS D D. Network Selection in a WiMAX-WiFi Environment [J]. Pervasive and Mobile Computing, 2011, 7(5): 584-594.

[4] HU Hao, ZHOU Wenan, ZHANG Shu, *et al*. A Novel Network Selection Algorithm in Next Generation Heterogeneous Network for Modern Service Industry[C]// Proceedings of the IEEE Asia-Pacific Services Computing Conference, (APSCC 2008): December 9-12, 2008. Yilan, Taiwan, China, 2008: 1263-1268.

[5] BARI F, LEUNG V C M. Automated Network Automated Network Selection in a Heterogeneous Wireless Network Environment[J]. IEEE Network, 2007, 21(1): 34–40.

[6] SGORA A, CHATZIMISIOS P, VERGADOS D D. Access Network Selection in a Heterogeneous Environment Using the AHP and fuzzy TOPSIS Methods[C]// Proceedings of the 2nd International Conference on Mobile Light weight Wireless Systems (MOBILIGHT 2010): May 10-12, 2010. Barcelona, Spain, 2010.

[7] WANG Lusheng, KUO G S. Mathematical Modeling for Network Selection in Heterogeneous Wireless Networks—A Tutorial[J]. IEEE Communications Surveys and Tutorials, 2013, 15(1): 271-292.

[8] CHAN P M L, SHERIFF R E, HU Y F, *et al*. Mobility Management Incorporating Fuzzy Logic for a Heterogeneous IP Environment[J]. IEEE Communications Magazine, 2001, 39 (12): 42-51.

[9] CHAN P M L, HU Y F, SHERIFF R. Implementation of Fuzzy Multiple Objective Decision Making Algorithm in a Heterogeneous Mobile Environment[C]// Proceedings of IEEE Wireless Communications and Networking Conference, 2002 (WCNC 2002): March 17-21, 2002. Orlando, FL, USA, 2002: 332-336.

[10] GUO Qiang, ZHU Jie, XU Xianghua. An Adaptive Multi-Criteria Vertical Handoff Decision Algorithm for Radio Heterogeneous Network [C]// Proceedings of IEEE International Conference on Communications (ICC 2005): May 16-20, 2005. Seoul, Korea, 2005, 4: 2769-2773.

[11] CHARILAS D E, MARKAKI O I, PSARRAS J, *et al*. Application of Fuzzy AHP and ELECTRE to Network Selection[C]// Proceedings of the 1st International ICST Conference on Mobile Lig-

htweight Wireless Systems (MOBILIGHT 2009): May 18-20, 2009. Athens, Greece, 2009.

[12] HE Qing. A Novel Vertical Handoff Decision Algorithm in Heterogeneous Wireless Networks [C]// Proceedings of 2010 IEEE International Conference on Wireless Communications, Networking and Information Security (WCNIS): June 25-27, 2010. Beijing, China, 2010: 566-570.

[13] BALASUBRAMANIAM S, INDULSKA J. Vertical Handover Supporting Pervasive Computing in Future Wireless Networks[J]. Computer Communications, 2004, 27(8): 708-719.

[14] WEI Qing, FARKAS K, PREHOFER C, *et al*. Context-Aware Handover Using Active Network Technology[J]. Computer Networks: The International Journal of Computer and Telecommunications Networking, 2006, 50(15): 2855- 2872.

[15] KASSAR M, KERVELLA B, PUJOLLE G. An Overview of Vertical Handover Decision Strategies in Heterogeneous Wireless Networks[J]. Computer Communications, 2008, 31(10): 2607-2620.

Biographies

LUO Lijuan, is now pursuing her Ph.D. degree in management science and engineering at Beijing University of Posts and Telecommunications, China. She focuses on communication engineering and has a deep understanding for technology and implementation. Her research interests mainly focus on consumer behaviours and electronic commerce. Email: luolijuan1987@gmail.com

LV Tingjie, Professor in School of Economics and Management, Beijing University of Posts and Telecommunications (BUPT), China. Currently, he is an Assistant President of BUPT and the Director of the E-Commerce Research Center of BUPT. His current research interests are in the areas of e-commerce, mobile commerce, information systems management, and communications management, etc. He has published papers in a number of international journals and conferences and authored several books in China.

CHEN Xia, Assistant Professor in Beijing University of Posts and Telecommunications (BUPT), China. She graduated from BUPT, and received her Ph.D. degree in 2007. She is a Lecturer in School of Economics and Management of BUPT. Her research interests are in the areas of e-commerce, information systems management and communications management. She has published several papers in relevant area in the domestic famous journals.