A Network Selection Scheme Based on Bee Colony Evolution

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***Abstract*—In the heterogeneous network environments of multiple networks overlapping, users wish to select the best network suiting his or her needs as a matter of course. There are three basis conditions, software defined radio (SDR), multimode intelligent terminals and network selection schemes to realize this always best connected (ABC) concept. Based on analyzing many factors of network selections, it is proposed that a network selection scheme based on bee colony evolution. It can find the optimal network selection solution, and use the grey relational analysis method, game analysis and genetic algorithm to solve the additional problems ensuring the rationality and efficiency of network selection. Simulation results show that this network selection scheme has better performances than the existing schemes in many evaluating indicators.**

Keywords—heterogeneous network environments; network selection schemes; always best connected (ABC); grey relational analysis method; game analysis; genetic algorithm

I. INTRODUCTION

Since applications and multiple device types have been rapidly developed in recent years, single wireless access technologies cannot satisfy the increasing demand of users. So there are many wireless access technologies appearing, we called heterogeneous wireless networks [1]. With the support of Software Defined Radio (SDR) and multimode intelligent terminals, users can select networks to use in the plenty of networks overlapping. It makes possible the Always Best Connected (ABC) concept [2], which allows users connectivity to applications using the devices and access technologies that best suit his or her needs at anytime anywhere. However, most of users do not know which the best is, and the single network selection based on Received Signal Strength (RSS) is inapplicability to the heterogeneous network environments. So users need more complex network selection schemes, which need to consider Quality of Service (QoS) [3] requirements, user preferences, mobile terminal conditions, access network conditions and other factors. In addition, network selection schemes have to solve 4 problems [4], including processing fuzzy information since users cannot accurately describe QoS, avoiding frequent handoffs to reduce the ping-pong effect probability, making users and network providers achieve win-win, and improving selection efficiency.

Chang et al. [5] designed a preference value-based cell selection scheme to ensure QoS requirements, maximize the number of calls, and reduce the frequent handoff probability. Redhika et al. [6] regarded the network selection problem as a fuzzy multiple criteria decision making, and designed a network selection scheme considering RSS, cost, bandwidth, velocity and user preference. Nguyen-Vuong et al. [7] proposed a user-centric network selection scheme based on a utility function with considering many factors. Sgora et al. [8] designed a network selection scheme in a WiMAX-WiFi environment based on [7]. But this scheme was designed from not only user-centric but also network-centric, and considered the collaborative schemes.

The abovementioned network selection schemes have been widely studied. However, network environments and factors of network selection schemes are not studied comprehensively at the same time. With the analyses of network selection, we propose a network selection scheme based on bee colony evolution. This scheme considers application types, QoS requirements, service cost, network provider preferences, coding scheme preferences, velocities and access network conditions, and uses the grey relational analysis method, game analysis and genetic algorithm to solve the additional problems ensuring the rationality and efficiency of network selection.

II. MODEL DESCRIPTIONS

A. Type of Applications and QoS Requirements

In this paper, we assume that there are 18 different types of applications according to ITU-T G.1000, and the set of application types is $ATS = \{AT_1, AT_2, \cdots, AT_{18}\}$. $QS_i = \{[BW_i^l, BW_i^h], [DL_i^l, DL_i^h], [JT_i^l, JT_i^h], [ER_i^l, ER_i^h]\}$ is the QoS requirement, where $i = 1, \ldots, 18$, and there are four parameters considered, including bandwidth, delay, delay jitter and error rate. Since it is difficult to describe QoS requirements and network providers need considering the general, these parameters are the interval form.

B. Access Network Model and Terminal Model

Assume that the sequence number of an access network is $m \in [1, M]$, where M is the total number of access networks. As shown in Table I, there are necessary parameters in the access network model. If $AB_m < AB_m^{\min}$, the network does not accept any of terminal requests to reduce the ping-pong effect probability. The service level set SL_m can offer many different QoS services to the supporting applications. In this paper, all the access networks support four different levels for each type of applications at most. They are L_1, L_2, L_3 and L_4 from high to low, and SL = { L_1 , L_2 , L_3 , L_4 }. Assume that k is the level provided by the access network to an AT_i type application, where $k \in SL_m$. Then, the QoS of k level services is $QS_{mi}^k = \{[bw_{mi}^{kl}, bw_{mi}^{kh}], [dl_{mi}^{kl}, dl_{mi}^{kh}], [jt_{mi}^{kl}, jt_{mi}^{kh}], [er_{mi}^{kl}, er_{mi}^{kh}]\}$, all of them are the subsets of the QoS parameters of AT_i type applications, such as $[bw_{mi}^{kl}, bw_{mi}^{kh}] \subseteq [BW_i^l, BW_i^h]$. For achieving win-win, network selection schemes should support cooperation among terminals or access networks. If there is any cooperation, sc_{mi}^k should be adjusted according to Equation (1), (2) or (3).

TABLE I. PARAMETERS IN ACCESS NETWORK MODEL

Name	Description
NP_m	Identification of network provider
NPS	Network provider set
NT_m	Identification of network type
NTS	Whole network type set
CS_m	Identification of coding scheme
CSS	Whole coding scheme set
CN_m	Coverage of network
HV_m	Highest velocity supported by network
FR_m	Frequency range of network
LS_m	Lowest signal strength of network
SAS_m	Application type set supported by network
TB_m	Total bandwidth
AB_m	Available bandwidth
AB_m^{min}	Network overload threshold
SL_m	Service level set supported by network
SL	Whole service level set
k	Service level provided by network
sp_{mi}^k	Service prime cost
sc_{mi}^k	Service cost

$$sc_{mi}^k = sc_{mi}^k - pc_{mi}^k \tag{1}$$

$$sc_{mi}^k = sc_{mi}^k + ph_{mi}^k \tag{2}$$

$$sc_{mi}^k = sc_{mi}^k + ph_{mi}^k - pc_{mi}^k \tag{3}$$

where pc_{mi}^k is the price cut, which access network providers must face, because of the cooperation among terminals. Likewise, ph_{mi}^k is the price hike, which users must face, because of the cooperation among access networks. Hence Equations (1)-(3) represent three conditions, which are terminals cooperating but access networks without cooperating, access networks cooperating but terminals without cooperating, and both of terminals cooperating and access networks cooperating, respectively.

Assume that the order number of a terminal is $n \in [1, N]$, where N is the total number of terminals. As shown in Table II, there are necessary parameters in the terminal model. $PC_n = \{PC_{n1}, PC_{n2}, \ldots, PC_{n|PC_n|}\} \subseteq CSS$ and $PP_n = \{PP_{n1}, PP_{n2}, \ldots, PP_{n|PP_n|}\} \subseteq NPS$ are sorted by preference degrees from high to low, and $HR_{ni} = \{AT_i, PC_n, PP_n, WP_n\}$.

TABLE II. PARAMETERS IN TERMINAL MODEL

Name	Description
TAS_n	Application type set of terminal
TCS_n	Coding scheme set of terminal
TF_n	Frequency range of terminal
TR_n	Lowest RSS of terminal
TV_n	Terminal velocity
TV_{th}	High velocity threshold
PC_n	Preference sequence in coding schemes
PP_n	Preference sequence in providers
WP_{ni}	Service cost the user is willing to pay for
HR_{ni}	Handoff request of terminal

C. QoS Satisfaction

The QoS satisfaction includes service level evaluation and QoS suitability. In this paper, the grey relational analysis method is adopted to evaluate service levels. According to handoff request HR_{ni} , level service k is made by network provider based on the access network conditions.

BS_{mi}^k is the fuzzy satisfaction for bandwidth according to Equation (4). Similarly, the fuzzy satisfactions for delay, delay jitter and error rate are DS_{mi}^k , JS_{mi}^k and ES_{mi}^k , which are calculated only by replacing U and u of Equation (5) with the corresponding parameters.

$$BS_{mi}^k = \frac{\frac{1}{2}(bw_{mi}^{kl} + bw_{mi}^{kh}) - \min_m \frac{1}{2}(bw_{mi}^{kl} + bw_{mi}^{kh})}{\max_m \frac{1}{2}(bw_{mi}^{kl} + bw_{mi}^{kh}) - \min_m \frac{1}{2}(bw_{mi}^{kl} + bw_{mi}^{kh})} \tag{4}$$

$$U_{mi}^k = \frac{\max_m \frac{1}{2}(u_{mi}^{kl} + u_{mi}^{kh}) - \frac{1}{2}(u_{mi}^{kl} + u_{mi}^{kh})}{\max_m \frac{1}{2}(u_{mi}^{kl} + u_{mi}^{kh}) - \min_m \frac{1}{2}(u_{mi}^{kl} + u_{mi}^{kh})} \tag{5}$$

Assume that k^* is the ideal service level, which has the best fuzzy satisfactions for the four parameters.

We regard the grey relational degree from the k level service to the ideal level service as the service level evaluation, $LE_{mi}^k = (GR_{mi}^{kB} + GR_{mi}^{kD} + GR_{mi}^{kJ} + GR_{mi}^{kE})/4$, where GR_{mi}^{kB} , GR_{mi}^{kD} , GR_{mi}^{kJ} and GR_{mi}^{kE} are calculated only by replacing U of Equation (6) with the fuzzy satisfactions for the parameters.

$$GR_{mi}^{kU} = \frac{\min_i \min_m \left| U_{mi}^k - U_i^{k^*} \right| + \frac{1}{2} \min_i \max_m \left| U_{mi}^k - U_i^{k^*} \right|}{\left| U_{mi}^k - U_i^{k^*} \right| + \frac{1}{2} \min_i \max_m \left| U_{mi}^k - U_i^{k^*} \right|} \tag{6}$$

SB_{mi}^k , SD_{mi}^k , SJ_{mi}^k and SE_{mi}^k are the suitability of four parameters to the QoS requirement of AT_i type application. Where SB_{mi}^k and SD_{mi}^k are calculated by Equations (7) and (8), where β is a constant. Similarly, SJ_{mi}^k and SE_{mi}^k are calculated by replacing the relevant parameters of Equation (8) with the corresponding ones.

In this paper, there are four coefficients introduced, such as ϖ_i^B, ϖ_i^D, ϖ_i^J and ϖ_i^E. They represent the importance of bandwidth, delay, delay jitter and error rate for the QoS of AT_i type applications, and $\varpi_i^B+\varpi_i^D+\varpi_i^J+\varpi_i^E=1$. So that the QoS suitability SS_{mi}^k is calculated by Equation (9).

$$SB_{mi}^k=\left(\frac{\frac{bw_{mi}^{kl}+bw_{mi}^{kh}}{2}-BW_i^l}{BW_i^h-BW_i^l}\right)^{\beta} \tag{7}$$

$$SD_{mi}^k=\frac{1}{2}-\frac{1}{2}\sin\frac{\pi}{DL_i^h-DL_i^l}\left(\frac{dl_{mi}^{kh}+dl_{mi}^{kl}}{2}-\frac{DL_i^h+DL_i^l}{2}\right) \tag{8}$$

$$SS_{mi}^k=\varpi_i^B\cdot SB_{mi}^k+\varpi_i^D\cdot SD_{mi}^k+\varpi_i^J\cdot SJ_{mi}^k+\varpi_i^E\cdot SE_{mi}^k \tag{9}$$

At the end, the QoS satisfaction SQ_{mi}^k is calculated by Equation (10).

$$SQ_{mi}^k=LE_{mi}^k\cdot SS_{mi}^k \tag{10}$$

D. Other Evaluating Indicators

If the service cost is sc_{mi}^k, SC_{n_im} is the satisfaction of a user for the service cost, as Equation (11).

$$SC_{n_im}=\begin{cases}1 & sc_{mi}^k\le WP_{ni}\\ 0 & \text{otherwise}\end{cases} \tag{11}$$

If the network provider and coding scheme are NP_{nm} and CS_{nm}, SP_{nm} and ST_{nm} are the satisfactions for the network provider and coding scheme, as Equations (12) and (13).

$$SP_{nm}=\begin{cases}\frac{1}{x^2} & NP_{nm}\in PP_n\\ 0 & \text{otherwise}\end{cases} \tag{12}$$

$$ST_{nm}=\begin{cases}\frac{1}{y^2} & CS_{nm}\in PC_n\\ 0 & \text{otherwise}\end{cases} \tag{13}$$

where x, y are the sequence numbers of NP_{nm}, CS_{nm} in PP_n, PC_n, $1\le x\le|PP_n|$ and $1\le y\le|PC_n|$.

If the velocity of a terminal is high at current, an access network with larger coverage should be considered to transfer. It can avoid frequent handoffs to reduce the ping-pong effect probability. SV_{nm} is the velocity satisfaction of access network to a terminal, as Equation (14).

$$SV_{nm}=\begin{cases}1 & TV_n<TV_{th}\\ \frac{1}{z^2} & TV_{th}\le TV_n\le HV_m\\ 0 & TV_n>HV_m\end{cases} \tag{14}$$

where y is the sequence number of NT_m in NTS sorted by the coverage from high to low, and $1\le z\le|NTS|$.

E. Game Analysis

For making users and network providers achieve win-win, a terminal and an access network play the game. Both of them have two policies, and the payoff matrices of them are TG and NG, as Equations (15) and (16).

$$TG=\begin{bmatrix}WP_{ni}-sc_{mi}^k & WP_{ni}-sc_{mi}^k\\ -\gamma\cdot(WP_{ni}-sc_{mi}^k) & -(WP_{ni}-sc_{mi}^k)\end{bmatrix} \tag{15}$$

$$NG=\begin{bmatrix}sc_{mi}^k-sp_{mi}^k & -\gamma\cdot(sc_{mi}^k-sp_{mi}^k)\\ sc_{mi}^k-sp_{mi}^k & -(sc_{mi}^k-sp_{mi}^k)\end{bmatrix} \tag{16}$$

where the rows or columns of them show the user or network provider willingness and unwillingness to accept in turn; the minus sign is the lost payoff; the penalty factor, $\gamma>1$, represents the potential negative effect in future. If $tg_{a^*b^*}\ge tg_{a^*b}\wedge ng_{a^*b^*}\ge ng_{ab^*}$, the pair of policies, $\{a^*,b^*\}$, achieves Nash equilibrium of the terminal payoff and access network payoff, where $a^*,b^*,a,b=1,2$.

F. Utility Calculations

The coefficient matrix $\Lambda=[\lambda_1\ \lambda_2\ \lambda_3\ \lambda_4\ \lambda_5]$ expresses the relative importance of factors, including QoS requirement, service cost, access network provider, coding scheme, and terminal velocity, and the sum of them is 1.

In this paper, we use an evaluation matrix $E_{n_im}=[SQ_{mi}^k\ SC_{n_im}\ SP_{nm}\ ST_{nm}\ SV_{nm}]^T$ and a control coefficient Ω, as Equation (17).

$$\begin{cases}\Omega=1 & \text{Nash equilibrium}\\ 0<\Omega<1 & \text{non-Nash equilibrium}\end{cases} \tag{17}$$

The utility of terminal is uu_{nm} and the utility of access network is nu_{nm}, as Equations (18) and (19).

$$uu_{nm}=\begin{cases}\Omega\cdot\Lambda\cdot E_{n_im}\cdot\frac{(WP_{ni}-sc_{mi}^k)}{WP_{ni}} & \text{terminal switches to network}\\ 0 & \text{otherwise}\end{cases} \tag{18}$$

$$nu_{nm}=\begin{cases}\Omega\cdot\Lambda\cdot E_{n_im}\cdot\frac{(sc_{mi}^k-sp_{mi}^k)}{sc_{mi}^k} & \text{terminal switches to network}\\ 0 & \text{otherwise}\end{cases} \tag{19}$$

Obviously, the bigger the utilities, uu_{nm} and nu_{nm}, the better.

III. ALGORITHM DESIGN

The genetic algorithm based on double bee population evolution [9] is a genetic algorithm introducing the process of bee multiplying. In a bee colony, the queen bee, who is the guider of bee colony multiplying, has good genes, and it can be replaced with the more excellent bee. As well as, the algorithm used by us has another alien bee colony to ensure the diversity of genes in the mating process. So this algorithm can seek the optimization in the iterative process.

A. Bee Colony

Every bee colony has a queen bee, many drones and many worker bees. Since worker bees don't participate in the multiplying, we assume the bee colony only has a queen bee and many drones. In bee colonies, every individual $IN = < CH_1, CH_2, \cdots, CH_N >$ is a solution of network selection problem. Chromosome $CH_n = < AN_n, k_n >$ expresses access network AN_n provides a k_n level service to terminal n, where $1 \le n \le N$, $1 \le AN_n \le M$, $k_n \in SL$.

B. Feasible Solution and Fitness Function

If $\forall n((TAS_n \subseteq SAS_m) \wedge (TF_n \subseteq FR_m) \wedge (TR_n \le LS_m) \wedge (TV_n \le HV_m) \wedge ((AB_m - bw_{mi}^{kh}) \ge AB_m^{\min}))$, network selection solution IN is feasible. It shows that the application type, working frequency, signal strength and supporting velocity accord with the demand of terminal, and it does not make the access network overload when the terminal transfers.

According to the abovementioned mathematical model, fitness function $F(IN)$ is defined as Equation (20).

$$F(IN) = \begin{cases} \sum_{n=1}^{N} \left(\frac{1}{uu_{nm}} + \frac{1}{nu_{nm}}\right) & IN \text{ is feasible} \\ +\infty & \text{otherwise} \end{cases} \tag{20}$$

C. Crossover and Mutation

The crossover operation is a linear crossover. CP is the crossover probability, and $0 < CP < 1$. Generate a random pure decimal ρ. If $\rho > CP$, copy both individuals as next generation individuals. Otherwise, execute the linear crossover and generate two new individuals $IN_1^{'}$ and $IN_2^{'}$. The linear crossover operation of chromosome is that $AN_{1n}^{'} = (\alpha_1 AN_{1n} + (1-\alpha_1) AN_{2n})$, $AN_{2n}^{'} = (\alpha_2 AN_{1n} + (1-\alpha_2) AN_{2n})$, $k_{1n}^{'} = (\alpha_1 k_{1n} + (1-\alpha_1) k_{2n})$, $k_{2n}^{'} = (\alpha_2 k_{1n} + (1-\alpha_2) k_{2n})$, where $\alpha_1, \alpha_2 \in [0,1]$.

MP is the mutation probability in all chromosomes of individuals, where $0 < MP < 1$. Randomly select a chromosome CH_n from an individual, and generate a random pure decimal δ. If $\delta > MP$, CH_n doesn't mutate. Otherwise, assign random values of the domains to AN_n and k_n in chromosome CH_n.

D. Algorithm Description

Step 1: Initialize the scale of bee colony S, crossover probability CP, mutation probability MP, upper limit of iteration times $N_{\max}$, current iteration time $NC = 0$, and bee colony $A(0)$ in which S individuals are all feasible solutions of network selection.

Step 2: Make the terminal and access network play the game in every chromosome CH_n of bee colony $A(0)$, and then determine the utilities of both sides. And regard the individual with the smallest fitness value as the queen bee Q_1 in $A(0)$.

Step 3: If $NC > N_{\max}$, Q_1 is the optimum solution, finish.

Step 4: Randomly generate the same scale bee colony $B(NC)$ in which S individuals are all feasible solutions of network selection. Make the terminal and access network play the game in $B(NC)$, and the individual with the smallest fitness value is the queen bee Q_2 in $B(NC)$.

Step 5: Randomly generate a random pure decimal r_1, and $r_2 = 1 - r_1$. And select $\lceil r_1 \times N/2 \rceil$ and $\lfloor r_2 \times N/2 \rfloor$ individuals from $A(NC)$ and $B(NC)$ in turn.

Step 6: Q_1 with the $\lceil r_1 \times N/2 \rceil$ individuals execute the crossover operation, and Q_2 with the $\lfloor r_2 \times N/2 \rfloor$ individuals execute the crossover operation.

Step 7: Select equal individuals from the new bee colonies after the crossover operation, and they form a bee colony $C(NC)$ with S individuals.

Step 8: Bee colony $C(NC)$ execute the mutation operation with ensure all new individuals are feasible, and the new bee colony is $D(NC)$.

Step 9: Calculate the fitness value of individuals, and select the one with the smallest fitness value as the queen bee Q_3 in $D(NC)$.

Step 10: If the fitness value of Q_3 is smaller than ones of Q_1 and Q_2, Q_3 is the $(NC+1)$th generation queen bee, and $D(NC)$ is the corresponding bee colony $A(NC+1)$; Otherwise, replace the worst individual of $D(NC)$ with the better one of Q_1 and Q_2, then $D(NC)$ is the bee colony $A(NC+1)$.

Step 11: $NC = NC + 1$, go to Step 3.

IV. Simulation Results and Discussions

Based on NS2 (Network Simulator 2), this network selection scheme (Scheme 1) is compared with the greedy algorithm based network selection scheme [10] (Scheme 2) and the QoS based network selection scheme [11] (Scheme 3). This paper uses three hexagonal honeycomb topologies with many different numbers and kinds of access networks. According to Table III, we set two kinds of user cases, and implement 500 times of experiments for different numbers of terminals as shown Fig. 1. The results include the QoS satisfaction, cost satisfaction, network provider satisfaction, coding scheme satisfaction, velocity satisfaction, summation utility of both sides, and running time.

TABLE III. USER CASES

User Case	Network provider (%)			Coding scheme (%)			Velocity (%)		
	1st	*2nd*	*3rd*	*1st*	*2nd*	*3rd*	*high*	*medium*	*low*
1	33	33	33	33	33	33	33	33	33
2	60	20	20	60	20	20	60	20	20

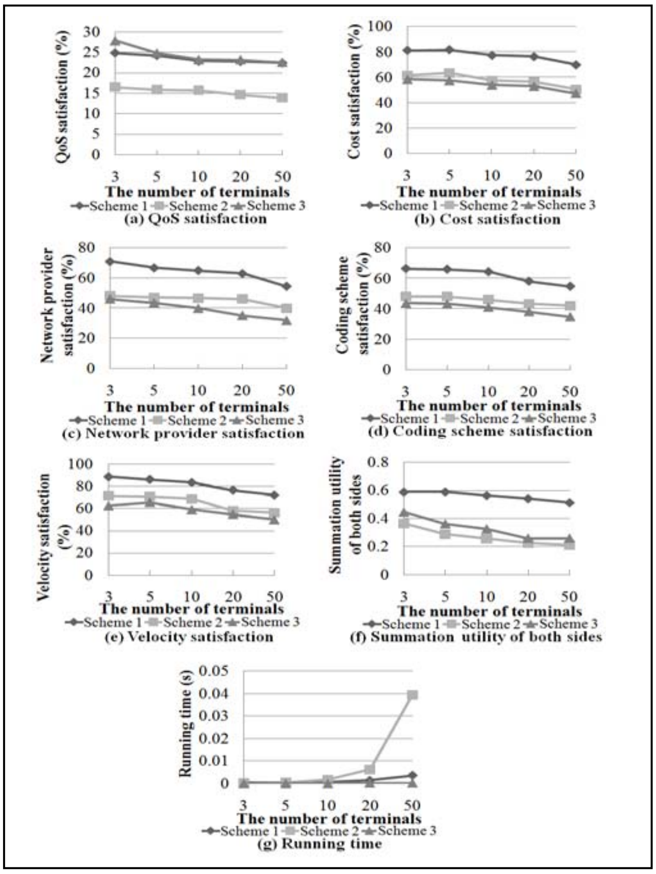

Fig. 1. Results of experiments.

As shown in Fig. 1, Scheme 1 has the similar QoS satisfaction with Scheme 3. But it considers many other factors at the same time. Because of this, Scheme 1 has better performances than the other two in cost satisfaction, network provider satisfaction, coding scheme satisfaction, and velocity satisfaction. With the increasing of terminals, all of the satisfactions fall, but Scheme 1 still has better performances. The most important thing is that Scheme 1 has the higher summation utility of both sides, while the utilities of Scheme 2 and Scheme 3 are pretty low. In such advantages, Scheme 1 takes rational time to seek the optimal network selection solution with the help of the genetic algorithm based on double bee population evolution.

V. CONCLUSIONS

In the heterogeneous network environments, we propose a network selection scheme based on bee colony evolution. As the ABC concept, this scheme makes users can select the best network at anytime anywhere with the help of SDR and multimode intelligent terminals. It considers application types, QoS requirements, service cost, network provider preferences, coding scheme preferences and velocities, and takes advantage of the grey relational analysis method, access network conditions, game analysis and genetic algorithm to solve the important issues of network selections. The simulation results show that this network selection scheme has better performances than the existing schemes in the abovementioned factors, and it ensures the profits of both sides. With the help of the genetic algorithm, our network selection scheme can seek the optimal solution in the rational time.

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REFERENCES

[1] M. Zekri, B. Jouaber, and D. Zeghlache, "A review on mobility management and vertical handover solutions over heterogeneous wireless networks," Computer Communications, vol. 35, pp. 2055-2068, October 2012.

[2] M. Louta and P. Bellavista, "Bringing always best connectivity vision a step closer: challenges and perspectives," IEEE Communications Magazine, vol. 51, pp. 158-166, February 2013.

[3] X. W. Wang, H. Cheng, and M. Huang, "Multi-robot navigation based QoS routing in self-organizing networks," Engineering Applications of Artificial Intelligence, vol. 26, pp. 262-272, January 2013.

[4] X. W. Wang, L. Guo, X. J. Li, and M. Huang, "Intelligent QoS handover decision scheme with ABC supported," Acta Electronica Sinica, vol. 39, pp. 748-756, April 2011.

[5] C. J. Chang, C. Y. Hsieh, and Y. H. Chen, "A preference value-based cell selection scheme in heterogeneous wireless networks," in: Proceedings of the 2010 IEEE Wireless Communications and Networking Conference, April 2010.

[6] K. Radhika and A. V. G. Reddy, "Network selection in heterogeneous wireless networks based on fuzzy multiple criteria decision making," in: Proceedings of the 2011 3rd International Conference on Electronics Computer Technology, part 6, pp. 136-139, April 2011.

[7] Q.T. Nguyen-Vuong, N. Agoulmin, and Y. Ghamri-Doudane, "A user-centric and context-aware solution to interface management and access network selection in heterogeneous wireless environments," Computer Networks, vol. 52, pp. 3358-3372, December 2008.

[8] A. Sgora, C. A. Gizelis, and D. D. Vergados, "Network selection in a WiMAX–WiFi environment," Pervasive and Mobile Computing, vol. 7, pp. 584-594, October 2011.

[9] X. Y. Lu and Y. Q. Zhou, "Genetic algorithm based on double bee population evolutionary," Computer Engineering and Applications, vol. 44, pp.71-74, May 2008.

[10] Y. J. Hu and J. K. Zhu, "A multiuser detector based on greedy algorithm for CDMA communication," Computer Engineering and Applications, vol. 39, pp.17-19, October 2003.

[11] Q.Y. Song and J. Abbas, "A network selection mechanism for next generation networks," in: Proceedings of the 2005 IEEE International Conference on Communications, vol. 2, pp. 1418-1422, May 2005.