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A Multi-flow Network Fairness Selection Scheme Based on Weighted Bigraph Model

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Abstract. The observably object of next-generation networks(i.e. 5G) is to support high bandwidth with high mobility .Various radio access technologies has different application scenarios, and these technologies will be seamlessly integrated in 5G network. How users can always select the best access network becomes an important problem. The existing methods are mostly concentrated in single flow network selection. In this paper, a multi-flow network selection model scheme based on bigraph is proposed. By calculating the satisfactions between flows and networks this scheme can distribute the flows on the object of fairness and most satisfaction. Analysis of the performance of the algorithm and prove the correctness of Algorithm. Numerical results show that the proposed schemes achieve significant satisfaction and Fair coefficient.

Keywords: bigraph, fairness, multi-flow, network selection

1 Introduction

In recent years, wireless communication technology has made great progress, Multi-wireless access networks, including GSM (Global System for Mobile Communications), UMTS (Universal Mobile Telecommunications System), WLANs (wireless local area networks), Bluetooth and WiMAX (worldwide interoperability for microwave access), have been or will be deployed around the world. The application scene and the providing service of different access technology are different, one separate access technology cannot meet the growing needs of mobile service, and future 5G mobile system will integrate multi-access technologies in a network to meet the needs of different users and QoS (Quality of Service) level [1-2]. The multi-mode mobile terminal in the future will also be able to support multi-air-interface, dual-mode mobile phone, which is now able to support both network of UMTS and WLAN, has been put into use in some areas. Multi-mode terminal transmission business flow on different access networks at the same time will be possible. At the same time, in order to reduce the complexity of the terminal and save power, it need to set up the special function entity in the network side, to select mechanism for different traffic network design, to locate bearing optimal network traffic fast and accurately, this can provide the best quality service for users. Network selection problem has become the research emphasis in the next generation of network control system, the standardization organizations such as 3GPP, SAE (System Architecture Evolution), the IEEE 802.21 will make the selection problem of the access network be one of problems that the future network need to solve [3].

In the aspects of standardization and system structure of network selection, Literature [1] presents a 4G network architecture, this architecture can provide the best network for multimode terminal selection service. 3GPP SAE standard just raised the problem without solving method; IEEE802.21 set the best network selection problem as one of the five major researches, while the 802.21 standard is still being formulated. In the study of network selection method, mostly focused on the ABC (always best connected) problem of single business flow. Literature [4-5] defines the concept and architecture of ABC problem. Literature [6] proposed a constrained dynamic network selection method, the model network

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selection problem can be converted to knapsack problem to solve, this can reduce power consumption and improve user satisfaction. Literature [2] presents a network selection mechanism, which combines both AHP (the analytic hierarch process) and GRA (gray relational analysis) method. The mechanism obtains the weight of the QoS according to the type of user preferences and the type of service, and then sorts the optional network by using the method of GRA, finally gains the optimum network of carrying the traffic flow. The solutions of the existing network selection problems are divided into the following categories according to the different parameters: (1) RSS (radio signal strength) threshold as the selection criteria [7]; (2) Considering the user's requirement for service and the expense of specific parameters in the network [8]; (3) Three factors are considered: QoS parameter, weight parameter and network priority parameter [9]. The selection method for single business flow network does not apply to solve the problem of multi-flow network: First, using these methods to solve the selection problem of the multi-flow network will become a multiple choice problem of single flow selection; this algorithm with high complexity can't get the best solution. Second, the network choice in the terminal side is not conducive to solve the fairness distribution problem of multi-flow network, unfair network distribution can cause most traffic flock to the same network and cause the quality of service decline. It should discriminate the satisfaction of different importance flows, in the case of insufficient bandwidth, reflect different services for different flows.

To solve these problems, this paper proposes a multi-flow network selection scheme based on bigraph matching for the network side (Inter Access System Anchor, IASA). Considering the QoS parameters, weighting parameters and user priority parameters; using AHP method to calculate the weight of various parameters in the system; according to the different parameters, calculating network satisfaction of business flow respectively; finally using Multi-flow Network Selection Fairness Selection algorithm (MFNSF algorithm) to distribute business flow; based on the fairness distribution of business flow, this scheme ensures the satisfaction is maximum of overall business flow. The network topology of the system is shown in Fig.1.

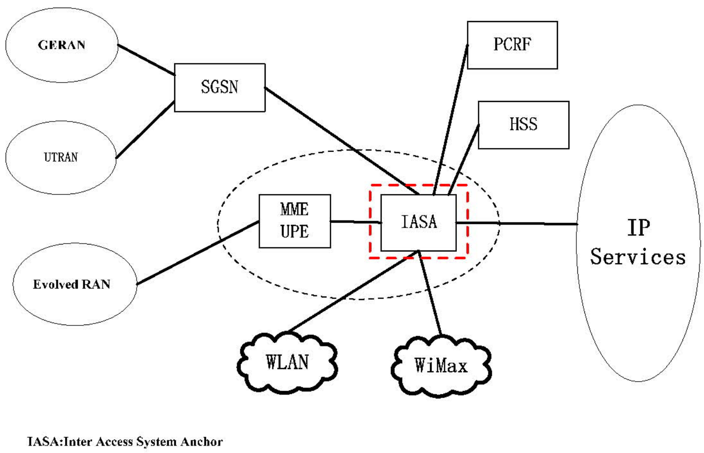

Fig. 1. Multi-flow network selection scheme network topology

The rest of this paper is organized as follows: Section II establishes the system model and proposes system objectives, Section III considers the fairness multi-flow network selection algorithm (MFNSF algorithm), the fourth simulates and analyzes the performance of the algorithm, and the fifth section gives conclusions and next steps.

2 System model and target

2.1 Bigraph model

The nature of multi-flow network can be expressed by the follow formula:

$$X \overset{R}{\underset{P}{\Leftarrow\!\Rightarrow}} Y \tag{1}$$

Among them, X represents the network business flow set which need to be selected for access; Y represents the available access network set; R represents the requirements of different business flows; P represents the current situation of the access network, looking for an optimal result from assigning multi-flow to multi-network for the business flow selection network.

We can also convert the above problem to the bigraph optimal matching problem. Fig.2 shows the relationship between business flow and the available network before the network selection, Fig.3 indicates a possible result of network selection. The edge in the graph shows the matching relationship between the business flow and the access network, the nodes represent the number of matching flows (or nodes).

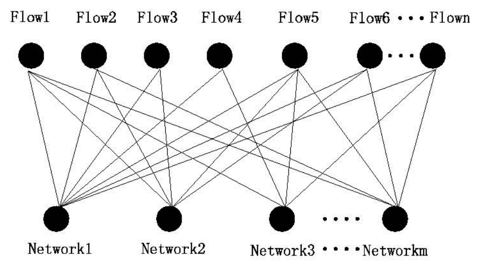

Fig. 2. Before network selection

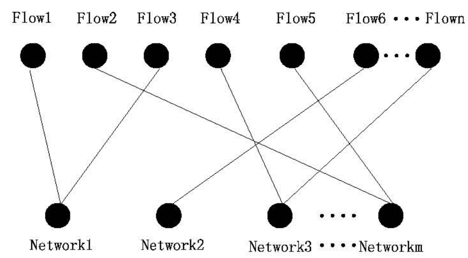

Fig. 3. After network selection

2.1.1 Definition of the node

In the Fig. 2, according to the class division of ITU for QoS and take into account such as users' preferences, network conditions and other factors such as the type of service. We selected five parameters to describe the network situation and demand of the traffic flow. The five parameters are security (α), power(β), Qos(q) (including delay(δ), packet loss rate(ε), jitter(γ), cost(η)) and bandwidth(bw). The first four parameters are used to calculate the satisfaction, the five, bandwidth is used to determine whether the network has the ability to carry the traffic.

Factors vector

$$\tilde{V} = (\alpha, \beta, q, \eta, bw) \tag{2}$$

Where $$\tilde{q} = (\delta,\ \varepsilon,\ \gamma) \tag{2a}$$

Next, define the bipartite graph model nodes and the satisfaction as shown in Fig.2 and Fig.3.

Definition 1: Service Node, let $\tilde{X} = \{x_1, x_2, \cdots, x_n\}$, $n \in R$, *where each* x_i *represents a traffic flow, each traffic flow demand* $\tilde{x}_i^R = (x_i^\alpha, x_i^\beta, x_i^q, x_i^\eta, x_i^{bw})$.

Definition 2: Network Node, let $\tilde{Y} = \{y_1, y_2, \cdots, y_m\}, m \in R$, where each node vector y_i represents a available access network, denote $\tilde{y}_i^P = (y_j^\alpha, y_j^\beta, y_j^q, y_j^\eta, y_j^{bw})$ as the situation of network.

Definition 3: Satisfaction: Let the degree of network j satisfy the demand of traffic flow i to be

$$M_{ij} = \begin{cases} S\tilde{a}t \times \tilde{W}, & x_i^{bw} \le y_j^{bw} \\ 0, & x_i^{bw} > y_i^{bw} \end{cases} \tag{3}$$

Where $S\tilde{a}t = (Sat_\alpha, Sat_\beta, Sat_q, Sat_\eta)$ is the satisfaction of various parameters. For different parameters there have different methods of calculation. $\tilde{W} = \{w_\alpha, w_\beta, w_q, w_\eta\}$ is the weight of each parameter.

2.2 Satisfaction computing

According to different types of parameters, the calculation method of satisfaction can be divided into three cases: For the first class which is parameters of interval, the service node requires the parameters must within an interval of (u_k, l_k), including delay, jitter and packet loss rate. The satisfaction of network j to traffic flow i can be obtained by equation (4):

$$Sat_{ij}^{k}=\begin{cases}1, y_j^k > u_k \\ \dfrac{y_j^k - l_k}{u_k - l_k}, l_k \le y_j^k \le u_k \\ 0, y_j^k < l_k\end{cases} \tag{4}$$

For the second class which is parameter of threshold, service nodes require that the parameter must be greater than a certain threshold t, such parameters include security, can be obtained by the formula(5):

$$Sat_{j}^{k}=\begin{cases}1, y_j^k \ge t \\ 0, y_j^k < t\end{cases} \tag{5}$$

For the third class which is deviation as small as possible, let the difference between the value provided by the network and value t required by the service node as small as possible. Such parameters include power consumption and the cost, which can be obtained by the formula(6):

$$Sat_{j}^{k}=\begin{cases}1, y_j^k < t \\ p^{\frac{y_j^k}{t}}, y_j^k \ge t\end{cases} \tag{6}$$

After obtaining satisfaction of various parameters, it can determine the weight of each parameter through AHP algorithm.

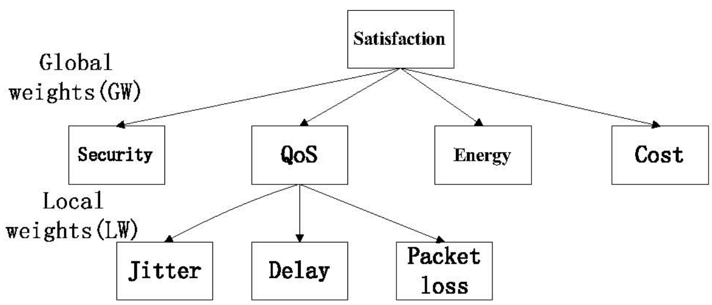

Fig. 4. AHP algorithm

Where $GW=\{w_\alpha, w_\beta, w_q, w_\eta\}$, $LW=\{w_\delta, w_\varepsilon, w_\gamma\}$, the final weight of all factors is : $W=\{w_\alpha, w_\beta, w_q w_\delta, w_q w_\varepsilon, w_q w_\gamma, w_\eta\}$, the weight of various parameters are as Table 1 and Table 2.

Table 1. GW weight factors

	W_α	W_β	W_q	W_η	GW
Security	1	2	1/3	2	0.2
Energy	1/2	1	1/6	1	0.1
QoS	3	6	1	6	0.6
Cost	1/2	1	1/6	1	0.1

Table 2. LW weight factors

	W_δ	W_ε	W_γ
Conversation	0.45	0.1	0.45
Stream	0.7	0.1	0.2
Background	0.1	0.8	0.1

Finally, find the overall satisfaction of network by equation(3).

To select the network for traffic, the only need is to find a subgraph G_l of bipartite graph G through a certain principle. Let the degree of $\tilde{X}$ in G_l is no more than 1 which is the result of a matching network selection. The following discussion is principles of the network selection in this mechanism: the principle of fairness.

2.3 Equity consideration

For the fairness of calculate the system, firstly satisfaction of network need to deal with the following normalization process:

$$M_{ij}^{*} = \frac{M_{ij} - M_{i}^{\min}}{M_{i}^{\max} - M_{i}^{\min}} \tag{7}$$

It can be seen from equation (7), traffic flow i finally choose the satisfaction of network $M_i^* \in (0,1)$, when M_i^*=1, traffic flow is access to the network with the greatest satisfaction. When M_i^*=0, traffic flow is executed with the minimal satisfaction. The following equity index of system can be defined by M_i^* and importance of traffic flow.

Definition 4: Equity Index

$$F = \frac{(\sum_{i}^{n} \frac{M_i^*}{v_i})^2}{n\sum_{i}^{n} (\frac{M_i^*}{v_i})^2} \tag{8}$$

Where M_i^* denote the ith satisfaction of traffic flow, $v_i \in (0,1)$ denote the importance of traffic flow, which is related to the type of traffic flow services and the waiting time of service. In general, the importance of real-time services is greater than non-real-time services.

It's not difficult to prove that, $F \in (0,1)$, with F grow bigger, the fairness of the systems became greater.

Especially when

$$\frac{M_1^*}{v_1} = \frac{M_2^*}{v_2} = L = \frac{M_m^*}{v_m} = M^{\%} \tag{9}$$

In this case, F=1, the systems meets the principle of proportion and fairness which defined in the literature [10], $M^{\%}$ is called the parameter of proportion and fairness of the system's satisfaction. So, in the design of algorithm, the value F should be as close as 1. In this paper, we define $F \in (0.9,1)$ which satisfies the fairness condition.

2.4 System target

Through the discussion in 2.1 and definition 4, it can drawn that the target problem of this algorithm is:

Target 1: Maximize $\sum_{i}^{n} M_i^*$, Subject to F, and the constraints of network bandwith, $\sum_{i=1}^{n} x_{ij}^{bw} \le y_j^{bw}$, for each j, x_{ij}^{bw} is the consumed bandwidth of traffic flow.

As can be seen from the target 1, algorithm of network selection should be considered from the following three aspects: Firstly, when avoiding conflict, transfer the same service node to the network of lower satisfaction, leading to some service node M_i too low, so that the value of F is too low too. Secondly, when set the initial value of $M^{\%}$, the value of M_i^* should be taken for the maximum in line with (7), to make $\sum_{i}^{n} M_i^*$ largest. Thirdly, it is necessary to consider the equity not only in one selection but also in many selections. If a traffic flow is sacrificed in a selection, then it's importance will increase, so that it will achieve greater satisfaction in the next time.

3. Algorithm of MFNSF

3.1 Algorithm of MFNSF

It can be seen by 2.3, the principle of system is finding the max $\sum_i^n M_i^*$ under the condition of max F. So the calculation formula is

$$M^{\%} = \frac{1}{\underset{i\in(1,2,\Lambda,n)}{Max}\ v_i} \quad \textbf{(10)}$$

To ensure the fairness principle of system, the value of the edge weight is equal to the distance of the normalized satisfaction/traffic flow in the margin and the degree of satisfaction with the fair poportion, the closer, the greater weight of the edge is.

$$\omega_{ij} = 1 - | M_{ij}^* - M^{\%} v_i | \quad \textbf{(11)}$$

The basic idea of the NFNSF algorithm is, find out the edge with the greatest weight of each service node, then assigned value to it.

$$L(x_i) = MAX\,\omega_{ij} \quad \textbf{(12)}$$

Then two situations maybe occur. (1) All bandwidth of network nodes are able to meet the needs of the service node, then the current allocation results is equal to the results of network selection in definition 1. (2) When the network node can not meet the service node, the results assigned need to be adjusted in some certain principles. The principles are as follows: find the network with the suboptimal weights in all service nodes which are in the conflict, and transfer the nodes with the smallest decline to the suboptimal node.

The specific processes of MFNSF algorithm are as follows:

Step1: Define the set of network nodes X, Y according to the definition 1 and 2.

Step2: Calculate satisfaction of every service node for network, as the weights of the biparitie graph G edge ω ij.

Step3: If there is only one service node in the figure, choose the node with Max ω ij as a result of network selection.

Step4: If there are more than one service node in the figure, assign value to the service node Gj and network node, L(xi)= Max ω ij, L(yj)=0 , i, j=1, 2 .. t, t = max(n, m).

Step5: Obtaining the set of edge, $E_l : \{(x_i, y_i) | l(x_i) + l(y_i) = w_{ij}\}$, and $G_l = \{X, Y_l, E_l\}$.

Step6: If find a subgraph $G_l^{'}$ in G_l which satisfied every degree of x_i in X, $D(x_i)$ =1 and $y_j^{bw} > \sum_{k\in N_{G_l}(y_j)} x_k^{bw}$, where $y_j \in Y_l$. If $N_{G_l}(y_j) \in X$ is the set of nodes which are adjacent to point Y_l, then $G_l \leftarrow G_l^{'}$ is the result, else take the next step.

Step7: Choose a subgraph $G_l^{'}$ in G_l with the value $D(x_i)$=1, $G_l \leftarrow G_l^{'}$, find the point y_j in set of Y_l which meets $y_j^{bw} < \sum_{k\in N_{G_l}(y_j)} x_k^{bw}$, let A $\leftarrow \{y_j\}$, B $\leftarrow \{N_{G_l}(y_j)\}$, if若 Y_l = A, take the step 10.

Step8: Calculated the value of a according to the following formula, a= $\min_{\substack{x_i\in B \\ y_j\notin A}}\{l(x_i) + l(y_j) - \omega_{ij}\}$, if $l(x_i) + l(y_j) - \omega_{ij}$<0, a= $+\infty$, take the step 10. $l^{'}(x_i) = \begin{cases} l(x_i) - av_i & ,x_i \in B \\ l(x_i) & ,其他 \end{cases}$, $l^{'}(y_i) = \begin{cases} l(y_i) - av_i & ,x_i \in A \\ l(y_i) & ,其他 \end{cases}$, calculating $E_{l^{'}}, G_{l^{'}}$ according to $l^{'}$.

Step9: Find x_0 in the set of X, make it ($E_{l^{'}}$ - E_l) $\in N_{G_{l^{'}}}(x_0)$, $E_{l^{*}}$ = $E_{l^{'}}$ -($N_{G_{l^{'}}}(x_0)$ -($E_{l^{'}}$ - E_l))=2 $E_{l^{'}}$ -

$N_{G_{l'}}(x_0)$ - E_l , $l \leftarrow l'$ ， $G_l \leftarrow G_{l'}$, then take the step 8.

Step10: Find a B with the $\min v_i$ of x_i , $X' = X - \{x_i\}$, re-calculate G_l' , $G_l \leftarrow G_{l'}$, take the step 6.

An example of the algorithm is as follows.

In Fig.5, traffic flow 1 and 2 choose the network 2 at the same time, but in one time network 2 can't meet them, according to the principle of the algorithm, service node will be transferred. As seen in Fig.6, the final result is, two traffic choose the optimal network, two traffic choose the suboptimal network, one traffic choose the third preferred network, and the algorithm adjusted four times in all.

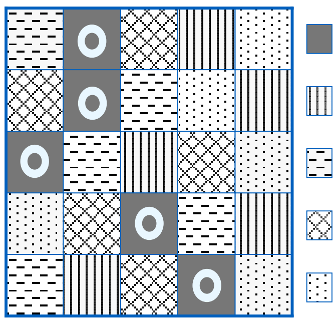

Fig. 5. Before the algorithm

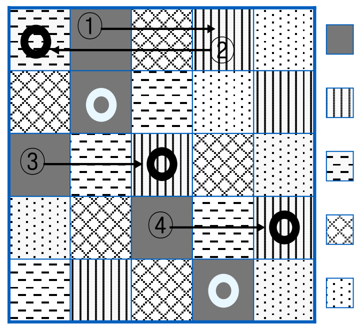

Fig. 6. After the algorithm

3.2 Analysis of correctness and complexity of the algorithm

It can be seen through the process of algorithm above, when the service node *i* is adjusted from network node k to k+1, satisfaction will change to:

$$\omega_i(k+1) = \rho\omega_i(k) \tag{13}$$

Proposition 1: formula (13) meet the two conditions defined by literature [11]: (1) Effectiveness (all ω_i are greater than 0) and (2) Stability (all ω_i are exponential convergence under the principle of maximum fairness).

Proof: Take (11) into (13) it can be drawn:

$$1-|M_i^*(k+1) - M^{\%}v_i| = \rho[1-|M_i^*(k) - M^{\%}v_i|] \tag{14}$$

It can be drawn from (3) and (9):

$$0 < M_i^* < 1 , 0 < M^{\%}v_i = \frac{v_i}{v_{\max}} < 1$$

When $M_i^*(k) > M^{\%}v_i$, $M_i^*(k+1) > M^{\%}v_i$, formula (13) will change into follows:

$$1-(M_i^*(k+1) - M^{\%}v_i) = \rho[1-(M_i^*(k) - M^{\%}v_i)] \tag{15}$$

by using some algebraic operations:

$$M_i^*(k+1) = (1+M^{\%}v_i) - \rho(1-M_i^*(k) + M^{\%}v_i) \tag{16}$$

By the process of algorithm it can be known:

$\because\ 0 < M_i^*(k) < M_i^*(k+1) < 1$

$\therefore\ M_i^*(k) < (1+M^{\%}v_i) - \rho(1-M_i^*(k) + M^{\%}v_i) < 1$

$$0 < \frac{M^{\%}v_i}{1-M_i^*(k)+M^{\%}v_i} < \rho < \frac{1+M^{\%}v_i - M_i^*(k)}{1-M_i^*(k)+M^{\%}v_i} = 1 \tag{17}$$

It also can be proved that:

(1) $M_i^*(k) > M^{\%}v_i$, $M_i^*(k+1) < M^{\%}v_i$,

(2) $M_i^*(k) < M^{\%}v_i$, $M_i^*(k+1) > M^{\%}v_i$,(3) $M_i^*(k) < M^{\%}v_i$, $M_i^*(k+1) < M^{\%}v_i$ 時

$$0 < \rho < 1 \quad \textbf{(18)}$$

Overall, when $\omega_i(k)$>0, $0 < \rho < 1$, formula (13) meets the conditions of (1) and (2).

It can be known by the literature [13] that when formula (13) satisfies the Effectiveness and stability, the algorithm is correct.

Complexity analysis, it can be drawn from the algorithm process in the table 3, MFNSF algorithm will be adjusted when the network bandwidth can not meet multi service flows at the same time. So, the complexity of the algorithm has a great relationship with the network performance and the traffic demand. In the best situation, the access network has a large bandwidth, and all kinds of traffic are accepted in optimal network, at this time, the complexity of the algorithm is *O(1)*; In the worst case, the traffic flow will be transferred to the worst network in turn due to the bandwidth constraints of the traffic network. At this time, the algorithm is degenerated into traditional multiple single traffic flow selection problem, and the complexity of algorithm turns out to be *O*(M^N), thus it is unable to apply in the actual deployment, and at this time, each traffic flow will be running on its poor access network resulting in a decline in overall satisfaction. Therefore, the algorithm must be constrained, set the threshold $K_{\max}$ in the number of network selection adjustment, the system will record the number of network selection adjustments when a multi service flow network is selected, and the algorithm will end when the number of the adjustment reaches the threshold. And in order to guarantee the higher overall satisfaction, it will block the traffic with the low degree of satisfaction in the network nodes which are insufficient capacity, then the complexity of algorithm is *O*($K_{\max}$).

Under actual operating conditions, the number of times which MFNSF algorithm adjusted is often less than the threshold, it can be seen from the analysis of the Figure 12 in chapter 4.6, under the simulation environment of this paper, the average number of times which MFNSF algorithm conducts network selection is between 1.5 to 2.5 due to the bandwidth factors.

3.3 Analysis of correctness and complexity of the algorithm

Definition 5: The communication overhead of the MFNSF algorithm is defined as follows: it can be divided into two parts which are *Cost1* and *Cost2*. *Cost1* is the overhead caused by the change of the service node for the reason that the new traffic flow arrival lead to the network reselection. And *Cost2* is the cost caused by the network reselecting signaling as a result of the appearance of the mobile terminal lead to the change of network node.

Since the implementation of the algorithm(including the) is carried out in the network side, the communication overhead caused by each network selected just includes the corresponding change that making by action of the network side to inform the mobile terminal.

Assuming that the mobile terminal can receive n kinds of traffic flows, the arrival rate of each traffic flow obeys the Poisson distribution, which are $(\lambda_1, \lambda_2, \Lambda, \lambda_n)$, then the total arrival rate of the mobile terminals obeys the Poisson distribution too, which are $\lambda_1 + \lambda_2 + \Lambda + \lambda_n$. During time t, the arriving probability of Ks traffic flows is:

$$P(\lambda, t, k) = \frac{(\lambda t)^k e^{-\lambda t}}{k!} (\lambda = \lambda_1 + \lambda_2 + \Lambda + \lambda_n) \quad \textbf{(19)}$$

It can be drawn that the signaling overhead of network reselection caused by the change of the service node is:

$$Cost_1 = \sum_0^{\infty} kP_k \quad \textbf{(20)}$$

Define t2 for the dwell time of mobile terminal in the most micro cell of all access network, assuming that the micro cell is approximately circular and the mobile terminal only change the position in most micro cell, then it can be drawn in the literature[15] that the dwell time is obey the exponential distribution of *1/u_{mi}*, and:

$$u_{mi} = \frac{E[v]L}{\pi S} \quad \textbf{(21)}$$

Define S, L for the area and perimeter of the micro cell, $E[v]$ for the average speed of mobile terminal. From this we can get the density distribution function of t2:

$$f_{t_2}(t_2) = u_{mi} e^{-u_{mi} t_2} \quad \textbf{(22)}$$

When the residence time of mobile terminal in cell is *t2<t*, then in the t time interval the network reselection will occur. Define P_u for the probability of network reselection caused by at least one change in the time t, and:

$$P_u = P[t_2 < t] = \int_0^t u_{mi} e^{-u_{mi} t_2} d_{t_2} = 1 - e^{-u_{mi} t} \quad \textbf{(23)}$$

Because of the non-memory specific of exponential distribution, the probability of change n times in the t time is $P_u^{\,n}$, it can be seen that:

$$Cost_2 = \sum_{i=1}^{\infty} i P_u^i = \frac{P_u}{(1-P_u)^2} \quad \textbf{(24)}$$

From definition 5 we can get that the communication overhead of MFNSF algorithm is:

$$Cost = Cost_1 + Cost_2 = \sum_{0}^{\infty} k P_k + \frac{P_u}{(1-P_u)^2} \quad \textbf{(25)}$$

From formula (25) it can be known that the communication overhead has a great relationship with the speed of the mobile terminal. When the mobile terminal is in motion, by formula (21) we can get that with the increase of speed *E[v]*, the parameter will increase too, leading the probability of network reselection in formula (23) and the overhead of communication growing too. If the mobile terminal is in high speed, the communication cost of the algorithm will become greatly large, so for the users of high speed it should connect the network with macro node and avoid switching too frequently.

Definition 6: it can be drawn in chapter 3.2, the complexity of network reselection is equal to the computational cost of MFNSF algorithm.

Due to the implementation of the MFNSF algorithm is on the network side, the mobile terminal dose not need to calculate, so the computational overhead is the adjusted times in the network side, which is equal to the time complexity of the algorithm.

4 Experimental and performance analysis

4.1 Simulation scenario

In this paper, the simulation scene is the extension of the scene in literature [2], as shown in Fig.7, the simulation area consists of 1 WiMAX network, 1 UMTS network and 5WLAN networks. We first consider the situation that when multi-mode terminal enter region B from A, there will increase 3 available access network for multi-mode terminal, which are WLAN2, WLAN4 and WLAN5. Then there are 7 available access network in scene B and the terminal will notify the IASA to reselect the access network. Assuming that there are 3 kinds of traffic at the same time which are the voice of the traffic, media type of video traffic and background data type of downloading traffic. The requirements for the parameters of the traffic flow are shown in Table 3, the importance of the three traffic flow are 1, 0.7 and 0.8. The access capability of each network can afford at a certain time are shown in Table 7. So we build a bipartite graph with 3 service nodes and 7 network nodes.

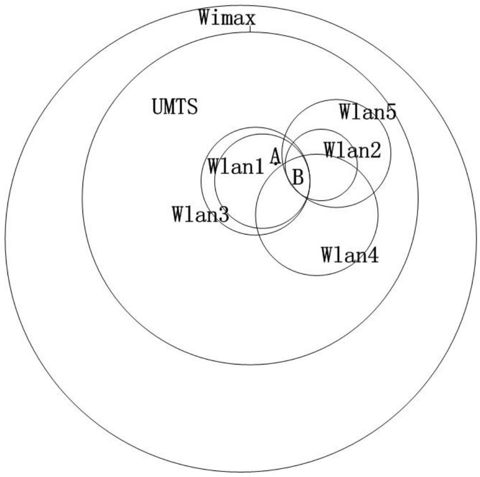

Fig. 7. Network selection simulation scenario

Table 3. Flow parameters

	Traffic flow 1	Traffic flow 2	Traffic flow 3
BW (Mb/s)	1	2	2
Jitter (ms)	6-9	8-10	15-30
Delay (ms)	15-45	20-45	50
Packet loss ratio (%)	0.07	0.07	0.07
Cost	1	1	0.7
Security	7	6	5

Table 4. Network parameters

	UMTS	WiMAX	Wlan1	Wlan2	Wlan3	Wlan4	Wlan5
BW (Mb/s)	2	5	11	11	11	11	11
Jitter (ms)	6	8	10	9	9	10	11
Delay (ms)	19	30	45	40	39	42	35
Packet loss ratio (%)	0.01	0.06	0.04	0.03	0.05	0.08	0.05
Cost	0.9	0.5	0.2	0.2	0.3	0.2	0.1
Security	8	7	6.5	6	5	6	5

The following are some simulation analysis. Respectively the ability of distinguish different types of traffic, the ability to ensure the fairness, the impact of the network load and the overall situation of the algorithm can be obtained.

4.2 Distinguish the performance impact of service types and mobility

In the decision to assign multiple traffic flows, the results should reflect the impact of the traffic flow and the degree of importance of the matching degree. Even if the network conditions change, for the high demand of traffic flow, the matching degree should be maintained at a relatively high value after the assignment. The ability of distinguish different types is the need to ensure fairness and the embodiment of algorithm stability.

Here we investigate the ability of MFNSF algorithm to distinguish different services. In the area of B, the assumption is that the need of the traffic flow stays constantly, changing the situation of the network, adjust delay and packet loss rate so as to change according to amplitude random variation 2%-5%. After calculating the matching degree of each traffic flow, 10 simulations are carried out, as shown in Fig.8. It can be seen that, when the situation of network changes, the matching degree of the three traffic flow will be consistent with the important degree of the network. The matching degree of traffic flow 1 is always greater than the traffic flow 3, which is higher than the 0.03~0.1. And the matching degree of traffic flow 3 is always greater than the traffic flow 2, higher than the 0.08~0.15. This shows that the MFNSF algorithm can allocate traffic flow according to the actual situation of the network and the traffic flow.

From the above analysis it can be seen, when the situation of network changes, the satisfaction of the terminal will be changed as a result of MFNSF algorithm. And when mobile terminal is in high speed, the satisfaction of traffic flow will change constantly, which will infect the continuity of the service quality. So for mobile terminal with high speed, is should be used as far as possible to reduce the change of the satisfaction of the service.

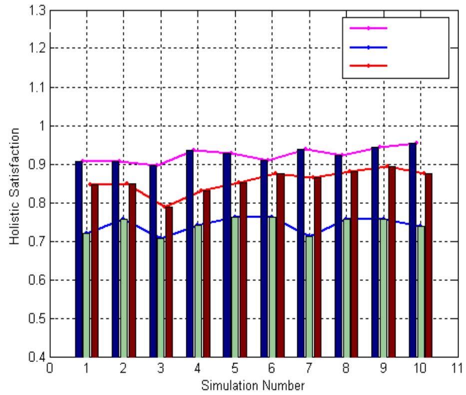

Fig. 8. Differentiated services

4.2.1 Fairness guarantee

In order to verify the ability of MFNSF algorithm to guarantee fairness, we choose to compare the simulation results to the algorithm in literature [12]. The algorithm in literature [12] is designed to solve the switching problem of traditional traffic flow. The thinking of this algorithm to solve the problems is, placing the traffic flow in a queue with a priority order, then execute the network selection from the head of the queue. This algorithm is quite simple, but it can not be well reflected in the fairness, there is not enough opportunity for the traffic flows which are at the end of the queue to obtain satisfactory network access.

In the scene shown in Fig.7, we assume that the demand for traffic flow is constant, under the conditions of network changing, comparing the fairness index of two algorithms. Set the parameters the same, which are the network delays and the packet loss rate random change according to the magnitude of the 2%~5%, execute 100 simulations. Where the horizontal axis represents the number of times, the vertical coordinate represents the system fairness index obtained by each allocation. The calculation method is given by definition 4 and the simulation results are shown in Fig.9. It can be clearly seen that, the fairness index of MFNSF algorithm has been maintained in the interval of 0.93~0.97. By definition 4, the fairness index of 1 indicates perfect fairness while greater index, more fair. So the MFNSF algorithm has a good fairness. As contrast, the fairness of the traditional algorithm does not exist a certain rule, and has a random fluctuation between 0.3~0.95 with the changes in the network situation.

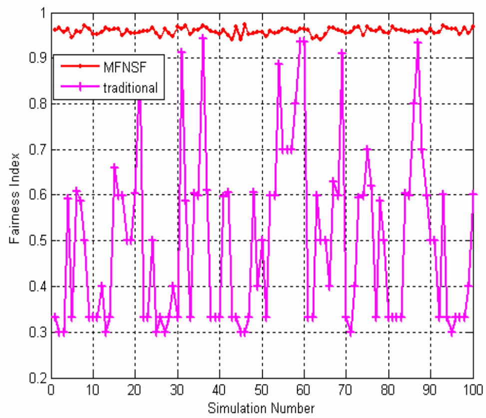

Fig. 9. Fairness index

4.2.2 Network load

The network load indicates the traffic number loaded on the network when the traffic has been switched and re-assigned. The paper evaluates the effect of MFNSF on the network load in A-area. As shown in Fig.7, A-area has one UMTS, two WLAN and one Wimax networks. The access capacity of the four networks has been demonstrated in table 4. In the area A, 10 traffics are assumed to switch at each time. Hence, a bipartite graph, which is consists of 10 traffic nodes and 4 networks, is constructed in the area A.

The simulation assumes there are 100 multi-mode terminals in area A in an interval of time, and 10 traffics are re-assigned in the network at each time. The requirement of bandwidth and time-delay are changed randomly in the range from 5% to 10%. The system then records the number of times that the traffics are assigned to the four networks. Fig.10a shows the simulation results, where the X-axis indicates the number of traffic switching, and the Y-axis indicates the total number of link between the traffic with different networks. As shown in the Fig.10a, the number of traffic loaded on the network increase with the number of traffic switching. However, the increasing trends is stable which means that the algorithm can assign the traffic to each network evenly.

To compare the performance, the paper also evaluates the performance of the algorithm in [12]. As shown in Fig.10b, the algorithm in [12] assigns the traffic intently to the better conditional network, while assigns less traffic to other networks. The algorithm in [12] results in the load of the better conditional network increases too quickly. However, the MFNSF algorithm could effectively avoid the network overload and balance the network load in the area in a period of time.

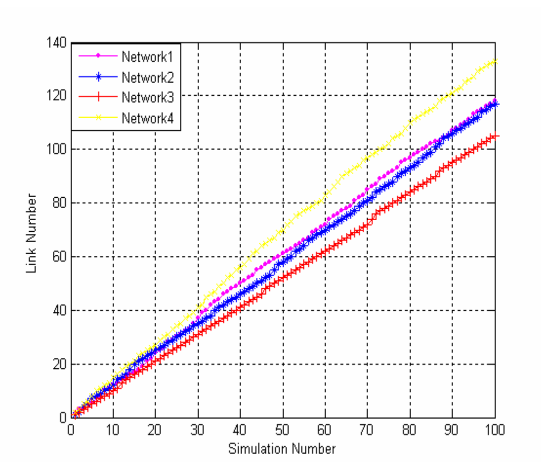

Fig. 10a. MFNSF algorithm network connection situation network connection situation

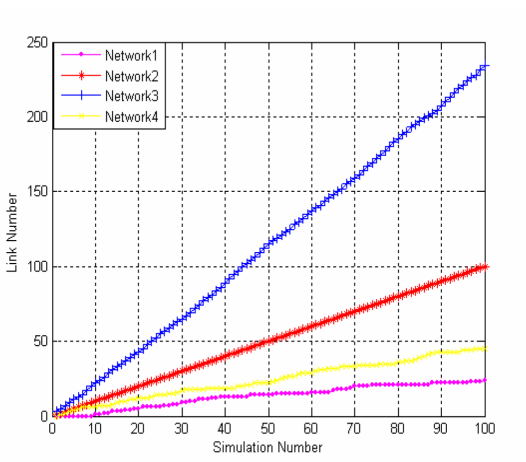

Fig. 10b. Traditional algorithm

4.2.3 Network matching degree

Next, the paper evaluates the average matching degree of MFNSF method. The method constructs the bipartite graph model in the A-area, and then evaluates the performance of four different conditions including the max satisfactory, min satisfactory, MFNSF and traditional unfairness method. The max satisfactory indicates the maximum matching degree of the traffic when the bandwidth is unlimited. The min satisfactory indicates the mean matching degree of the traffic when the traffic selects minimal matched network. The traditional unfairness method is the traffic switching method when weighting the bipartite graph without consideration of the significance of the traffic.

In order to get the average matching degrees of the four algorithms, the simulation of system assumes there are 100 terminals, each terminal runs 10 kinds of traffic, and both the requirement of traffic and network capacity change randomly in the range from 2% to 5%. As shown in Fig.11, the maximum matching degree is about 0.95, and the minimum degree is about 0.7. The degree of MFNSF is about 0.82 which is similar with the max satisfactory method while less than the traditional unfairness method. Although the MFNSF achieves high fairness at the expenses of the matching degree, the overall matching degree of MFNSF is still high enough for the system.

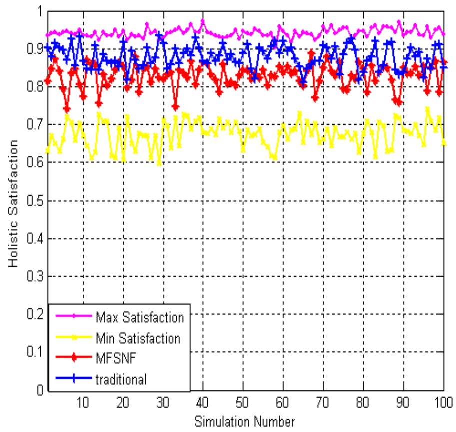

Fig. 11. Average match degree

4.2.4 The validity and complexity of the algorithm

Fig.12 shows the average adjustment times of MFNSF method when selecting the network under the average matching degree as shown in Fig.11. The value in Fig.12 indicates the mean times of the all traffics adjusting the networks selection because of the limited bandwidths in the progress of network selection. As shown in the proof the Proposition 1, MFNSF meets the requirements of both validity and reliability. Actually, the satisfactory of network selection is always large than zero, as shown in Fig.11. Furthermore, Fig.12 demonstrates that the method is of good convergence. However, the adjustment times of network selection depends on the traffic requirements and network conditions.

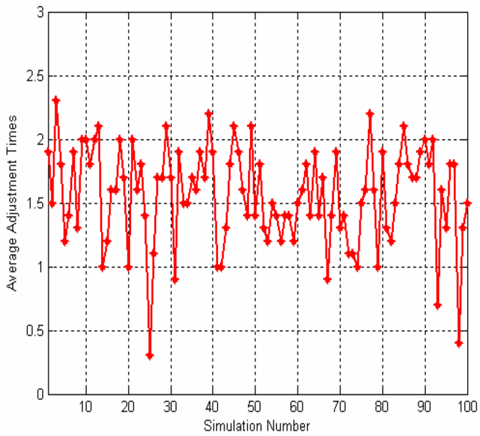

Fig. 12. The average number of adjustments

5. Conclusion

This paper presented a method for solving the problem of multi-flow selection network. The method is based on the design of bipartite graph matching model, which satisfies the network capacity and the requirements of the traffics, reconciling both the user satisfactory and fairness aspects. The theory analysis and experimental results demonstrated that the proposed method can achieve better overall satisfaction on the premise of system fairness.

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