A Load Balancing Vertical Handoff Algorithm Considering QoS of Users for Heterogeneous Networks in Power Communication

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Abstract. With the increase of the number of users and the complexity of services, only single communication network cannot meet all its requests in power communication networks. Therefore, heterogeneous networks are an effective solution. Vertical handoff (VHO) is an important step in the process of heterogeneous network convergence. An appropriate handoff algorithm can improve the quality of service (QoS) of users. In order to solve the problem of network congestion caused by a large number of users connecting to partial networks in heterogeneous networks, a vertical handoff algorithm based on load balance is proposed. Among the networks that can meet users’ requirements, the most load-balancing network is obtained using optimal algorithm. In addition, to consider users’ requirements and ensure the QoS of network service, we use analytic hierarchy process (AHP) to weight different networks. This algorithm can take full use of the various network resources, so that the distribution of the load among networks is average. The simulation results show that the proposed algorithm can select the network according to the user's demands and each network has close network utilization under the algorithm.

1. Introduction
Nowadays, with the increase of the number of users and service demands, improving the load requirements of the existing network are continuously needed. Besides, the structure of the network system is becoming more complicated. In such situation, the heterogeneous network fusion is an effective solution [1-4]. Communication technology has developed rapidly in recent decades, bringing a variety of communication networks coexisting. These networks, such as 3G, 4G, WLAN and WiMax, are widely used in the world. Usually, they each takes advantages over others in access mode, bandwidth, delay, users experience or other aspects and it is difficult to replace each other. Therefore, in a short period of time, it is inevitable that multiple communication networks coexist. When the user moves or the signal status changes, a network with better quality of service may be selected among various available networks to meet the needs of users. The process of handoff between different types of networks is called vertical handoff. Correspondingly, the process of switching between networks of the same type is called horizontal handoff. The horizontal handoff will not change the network state after switching, and thus is relatively simple. While the vertical handoff is more complicated as it needs to comprehensively consider various attributes of different networks.
Similarly, in the power system, the scale of the power communication network has gradually expanded and the structure has become increasingly complex. In the face of the ever-changing new power system business and the increasingly complex power network structure, the traditional power communication network can no longer guarantee the safe and stable operation of the power network. In power communication network, 1.8GHz dedicated wireless network, optical fiber network, power line communication technology (PLC) and public wireless network cannot meet all the requirements alone. Therefore, suitable vertical handoff algorithms are needed in the power communication network to select a suitable access network for the user according to his needs.

At present, the vertical handoff algorithms are mainly divided into three categories: 1) based on received signal strength (RSS) [5-7]. This type of algorithm selects the best network based on the received signal strength. However, because only a single parameter is considered and the signal strength varies greatly in the wireless channel environment, the algorithm is easy to handoff frequently at the edge of the network, that is, the so-called “ping-pong effect”. On this basis, there are many improved algorithms to reduce the “ping-pong effect” by setting the decision threshold or the dwell time to improve the switching performance. 2) based on multi-attribute decision [8-11]. Such as simple weighting method, analytic hierarchy process, approximating ideal solution sorting method. This type of algorithms consider various factors such as delay, bandwidth, access rate, tariff, and moving speed to select the optimal access network for the user. Due to the consideration of various factors, this type of algorithm takes into account the network state and user requirements, and thus has better switching performance. 3) based on artificial intelligence and fuzzy networks [12, 13]. This kind of algorithms can comprehensively consider the unclear and explicit attributes in the actual, such as user preferences, according to different fuzzy logics to improve the switching performance. The purpose of the above algorithm is to select the optimal access network for the user to meet the needs of the user, but this will cause a large number of users to access the network with better network quality, causing some network congestion and some networks to be idle. Network congestion will reduce the user experience, and the imbalance of network load will also waste resources [14, 15].

In order to solve the above problems, this paper proposes a vertical network selection algorithm based on load balancing. The algorithm first divides all users into two groups according to whether they need to switch networks. When the user cannot meet the user's needs due to mobile or network status changes, define this type of user into a group that needs to be switched. For users who need to switch, the equilibrium problem is transformed into an optimization problem by constructing an allocation matrix. Then, according to the optimal algorithm, a network that balances the load utilization of each network is selected in the candidate network that meets the user requirements, so as to improve resource utilization rate. In addition, in order to fully consider the user's needs, the analytic hierarchy process (AHP) [16] is used to weight each network according to user requirements. By combining network weights with load balancing algorithms, both network load balancing and user quality of Service (QoS) are considered. The proposed algorithm can be used not only in the general wireless network but also in the power communication network system.

The rest of this paper is as follows. Section 2 introduces the network model and the third section proposes the network equalization algorithm. The weight estimation method is proposed in section 3 and simulations are given in section 4 to validate the effectiveness of the proposed method, and finally we conclude this paper in section 5.

2. Network Model
This section will introduce the network model [14] and parameters definition of the paper.

Assume that there are two networks: LTE and micro-power wireless in the heterogeneous network. The coverage of the LTE network is larger and a total of $M$ base stations (BSs) are defined as $BS = \{b_1, b_2, ..., b_M\}$, while the coverage of the micro-power wireless network is smaller and a total of $N$ access points (APs) $AP = \{a_1, a_2, ..., a_N\}$. There are $K$ mobile users (MUs) coexisting in the heterogeneous network defined as $U = \{u_1, u_2, ..., u_K\}$. Now, users are divided into two categories. If a user is in good connection state in the original network and does not need to perform handoff, then the user is
classified as a holding group. Otherwise, it is classified as a handoff group and is represented by \( U_{\text{hold}} \) and \( U_{\text{handoff}} \), respectively.

\[
U = U_{\text{hold}} + U_{\text{handoff}}
\]  

(1)

where \( U_{\text{hold}}^{\text{BS}} \) and \( U_{\text{hold}}^{\text{AP}} \) are represent users in holding group that connect to the BS and AP.

Define the transmission rate of the \( j \)-th group that is connected to the \( i \)-th BS as \( r_{ij} \) (where \( i = 1,2,\ldots,M+N; j = 1,2,\ldots,K \)). Then for user in well condition \( u_j \in U_{\text{hold}} \), the load for the \( i \)-th BS and AP can be expressed as

\[
p_{ij}^{\text{BS}} = \sum_{u_j \in U_{\text{hold}}^{\text{BS}}} r_{ij}, i = 1,2,\ldots,M
\]  

(2)

and

\[
p_{ij}^{\text{AP}} = \sum_{u_j \in U_{\text{hold}}^{\text{AP}}} r_{ij}, i = M+1, M+2,\ldots, M+N
\]  

(3)

To calculate the load for handoff users, define an allocation matrix whose elements are zeros or ones \((x_{ij})_M \times N\), where \( x_{ij} \) is based on the allocation condition of the \( j \)-th user in the \( i \)-th network. If the \( j \)-th user is connected to the \( i \)-th network, then \( x_{ij} = 1 \). Otherwise, \( x_{ij} = 0 \).

\[
x_{ij} = \begin{cases} 
1, & \text{if } F(u_j) \geq F_{th} \\
0, & \text{if } F(u_j) < F_{th}
\end{cases}
\]  

(4)

\[
\sum_{i=1}^{M+N} x_{ij} = 1
\]  

(5)

where \( F(u_j) \) is the performance evaluation function that reflects the network state, such as RSS or multi-attribution function. If \( F(u_j) \) is larger than the threshold \( F_{th} \), then current network can meet the user and the user is connected to this network, otherwise is not connected. Equation (5) means one user can only connect to one candidate network.

We can calculate the load of handoff user to BS or AP under one possible allocation case \( X \in X \) by the defined allocation matrix

\[
q_i(X) = \sum_{u_j \in U_{\text{handoff}}} r_{ij} x_{ij}, \quad i = 1,2,\ldots,M+N
\]  

(6)

Then, for a network with bandwidth \( B_i(i = 1,2,\ldots,M+N) \), its network load rate can be represented as

\[
\eta_i = \frac{p_{ij} + q_i(X)}{B_i}, \quad i = 1,2,\ldots,M+N
\]  

(7)

3. Load Balancing Vertical Handoff Algorithm

According to [14], for a set of mean-determined sequences, the sum of squares of the series can be used to indicate the degree of deviation of the series. For a sequence of \( N \) points \( \{x_i\}, i = 1,2,\ldots,N \), can be expressed as
where \( m \) is the sequence mean. It can be seen that for a sequence with determined mean, the smaller the sum of the squares of the sequence points is, the smaller the sequence variance will be. Based on this nature, we can construct a function that measures network load balancing.

For a group of users who need to switch handoff, the transmission rate required by each user is determined, then for a certain allocation situation \( X \in X \), the load required for the entire network \( \sum_{i=1}^{M+N} \left( p_i + q_i(X) \right) / B_i \) is a constant value, so its mean value is determined. According to (8), the degree of deviation of a sequence of points can be expressed by the sum of squares

\[
\sum_{i=1}^{M+N} \left( p_i + q_i(X) \right)^2 / B_i = \sum_{i=1}^{M+N} \eta_i^2
\]  

According to equation (8), when (9) gets the minimum, the degree of deviation of this \( M+N \) point is the lowest, that is, the variance is the lowest, which means that the network load rates are the closest for all networks, then the network load balancing is achieved. Therefore, to achieve load balancing, it is to solve the following optimization problems.

\[
\min_{X \in X} \sum_{i=1}^{M+N} \left( p_i + q_i(X) \right)^2 / B_i
\]

subject to \( p_i + q_i(X) \leq B_i, i = 1, 2, \ldots, M+N \)

where the constraint condition (11) requires that the network load cannot exceed its available bandwidth. The above optimization problem is a 0-1 programing problem, which can be solved by algorithms such as branch definition method and implicit enumeration method [17, 18]. Since there is only one non-zero element in each column in the allocation matrix, the amount of computation for solving this problem is low.

Generally, in a heterogeneous network, parameters such as bandwidth, delay, transmission rate, and packet loss rate of different networks are different, and certain network may suit for particular services. In order to fully consider the user's preference, this paper uses analytic hierarchy process (AHP) to weight the two networks in the text according to different service types to meet the user's QoS requirements.

AHP is a multi-objective decision-making method that combines quantitative and qualitative properties. When analyzing complex problems with multiple attributes, it is often difficult to accurately judge the relationship between the various factors. AHP can improve comparison accuracy by using a two-two factor comparison method to avoid comparing all factors together and using relative scales to compare properties.

This paper uses the basic 1-9 level AHP to determine the weight of the two networks, the specific steps are as follows

1) Establish hierarchies

Divide the problem into a target layer, an attribute layer, and a solution layer. The target layer indicates the direction of the problem solving, that is, meets the user's QoS requirements; the attribute layer lists the attributes that affect the target, such as bandwidth, delay, and tariff; the solution layer lists the solutions to solve the problem. In this paper, there are two types optional network: LTE and WLAN.
2) Construct the judgment matrix

The judgment matrix \( M = \{ m_{ij} \} \in \mathbb{R}^{N \times N} \) is constructed according to the degree of importance between different attributes, where \( N \) is the number of attributes, and each element of the judgment matrix needs to satisfy \( m_{ij} > 0, m_{ij} = 1 / m_{ij}, m_{ii} = 1 \).

3) Weight calculation and verification

The root method or the sum method is used to obtain the maximum eigenvalue of the judgment matrix and its corresponding eigenvector, and the weights of different attributes are obtained after normalization. In order to prevent judgment errors, it is necessary to check the consistency of the judgment matrix.

4) Weight synthesis

By multiplying the weights of the attributes obtained above and the normalized weights of the actual attributes, the weights of different networks can be obtained. The normalized weights of the actual attributes are normalized in different ways according to their benefit type or cost type [19].

Through AHP, the weights of the two networks are calculated, which can reflect the type of service that the user prefers. Combining this weight \( \omega_i (i = 1, 2) \) with the equalization algorithm (10), the vertical handoff algorithm that finally considers user QoS and network load balancing is obtained.

\[
\min_{x \leq X} \sum_{i=1}^{M+N} \omega_i \left( \frac{p_i + q_i(X)}{B_i} \right)^2
\]

subject to \( p_i + q_i(X) \leq B_i, i = 1, 2, ..., M + N \) (12)

According to the above process, the flow of the algorithm is shown in Fig.1.

![Flow chart of the proposed algorithm](image)

Figure 1. Flow chart of the proposed algorithm

The advantages of the proposed algorithm in this paper are summarized as follows:

1) The proposed algorithm weights the network under different services according to user needs and preferences that fully considers users’ preference;

2) In the network switching process, the objective function is the minimum value of the network load rate deviation, so the obtained network switching scheme can distribute the load evenly to each network. There will be no partial congestion of the network due to load imbalance in the RSS based algorithms, thus effectively improving resource utilization;

3) Due to the sparsity of the distribution matrix \( X \), the computational complexity is low.
4. Simulations

4.1 Network Parameters

The heterogeneous network in this paper consists of two LTE base stations and five micro-power wireless AP access points. The parameters are shown in Table 1. Among them, the coverage of the two LTE base stations is larger, overlapping to some extent, and the other five micro-power wireless access points are evenly distributed within the coverage of the LTE base station. In the simulation, the coverage of these two LTE networks is bounded, and it is assumed that all users do not exceed the boundary during the motion.

| Network | LTE | Micro-power wireless AP |
|---------|-----|-------------------------|
| RSS(dBm) | -110~55 | -85~55 |
| Bandwidth(Mb/s) | 2~5 | 10~20 |
| Package loss(10^-6) | 1~30 | 1~30 |
| Delay(ms) | 50~80 | 100~150 |
| Jitter(ms) | 5~10 | 10~20 |
| Tariff (yuan/MB) | 0.2~1 | 0.01~0.03 |

4.2 Network Parameters

Nowadays, heterogeneous networks can provide users with multiple types of services [20], such as voice services, data services, multimedia services, and the like. Each service has different QoS requirements, so network parameters can be weighted according to different service requirements to meet user needs. This paper considers both real-time and non-real-time services, where real-time services are sensitive to delay and non-real-time services require less. According to the 1-9 level AHP introduced in the section 3, the comparison matrix of the two services is

$$ C_1 = \begin{bmatrix} 1 & 1/7 & 3 & 1/5 \\ 7 & 1 & 9 & 3 \\ 1/3 & 1/9 & 1 & 1/7 \\ 5 & 1/3 & 7 & 1 \end{bmatrix} \quad C_2 = \begin{bmatrix} 1 & 7 & 5 & 3 \\ 1/7 & 1 & 1/3 & 1/5 \\ 1/5 & 3 & 1 & 1/3 \\ 1/3 & 5 & 3 & 1 \end{bmatrix} $$ (14)

where the parameters are bandwidth, delay, tariff and packet loss rate, respectively. Finally, the weights of the two networks under the two services are shown in Table 2.

| Service | LTE | Wireless AP |
|---------|-----|-------------|
| Real-time | 0.5476 | 0.4524 |
| Non-real-time | 0.3436 | 0.6564 |

4.3 Load Balancing Algorithm Validation

As shown in Fig.2, assume that initially 100 mobile users are evenly distributed in the range of the base station, moving in a random direction within the coverage at a speed of 0~20m/unit time, and assume that the user does not move beyond the range of the base station. The rate of each user demand is randomly selected among \([64\text{kbps}, 128\text{kbps}, 192\text{kbps}]\). The simulation is performed that we sample every 1000 unit time, and the vertical handoff algorithm is used to allocate the network to the user and calculate the network load. A total of 20 samples are taken. Perform 20 simulations independently, and use the average network load rate of 20 simulations to characterize the performance of the equalization performance.
Fig. 2. Network topology model

Fig. 3 shows the comparison of the equalization performance between the normal RSS algorithm and the load balancing algorithm in real-time and non-real-time services. The RSS algorithm only uses RSS as a basis for judging the network with the strongest received signal strength. It can be seen that the network load rate variance of the proposed algorithm is smaller than the RSS algorithm, which means that the proposed algorithm can distribute the load more evenly to the network, thus meets the requirements and improve resource utilization. Under different services, the proposed algorithm can all achieve better balance effect.

Fig. 3. Load rate variance comparison between different algorithm

Fig. 4 and Fig. 5 show the network load under 20 samples in one simulation of different algorithms. It can be seen that the RSS algorithm only distributes the load according to the received signal strength, so there will be a situation in which the load distribution of some network is idles. After using the proposed balancing algorithm, the utilization rates of all networks are approximately the same. A micro-power wireless AP network with a larger bandwidth can allocate more load than LTE, and the load of the same network is roughly the same.
Fig. 4. Load state of real-time service using load balance algorithm

Fig. 5. Load state of real-time service using RSS based algorithm

Fig. 6. Number of access users using different algorithms

5. Conclusion
The traditional vertical handoff algorithm in heterogeneous network selection aims to select the optimal network solution for the user, but this may cause partial networks to access too many users, causing network congestion and affecting the user's QoS experience. The proposed network load balancing
algorithm in this paper transforms the problem of network equalization into an optimization problem by constructing a network allocation matrix in the network that meets the user's needs. Then the optimal allocation method is obtained by using the optimization algorithm to achieve the balanced network utilization effective. In addition, AHP is used to weight different networks to ensure the QoS requirements of different services. Simulation results demonstrate the effectiveness of the proposed algorithm. The proposed algorithm is general that can be applied to various heterogeneous networks, such as public wireless networks, power system communication networks, etc.

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7. References
[1] A. K. Salkintzis, Interworking techniques and architectures for WLAN/3G integration toward 4G mobile data networks[C]. IEEE Wireless Commun., vol. 11, no. 3, pp. 50–61, Jun. 2004.
[2] Mariem Zekri, Badii Jouaber. A review on mobility management and vertical handoff solutions over heterogeneous wireless networks[J]. Computer Communications. 2012 (17)
[3] Yang Qimin. Radio Resource Allocation and Load Balance Based on New Type Heterogeneous Network [D]. Beijing Jiaotong University, 2016.
[4] Zekri M , Jouaber B , Zeghlache D. A review on mobility management and vertical handover solutions over heterogeneous wireless networks[J]. Computer Communications, 2012, 35(17):2055-2068.
[5] Mohanty S, Akyildiz I F. A Cross-Layer (Layer 2 + 3) Handoff Management Protocol for Next-Generation Wireless Systems[J]. IEEE Transactions on Mobile Computing, 2006, 5(10):1347-1360.
[6] WANG Ruiqian, GUO Mingxiao, HAO Bin. A New Algorithm for Vertical Handoff Between LTE and WLAN [J]. Electronic Science and Technology, 2016,(04):53-55+62.
[7] BO S, LIN L, and FENG D. The multi-attribute vertical handoff algorithm based on node mobility[C]. 2014 5th IEEE International Conference on Software Engineering and Service Science (ICSESS), Beijing, 2014: 1146-1149.
[8] PAN Su, LIANG Yu, LIU Shengmei. A Multi-attribute Vertical Handoff Decision Algorithm Based on Motion Trend Quantification [J]. Journal of Electronics & Information Technology, 2016,(02):269-275.
[9] YU Chenghai, XU Libo, MA Dawei, WANG Feng, WANG Jiawen. An Improved Vertical Handoff Algorithm Based on Utility Function with Introduction of Pre-judgment and Speed Threshold [J]. Journal of Zhejiang Sci-tech University (Natural Sciences), 2016,(06):872-879.
[10] T. Velmurugan, Sibaram Khara, S. Nandakumar, B. Saravanan. Seamless Vertical Handoff using Invasive Weed Optimization (IWO) algorithm for heterogeneous wireless networks[J]. Ain Shams Engineering Journal, 2015:
[11] Sandra Brigit Johnson, Saranya Nath P, TVELMURUGAN.. An Optimized Algorithm for Vertical Handoff in Heterogeneous Wireless Networks[C], Proceedings of 2013 IEEE Conference on Information and Communication Technologies (ICT 2013)
[12] Guo Qiang, Zhu Ruohan, Zhang Xiaomeng. Fuzzy neural network based on genetic tabu algorithm to optimize vertical switching algorithm[J]. Application Research of Computer, 2016,(03):840-842+847.
[13] Liu Xia, Jiang Lingge. A Novel Vertical Handoff Algorithm Based on Fuzzy Logic in Aid of Grey Prediction Theory in Wireless Heterogeneous Networks[J]. Journal of Shanghai Jiaotong University(Science),2012,(01):25-30.
[14] SuKyoung Lee, Kotikalapudi Sriram, Kyungsoo Kim, Yoon Hyuk Kim, Nada Golmie. Vertical Handoff Decision Algorithms for Providing Optimized Performance in Heterogeneous Wireless Networks[C]. IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 58, NO. 2, FEBRUARY 2009.
[15] Wenson Chang, Heng-Tien Wu, Yinman Lee, Szu-Lin Su. Efficient Load-Aware Vertical Handoff for HetNet with Poisson-Point-Process Distributed Traffics[C]. IEEE Wireless Communications and Networking Conference (WCNC 2016).

[16] LIU Jun, LI Xiaonan. Handover algorithm for WLAN/cellular networks with analytic hierarchy process [J]. Journal on Communication, 2013,(02):65-72.

[17] R. Fletcher and S. Leyffer, Numerical experience with lower bounds for MIQP branch-and-bound[J]. SIAM J. Optim., vol. 8, no. 2, pp. 604–616, 1998.

[18] The CVX Users’ Guide Release 2.1. Available: http://cvxr.com/cvx/doc/

[19] Hu Xiao. Research and Development on Handover Technology in Heterogeneous Wireless Network [D]. Beijing Jiaotong University, 2016.

[20] 3GPP. QoS Concept and Architecture[S], TS 23.107 (v9. 2.0), June 2011.