Research on Energy Consumption Optimization Technology of Heterogeneous Network in Computer Communication Industry

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Abstract. In the environment of heterogeneous network nodes, the virtual network mapping problem of energy consumption optimization is not to minimize the number of working nodes and links. In order to study the energy consumption analysis of multi-mode terminals in wireless heterogeneous networks, by investigating the working mechanism of the terminal, using the energy-aware virtual network mapping heuristic algorithm to describe the communication state of the terminal, the energy consumption analysis equation of the terminal is obtained. The analysis results show that terminal energy consumption increases with the increase of call arrival intensity and call duration; the ratio of terminal energy consumption to voice services and the probability of discovering heterogeneous networks are in an approximately linear relationship; the heterogeneous network modules enter low energy consumption waiting state does not save terminal energy consumption.

Keywords: Computer communication, heterogeneous network, energy consumption, optimization, heuristic algorithm.

1. Introduction
Heterogeneous network, that is, superimposed deployment of a large number of small cells within the signal coverage of traditional macro base stations, is a new type of network architecture that can effectively increase cellular network capacity. In addition, as the service distance becomes shorter, heterogeneous networks can also greatly improve the quality of service (QoS) for cell edge users. However, it is impractical to deploy a high-speed backhaul link for each small cell to access the core network. Therefore, a backhaul link with a limited rate has become a bottleneck for the improvement of heterogeneous network capacity. Studies have shown that most of the mobile data transmitted in cellular networks is repeated, such as some popular program videos. In a cellular network, repeatedly sending the same content to different users through the backhaul link seriously wastes network resources, and easily causes network congestion and high user service delays. If the content required by users is scattered and stored in small cell base stations to make the content closer to users, it can effectively solve the problems of high latency and high congestion during peak network transmission. This is the so-called edge cache technology [1]. Based on the above factors, the combination of
heterogeneous network and edge cache technology can effectively alleviate the load on the network backhaul link and reduce the service delay of the heterogeneous network.

At present, since the energy consumption of network nodes and links is not sensitive to traffic load, operators can achieve energy saving by putting idle nodes and links in the network in low power consumption mode or even shutting down under the premise of meeting virtual network resource requests. To this end, this paper studies the virtual network mapping problem of heterogeneous energy consumption optimization of network nodes. First, establish the load energy consumption model of network nodes and links, and with the goal of minimizing the energy consumption of the mapping, construct the mathematics of the virtual network mapping problem [2]. Then, a heuristic algorithm for energy-aware virtual network mapping is designed to solve the model.

2. System Model

2.1. Heterogeneous network model

This article considers a heterogeneous network with a two-tier structure, including one MBS and multiple SBSs. The overall network architecture is shown in Figure 1. Figure 1 in a two-layer heterogeneous network architecture network with caching capabilities, MBS and SBS are equipped with a certain amount of cache space, among them, MBS can cache $N_a$ video files, and SBS can cache $N_s$ video files. Without loss of generality, assuming that all video files are of the same size, Fbit, there are a total of $N_f$ video files in the remote server file library. In this heterogeneous network, both MBS and SBS can be directly connected to the back-end core network, that is $P_s$, both MBS and SBS can directly request content services from remote servers. The network adopts a closed access strategy. Only SBS authorized users can connect to SBS, and non-SBS authorized users cannot connect to SBS, even if the user is very close to SBS. However, SBS authorized users can establish a connection with MBS. In order to avoid inter-layer interference, it is assumed that the spectrum resources used by MBS and SBS are orthogonal, so that there is no cross-layer interference between macro cells and small cells [3]. The service radius of MBS is $R_m$, the service range is called macro cell, and the transmission power of MBS is $P_m$. The service radius of SBS is $R_s$, and its service range is called small cell, and the transmission power of SBS is. The macro cell and the small cell overlap, and the distribution of SBS in the macro cell obeys the homogeneous Poisson point process (HPPP) with a density of $F\lambda_s$. In this article, the transmitting units of all network nodes are single-antenna, and half-duplex working mode. In addition, this article mainly focuses on the interference problem in the macro cell, and does not consider the interference between the macro cells, which needs further study in the future.

2.2. Energy consumption model

The energy consumption generated by the virtual network request mapping to the network mainly includes two parts: node energy consumption and link energy consumption.

2.2.1. Node energy consumption. Nodes in the network mainly refer to servers, and their power consumption mainly includes two parts: basic power consumption and dynamic power consumption. Basic power consumption refers to the power consumption when the server is unloaded and has nothing to do with the load, while dynamic power consumption refers to the power consumption related to the load [4]. Existing studies have shown that the power consumption of a server node has an approximately linear relationship with its CPU utilization, while other parts of the server such as memory and storage have relatively low power consumption. Therefore, this article uses equation (1) to estimate the power consumption of network node $j$.

$$PN_j = P_b + P_d \cdot util(n_j)$$  (1)
Among them, \( P_b \) represents the basic power consumption of node \( j \), \( P_m \) represents the maximum power consumption when node \( j \) is running at full load, and \( P_d = P_m - P_b \) represents the energy consumption factor related to node \( j \) and CPU utilization \( \text{util}(n_j) \). Then, the new power consumption mapped from the virtual node \( i \) to the network node \( j \) is

\[
\Delta PN_j = \begin{cases} 
P_b + P_d \cdot \text{util}(n_j) & PS_j = 0 \\
P_d \cdot \text{util}(n_j) & PS_j = 1 
\end{cases}
\]  

(2)

Among them, \( PS_j \) indicates the state of node \( j \) before node \( i \) is mapped, \( PS_j = 0 \) indicates that node \( j \) is in a closed state, \( PS_j = 1 \) indicates that node \( j \) is in a working state, and \( \Delta \text{util}(n_j) \) indicates the newly added CPU utilization rate mapped from virtual node \( i \) to network node \( j \). Let \( x_j' \in \{0,1\} \) denote the mapping relationship between virtual node \( i \) and node \( j \). If virtual node \( i \) is mapped to node \( j \), then \( x_j' = 1 \), otherwise \( x_j' = 0 \). Therefore, the energy consumption of the virtual network request mapped to the network node is

\[
\Delta EN = \sum_{i \in N} \sum_{j \in N} x_j' \int_{t_a}^{t_b} \Delta PN_j dt
\]

\[
= \sum_{i \in N} \sum_{j \in N} x_j' \int_{t_a}^{t_b} (1 - PS_j) P_b dt + \sum_{i \in N} \sum_{j \in N} x_j' \int_{t_a}^{t_b} P_d \cdot \text{util}(n_j) dt
\]  

(3)

2.2.2. Link energy consumption. Link energy consumption mainly includes the energy consumption of sending and receiving data packets at both ends of the path (working nodes) and the energy consumption of intermediate nodes forwarding data packets. Existing research generally believes that a dedicated offline engine is deployed in network virtualization to efficiently process data packets and maintain low processing latency. The power consumption \( P_n \) of the engine is close to whether the port is running at full load or no load [5]. According to the above analysis, the power consumption of sending and receiving data packets of virtual link \( l_{uw} \) mapped to the working node of the network is

\[
P_{uw} = \begin{cases} 
P_n & PS_u = 0 \\
0 & PS_u = 1 
\end{cases}
\]  

(4)

In the same way, the power consumption of forwarding data packets mapped from virtual link \( l_{uw} \) to the intermediate nodes of the network is

\[
P_{uw} = \begin{cases} 
P_b + P_n & PS_u = 0 \\
0 & PS_u = 1 
\end{cases}
\]  

(5)

Let \( PI_j \in \{0,1\} \) denote whether node \( j \) is only an intermediate node, if node \( j \) only acts as an intermediate node to undertake data packet forwarding tasks, then \( PI_j = 1 \), otherwise \( PI_j = 0 \), then \( PI_j \) is

\[
PI_j = \min \left\{ \sum_{i \in L} x_j', \sum_{i \in L} x_j', f_{ij} \cdot \left( 1 - \sum_{i \in N} x_j' \right) \right\}
\]  

(6)
Among them, \( f_{uv}^w \in \{0,1\} \) represents the mapping relationship between virtual link \( l_{uv} \) and link \( l_{ij} \). If virtual link \( l_{uv} \) is mapped to link \( l_{ij} \), then \( f_{uv}^w = 1 \), otherwise \( f_{uv}^w = 0 \). Therefore, the link energy consumption of the virtual network request mapped to the network is

\[
\Delta E L = \sum_{w=1}^{\Delta} P_{uv} \int_{t_a}^{t_b} dt
\]

\[
= \sum_{w=1}^{\Delta} \left( \sum_{j \in N_j} \sum_{l \in L} \int_{t_a}^{t_b} (1 - PS_j) P_l dt + \sum_{w=1}^{\Delta} \sum_{j \in N_j} (1 - PS_j) (P_l' + P_n) dt \right)
\]

(7)

3. Energy consumption optimization analysis

3.1. Power control game based on user pair scheduling
In a two-layer heterogeneous network, cross-layer interference caused by spectrum reuse between cells restricts the improvement of system performance. In order to alleviate the impact of interference, a user selection power control algorithm based on non-cooperative game theory is proposed. Traditional methods generally use a random way to schedule users. Figure 1 shows the percentage of the average channel capacity of the macro cell when the macro cell link quality assurance is performed in the micro cell, when a given SINR value is exceeded [6]. Compared with other power control methods, the proposed algorithm has significant advantages in improving the average channel capacity of the macro cell.

Figure 1. Average channel capacity of macro cell

3.2. Joint optimization of partial spectrum reuse and base station sleep model
The partial spectrum reuse scheme only allows the micro cell to reuse part of the spectrum, thus reducing the interference to the macro cell and at the same time improving the energy efficiency of the network. This paper proposes a model for joint optimization of PSR and BSS. First, derive the coverage probability of macro cells and micro cells in a heterogeneous network; then, maximize the coverage probability through the best PSR factor and cell active probability; finally, based on the best PSR factor and the active probability ratio (APR) of the base station [7]. To minimize energy consumption. In a heterogeneous network, the advantages of these two technologies are combined to improve the energy efficiency of the system from the two dimensions of spectrum efficiency and base station density. Figure 2 shows the energy consumption in four cases in a heterogeneous network.
4. Design and development of energy supervision visualization system

4.1. Multi-protocol self-conversion energy data collector
The energy consumption comprehensive data collector combines water, electricity, combustible gas, heat energy carrier and other auxiliary parameter sensors to form a seamlessly connected heterogeneous network. The collector is developed based on relevant communication standards, compatible with various communication protocols, and can be flexibly applied various energy monitoring occasions. Figure 3 shows the structure of the heterogeneous network of the collector.

![Figure 3. Partial structure diagram of the collector heterogeneous network](image)

4.2. Flexible data transmission heterogeneous network
The data transmission heterogeneous network is mainly composed of multiple integrated energy data collectors, which are connected by different communication protocols, and finally realize that all integrated energy data collectors can communicate with the database server through the network [8].

4.3. Database supporting multiple storage engines
The platform database uses Oracle's Oracle database, which is a relational database management system that provides distributed processing capabilities and can easily implement data warehouse operations. Oracle database provides multiple database connection methods such as TCP/IP, ODBC...
and JDBC, and provides management tools for managing, checking, and optimizing database operations. It supports large databases and can handle large databases with tens of millions of records. Kind of storage engine. The design structure of the database is shown in Figure 4.

![Figure 4. Database structure design](image)

5. Conclusion
This paper studies the virtual network mapping problem of energy consumption optimization in the heterogeneous environment of network nodes. Due to the heterogeneous energy consumption of network nodes, the dynamic energy consumption generated by the virtual network mapping to the network is also different. At this time, the virtual network mapping problem of energy optimization is not to minimize the number of working nodes and links. Compared with traditional energy-efficient virtual network mapping algorithms, PSR and BSS methods improve the virtual network request acceptance rate and network revenue, reduce running time, significantly reduce the energy consumption of virtual network mapping, and the heterogeneity of network nodes the larger the energy consumption advantage, the more obvious.

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References
[1] Gabry, F., Bioglio, V., & Land, I. On energy-efficient edge caching in heterogeneous networks. IEEE Journal on Selected Areas in Communications, 34(12) (2016) 3288-3298.
[2] Xu, J., Ota, K., & Dong, M. Saving energy on the edge: In-memory caching for multi-tier heterogeneous networks. IEEE Communications Magazine, 56(5) (2018) 102-107.
[3] Du, R., Liu, Y., Liu, L., & Du, W. A lightweight heterogeneous network clustering algorithm based on edge computing for 5G. Wireless Networks, 26(3) (2020) 1631-1641.
[4] Wang, X., Yang, L. T., Kuang, L., Liu, X., Zhang, Q., & Deen, M. J. A tensor-based big-data-driven routing recommendation approach for heterogeneous networks. IEEE Network, 33(1) (2019) 64-69.
[5] Zhou, Z., Xiong, F., Xu, C., He, Y., & Mumtaz, S. Energy-efficient vehicular heterogeneous networks for green cities. IEEE Transactions on industrial Informatics, 14(4) (2017) 1522-1531.
[6] Wu, H., & Wolter, K. Stochastic analysis of delayed mobile offloading in heterogeneous networks. IEEE Transactions on Mobile Computing, 17(2) (2017) 461-474.

[7] Wang, T., Li, P., Wang, X., Wang, Y., Guo, T., & Cao, Y. A comprehensive survey on mobile data offloading in heterogeneous network. Wireless Networks, 25(2) (2019) 573-584.

[8] Chakareski, J., Naqvi, S., Mastronarde, N., Xu, J., Afghah, F., & Razi, A. An energy efficient framework for UAV-assisted millimeter wave 5G heterogeneous cellular networks. IEEE Transactions on Green Communications and Networking, 3(1) (2019) 37-44.