Journal of Electronics and Information Science (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/jeis.2024.090106
ISSN 2371-9524 Vol. 9 Num. 1

Research on interference coordination techniques in heterogeneous cellular networks

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Keywords: Wireless Networks, Interference Coordination, Heterogeneous Cellular Networks

Abstract: Spectrum is an important but very scarce resource in broadband wireless networks. With the rapid growth of the wireless network scale, the limited spectrum resources have been unable to meet the increasing mobile traffic. In order to relieve the network pressure and improve the utilization efficiency of spectrum resources, the spectrum resource management mechanism has received wide attention. This paper first describes the basic situation of spectrum resource shortage in wireless communication, and presents the problem of heterogeneous cellular network; then, classify the traditional interference coordination method, summarizes its advantages and disadvantages, and provide reference and help for researchers in related fields.

1. Introduction

With the booming development of mobile communication technology, the number of mobile users and data volume around the world show a blowout trend[1]. In order to realize a large number of equipment access, meet the demand of a large number of different business, the future mobile cellular network will take in the macro cellular cell running various Small Cell, such as pico base station, femto base station, relay base station Relay and Device-to-Device (D2D), form multiple heterogeneous cell network, in order to obtain cell capacity expansion, business service quality optimization, load balancing, cell edge user performance improvement such as performance gain.

As shown in Figure 1, in a macro cellular area, the multiplexing of the same frequency resources between multiple small cellular links, D2D links and macro cellular links will bring the inter-layer interference problem, which requires more complex interference coordination technology to solve. The complexity is mainly reflected in the fact that for users in the community, choosing access to different links can avoid the serious interference caused by the link transmitter being too close to the receiver of another link.

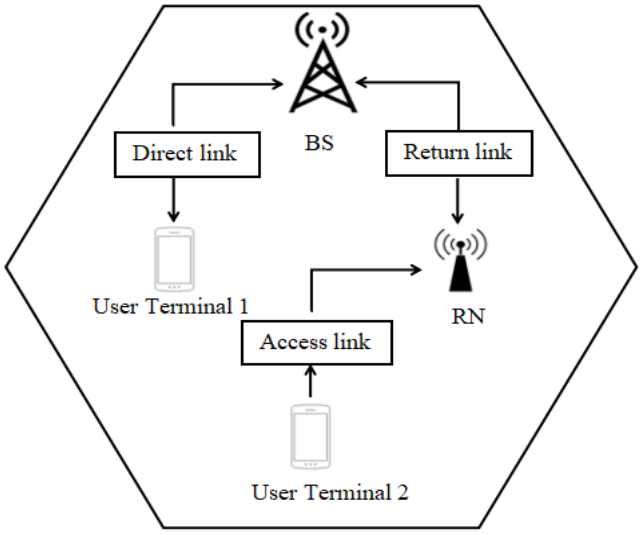

Figure 1: D2D structure diagram

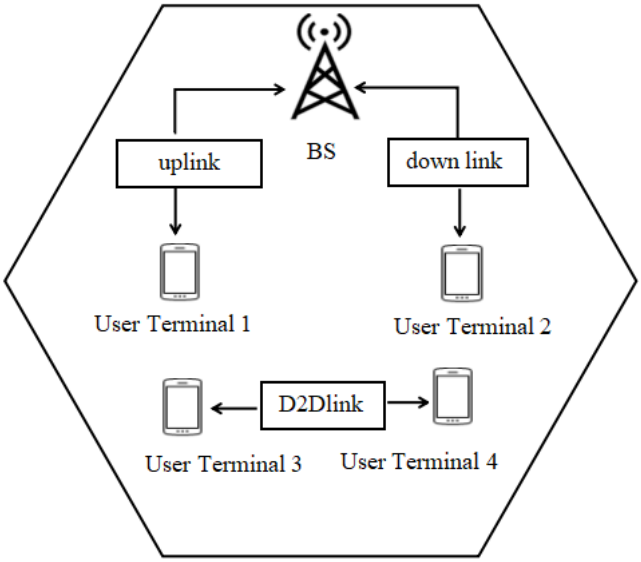

Figure 2: Relay communication structure diagram

In Figure 2, the link selection of users, link resource reuse strategy and link emission power control of reuse resources are interrelated, which determines the degree to which interference affects the system performance of macro cellular cells. The number of base stations (including macro cellular base stations, small cellular base stations and D2D transmitters), the number of users, the number of resources and the accuracy of transmission power control jointly determine the dimensions of these problems.

2. Introduction to heterogeneous networks

Heterogeneous cellular network refers to the introduction of small cellular emission nodes [3], such as Micro Base Station (MBS), Pico Base Station (PBS), Femtocell Base Station (FBS), relay node (RN), Device-to-Device (D2D). The above node features are shown in Table 1. Traditional macro cellular networks have large coverage and thus serve as the first layer of heterogeneous cellular networks. Due to the flexible deployment and low emission power, small cellular nodes are usually used as the second layer of cellular heterogeneous network to divert the macro cellular load

and improve the QoS of blind spots.

Table 1: Summary of the characteristics of each node

Base station type	transmitting power	coverage area	application scenarios
Micro base station	3-5w	100-300m	Cover of outdoor hotspots
Micro base station	Outdoor: 25 mw-2w Indoor: less than 100 mw	Outdoor: 50-100m Indoor: 30-50m	Indoor and outdoor supplementary coverage
Femtocell	Less than 100 mw	10-20m	Small indoor coverage
Relay base station	100mw-1w	300m	The edge signal is strengthened

3. Approaches to Resolving Coordinated Interference

At present, domestic and foreign researchers coordinate the coordination of heterogeneous cellular network including D2D and small cells. Through exploration and practice, the technical solutions used mainly include: heuristic interference coordination, based on convex optimization Interference coordination, based on intelligent optimization algorithm, matching theory based interference coordination, based on Interference coordination of game theory and that based on reinforcement learning.

3.1. Heuristic method

The heuristic algorithm is proposed by the relative optimization algorithm, which is an empirically constructed algorithm. It can give a feasible solution in the case of acceptable complexity. The degree of deviation from this feasible solution and the optimal solution is generally unpredictable.

Each base station is calculated according to the minimum SINR to control the distance between the same frequency interference.[4]A partial frequency multiplexing strategy was used to assign different frequency resources to different links in the overlapping regions to reduce interference. Link groups with low mutual interference are formed, frequency resources are allocated by a dynamic management algorithm based on coloring theory, and the emission power of links within the group is controlled by the lowest SINR.

3.2. Convex optimization

The convex optimization algorithm is a focal point in academia, known for its clear optimization goals, efficient computing, and robust mathematical modeling. It offers mature solutions and transforms non-convex problems into solvable convex ones, ensuring that the local optimal solution is also the global optimal solution.

In literature [5], the Charnes-Cooper transformation method is used to transform the energy efficiency maximization problem based on base station selection and resource allocation into a convex optimization problem, and the external approximation algorithm (Outer Approximation Algorithm) is used to solve it.

3.3. Intelligent optimization algorithm

To solve the optimization problem, it is difficult to solve it directly by convex optimization method, and some researchers proposed the interference coordination method based on intelligent optimization algorithm. Intelligent optimization algorithms refer to invented optimization

algorithms inspired by the intelligent behavior of certain natural phenomena or biological groups.

Literature [6] suggests an immunization algorithm for resource allocation, maximizing D2D transmission rates while ensuring QoS. Despite reliable optimization, it faces challenges like slow speed and potential local optimization in extensive solution spaces.

3.4. Game theory

Game theory is a mathematical approach to study the strategic equilibrium problem of game players when multiple individual behaviors influence each other. It considers the predictive and actual behavior of individuals in the game, and studies their optimization strategies.

Literature [7] uses the Nash Nash Bargaining model to optimize the frequency multiplexing problem between D2D and macro cells by maximizing the payout function of the bargaining coefficient, and finally obtains the optimal solution using the maximum weight maximum flow algorithm and the Lagrange multiplier method. Literature [8] models the same frequency interference coordination problem of D2D link, micro cellular link and macro cellular link into Potential Games problem, in which the player strategy is updated iteratively through Message Passing route, and finally Nash can be the equilibrium solution.

4. Conclusion

In this paper, we discuss the interference coordination problem of the heterogeneous cellular network as the core, and summarize the main technical routes to solve the interference coordination problem in recent years. Firstly, the heterogeneous cellular network architecture and features are briefly introduced, and then the research field of wireless resource management is summarized from the aspect of interference coordination, introducing the common solution theories and methods, such as heuristic algorithm, convex optimization, intelligent optimization algorithm, game theory, reinforcement learning, etc., the existing research methods and ideas to provide reference and help for researchers in related fields.

Acknowledgements

This work is supported partly by the school project of Nanchang Institute of Technology,(Project No: NLZK-23-07)

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