



Survey Paper on Hand-Over Based Load Balancing Issues in 5G Heterogenous Networks.

Ezeilo Ifeoma Kelechukwu¹, Ehikhamenle Matthew²

¹Center For Information And Telecommunication Engineering University Of Port Harcourt Rivers State, Nigeria

²Center For Information And Telecommunication Engineering University Of Port Harcourt Rivers State, Nigeria

Email : windofgreatness@gmail.com, ik.ezeilo@unizik.ed.ng, matthewehikhamenle@uinport.edu

ABSTRACT:

5G systems' quality of service is deteriorated by load imbalance in heterogeneous networks (HetNets), which happens when larger cells get crowded while smaller cells are left under utilised. The challenges presented by dynamic user behaviour and real-time traffic changes are highlighted in this paper's examination of handover-based load balancing problems in 5G HetNets. Although various solutions have been put forth, a survey of the literature reveals that there is still a significant gap in understanding these dynamic properties. We look at handover-driven strategies, such as intelligent overload management frameworks, neural network-based overload detection, and vertical handover methodologies. Simulation and experimental findings from prior studies indicate that such approaches can reduce latency and improve throughput, though trade-offs still exist in terms of signaling overhead and stability. This survey highlights the necessity for adaptive, intelligent, and real-time handover strategies to effectively mitigate load imbalance and enhance network performance in 5G HetNets.

Keywords: 5G networks; Heterogeneous networks (HetNets); load balancing; handover; vertical handover; quality of service (QoS); machine learning; intelligent optimization.

1. Introduction

The fifth generation (5G) of mobile networks was introduced to support unprecedented demands for high data rates, ultra-low latency, massive connectivity, and enhanced user experience. Central to achieving these objectives is the deployment of Heterogeneous Networks (HetNets), where macrocells coexist with small cells such as micro, pico, and femto cells. This layered architecture provides wider coverage, increased capacity, and improved spectral efficiency. However, it also introduces significant challenges in network management, particularly with respect to load balancing. The invention of the 5G network was tailored towards providing improvement to broadband speed, low latency, massive user connectivity, high wireless transmission and reception connectivity, energy management, and improved efficiency among many other benefits (Ullah et al., 2023). In the realization of these benefits, the administrators of the 5G network deployed the use of Radio Network Controllers (RNC) which allows the integration of multiple cells in a heterogeneous format (5GPPP, 2020; Okasaka et al., 2016); however, while this integration of cells has the potential to offer the afore mentioned benefits, Polgar and Varga (2023) revealed that it also has its consequences such as issues of interference, uneven distribution of resources, leading to congestion, call drop, increases energy consumption, handover failure, among, etc (Ohaneme et al., 2020; Uguru et al., 2021; Chinedu et al., 2023). Furthermore, new services for 5G networks and beyond are surely in the works thanks to mobile broadband (eMBB), ultra-reliable low latency communication (uRLLC), and massive machine type communications (mMTC). Kuruvatti et al (2019). According to Hassan and Fernando (2020), one major reason for these challenges in 5G heterogeneous network was due to the cells (micro, pico, femto, and macro) having different transmission power, data rates capabilities, coverage areas, and hence making it a challenging task for the conventional algorithms in the RNC to ensure efficient management of user equipment. Among these resulting problems of 5G HetNet, Shami et al. (2019) revealed that specifically load balancing problem has continued to gain increased research attention

Load imbalance occurs when macrocells are overutilized while small cells remain underutilized, resulting in congestion, dropped calls, increased latency, and degraded quality of service (QoS) Suresh et al. (2022). Effective load balancing in HetNets is, therefore, a critical issue in the successful deployment and operation of 5G systems. Among the various mechanisms proposed, handover-based load balancing has received considerable attention, since handovers directly determine how users are redistributed across cells.

This paper reviews the challenges related to handover-based load balancing in 5G heterogeneous networks (HetNets). It explores the main factors that cause load imbalance, discusses the role of handover processes, and highlights current solutions proposed in existing studies. Through an analysis of their performance, drawbacks, and potential improvements, the paper offers valuable insights into how adaptive and intelligent handover strategies can enhance the overall efficiency and performance of 5G networks.

2.1 Heterogeneous Networks and Their Role in 5G

HetNets consist of a mixture of cells with varying sizes, power levels, and coverage areas. Macrocells cover wide areas and provide mobility, while micro, pico, and femto cells improve localized capacity and indoor coverage. This multi-tiered deployment is essential for meeting 5G's requirements of high throughput, ultra-low latency, and energy efficiency. However, the coexistence of cells with different characteristics introduces complexity in managing interference, resource allocation, and mobility. According to Jie Zhang (2012), small cells have low power wireless access points that can use licenced or unlicensed spectrum. Small cells guarantee QoS (quality of service) by providing different sets of frequencies from neighbouring cells.

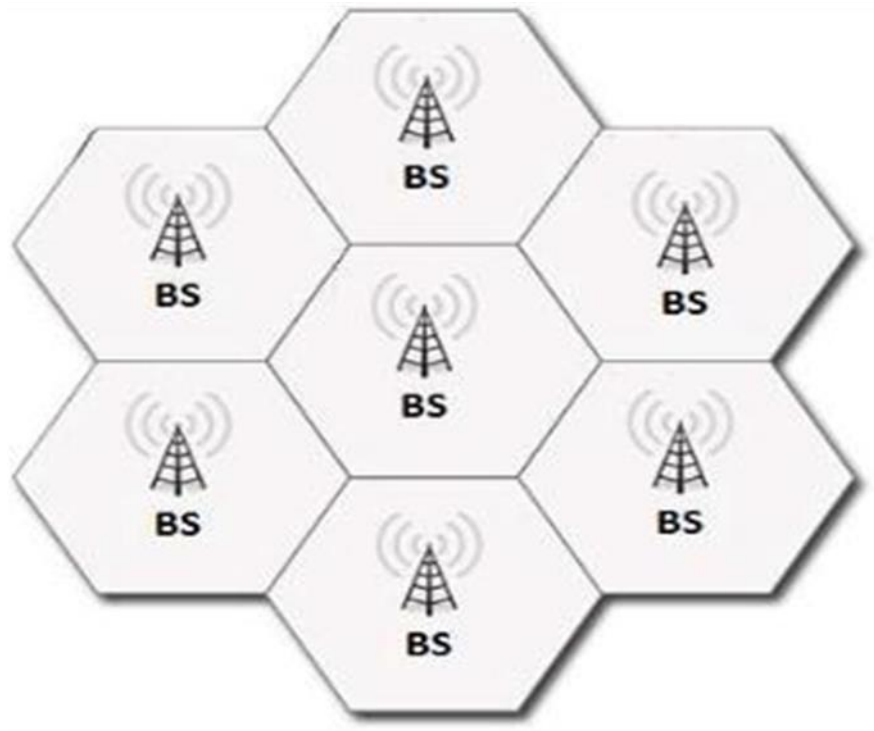


Figure2.1: Structure of a Cell (Muhammed.R.U. et al,2009)

Table2.1: Comparison of Different Types of Cellular Cells

Type of Cellular Cells	Cell radius (coverage area)	Output Power (Watt)	Application
MacroCell	1-35Km	20W-60W	Rural areas with minimum amount Of traffic
MicroCell	200m -2km	5W -10W	Urban areas with high dense traffic
PicoCell	4m– 200m	0.1W-0.5W	Building environment such as Shopping malls and subways, train stations, airport
FemtoCell	1m– 10m	0.02W -0.1W	Indoors such as offices and Residential areas

2.2 Load Balancing in 5G HetNets

Load balancing means the even allocation of network traffic among available resources to guarantee efficient utilization of cells. Without effective load balancing, macrocells become overloaded while small cells remain idle. This leads to congestion, call drops, and poor user experience. Load balancing is further complicated in 5G HetNets by:

- Variations in cell coverage areas and transmission powers
- User mobility and unpredictable behavior
- Real-time traffic fluctuations

- High service expectations such as ultra-reliable low-latency communication (URLLC)

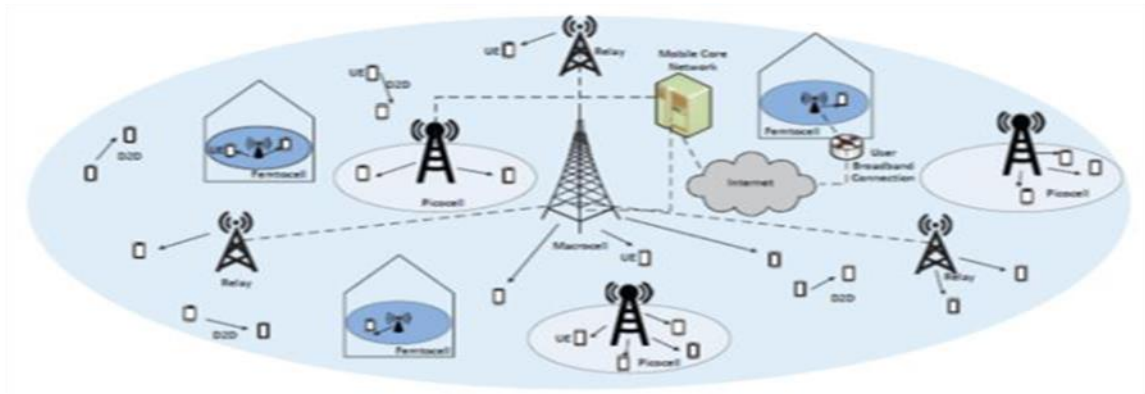


Figure 2.6 Communication in Multi-tier Network (Ekramet al, 2014)

2.3 Handover in HetNets

Handover is the process by which a user's connection is transferred from one cell to another as mobility or traffic conditions change. There are two main types:

- **Horizontal handover**, occurs between cells of the same type (e.g., macro-to-macro).
- **Vertical handover**, occurs between different cell types (e.g., macro-to-micro).

In HetNets, vertical handover is particularly important because it allows redistribution of users from overloaded macrocells to underutilized small cells. However, frequent or poorly managed handovers may increase signaling overhead, reduce throughput, and negatively affect QoS.

2.4 Existing Approaches to Handover-Based Load Balancing

Several methods have been proposed in literature which are basically classified into three approaches:

- **Reactive (Active) approaches:** These techniques apply corrective measures once congestion is detected. Examples include utility-based handover and weight-function approaches. While effective, they may react too late, after QoS is already degraded.
- **Proactive approaches:** These systems anticipate network congestion beforehand and initiate preventive handovers. This approach is largely driven by artificial intelligence and machine learning models like neural networks and clustering algorithms. For example, deep learning methods have been employed to forecast traffic trends and enhance handover performance.
- **Hybrid approaches:** Combining reactive and proactive methods to balance trade-offs between responsiveness and computational overhead.

3. REVIEWS

This section provides an extensive review of studies related to user association, load balancing methods, and the use of machine learning techniques in heterogeneous mobile networks.

Hatipoglu et al. (2020) proposed a handover-based load balancing algorithm tailored for 5G heterogeneous networks. Their approach dynamically adjusts the Handover Margin (HOM) and Time to Trigger (TTT) parameters based on user mobility and received signal reference power. The algorithm ensures an even distribution of network load among nearby base stations (BSs) while minimizing handover failures (HOF) and ping-pong effects (HOPP). Simulation results demonstrated that the proposed technique significantly reduced the standard deviation of BS loads, effectively achieving load balance and mitigating network congestion. Notably, the algorithm achieved over 60% improvement in HOF reduction and about 63% better load distribution across the network.

Similarly, Basu et al. (2020) introduced an adaptive control plane approach for load balancing within SDN-enabled 5G networks. Their framework strategically positions controller and hypervisor components across hierarchical control (H-C) planes to achieve optimal balance. The proposed method effectively maintained service latency within acceptable limits and demonstrated adaptability to various network topologies beyond the case study on AT&T's North American infrastructure. Although the study did not include detailed performance results, the authors highlighted that future work would explore AI-driven task offloading between the hypervisor and control planes to further enhance resource utilization and network efficiency.

In another study, Hasan et al. (2021) explored the use of the Constriction Factor Particle Swarm Optimization (CFPSO) technique for achieving efficient load balancing and cell association in 5G heterogeneous networks. Their model aims to improve the throughput and overall performance of 5G LTE-Advanced Heterogeneous Networks (5GLHNs) by employing intelligent load distribution mechanisms.



balancing algorithm and the CFPSO method for cell attachment. The aim of this strategy is to shift traffic of Macro eNodeBs (MeNB) Users. The study focused on transferring Macro User Equipments (MUEs) to smaller cells known as Home eNodeBs (HeNBs). The proposed method demonstrated significant performance improvements, achieving up to a 44.08% increase in throughput compared to the existing index-based method and a 94.20% improvement over the Matching with Minimum Quota (MMQ) technique, based on implementation results.

Similarly, Wang (2021) explored a cell clustering optimization algorithm aimed at enhancing load balancing in 5G networks. To evaluate the algorithm's effectiveness in balancing load, improving data transmission rates, optimizing resource allocation, and enhancing system performance, the study first reviewed existing cell-clustering methods. It then introduced an optimized cell-clustering algorithm designed for 5G network architecture, integrating both path loss and load balancing considerations. Simulation results revealed that with 80 deployed micro base stations, the proposed approach achieved a balance level of 78.48%, demonstrating a clear improvement over traditional models.

Abbasi et al., (2022) presented an efficient traffic load balancing algorithms for resource optimization in SDN-driven 5G networks. In the context of SDN-driven 5G networks, the study's goal was to achieve efficient network resource allocation while lowering Operating Expenditure (OPEX). The Heuristic Paths Re-computation (HPR) method performs exceptionally well in resource allocation within this framework. We provide two traffic load balancing algorithms, namely Load-Balancing Breadth-First Search (LBB) and Iterative-Deepening Depth-First Search (IDDFS), to improve network scalability and OPEX efficiency in large-scale 5G networks. The Depth-First Search (DFS) method is used by the suggested IDDFS algorithm to prioritise pathways with the maximum bandwidth while limiting the depth of each search. In addition, the IDDFS algorithm guarantees load balancing while drastically lowering space overhead. As a result, in comparison to the LBB algorithm, the suggested IDDFS method improves the efficiency of global optimisation and decreases or even eliminates pointless searches. The results demonstrate that the network throughput for HPR increases from 940 to 2020; for LBB, it increases from 1250 to 2570; and for IDDFS, it increases from 1330 to 3380.

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Most reviews and research papers on load balancing in 5G heterogeneous networks (HetNets) were carried out across various network environments, including Software-Defined Networks (SDNs), Internet of Things (IoT) networks, and others having different methodologies to achieve load balancing. As a result, many of these studies did not specifically focus on the unique characteristics of 5G HetNets. Because many papers on load balancing covered varied network environments and sometimes narrowed their scope to specific components, such as small cells or IoT networks, they often did not fully consider the unique challenges and characteristics of 5G HetNets. Consequently, these reviews may not provide comprehensive insights into the 5G-specific load balancing issues faced in a true heterogeneous network setting.

Methods

This paper adopts a survey methodology. A systematic review of scholarly articles, conference papers, and technical reports published between 2014 and 2025 was conducted. Sources included IEEE Xplore, Springer, Elsevier, and open-access repositories. Studies were selected based on relevance to handover-based load balancing in 5G HetNets. The selected works were then categorized according to their methodological approach (reactive, proactive, or hybrid) and evaluated in terms of performance metrics such as latency, throughput, signaling overhead, and QoS improvement.

4. Results and Discussion

4.1 Performance of Reactive Approaches

Reactive methods like UMLB-HO (Utility-based Mobility Load Balancing with Handover Minimization) have shown noticeable improvements in managing network traffic. However, their effectiveness is constrained because they only respond after congestion has already occurred, making them slower to address emerging issues.

. They may also cause increased handover failures in highly dynamic environments.

4.2 Performance of Proactive Approaches

AI-based proactive models show significant promise. Neural network models trained on real traffic datasets can predict congestion before it occurs and trigger handovers intelligently. These methods achieve improved latency reduction (up to 5–10%) and better throughput compared to reactive techniques. However, they require substantial computational resources and accurate real-time data.

- Dynamic traffic patterns: Existing models struggle to adapt in real time to sudden surges or drops in demand.
- Signaling overhead: Frequent handovers increase control signaling, leading to inefficiency.
- Interference management: Redistribution of users may increase co-channel interference if not coordinated.
- Integration with 5G features: Many solutions lack integration with advanced 5G technologies like network slicing, edge computing, and massive MIMO.

4.5 Comparative Insights

A synthesis of surveyed studies indicates that:

- Proactive handover strategies outperform reactive ones in terms of QoS metrics.
- AI/ML-based approaches offer adaptability but face issues of complexity and scalability.
- Hybrid approaches represent a promising direction, though research is still evolving.

5. Conclusion

This review emphasizes the pivotal role of handover mechanisms in mitigating load balancing challenges within 5G heterogeneous networks (HetNets). Load imbalance continues to pose significant difficulties, largely due to variations in cell capacity, user movement, and fluctuating traffic patterns. Although reactive methods offer temporary solutions, proactive and intelligent handover techniques hold greater promise for long-term efficiency. The incorporation of machine learning, edge computing, and adaptive algorithms is shaping the future direction of load balancing in HetNets. Future research should aim to develop scalable, real-time, and context-aware handover frameworks capable of seamlessly adapting to the complexities of modern mobile networks and supporting the evolution toward 6G technology.

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