

Sum-Rate Systematic Intercell Interference Coordination Techniques for 5G Heterogeneous Networks

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Abstract

In the next generation of wireless networks, small base stations are being adopted to increase the system's speed and capacity. However, this adoption increases the likelihood of inter-cell interference, which can degrade performance the system. This report discusses different approaches to managing interference that can mitigate these effects. Currently, a few techniques are already in use in 4G systems, while others have been suggested but not put into practice. The purpose of this study is to conduct an analytical examination of the different and various interference management methods that could be utilized in Heterogeneous Networks (HetNets), focusing specifically on HetNets with high density of small cells as they are expected to be part of the network topology for 5G networks and beyond. The study involved implementing time-based enhanced inter-cell interference coordination (eICIC) by establishing coordination between macro and small base stations. The results showed that robust communication with low latency is essential, and backhaul connections play a critical role in achieving this. Consequently, the network's sum-rate was increased.

Keywords: HetNet, Sum-rate, Interference, eICIC

1. Introduction

The previous trend of mobile communications that mainly focused on voice services is no longer relevant today. Presently, the increased usage of mobile devices centers around the need for data services that offer rapid data transmission rates to cater to various smartphone applications and other multimedia services. To monitor and anticipate the present and future consumption of mobile data communications, Cisco, a leading networking equipment manufacturer, produces an annual publication known as the Virtual Network Index (VNI) report. The report provides valuable insights into the trends and patterns of mobile data usage, enabling businesses to make informed decisions regarding their network infrastructure and mobile communication strategies. The latest produced VNI complete forecast updated record of 2017 to 2022 shows that the global IP traffic raised 3-fold between the year 2017 to 2022 with 26% Compound Annual Growth Rate (CAGR) (Barnett et al., 2018). According to a report from February 2015, the amount of mobile data traffic around the world increased by 69 percent in 2014, which is approximately 30 times more than it was in 2000. Moreover, a study conducted by Ghosh and colleagues in 2012 revealed that the demand for mobile data has been increasing by 100 percent each year since 2008. This trend suggests that there may be a 1000-fold increase in demand from 2007 to 2016.

In the past, various techniques were used to manage interference in mobile communications such as GSM, CDMA, and WCDMA. The rapid development of new technologies such as small cells deployment, advanced radio access technologies, and new backbone connections has brought about the need for new interference management techniques in next-generation HetNets. Traditional methods may no longer be effective in addressing the upcoming challenges posed by these advancements. To address these challenges, researchers are exploring and evaluating new interference

management techniques to determine their effectiveness in dealing with the anticipated high levels of interference. These techniques are specifically designed to improve the output of small cell edge users and ensure equitable utilization of cells across different tiers in HetNets.

One such technique currently employed in LTE-A is time-based Enhanced Inter-cell Interference Coordination (eICIC). eICIC focuses on enhancing the sum-rate performance of small cell edge users while also ensuring that cells across different tiers are utilized fairly. It operates by exploiting the differences in propagation delay between small cells and macro cells to mitigate inter-cell interference. Overall, the need for new interference management techniques arises from the significant changes in the network architecture and advancements in technology. eICIC is an example of a technique that has been developed to address these changes and has proven to be effective in mitigating interference in HetNets. However, ongoing research and evaluation of new techniques will continue to be necessary to ensure efficient and effective network performance.

Numerous scholars have conducted research to devise an analytical framework that can be employed in Heterogeneous Networks (HetNets) for interference management techniques. HetNets are networks that comprise various types of nodes with different characteristics, such as different frequency bands, transmission power, and transmission range. The interference between these nodes can adversely affect network performance, and therefore, it is crucial to mitigate it. To address this issue, researchers have proposed various interference management techniques. However, it is challenging to compare and evaluate these techniques due to the heterogeneity of the network nodes. Therefore, an analytical framework is required to assess the performance of these techniques systematically.

This analytical framework should take into account various factors, such as the number and type of nodes, network topology, interference models, and the type of interference management technique used. The framework should also consider the impact of various parameters, such as the transmission power, bandwidth, and channel conditions). Faizan et al. (2017) carried out a review on Coordinated Multi-Point Operation for LTE-A with a brief insight into the CoMP technology comprising of its architecture, sets, and potential methods that can be employed in the future network. Analysis of the effect of improved Inter-Cell Interference by (Jember et al., 2021) also discussed these issues. Long-Term Evolution-Advanced (LTE-A) technology is a high-speed wireless communication standard that has become widely used in recent years. One of the challenges in deploying LTE-A networks is optimizing the network topology to achieve maximum performance. In heterogeneous networks (HetNets), which consist of multiple types of base stations with varying coverage and capacity, achieving an optimal topology is particularly challenging.

One potential solution to this challenge is enhanced inter-cell coordination (eICIC), which involves the coordination of neighboring cells to reduce interference and improve network performance. eICIC can be implemented through several techniques, including almost blank subframe (ABS) and coordinated multipoint (CoMP). ABS involves the selective disabling of certain subframes in a cell to reduce interference with neighboring cells, while CoMP involves the coordinated transmission and reception of data between multiple cells.

Simulations have shown that eICIC can significantly improve HetNet topology metrics, particularly in dense urban environments. ABS can improve coverage probability by up to 80% and average user throughput by up to 60%, while CoMP can improve spectral efficiency by up to 50%. However, the effectiveness of eICIC depends on several factors, including the density of base stations, the level of coordination between cells, and the type of eICIC technique used. eICIC is a promising solution for improving the topology of HetNets in LTE-A technology. By reducing interference and improving network coordination, eICIC can significantly improve coverage probability, average user throughput, and spectral efficiency. Future research should focus on optimizing the implementation of eICIC to maximize its benefits in different environments and deployment scenarios. The statement suggests that there are ongoing investigations concerning certain ideas that were presented, and these ideas are likely to undergo modifications as they undergo standardization. Standardization refers to the process of establishing a uniform set of rules and guidelines for a specific technology or industry. The analysis was carried out using the Cell Range Extension technique, which allows for the extension of the coverage area of a cell by increasing the maximum distance between the cell and its users. Overall, the statement highlights

ongoing research efforts aimed at improving the performance of LTE-A networks through the adoption of Enhanced Inter-Cell Interference Coordination and Cell Range Extension techniques.

In the work of (Jyothsna et al., 2021) which interference is mutual between Pico cell Macro cell within Long Term Evolution – Advanced (LTE-A) framework was analysed. Aerial–Ground Interference and UAV Placement Coordination was studied by (Kumbhar and Guvenc, 2020) where optimized location and placement problem of UABS in an AG-HetNet making use of the genetic algorithm with descriptions of the definition of fifth percentile spectral efficiency and the UABS-based AG-HetNet model, different path-loss models as a function of network parameters. Rayleigh fading channel was used in presenting AG-HetNet design guidelines. Finally, they analyse and compares the fifth percentile spectral efficiency of the HetNet using extensive MATLAB for simulation for various intercell interference coordination techniques.

As mobile networks transition from 4G to 5G, one of the biggest challenges they face is managing interference between different cells in the network. This is especially important as networks become more densely populated with macro and small cells working together in what's known as a Heterogeneous Network (HetNet), in order to provide high data rates.

The 3GPP system, which includes both LTE and its evolution towards 5G, has developed a solution called the Enhanced Inter-Cell Interference Coordination (e-ICIC) framework. One key component of this framework is the Almost Blank Subframe (ABS) scheme, which is designed to mitigate interference between small cells and macro cells.

The way the ABS works is by muting some of the macro cell transmissions in selected subframes. This decreases interference to small cells and helps to orthogonalize macro and small cell transmissions in the time-domain. In other words, it helps to ensure that macro and small cell transmissions don't overlap in time and interfere with each other.

Overall, the e-ICIC framework and the ABS scheme are critical tools for managing interference in HetNets and ensuring that mobile networks can continue to deliver high data rates as they transition to 5G. This is evidence in the work of (de Melo et al., 2021) where average convergence/divergence methods based on knowledge of trading were used to propose a real time ABS e-ICIC algorithm.

Section two of this work presents an overview of mobile networks. Section three presents a detailed discussion on the degree of interference in next generation networks. Section four is the simulation results and section five are the conclusion.

2. Heterogeneous Networks

Heterogeneous mobile networks (HetNets) are mobile networks consisting of both high-power and low-power base stations arranged in layers, as depicted in Figure 1.

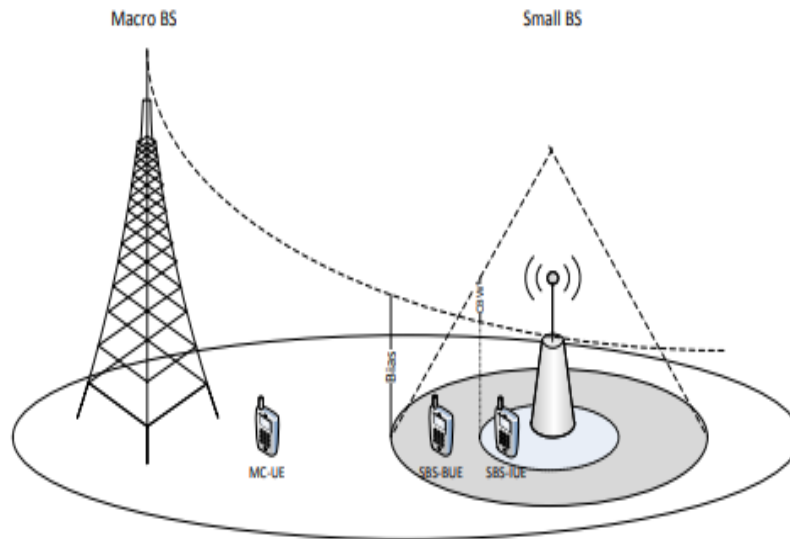


Figure 1: Macro and Small Cell Deployment (Ghosh et al., 2012).

2.1 Network Densification

A common method of meeting the increasing demands of mobile data traffic is to deploy more base stations to improve spectral efficiency. However, this approach is becoming less feasible as it increases costs and energy consumption. A way to approach this in simpler terms is by using low power nodes known as Small Base Stations, which is a more innovative method. Small base stations come in different types such as Micro Base Stations, Pico Base Stations, and Femto Cells. These small cells are designed to transmit signals outdoors using lower power, usually between 250 milliwatts to 2 Watts. (Damjanovic et al., 2011). To improve network coverage and capacity, telecommunication companies add small base stations to their existing Macro base station networks. This creates a Heterogeneous Network, which includes multiple layers of base stations. In this network, Macro base stations offer wider coverage, while small base stations are installed in targeted areas where coverage may be weak or where there is high traffic (Ghosh et al., 2012).

2.2 Interference Challenges for HetNets

As the demand for mobile network increases, it is important to use the physical resources on the wireless channel efficiently. One way to achieve this is to use all the available bandwidth in every base station. However, if all base stations use the entire frequency, interference will also increase. In Heterogeneous Networks (HetNets), which have a dense network of different tiers of base stations, the interference between the small-cells, macro-cells and interference that occurs between two neighbouring small cells or macro cells, also known as intra-tier interference is a significant concern when designing a network.

Compared to homogeneous networks (HomoNets), HetNets face more significant interference difficulties due to several factors. One of the main reasons is the difference in power transmission between small cells and macro-cells. Small-cells typically have a lower transmission power compared to macro-cells, which can lead to interference issues when both types of base stations are deployed in the same area. Interference occurs when the signal from one cell interferes with the signal from another cell, leading to a reduction in network performance.

Another factor contributing to interference in HetNets is the high number of base stations. HetNets can comprise several small cells and macro cells within a given area, leading to a higher density of base stations. This increased density can cause intercellular interference, where multiple base stations compete for the same frequency resources, leading to a degradation in network performance.

Furthermore, the utilization of multi-tiers for network topology is another factor that can lead to interference difficulties in HetNets. Multi-tier HetNets involve several layers of base stations, with small cells deployed under macro

cells. The different tiers use different frequency bands, and the deployment of small cells in the same frequency band as macro cells can cause interference.

To overcome these interference difficulties, several techniques have been developed, including interference management, spectrum allocation, and power control. Interference management involves coordinating transmissions between base stations to minimize interference, while spectrum allocation ensures that each base station operates on a different frequency band to avoid interference. Power control involves regulating the transmission power of base stations to ensure that each base station operates within its coverage area and does not interfere with other cells.

In conclusion, HetNets face more significant interference difficulties compared to HomNets due to several factors, summarized as differences in power transmission, a high number of base stations, and the utilization of multi-tiers for network topology. However, with the development of various interference management techniques, HetNets can provide enhanced network coverage and capacity, making them an integral part of the evolving wireless communication ecosystem. (Hossain et al., 2014). Furthermore, end-users or Closed Subscriber Groups (CSG) may deploy base stations that can cause interference and limit public access.

2.3 Introduction to Interference Management Techniques

As mobile technology has advanced over time, the way we use the available spectrum has also changed. We now use techniques like multiplexing and multiple access to make better use of the available bandwidth. However, there is a downside to this approach. When we increase the bandwidth utilization, we increase the possibility of frequency interference. Inter-cell Interference (ICI) is a problem that occurs frequently in mobile networks. There are several factors that can affect ICI, including the layout of the cell, the pattern of frequency reuse, the transmission power used, and the techniques used for multiple access. One major factor that influences ICI is the system bandwidth. Throughout time, the capacity of the system to handle data has grown from 200 kilohertz during 2G GSM, to 5 megahertz during 3G WCDMA (Wideband Code Division Multiple Access), and finally to 20 megahertz with 4G LTE. However, the range of frequencies available for mobile communication has not expanded, leading to potential issues in accommodating the increase in data capacity. To meet future mobile requirements and provide higher data rates, we need to increase spectrum efficiency (Zhou et al., 2014).

In older mobile generations, a technique called Interference Management (IM) was used to manage signal interference. For example, in 2G systems, a method called Cell-Planning was used in GSM networks. To improve network efficiency, we used frequency re-use strategies across the network layout. To clarify, we applied a frequency re-use factor of "n" in each location area. This means that every frequency that was utilized in one cell was also used in another cell that did not have the same frequency. The purpose of doing so was to prevent any interference between cells that had similar frequencies. To illustrate this, Figure 2 shows a typical hexagonal cell layout used in a GSM system (Goldsmith, 2005).

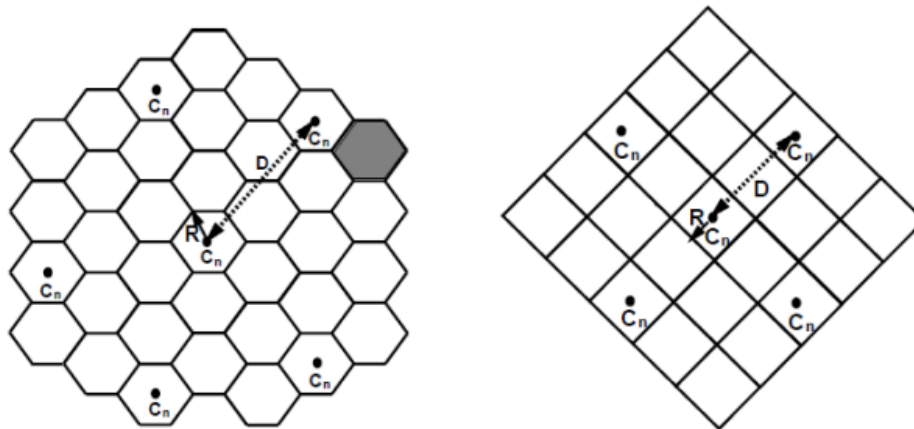


Figure 2: Hexagonal Layout for Cellular Planning (Zhou et al., 2014)

In 3G networks, the radio interface uses a technique known as code division multiple access (CDMA) to operate. This technique allows multiple users to share the same frequencies while each user is assigned a unique spreading code. Due to this method, the coefficient of frequency reuse is one (1). In CDMA systems, there is a known issue called the near-far problem. This happens due to the fact that all mobile stations (MS) transmit with the same power, which means that signals from MSs located near the base station (BS) are received with greater strength than signals from MSs located at the edge of the cell. To tackle this problem, power control techniques are employed at the BSs to adjust the transmission power of each MS (Zhou et al., 2014).

In mobile network systems, the bandwidth of the available frequency spectrum determines the maximum amount of data that can be transmitted over the network. To improve the mobile network performance, newer 4G systems like LTE and LTE-A have implemented certain changes, including the use of a wider bandwidth of 20 MHz.

By increasing the bandwidth, the amount of data that can be transmitted over the network is also increased, leading to faster data transfer rates. This is because more frequency spectrum is available for data transmission, enabling more data to be transmitted simultaneously.

Another key modification in these newer systems is using transmissions technique called Orthogonal Frequency Division Multiplexing (OFDM) in the air interface. OFDM allows for the efficient transmission of large amounts of data over the network by dividing the available frequency spectrum into multiple subcarriers, each carrying a small amount of data.

By dividing the data into small subcarriers, OFDM allows for more efficient use of the available frequency spectrum, reducing interference and improving the overall quality of the transmitted signal. Additionally, OFDM also enables better resistance to fading and multipath propagation, which can often cause signal distortion and affect network performance.

The use of a wider bandwidth and OFDM transmission technique in newer 4G systems like LTE and LTE-A helps to improve mobile network performance by increasing data transfer rates, reducing interference, improving signal quality, and providing better resistance to signal distortion. Older 2G and 3G systems relied on a technique known as IM, which is not suitable for the increased demands of modern mobile networks. To address this issue, the industry is now exploring the use of Homogeneous Networks (HomoNets) in the 3GPP LTE release 8/9. HomoNets aim to improve network performance by combining multiple base stations of various sizes and capacities into a single network. By doing so, the network can more effectively manage data traffic and provide more consistent and reliable service to users. In essence, these changes in technology and network architecture are geared towards providing users with faster and more reliable mobile network service. They are designed to accommodate the increased demand for data transfer and to improve network efficiency, all while ensuring the best possible user experience. These networks utilize frequency based inter-cell interference coordination (ICIC) schemes, one of which is fractional frequency reuse (FFR), depicted in figure 3. FFR divides each cell into two areas, namely the cell edge and the cell center, and the frequency into a major band and a minor band. The major band with a suitable frequency reuse factor is used by cell edge mobile stations (MSs), while the minor band with a frequency reuse factor of one is used by cell center MSs. This is because the base station transmits at a low frequency in the minor band, thereby avoiding interference with other cells (Zhou et al., 2014).

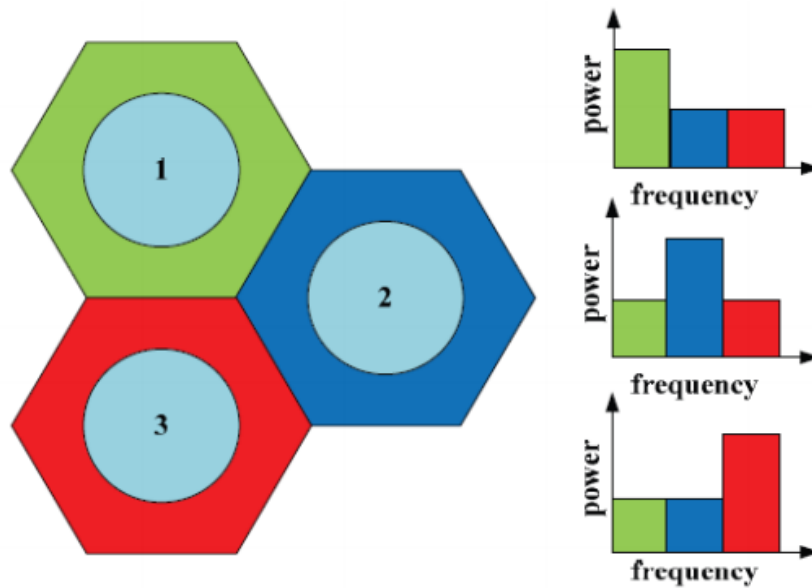


Figure 3: Soft Reuse Cellular Planning (Kumbhar et al., 2019)

2.4 Time-Domain Enhanced Inter-cell Interference Coordination (eICIC)

Time-Domain Enhanced Inter-cell Interference Coordination (eICIC) is a technique used in wireless communication networks to manage inter-cell interference (ICI). ICI is a phenomenon where signals from multiple cells interfere with each other, reducing the signal quality and capacity of the network. eICIC is designed to mitigate this interference by allowing cells to coordinate their transmission schedules. Specifically, eICIC allows cells to allocate different time-domain resources (i.e., time-frequency blocks) to different users in different cells. In other words, the cells can coordinate their transmissions such that they do not interfere with each other. There are two main types of eICIC: almost blank subframes (ABS) and range expansion (RE). In ABS, some subframes are designated as "blank" or "almost blank," meaning that the cell does not transmit any data during those subframes. This reduces the interference experienced by neighboring cells during those subframes. In RE, the cell reduces its transmission power in certain areas of the cell, such as near the cell edge, to reduce interference with neighboring cells. eICIC is particularly useful in heterogeneous networks (HetNets), where cells of different sizes and capacities are deployed in the same area. In HetNets, interference can be particularly problematic, and eICIC can help to improve network performance and capacity to increase mobile network capacity, a second tier of Small Cells (SCs) is being introduced alongside the existing Macro Cells (MCs). However, this comes at a cost of higher interference levels. Since MCs transmit at higher power than SCs, the SCs can only be effectively used by users in close proximity. One way to deal with this problem and encourage more use of SCs is to add an offset value called Cell Range Expansion (CRE) to the received power of the SCs. This makes their signal strength stronger compared to MCs (Arulselvan et al., 2013). Figure 4 depicts user location and RSS from each Base Station (BS). Adding the bias value results in a group of users who are at a disadvantage between the coverage areas of the SCs and MCs. These users are drawn towards SCs because of the CRE, but they experience significant interference from MCs, which transmit at higher power (Arulselvan et al., 2013).

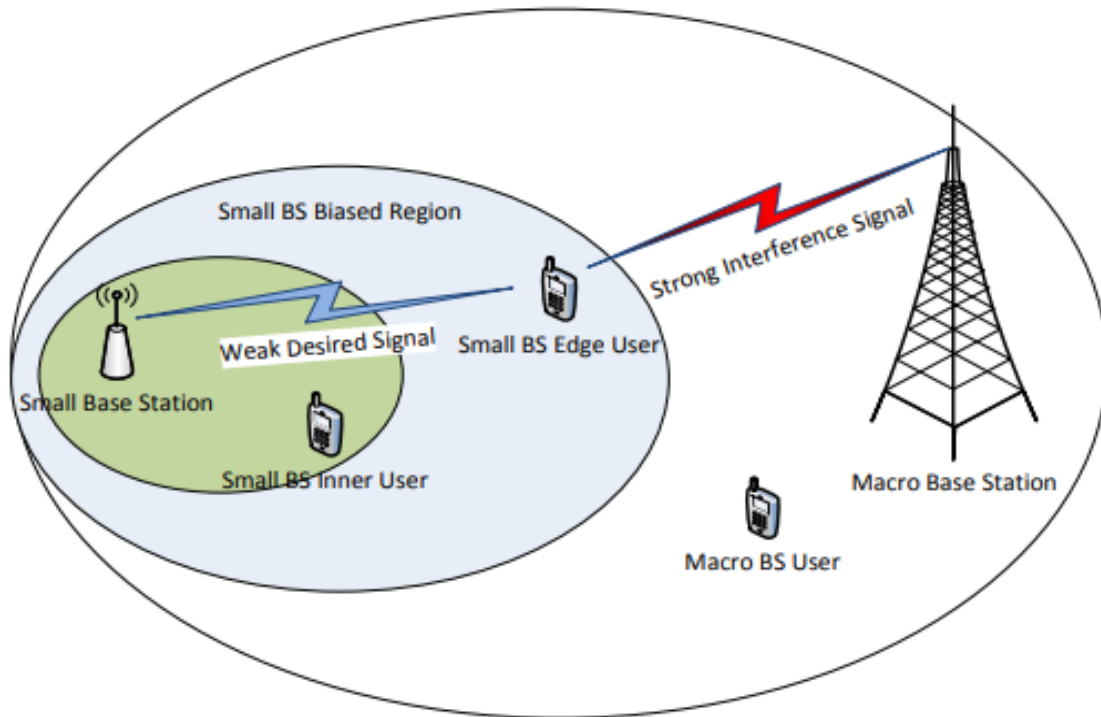


Figure 4: Cell Selection with Cell Range Expansion (Arulselvan et al., 2013)

The 3GPP introduced a method called Enhanced Inter-cell Interference Coordination (eICIC) used for protecting the downlink-service of the Small Cells to the users on the edge. This method manages the allocation of resources between two types of users in LTE, namely MCs (Macro Cells) and SCs (Small Cells). The downlink frame structure in LTE consists of 10 sub-frames, which can be scheduled to serve either MC or SC users. Each sub-frame can be classified as a conventional sub-frame or an Almost Blank Sub-frame. In the conventional sub-frames, both MC-UE and SC-IUE are served as usual. During ABS sub-frames, the SC serves only the SC-BUE, and the MC refrains from transmitting to prevent any disruption to the SC-BUE's signal. The introduction of ABS sub-frames to the downlink frame benefits the SC-BUEs, as they gain some throughput from the overall capacity. After ABS sub-frames are introduced, the system's overall performance decreases to approximately 33 Mb/s. The reason behind this is that the number of single-carrier baseband processing unit endpoints (SC-BUEs) is lower compared to the multi-carrier user equipment (MC-UEs) and single-carrier intermediate frequency processing unit endpoints (SC-IUEs). Hence, when specific sub-frames are assigned to cater to the SC-BUEs, it results in a reduced availability of resources for the MC-UEs and SC-IUEs. This can lead to a decrease in the quality of service (QoS) experienced by the MC-UEs and SC-IUEs. To elaborate further, the allocation of resources to different types of endpoints plays a crucial role in ensuring an optimal user experience. The availability of resources depends on several factors, including the number of endpoints of each type, the frequency of resource allocation, and the amount of data being transmitted. In the case of SC-BUEs, due to their lower number, their allocation of resources can impact the overall resource availability for other types of endpoints. As a result, it becomes crucial to carefully allocate resources to ensure that all endpoints receive optimal QoS. As the ratio of ABS (Almost Blank Subframes) increases in a wireless communication system, the overall sum capacity of the system decreases. However, increasing the ratio of ABS can improve the throughput of SC-BUEs (Small Cell-Base Station User Equipment). Nevertheless, it will also reduce the total throughput of MC-UEs (Macro-Cell User Equipment) and SC-BUEs.

3. Methodology

It is challenging to simulate a wireless network model because of its complexity, especially when examining multi-tier networks. Therefore, certain assumptions are made to simplify the analysis of the IM techniques while considering the basic deployment requirements. These assumptions include:

- The network has two levels: Macro and Small Cells. This means that the wireless network is comprised of two types of cells, which are the Macro and Small Cells. The Macro cells are the larger cells that cover a wider area, while the Small Cells are the smaller cells that cover a smaller area.
- The values for Small Cells are based on typical specifications by 3GPP, and they are assumed to be planned by the operator and have a fixed structure. This means that the Small Cells are assumed to be planned and deployed by the network operator and follow standard specifications set by the 3GPP (Third Generation Partnership Project). They are also assumed to have a fixed structure, which simplifies the analysis.
- The network does not take power control features into account for Macro or Small Cells. This means that the power levels of the Macro and Small Cells are assumed to be fixed and not controlled by any power control mechanism, which simplifies the analysis.
- The simulation is conducted in a city outdoor setting, with users evenly spread out and no movement considered. This means that the simulation is conducted in an outdoor setting in a city environment. The users are assumed to be evenly spread out, and their movement is not considered, which simplifies the analysis.
- Both tiers use the licensed spectrum, and the cell layout follows a hexagonal shape. This means that both the Macro and Small Cells use licensed spectrum, which is assumed to be available. The cell layout for both tiers is assumed to follow a hexagonal shape, which is a standard layout used in wireless networks.
- All base stations in both levels use omni-directional antennas. This means that all the base stations in both the Macro and Small Cells use omni-directional antennas, which radiate the signal equally in all directions. This assumption simplifies the analysis by eliminating the need to consider directional antennas.

In this research work, seven large cell towers were set up in a hexagonal pattern, with three smaller cell towers placed within the coverage area of each large cell tower. All the base stations used antennas that transmit signals in all directions. The large cell towers were spaced 500 meters apart, while each small cell tower was positioned at a distance of 0.3 times the distance between the large cell towers. MATLAB was used as a simulation tool. Below you can find more details about the simulation parameters in Table 1.

Table 1: Simulation Parameter

Parameter		Value	
Environment Scenario		Outdoor Urban	
Carrier Frequency		2 GHz	
Bandwidth		10 MHz	
Macro Base Station	Number	7	
	ISD	500m	
	Transmission Power	46dBm	
	Antenna Pattern	Omni	
Small Base Station	Number	21	
	Distance to MC	0.3 ISD	
	Transmission Power	30dBm	
	Antenna Pattern	Omni	
Active Users	Distribution	Random Distribution	
	Number	32	
	Mobility	N/A	
Channel	Path Loss	MC-UEs	$128.1+37.6\log_{10}(R[\text{km}])$
		SC-UEs	$140.7+36.7\log_{10}(R[\text{km}])$
	Shadowing		10dB
Physical Resource Allocation		LTE standard OFDMA Frame	
		50 PRB	
		Multi-User Diversity	
Monte-Carlo Iterations		50000	

The simulation uses a general algorithm to calculate the SINR. To obtain the SINR values for user k , a set of equations is used to calculate the SINR values for MC-UEs, SC-BUEs, and SC-IUEs:

$$SINR_{SC-BUE}(k) = \frac{P_{Rx}(SC)}{\sum_{i=1, i \neq k}^S P_i(SC) + N_0} \tag{1}$$

$$SINR_{SC-BUE}(k) = \frac{P_{Rx}(MC)}{\sum_{i=1, i \neq k}^M P_i(MC) + \sum_{i=1, i \neq k}^S P_i(SC) + N_0} \tag{2}$$

$$SINR_{SC-BUE}(k) = \frac{P_{Rx}(SC)}{\sum_{i=1, i \neq k}^M P_i(MC) + \sum_{i=1, i \neq k}^M P_i(SC) + N_0} \tag{3}$$

In simpler terms, “ $P_{Rx}(SC)$ ” represents the power of the signal received from small cells (SCs), while “ $P_{Rx}(MC)$ ” represents the power of the signal received from macro cells (MCs). “ $P_i(MC)$ ” represents the interference signal power from neighboring macro cells, and “ $P_i(SC)$ ” represents the interference signal power from neighboring small cells. “ N_0 ” represents the noise power. “ S ” and “ M ” represent the total number of small cells and macro cells, respectively.

4. Result

4.1 Sum Capacity with ABS

In order to achieve the best ABS sub-frame ratio, it's important to take into account fairness in serving different types of users, including MC-UEs, SC-BUEs, and SC-IUEs. Optimizing the ABS ratio can greatly improve the performance of HetNets, which has been the focus of other studies on eICIC optimization. This particular study aims to explain the technique's concepts and highlight its advantages and trade-offs. Figure 5 displays the sum capacity of HetNet using eICIC.

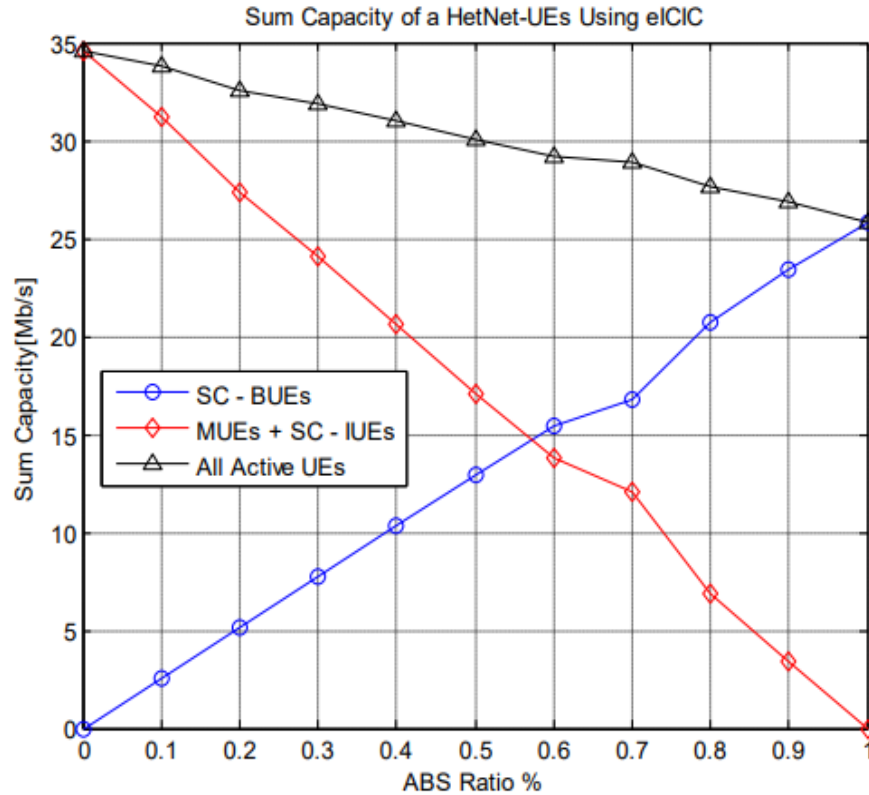


Figure 5: Capacity Variation with Different ABS Subframe Ratio

4.2 ABS and CRE Relation

Figure 6 is a graph that shows the sum capacity of a HetNet with 10% ABS and an increasing number of sub-frames. The sum capacity refers to the total amount of data that can be transmitted through the network. The sub-frames are the basic units of time in the LTE network, and an increase in the number of sub-frames means that more time is available for data transmission.

In communication networks, the term "sum capacity" refers to the maximum amount of data that can be transmitted through the network. This is influenced by various factors such as bandwidth, modulation, coding schemes, interference, and signal-to-noise ratio.

In the Long-Term Evolution (LTE) network, the time is divided into equal slots called sub-frames, which are the basic units of time for transmitting data. Each sub-frame consists of a fixed number of symbols, and the duration of a sub-frame depends on the system bandwidth.

An increase in the number of sub-frames means that there is more time available for transmitting data. This can be achieved by reducing the duration of each sub-frame or increasing the overall duration of a transmission cycle.

However, increasing the number of sub-frames can also lead to an increase in interference and a decrease in signal-to-noise ratio, which can negatively impact the overall network performance. Therefore, network designers need to carefully balance the number of sub-frames with other factors such as system bandwidth, modulation, and coding schemes to optimize the network's sum capacity while maintaining a satisfactory level of network performance.

The graph shows that as the number of sub-frames increases, the sum capacity of the HetNet also increases. This is because more time is available for data transmission, and therefore more data can be transmitted through the network. However, the graph also shows that there is a limit to the increase in sum capacity, and beyond a certain point, the increase in sub-frames does not lead to a significant increase in sum capacity. There are four (4) curves in the figure, each representing different CRE values, which show how the CRE biasing parameter affects the required number of ABS sub-frames. As the CRE value is raised, greater number of active UEs switch to the SCs from MC, resulting in more SC-BUEs to be available, that need sub-frames ABS to be guided from MC-ICI. The results in the figure illustrates that increasing the CRE value leads to an increase in the total sum capacity of the system. This is because having ABS sub-frames in the DL frame enables the SC-BUEs to be served without being affected by MC-ICI, which boosts the total capacity. Therefore, the required ABS and CRE values are interconnected, and the effectiveness of implementing eICIC on a HetNet is dependent on the number of SC-BUEs showed by the CRE value

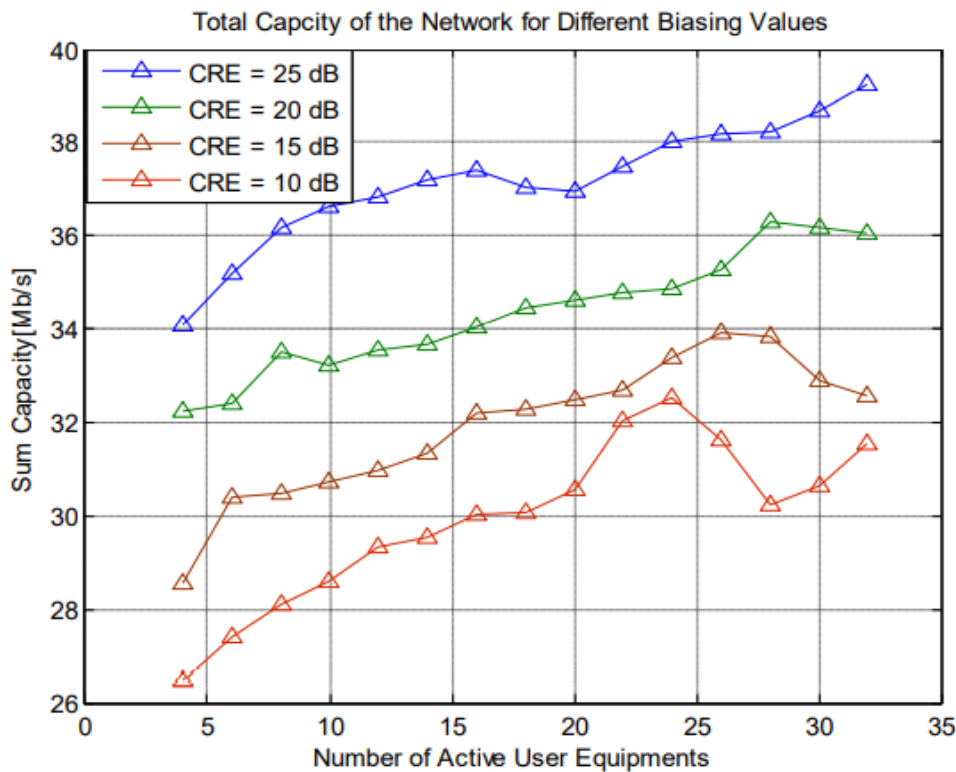


Figure 6: The Sum Capacity at 10% ABS & CRE = 25,20,15 and 10 dBs

5. Summary

Sum-Rate Efficient Inter-cell Interference Coordination (ICIC) technique is a novel method for managing interference in heterogeneous networks (HetNets). HetNets consist of different types of cells, such as macrocells, microcells, and picocells, each with different coverage areas and transmission powers. The presence of multiple cells can lead to interference between neighboring cells, which can degrade the network's performance.

The Sum-Rate Efficient ICIC technique aims to minimize interference between neighboring cells and improve the network's overall performance by dynamically allocating resources to each cell. This technique takes into account the time-varying nature of wireless channels and adjusts the allocation of resources accordingly. Specifically, the enhanced Inter-Cell Interference Coordination (e-ICIC) technique was used to improve the network's performance in areas where the macrocell covers the same area as the small cells. To evaluate the effectiveness of the Sum-Rate Efficient ICIC technique, the researchers conducted simulations at the system level. The simulations showed that the technique can significantly reduce interference between neighboring cells and improve the network's overall performance. The technique was found to be particularly effective in HetNets with a high density of small cells and in areas where the macrocell coverage overlaps with small cell coverage.

The Sum-Rate Efficient ICIC technique is a promising method for managing interference in HetNets with different types of cells. Its effectiveness has been demonstrated through simulations, and it has the potential to improve the performance of mobile networks in real-world scenarios.

6. Conclusion

This research work has established that, it is possible to transfer some of the active user equipment from macro-cells to small-cells by using cell expansion to balance the cell association between the two. The extent to which small-cells are utilized depends on the value of the bias that is added to their received signal strength. If the bias value is high, small-cells will be used more frequently. Conversely, if the bias value is low, small-cells will be used less often, and it's important to choose the best bias value to ensure effective cell association.

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