Optimization Techniques for Interference Models in Machine-to-Machine (M2M) Communication: A Survey

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Abstract

As massive devices with a 10,000-fold increase in connectivity are anticipated, Machine-to-Machine (M2M) communication based on ultra-dense heterogeneous networks (HetNets) is one of the effective options for enhanced coverage and capacity in 5GB cellular networks. Cross-tier and co-tier and interferences, however, are both factors that limit the performance in multi-tiered architecture. Effective resource allocation approaches can manage interferences, but as the density of the HetNets grows due to the haphazard and unforeseen deployment of M2M devices, so does their complexity. In the modelling of interference problems, deploying the appropriate optimization scheme is the eccentric challenge that is attributed to the speedy convergence of the interference problem at the performance cost of other figure of metrics. This paper surveys some of the optimization techniques employed by researchers

Keywords: Optimization, 5GB, Machine-to-Machine (M2M), Interference

Introduction

Future 6G wireless communications requirements mandate that enormous data-driven applications and a growing user base be supported. (Qadir *et al.*, 2023). Interference as in 5G and Beyond (5GB) will create series of degrading problems in the communication channel due to ultra-dense nature, reduction in inter-cell distance, and heterogeneity of the network. This proximity reduction will creates compromising challenges relative to resource allocation, and interference management in Machine-to-Machine (M2M) communication (Saied, 2021). A key component of 5GB cellular communication is M2M communication, which is the establishment of direct communication links between two or more devices using the licenced band uplink frequency. (Barman & Roy, 2020).

For secured high quality of service requirements, heterogeneous data transmission in M2M communications use licenced cellular spectrum. M2M communications increase spectrum efficiency and add to high system capacity by reusing spectrum resources. The integration of M2M communication will significantly enhance the coverage extension via the provision of connectivity among the M2M pairs, decongestion of the evolved NodeB (eNodeB) and spectrum enhancement due to frequency reuse.

By 2030, 5GB cellular communication hopes to connect 5016 billion devices (Chowdhury et al., 2020) thanks to important innovations such massive MIMO, millimetre wave transmission, and beam division multiplexing. In order to provide ultra-high-speed connectivity, ultra-low-latency communication, and highly scalable low-latency machine-type communication, 5GB networks will attain extreme network capabilities. Numerous novel services and applications, such as connected autonomous vehicles (CAVs), energy internet, space and deep-sea connectivity, holographic teleportation, and the next industrial revolution known as Industry 5.0, will be made possible by these 5GB networks. (De Alwis *et al.*, 2022).

In the 5GB network the density per unit square area and number of users will increase exponentially, hence the data transmission has shown higher propensity to equally dramatic growth, hence the necessity for urgent higher spectrum efficiency and increased system capacity (HU *et al.*, 2022). However, M2M communication can cause interferences, including interference from M2M users sharing resources or interference among multiple users and multiple-cells. Several highlighted factors the such as transmitted power of the M2M devices, multiple access strategies, frequency reuse techniques, topology of the network, suitable mode of transmission, location restriction have significant impact on the scale of interference in the network (Kamruzzaman *et al.*, 2022). The influence of interference becomes the centric factor that impedes the user's maximizing the achievable throughput, limiting the network capacity and performance of the Machine-Type-Devices (MTDs). The degrading impact of interference worsen the communication link in 5GB network which is has become a source of worry for both industrial and research community, as the demand for spectral resource utilisation increases.

The underlay of M2M devices on the cellular network provides for the coordination of interference among the various device tiers of device communications. According to the convectional base station (BS) paradigm, the BS is only set up to provide interference measurements to its native access point, which causes their separate networks to implement interference mitigation measures. The ETSI standardization architecture of 5GB allows for interference measurement capabilities by M2M devices. So that they can enhance the potential to effectively scope and mitigate the problem of interference (Tesanovic et al., 2012).

Interference is a recognized problem that has resulted from the heterogeneity and clustering of several devices possessing variegated characteristics relative to quality of service demand and throughput requirements. The fundamental performance metrics and quality of service must be optimised in order to provide the best trade-off between various pairings at the expense of other performance metrics in order to increase the effectiveness of various interference mitigation algorithms. The interference mitigation schemes always result in optimisation problem due to the complexity of the models and the requirement of reduced computational overhead and energy efficient in the design of interference mitigation schemes. The contribution of this work, surveys the related as work in respect to optimisation schemes that have been employed in the mitigation of interference. Section II surveys the related work, section III dissects the open issues and section IV discusses the conclusion.

Related Works

The problem of interference mitigation in a distributed with consideration in a multi-cell environment was proposed by HU et al., (2022) to maximise the user supporting ratio of small cells. the interference problem optimization problem is formulated as a non-convex problem. The limitation of traditional non-convex optimisation scheme to motivated the non-cooperative game problem couple with power interaction policy was proposed in abid to obtain the optimal. The Nash equilibrium solution was utilised by allowing each user paid a certain price as the utility function to enhance the Signal-Interference-to-Noise-Ratio (SINR). However, the predictive power approach was utilised to associate the optimal power to users within and across neighbouring cell for efficient energy management. Simulation results shows an improvement in the performance gain based on the employed optimisation scheme to mitigation the inter-cell interference in comparison to traditional schemes. It has been established by the authors, that the SINR threshold and the QoS threshold of each user in the cell are determined by the initial power of the each M2M pair and the distance of M2M pair from the eNodeB. The complexity of the algorithm resulting from the challenge maximizing the number of users attaining the QoS threshold and the resultant solution are drawbacks of the scheme. Therefore, the attainment of the highest scheduling time is the condition for the scheme to attain convergence of the optimal solution, hence, increasing the computational overhead.

Furthermore, Achki et al., (2020) proposed a multicriteria Analytic Hierarchy Process (AHP) to investigated the energy efficient user association and interference mitigation in order to minimise both the cost function of user association and interference problem. The multi criteria considered for optimisation include the distance from the Base Station (BS), the SINR and the transmit power of various M2M devices was exploited in resolving the decision problems of obtaining the optimal user association. The improvement in interference minimisation and energy efficiency depends on the cost values of the user association with the BS. The optimization algorithm can only mitigation the interference in M2M devices that shared the same spectrum without consideration for other forms of interferences such as the mutual interference and the cross-tier interference.

Emerging 5GB non-public networks (NPNs) also need to handle a lot of uplink traffic for things like industrial IoT. Sharing spectrum between the uplink and downlink is one approach to boosting NPNs' uplink throughput. An adaptive asymmetric successive interference cancellation (SIC) approach is used to reduce interference from downlink public base stations was proposed by (Li et al., 2021). The study looks at a straightforward downlink- and-uplink frequency reuse scenario in which orthogonal frequency-division multiple access (OFDMA) is used to connect with different users while uplink non-public BS and downlink public BS coexist in the same space. The formulation of the interference minimization problem led to a mixed-integer non-convex problem that is difficult to solve optimally in terms of increasing the uplink throughput. Also, on the downlink, problem was formulated as a resource allocation which is also a non-convex problem due to its non-convex constraints. Li et al., (2021) proposed an alternating-optimization technique to address the resource allocation problem by utilising the user scheduling and subcarrier allocation. Simulation result proved that the uplink throughput was maximized but however, the optimization complexity increases the computational overhead to the scheduling problem. When compared to benchmark methods that do not take this into account, the suggested architecture greatly improves common uplink throughput.

Although intercell spectrum sharing improves 5G network performance, it is plagued by co-channel interference. By minimising interference, the work by Wang et al., (2019) optimises power allocation to maximise throughput. Although the problem is nonconvex, the objective function is converted to a convex optimisation problem using the DC programming method. The simulation results demonstrate the effectiveness of the suggested system. The reduction of cross-tier and co-tier in the cell with high interference prevalence is particularly important., Iqbal et al., (2021) proposed a Q-learning scheme that mitigates the interference and also effectively allocate resources. As the unplanned deployment of M2M devices linearly increases in complexity in an heterogenous network the necessity for efficient interference. With the objective of mitigating both cross-tier and co-tier with maximizing the transmission rate and the ergodic capacity of the network, the authors formulated the objective function as a non-convex interference problem and employed an adaptive solution using the concept of Reinforcement Learning framework.

The influence of cross-tier interference was investigated by Agarwal et al., (2020), in mitigating the heft interference influence become degrading when Macro-cell user are found within the vicinity of femto cell BS. The Quality Efficient Femtocell Offloading Scheme (QEFOS), which is suggested in this research, chooses the customers who are most negatively impacted by the interference they encounter and offloads them to nearby Femto cell BSs. Using the QEFOS technique, users of the HetNet are divided into three groups according to the level of interference they experience and whether they are connected to MBSs or FBSs. After categorization, the users who are most affected by interference are transferred to nearby FBSs. In extreme cross-tier interference situations, QEFOS performs better than competing solutions in terms of QoS measurements and the estimated QoE that customers feel.

Open issues

The interference problem has been the most compromising challenge that have encounter in the cellular era. However, the impact on the communication link is severely degraded which has a significant consequence on the QoS, the reliability of the communication link and the performance cost. Consequently, the network providers dedicate a lot of time and resources in mitigating the impact of this problem, However, the design of interference models necessitates a computationally simple and low-complexity optimisation problem, which causes the best solution to quickly converge.

Conclusion

The impact of interference in the 5GB network is anticipated to be severe considering the close proximity of the various devices cluster in a dense area. The inter-distance will be decreased with M2M devices interfering with one another over space and time, competing for radio resources. The interference influence degrades the communication channels and hence the necessity to model the interference problem with a efficient optimization algorithm for effective speedy and effective convergence.

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