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Resource Allocation and Management in Machine-to-Machine (M2M) Communication in Underlay In-Band Cellular Network: A Survey

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The adoption of 5G network standard as the next futuristic network has dynamically shaped the path for new features in communication standards, with support for integration of variegated device with different service Quality-of-service requirements. The tends to support massive connectivity of devices with delay tolerant requirements and specific quality of service requirement which also support various Internet-of-Things (IoTs), Device-to-Device (D2D) Communication, Machine-to-Machine (M2M) Communications and several other applications. M2M communication when underlaid with cellular communications are faced with compromising challenges when integrated into cellular networks. Due to their proximity in close location, the M2M user devices can communicate with one another without utilizing the Base Station and this enhances the spectral efficiency, reduces in the latency, energy efficiency and several benefits of M2M communications. However, there are more impending challenges which can compromise the benefits of M2M, these includes interference, resource allocation problem and power control challenges. These challenges tend to degrade the performance efficiency gain of the integration of M2M into cellular network. The purpose of this paper is to give an overview of some of the methods and approaches. and provide some insight to the open issue that are affecting resource allocation in M2M underlaid in a cellular network.

Keywords: *5G, Machine-to-Machine (M2M) Communication, Resource Allocation, Spectrum, Power, Interference*

1 INTRODUCTION

The next generation of wireless network 5G and beyond has been designed with the peculiarity of improving the system capacity, reducing the latency, performance enhancement relative to spectral efficiency, energy efficiency, reliability improvement based on the stringent requirements of specific applications(Saied, 2021). With consideration on the exponential rise in number of portable devices, the density of such communication devices will sprout the exchanging of large volume of data and information including multimedia data whose control and management of the traffic is sole the responsibility of the core network (Zeb et al., 2021). However, this ever-growing need necessitate for a network which can support the high data rate requirements, high mobility, dynamic flexibility, massive connectivity and wider bandwidth that supports the various service requirement with lowest possible latency or delay, the scarcity of spectral resources is not sufficient to meet the high-speed connectivity and reliability offered by the current 4G or convectional cellular, which necessitate the novel 5G architecture (Dejen et al., 2022). Machine-to-Machine (M2M) communication has been envisioned to satisfy the broad and complex need of the next generation standard, and it is being investigated as one of the new technologies that will support and meet the ever-growing need of the 5G standard. Massive number of devices connected together to autonomous communicate among themselves is referred to Machine-to-Machine Communication (Singh et al., 2021). In M2M communications, two or more wireless machines can communicate in close proximity directly with (In-band M2M communication/ licensed spectrum) or without (Out-band M2M communication / Unlicensed spectrum) the influence of the Base Station (BS) as shown in Fig 1.

In accordance with 5G network standards, M2M communication allows two users to connect directly over a shared channel without the need for a base station. Although users can utilize other devices to relay signals to each other if they are beyond the range of each other's transmissions. Additionally, an M2M pair connects with one another by building an M2M link, whereas a cellular connection is generated when a cellular user connects with a BS. M2M links utilise the same uplink channel resource as the cellular link in an M2M underlaid with cellular network (Krishna & Hossain, 2020). Keeping in mind that each link must be given enough power for each transmitter so that it can connect with its receiver despite background other links utilising the same channel can cause a lot of noise and interference. In addition, the signal-to-interference plus noise ratio (SINR) criteria for the receiver link must be satisfied by the transmitter's authorised power. Depending on the required data rate, each link needs a specific degree of SINR. Cellular link can utilized only one particular channel under a BS, but if each link sharing the channel has the required SINR, many M2M links may share a cellular channel (Ghosal & Ghosh, 2021).

The scalable nature of M2M, coverage area and its IP connectivity, the use of Optimistic technology Long-Term Evolution (LTE)/Long-Term Evolution Advance (LTE-A) can support the different and stringent peculiarities of M2M communications. Its adoption in variegated areas of endeavour includes but not limited to industrial automation (North & Muniraj, 2021), telemetry (Lo *et al.,* 2013), Supervisory Control and Data Acquisition (SCADA)(Verma *et al.,* 2016), and many more. Some of the developmental factors that attracted attention regarding the aspect of M2M communication comprises of privacy and security related issues, device enhancement capacity, high-end- application requirements and coverage improvement.

However, the unique characteristics of M2M communication device distinguishes it from its counterpart Human-to-Human (H2H) communication that employs the conventional cellular network. This includes the peculiarity of massive M2M data that is been generated from massive connected devices, and the periodic nature of the packet generation which is specifically event-driven (Xia *et al.,* 2020). Furthermore, the frequency of the data generated is relatively high in comparison to the small data size, which have found application in wide range of delay tolerant and throughput required use cases. Consequently, M2M communication classically consist of burst data with variegated set of Quality of Service (QoS) requirements different from its H2H counterpart made up of low bandwidth data. Predominantly, the M2M communication is uplink-based which simultaneous compete with the uplink traffic of H2H communication resulting into interference and radio resource management problems (Alhussien & Gulliver, 2020). However, some critical problems associated with integrating or underlaying the M2M communication into cellular networks include but not limited to: issues with decision-making criterion for radio resource management (Song *et al.,* 2020), coordination of interference (Siddiqui *et al.,* 2021), power management allocation (Sobhi-givi *et al.,* 2020), and mode selection issues (Ahmad *et al.,* 2022) as illustrated in the Fig. 2. This integration compromises the ability to maximize the gain of integrating the M2M communication into cellular networks via spectral degradation, if improper resource allocations that guarantee reliability, high data rate and enhance spectral efficiency are not optimally utilized.

The imperative of resource allocation entails that multiple network requirements are intelligently and dynamically assigned swiftly. The resources assigned in include power control, bandwidth distribution, rollout strategies, and association distribution in 5G (Kamal *et al.,* 2021). Thus, the efficient allocation of spectral resources reduces the influence of co-tier interference within network assisted communication, thereby improving the spectral efficiency with enhance network throughput, the cell coverage area is increased and the ultra-low latency is achieved. Consequently, the inefficient extraneous power allocation from neighbouring cells results into cross-tier interference which is resultant from two possible factors, firstly, the transmitter power is not limited within the nominal frequency range hence the spectrum of the generated signal may extend over large frequency range and secondly, at the receiver end, the radiation from the desired channel is suppressed insufficiently by receiver filter and in turn passed as interferences in the demodulator. In-band M2M communication's main advantage is an increase in the cellular network's spectral efficiency, but the monumental drawback that characterize the in-band model entails the high computational overhead that the BS and yet the severity of interference.

2 RELATED WORKS

The issues surrounding the problem of resource allocation in M2M communication have be studied by several authors considering the different perspective the situation needed to be tackled from. In a study conducted by Ghosal & Ghosh, (2021), which considered the underlaid setting, both cellular and D2D users may obstruct one another when they are using the same channel resources. In an effort to lessen the interference issue, the authors proposed to jointly tackle the channel and power allocation problem in a design that combines the pairing of one cellular link with numerous D2D links. However, the strategy adopted proved effective in terms of cost and energy efficiency, but however, the study was limited due to the multiple of D2D users that can reuse a single cellular link thereby imposing co-tier interference and also resulting in resource scheduling problem. It may have been more illustrative to broaden but not limit the number of reusable cellular links to a single link to be reused by D2D pairs.

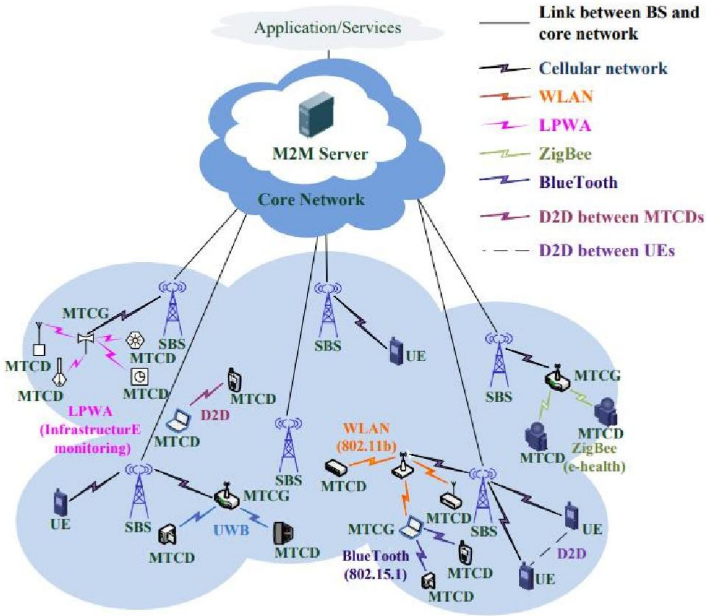

Fig.1 Topology of M2M communication in UDNs, where SBS, UE and MTCD represents small cell base station, user equipment for both H2H and M2M Communications in cellular network, M2M device, and M2M gateway, respectively (Chen *et al.,* 2017)

Furthermore, in enhancing the spectral resource allocation in Hetnets with consideration in an ultra-dense network, the influence of interference degrading system throughput was studied. However, Zhao *et al.,* (2015) proposed an enhanced spectrum allocation algorithm with consideration of user's rate demand in heterogenous network. The study was limited in terms of its consideration to two-tier network without taking into account other communicating M2M devices that do not utilize the cellular spectrum. This was significant because it improved the system throughput while equally guaranteeing the user fairness. Moreso, nature inspired resource allocation techniques which utilises Bee colony algorithm coupled with artificial intelligent was proposed by (Llerena & Gondim, 2020). Considering the impact of social relationships in the midst, the study's emphasis on M2M users in a socially responsible radio resource allocation, the algorithm can also predict how many M2M users will be admitted into the cellular network. Hence, the proposed approach made a strong effort to actively maintain the weighted system throughput while simultaneously attempting to meet the QoS criteria for both the M2M underlaid and cellular users. Despite the improved performance which show significant achievement over similar greedy algorithms improving the reusability factor, the proposed algorithm was limited in its consideration with respect to the use of few performance parameter and the mobility of the M2M users was not considered. Similar research was done on the issue of resource allocation with regard to power allocation, energy efficiency, and resource block assignment, Jameel *et al.,* (2020) based its assumptions that the resource allocation performed with regards to energy efficiency is based on the greedy algorithm method which on the long run causes system performance degradation. However, based on the limitation, a dynamic wireless power transmission and resource strategy was proposed, this technique dynamically improved the power level and system resources based on dynamic reconfiguration. This achievement account for the high trade-off between the power and capacity with adequate priority to Quality of Service (QoS) requirement. The study will have found more applicable usage if it had broadened its scope to further considered the interference problem. Table 1 highlights some of the important KPIs used to evaluate the performance of some resource allocation techniques. Also, the issue of power consumption reduction and energy efficiency improvement for multi-pair D2D communication in underlying cellular networks was studied by Hashad *et al.,* (2020). Resource allocation problem was modelled into a complex mixed integer.

TABLE 1: PARAMETERS OF EVALUATION

	SNR	Latency	Packet Loss	Throughput	Energy Efficiency	Resource Block	Fairness	Average Use Demand	Access Rate	Overhead	Spectrum Reuse factor	Outrage Probability	Power Consumption	Reliability	Ergodic Capacity	Overhead
(Ghosal & Ghosh, 2021)			*	*												
(Jameel *et al.*, 2020)					*	*										
(Zhao *et al.*, 2015)				*			*	*								
(Llerena & Gondim, 2020)				*					*							*
Wang *et al.*, 2021)											*					
(Zeb *et al.*, 2021)											*	*			*	
(Ruan *et al.*, 2020)		*														
(Hashad *et al.*, 2020)	*			*	*				*							
Hussein *et al.*, (2021)											*					

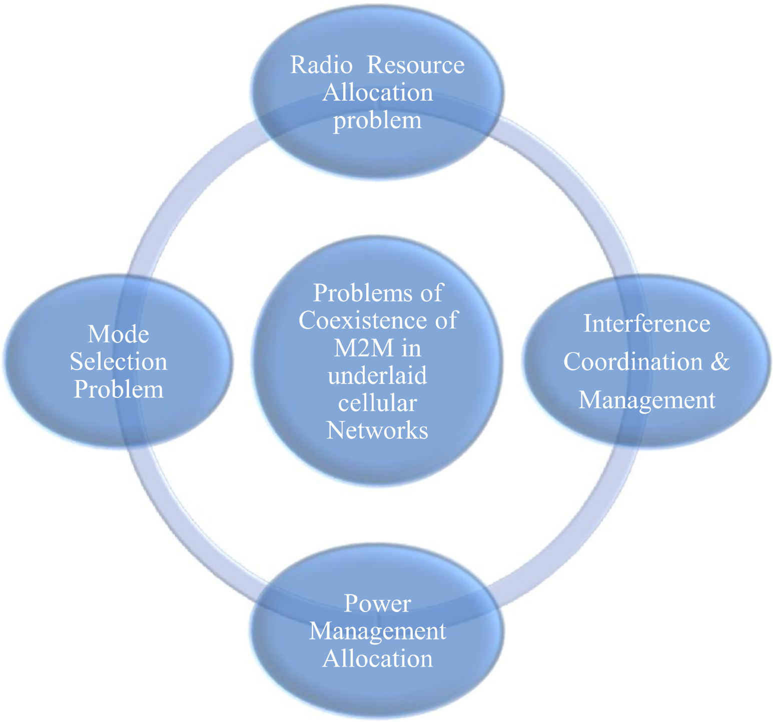

Fig 2: Problems of Coexistence of M2M in underlaid Cellular Networks

Resource allocation problem was modelled into a complex mixed integer problem which is associated with interference mitigation techniques. However, the application of convex optimization method complicated the possibility to attaining a global solution to the problem. Also, this can be improved upon by ensuring the successful decoding at the receiver and effective utilization of network resources which entail creating a balance between adequate interference management and resource allocation. To cut back on overall power consumption, a primal-dual algorithm was presented. A non-linear fractional programming technique was then used to further construct a second primal-dual algorithm, which was used to maximise energy efficiency. In relation to the efficacy of the strategy, Hashad *et al.,* (2020) proved that maximizing the available energy will decrease the transmission power. Additionally, these results demonstrated that efficient resource allocation will enhance both spectral efficiency and energy efficiency. However, the study was limited in scope as its focused on multi- pair M2M.

Current Long-Term Evolution's (LTE) limitations relative to the diverse needs of 5G services' users and applications and the necessity to radically enhance the massive adoption on massive Machine-Type Communication (mMTC) use cases that support widespread connection and a variety of QoS requirements. Sadi *et al.,* (2020)on the basis of the restriction of maximising the spectral efficiency and traffic demand of mMTC devices, research was conducted into the radio resource allocation for mMTC and the allocation of resources in a semi-persistent manner was demonstrated. The study demonstrated significant improvement in the spectral efficiency but however, the power and interference problem were not considered.

In the wireless network, the closeness of the various M2M users enhances user dependability, traffic offloading, greater throughput, delayed time, spectral efficiency, and energy efficiency, which is not achievable with standard cellular connection (Rathi & Gupta, 2021). The better re-utilization of radio of cellular network communication will unequivocally ensure that management of radio spectrum and reduction in communication delay can be guaranteed provided the challenges associated with resource management, such as throughput issues, interference issues and several other; are surmounted.

2.1 Open Issues

The issue of resource allocation is marred with a lot of challenges which ranges from interference due to spectral reuse of resources. This causes the issue of interference that result from co-channel interference and the heterogeneity based on the ultra-density of so many devices. Equally, the user density also sprouts out the pairing issues based on the cluster and density of the user, this create serious challenges that arise in term of creating communication links and sending acknowledgement between devices. Furthermore, the connection issues can affect the budget link in respect of creating an effective and reliable communication between the cellular and M2M devices, as several factors such as fading both slow and fast fading resulting from variation of distance relative to the servicing BS and the M2M devices (Azari & Masoudi, 2021). In addition, the path loss factor also affects the rate of fading and the in-depth interference. Another point of concern, is the problem of mode selection, as its concern the requirements for the use of cellular link or the M2M communication link in the transfer of data considering the distance. Concerns are being raised regarding the quality of key parameters Indicators (KPIs) with their pre-defined threshold.

In addition, the stringent requirements of M2M communication such as having low memory, reduced energy use and minimal processing overhead. Based on the low power nature of the M2M devices, optimizing the power consumption is a serious challenge that has to be overcomed. The underlay communication involving the cellular BS and the low powered M2M consumes more power due to the necessity of frequent communication, acknowledgment and synchronization between the BS and the M2M.

CONCLUSION

The adoption of 5G standard has bring about new challenges, with respect to application requirements, QoS and open new areas of application that are different from the current LTE standards. These standards have created new challenges based on the massive integration of several devices within the cellular networks. Challenges ranging from interference mitigation, resources allocation and power control are the most prominent since that have high propensity to degrade a cellular network capacity and links. This paper has surveyed and highlighted some of challenges and techniques that have been employed to mitigate the compromising situation of resource allocation with respect to the 5G standards.

REFERENCES

Ahmad, T., Chai, R., Adnan, M., & Chen, Q. (2022). Low-Complexity Heuristic Algorithm for Power Allocation and Access Mode Selection in M2M Networks. *IEEE Internet of Things Journal*, *9*(2), 1095–1108. https://doi.org/10.1109/JIOT.2021.3079213

Alhussien, N., & Gulliver, T. A. (2020). Optimal Resource Allocation in Cellular Networks with H2H / M2M Co-Existence. *IEEE Transactions on Vehicular Technology*, *9545*, 1–13. https://doi.org/10.1109/TVT.2020.3016239

Azari, A., & Masoudi, M. (2021). Interference management for coexisting Internet of Things networks over unlicensed spectrum. *Ad Hoc Networks*, *120*(June), 102539. https://doi.org/10.1016/j.adhoc.2021.102539

Chen, S., Ma, R., Chen, H., Zhang, H., Meng, W., & Liu, J. (2017). Machine-to-Machine Communications in Ultra-Dense Networks – A Survey. *IEEE Communications Surveys & Tutorials*, *19*(3), 1478–1503. https://doi.org/10.1109/COMST.2017.2678518

Dejen, A. A., Wondie, Y., & Förster, A. (2022). Survey on D2D Resource Scheduling and Power Control Techniques : State-of-art and Challenges. *EAI Endorsed Transactions on Mobile Communications and Applications Research*, *7*(21), 1–30. https://doi.org/10.4108/eai.4-5-2022.173977

Ghosal, S., & Ghosh, S. C. (2021). A randomized algorithm for joint power and channel allocation in 5G D2D. *Computer Communications*, *179*(2021), 22–34. https://doi.org/10.1016/j.comcom.2021.07.018

Hashad, O., Fouda, M. M., Eldien, A. S., Mohammed, E. M., & Elhalawany, B. M. (2020). Resources Allocation in Underlay Device- to-Device Communications Networks : A Reduced-Constraints Approach. *IEEE Access*, *8*, 228891–228904. https://doi.org/10.1109/ACCESS.2020.3046417

Jameel, F., Khan, W. U., Kumar, N., & Riku, J. (2020). Efficient Power-Splitting and Resource Allocation for Cellular V2X Communications. *IEEE Transactions on Intelligent Transportation Systems*, *22*(6), 3547–3556. https://doi.org/10.1109/TITS.2020.3001682

Kamal, M. A., Raza, H. W., Alam, M. M., Su'ud, M. M., & Sajak, A. binti A. B. (2021). Resource Allocation Schemes for 5G Network : A Systematic Review. *Sensors*, *21*(6588), 1–45.

Krishna, S., & Hossain, F. (2020). A location-aware power control mechanism for interference mitigation in M2M communications over cellular networks. *Computers and Electrical Engineering*, *88*(March), 106867.

https://doi.org/10.1016/j.compeleceng.2020.106867

Llerena, Y. P., & Gondim, P. R. L. (2020). Social-aware spectrum sharing for D2D communication by artificial bee colony optimization. *Computer Networks*, *183*, 107581. https://doi.org/10.1016/j.comnet.2020.107581

Lo, A., Law, Y. W., & Jacobsson, M. (2013). A Cellular - Centric Service Architecture for Machine - to - Machine (M2M) Communications. *IEEE Wireless Communications*, *20*(5), 143–151. https://doi.org/10.1109/MWC.2013.6664485

North, S. M. E., & Muniraj, P. (2021). ScienceDirect ScienceDirect ScienceDirect. *Procedia Manufacturing*, *53*, 52–58. https://doi.org/10.1016/j.promfg.2021.06.009

Rathi, R., & Gupta, N. (2021). Game theoretic and non-game theoretic resource allocation approaches for D2D communication. *Ain Shams Engineering Journal*, *12*(2), 2385–2393. https://doi.org/10.1016/j.asej.2020.09.029

Sadi, Y., Erkucuk, S., & Panayirci, E. (2020). Flexible Physical Layer based Resource Allocation for Machine Type Communications Towards 6G. *2020 2nd 6G Wireless Summit (6G SUMMIT)*, *16*, 1–5. https://doi.org/10.1109/6GSUMMIT49458.2020.9083921

Saied, A. (2021). *Resource Allocation Management of D2D Communications in Cellular Networks*. Concordia University.

Siddiqui, U. A. M., Qamar, F., Ahmed, F., Nguyen, Q. N., & Hassan, R. (2021). Interference Management in 5G and Beyond Network : Requirements , Challenges and Future Directions. *IEEE Access*, *9*, 68932–68965. https://doi.org/10.1109/ACCESS.2021.3073543

Singh, U., Dua, A., Tanwar, S., Kumar, N., & Alazab, M. (2021). A Survey on LTE / LTE-A Radio Resource Allocation Techniques for Machine-to-Machine Communication for B5G Networks. *IEEE Access*, *9*, 107976–107997. https://doi.org/10.1109/ACCESS.2021.3100541

Sobhi-givi, S., Shayesteh, M. G., & Kalbkhani, H. (2020). Energy-Efficient Power Allocation and User Selection for mmWave-NOMA Transmission in M2M Communications Underlaying Cellular Heterogeneous Networks. *IEEE Transactions on Vehicular Technology*, *69*(6), 1–17. https://doi.org/10.1109/TVT.2020.3003062

Song, Q., Nuaymi, L., & Lagrange, X. (2020). Survey of radio resource management issues and proposals for energy-efficient cellular networks that will cover billions of machines. *EURASIP Journal on Wireless Communications and Networking*, *2016*. https://doi.org/10.1186/s13638-016-0636-y

Verma, P. K., Verma, R., Prakash, A., Agrawal, A., Naik, K., Tripathi, R., Khalifa, T., Alsabaan, M., Abdelkader, T., & Abogharaf, A. (2016). Machine-to-Machine (M2M) communications : A survey. *Applications, Journal of Network and Computer*, *66*, 83–105. https://doi.org/10.1016/j.jnca.2016.02.016

Xia, N., Chen, H., & Yang, C. (2020). Radio Resource Management in Machine-to-Machine communications -A Survey. *IEEE Communications Surveys & Tutorials*, *20*(1), 1–39. https://doi.org/10.1109/COMST.2017.2765344

Zeb, J., Hassan, A., & Nisar, M. D. (2021). Joint power and spectrum allocation for D2D communication overlaying cellular networks. *Computer Networks*, *184*(2021), 107683. https://doi.org/10.1016/j.comnet.2020.107683

Zhao, L., Zhao, H., & Huo, G. (2015). An enhanced spectrum resource allocation algorithm in Hetnets. *China Communications*, *12*(10), 182–192. https://doi.org/10.1109/CC.2015.7315069