THE ASIAN BULLETIN OF BIG DATA MANAGEMENT
Vol.5. Issue1 (2025)
https://doi.org/ 10.62019/abbdm.v5i1.294

ASIAN BULLETIN OF BIG DATA MANAGEMENT
ISSN (Print): 2959-0795
http://abbdm.com/
ISSN (online): 2959-0809

Efficient Resource Management for IoT Devices in Mobile Networks Using Packet Collection and Forwarding in Transportation Systems

Yousra Tajamal[1], Dr. Ahmad Khan*, Shahbaz Ahmad, Muhammad Mursaleen Akbar, Tanveer Ahmad, Hafiz Muhamad Naeem Ahmad

Chronicle

Article history

Received: Jan 3, 2024
Received in the revised format: Jan 27, 2024
Accepted: Feb 9, 2025
Available online: Feb 10, 2025

Yousra Tajamal[2], Dr. Ahmad Khan*, Shahbaz Ahmad, Muhammad Mursaleen Akbar, Tanveer Ahmad and Hafiz Muhamad Naeem Ahmad are currently affiliated with the Faculty of Computer Science & Information Technology, The Superior University Lahore, Pakistan.

Corresponding Author*
ahmad.khan.fsd@superior.edu.pk

Abstract

The Internet of Things (IoT) and Machine Type Communication (MTC), also known as Machine-to-Machine (M2M) communication, have led to significant advancements in various industries, resulting in a notable increase in IoT devices in recent years. A range of communication technologies, including Low Power Wide Area Networks (LPWAN), Narrow Band IoT (NB-IoT), Long-Term Evolution (LTE), LTE-Advanced (LTE-A), and emerging 5G & 6G cellular networks, have been deployed to connect IoT sensors and devices. LTE and LTE-A are particularly effective for IoT device interoperability due to their widespread availability. However, the current cellular mobile networks are primarily designed to cater to broadband services and human-based communication (H2H), which poses challenges for handling the narrowband traffic generated by IoT devices, especially when millions of devices communicate within a single cell, such as during transportation. In transportation systems, where containers carrying various goods require continuous data transmission, this massive volume of IoT traffic can overwhelm network resources, leading to inefficient spectrum usage. This paper proposes an innovative solution to address these challenges by introducing a resource management framework that utilizes packet collection and forwarding techniques. Specifically, the system employs an intermediary node, termed the Packet Collection and Forwarding (PCF) node, which temporarily stores small packets in a buffer. Once the buffer reaches capacity, these tiny packets are aggregated into a larger packet and forwarded to the recipient, reducing network congestion and enhancing resource allocation efficiency. Additionally, the system incorporates strategies to minimize delays in the micro-packet collection process, ensuring minimal impact on communication latency. By leveraging this approach, the proposed system optimizes network performance, reduces energy consumption, and supports scalable, sustainable IoT solutions in mobile networks, particularly in transportation systems. Simulation results demonstrate significant improvements in resource management, throughput, and overall network efficiency, contributing to the development of robust IoT infrastructures for dynamic environments.

Keywords: Internet of Things, Machine Type Communication; PAC NODE; LTE; Transition probabilities.

INTRODUCTION

Emotion The integration of Artificial Intelligence (AI), machine learning (ML), and the

Internet of Things (IoT) has brought revolutionary changes to various industries, enabling smarter, more efficient systems. These advancements have enhanced data processing, decision-making, and resource management, driving innovation in sectors such as transportation, healthcare, and manufacturing [1][29]. The concept of networked gadgets appeared more futuristic at the time, something that could only be found in science fiction. It was nearly unthinkable that machines could independently exchange data, decide what to do, or coordinate operations without human supervision [1][27]. However, this landscape has seen a significant transformation with the advent of Machine Type Communication (MTC) and the Internet of Things (IoT) in the present day. The way we work, live, and engage with our surroundings has changed as a result of these developments. These days, IoT enables important data to be communicated to centralized servers from common products like refrigerators and washing machines. It also makes it feasible to remotely control air conditioning systems, pilot drones, and drive cars [2]. Not only do these technological developments offer great ease, but they also mark a paradigm shift in how we view and use technology. Although security challenges also grow with the enhancement in technology [2][30][31]. The IoT ecosystem is based on a variety of equipment, sometimes referred to as devices, that may communicate with one another in MTC and IoT networks in an intelligent and autonomous manner without the assistance of a human [3].

One of the main features of the Internet of Things is the autonomous interaction of devices, which has its origins in industrial automation and the application of similar concepts through Supervisory Control and Data Acquisition (SCADA) systems. SCADA systems were created to enable the management and visualization of industrial processes by connecting computers to sensors, actuators, and other equipment. Thus, the concept of machines interacting with one another without the need for human interaction was not totally novel, but the Internet of Things has made it more commonplace. A vast range of applications made possible by the Internet of Things (IoT) make it easier to use IP-connected devices, including actuators and sensors, in a variety of contexts, including homes, workplaces, hospitals, and more. Our interactions with the world around us have been revolutionized by these applications, which have improved the intelligence, efficiency, and responsiveness of our surroundings. For instance, IoT devices in smart homes can automate security, heating, and lighting based on user behavior, improving both the comfort and energy efficiency of living areas.

IoT devices in the healthcare industry can transfer data to healthcare providers and monitor patients' vital signs in real-time, allowing for timely interventions and individualized care. IoT makes predictive maintenance possible in industrial settings by allowing machines to alert operators to possible problems before they cause expensive downtime. The Internet of Things' widespread connectivity, devices' easy accessibility, affordability, small size, and—most importantly—scalability are the main factors driving its current expansion [4][26]. The importance of any device connecting to a network rises as more of them do, leading to a synergistic effect that raises the network's overall value. Large-scale data ecosystems can be created because to this connectedness, where data from many sources can be combined, examined, and utilized to produce insights or program decisions. Improved customer service increased operational efficiency, and new revenue streams are all possible outcomes for firms. More comfort, security, and customization in daily life could result for individuals. These solutions offer a degree of flexibility and usability and are ideally suited for managing equipment locally. With short-range wireless networks, devices may be reliably connected across short distances, which is why they are so common in homes, businesses, and industrial settings. But since this approach doesn't provide global connectivity, it has drawbacks, especially regarding range. As a result, even if short-range wireless networks are effective at managing devices inside a small space, they are not appropriate for situations in which devices must send or receive data from far places. Imagine, for instance, that a physician must operate on a patient who lives abroad at a long, long distance. Short-range wireless technologies would not be sufficient in such a situation. Rather, long-range (LoRa) connection technologies, internet, cellular networks, WiMAX, and Sigfox would be needed. Due to the long-distance communication capabilities of these technologies, connectivity can be maintained over large geographic areas. Particularly Sigfox and LoRa stand out for their capacity to enable low-power, wide-area (LPWA) networks, which are necessary for Internet of Things applications that need dependable, long-range communication with low-power consumption [5][23]. These innovations have made it possible for IoT applications to operate in remote or difficult-to-reach locations where conventional communication networks might not be practical or affordable [26]. The development of cellular mobile systems serves as another example of how IoT has changed things.

Broadband and human-based communication services, including file uploading and downloading, texting, voice communication, and multimedia message services (MMS), were the original goals of cellular mobile systems. The bulk of data in conventional Human-to-Human (H2H) communication moves from the network to the user down-stream, while control information is sent uplink [5]. Due to the nature of H2H communication, large file transfers and services like video streaming demand a lot of bandwidth and high data rates [6]. But these traditional cellular networks weren't designed to meet the needs of the Internet of Things. Unlike H2H communication, the IoT does not generally broadcast a massive stream of data and doesn't need a broad bandwidth, or a high data rate [7] Why does this matter: This is because it's steered the creation of technologies and communication protocols specifically created for the Internet of Things. For example, cellular technologies LTE-M and Narrowband IoT (NB-IoT) have been designed for IoT applications. These technologies are well suited to Internet of Things deployments in urban and rural regions due to their enhanced coverage, power requirements, and capability to connect thousands of devices.

One of the challenges of adapting cellular networks for the Internet of Things was the very large number of devices with differing service needs [8]. The admissibility requirements of the low-power, sporadic communication of IoT devices differ drastically; actually, this is in contrast to H2H communication, where the H2H ISS is often definable as structured and with specific application requirements. It is also essential to consider the battery life of IoT devices. User equipment typically has a battery life of several days to a week in H2H communication, while many IoT devices are expected to survive for years between battery changes. To support the vast scope and diversity of IoT deployments, this has prompted the creation of low-power communication protocols and the optimization of network resources. For example, low-power IoT devices may run for extended periods of time in the field without always needing new batteries because of the support provided by LoRa and Sigfox. This is especially crucial for Internet of Things applications like asset tracking and environmental monitoring that are in remote or difficult-to-reach areas. Since cellular mobile services were introduced, the emphasis on low power, low data rate, and low latency has changed the landscape of mobile communication networks. Service providers have made significant efforts to improve these features. The need for scalable, effective, and dependable communication networks will only grow as the Internet of Things expands. The way various technologies—wired, wireless, long-range, and short-range—interact will be crucial in constructing the infrastructure required to handle the billions of devices that are anticipated to be connected in the upcoming years. This will call for developments in data management, cybersecurity, and device interoperability in addition to communication technology breakthroughs. The Internet of Things' transformation from a theoretical idea in the 1990s to a pervasive reality today is evidence of the speed at which technology (specially AI and machine learning in the field of computer science)is developing and the limitless opportunities it presents[28]. We may anticipate even more significant changes in the way we work, live, and engage with the world as IoT develops. The potential uses of IoT are numerous and varied, ranging from smart cities that optimize traffic flow and lower energy consumption to personalized healthcare that adjusts to the needs of individual patients. The Internet of Things journey is far from finished, and as new technologies emerge and current one's advance, the limits of what is feasible will keep growing and Cellular technology is the best choice for controlling IoT and M2M (Machine-to-Machine) data traffic, as was covered in the introduction section.

This is especially true for mobile entities, like containers, which may easily retain contact by connecting to the closest cellular tower as they travel across different places. IoT data flow differs greatly from traditional Human-to-Human (H2H) communication in its properties, making it difficult to integrate into current cellular networks [9]. Researchers and cellular mobile communication service providers are battling these issues, particularly as the IoT and M2M sectors grow quickly. It is getting harder and harder to integrate IoT devices, including sensors—into the current cellular infrastructure in a way that doesn't com-promise performance or dependability due to the sheer volume of these devices being used [10]. This is since the current mobile networks, which are not built to manage such a large volume of tiny, frequent data transmissions, would be overwhelmed by the increasing traffic created by IoT devices. Despite this obstacle, estimates show that, albeit from a reduced baseline, the yearly growth rate of mobile data traffic between 2023 and 2029 will stay constant. According to [25] that by 2029, the total amount of mobile data traffic worldwide—apart from Fixed Wireless Access (FWA)will have tripled to 313 exabytes (EB) each month.

Nevertheless, the overall mobile network traffic is expected to increase by a ratio of 3.5 when FWA is considered, reaching around 466 EB per month by the end of the projected period. The necessity for network improvements to accommodate the increase in data traffic brought on by IoT devices is highlighted by this significant development. In the future, connecting many IoT devices in one cell will be necessary, necessitating simultaneous connections. As was said in the beginning, cellular networks have a capacity limit on the broadband services they can offer. A small number of users—few hundred—could be connected in a single cell [13]. Physical Re-source Blocks (PRBs) are allotted to users in a cell on a demand basis [14]. A single PRB has 12 subcarriers, each of which has the capacity to send megabytes of data over a good channel [1]. Compared to H2H based communication, the Internet of Things requires far fewer resources (PRBs) for data transmission because IoT devices have smaller data sets [15]. As a result, it would be a waste of resources to provide a machine with a full PRB. For instance, temperature, light intensity, and humidity sensor would only need a few bytes to transmit data, but allocating a single PRB to these devices would be a waste of resources (PRBs). Additionally, the PRBs are one of the most valuable resources and are restricted in LTE and LTE-A (1200 in the best-case scenario). As a result, the system would be overwhelmed by the rise in IoT data traffic, and regular data traffic (H2H based data traffic) would also be impacted. In order to integrate Internet of Things data traffic into the cellular system, either a new dedicated system would be deployed, or the existence system should be optimized.

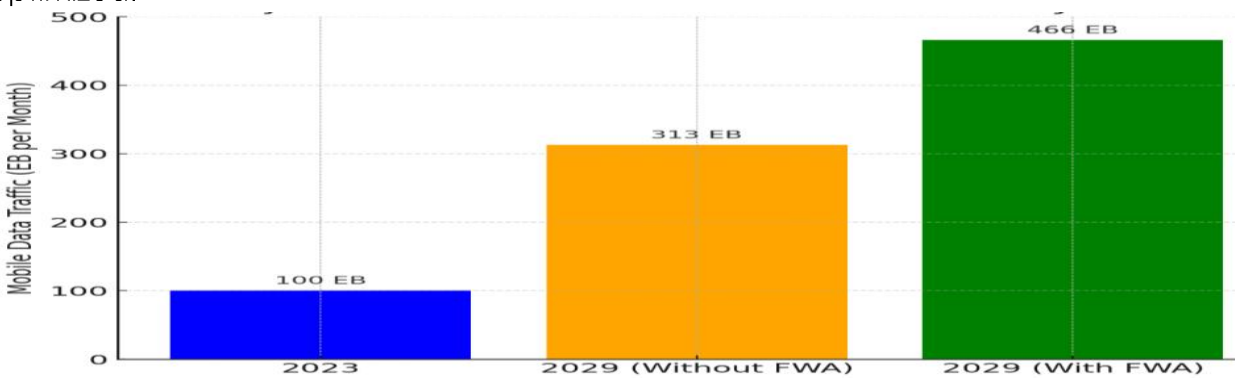

Figure 1:
Projected Mobile Growth Rate of Mobile Data Traffic by 2029 [25]

LITERATURE REVIEW

In wireless communication, spectrum is more valuable than many other essential resources since it is a finite and rare resource. The electromagnetic spectrum is a valuable resource in the field of communications since it is limited. Most countries, including Pakistan, entrust spectrum management to government agencies in order to guarantee its fair and effective usage. These agencies, including the Pakistan Telecommunication Authority (PTA), are in charge of regulating and allocating spectrum, making sure that it is utilized successfully and efficiently [16]. In the realm of cellular mobile communication networks, a particular spectrum band has been allocated to a service provider. Thus ends up a requirement for the service provider to make the majority of successful band utilize and in the end ensure respectable and the quality communications service provision. The efficient management of these resources is what the core and access networks that make up the communication system as a whole rely on, as do radio networks. The underlying concept is a set of techniques and algorithms described as radio resource management (RRM). Radio resource management (RRM) in cellular networks is designed to optimize radio resource utilization to minimize latency, maximize data rates, and improve overall network efficiency.

The aim is to ensure that the limited spectrum resource is allocated as per the requirements of the growing MTC and H2H communication with the increasing prevalence of the Internet of Things (IoT). In MTC's context, the problem of effectively managing radio resources is more challenging. Compared with traditional H2H communication, in which data traffic is more manageable and predictable, MTC consists of massive number of devices exchanging small amounts of data, often in a burst mode. If not properly managed, this can lead to network congestion and inefficiencies. Since LTE and LTE-A are the standards used for cellular communication today, research has focused on developing RRM techniques for MTC within these networks. A literature review shows that a considerable amount of this research has been conducted. Uplink scheduling refers to the procedure of determining how MTC devices transmit data to the base station, which is crucial since it affects communication reliability and efficiency. The authors [17] proposed a packet aggregation mechanism, where the load per fixed is characterized as fixed MTC traffic, that is, a fixed number of PRBs are allocated for MTC traffic. PRBs between MTC and IoT traffic are not a dynamic resource in this system, so while this makes scheduling easier the system may find itself inefficient if the demand for either type of traffic varies. The authors from another study [11] &[18] considered various access methods and the complexities caused by network congestion that occur when a huge number of devices are attached simultaneously. This is compounded by the explosion of IoT and MTC devices which creates significant concerns regarding network congestion that can occur in industrial or densely populated urban environments where thousands of devices may be attached to a single cell. Several approaches have been suggested to address these challenges, including new Medium Access Control (MAC) layer protocols designed to meet the unique needs of MTC traffic. P. Orim et al. provided a broad analysis of MTC research classes. [19], mainly focusing on MAC layer issues. The MAC layer is one of the most critical components of RRM, which controls the access of devices to the communication channel.

Orim and others (2020) discussed the need for MAC protocols that efficiently accommodate the many devices of MTC networks while minimizing latency and avoiding collisions. In that paper, they also wrote about the importance of designing protocols that can differentiate between MTC and H2H traffic so that the specific needs of each type of communication can be fulfilled. Liu et al. [20] gave a comprehensive review on the latest development strategies and applications of MTCs. Their study shows how MTC has evolved from niche use to an essential component of modern communications networks. They also explored the various challenges of integrating MTC into existing cellular networks, particularly with respect to security, dependability and scalability. As MTC grows, these obstacles will become increasingly apparent, requiring never-ending study and ingenuity. The authors in [21][22] conducted an insightful survey on state-of-the-art methods and scheduling approaches to efficiently manage radio resources in MTC networks. They categorized schedulers into two major types: channel-based and de-lay-based. (1) The delay-based schedulers (E->B), which allocate resources based on each device's delay budget, ensuring timely transmissions of time-sensitive data. Channel-based schedulers are designed to maximize the channel and give precedence to devices with the highest signal-to-noise ratio (SNR). One of the major issues that authors point out is the inability to discern H2H and MTC traffic. This could then lead to improper resource allocation and eventual deterioration of network performance.

In a re-trying phase, the authors [23], proposed a two-phase non-orthogonal resource allocation mechanism, with respect to machines and User Equipment (UE) and Internet of Things (IoT) device. In the first phase, UEs are allocated with radio resources, and such devices tend to have wide bandwidth and low latency requirements. In the second phase, resources are allocated to MTC devices based on a semi-distributed and centralized mechanism. The centralized approach maintains a complete history of channel gain; thus, resources can be deployed with increased efficiency. The semi-distributed method, conversely, is more generalized, but may work less effectively due to not maintaining a strong record of the interfere between channels. This method aims to ensure coexistence of traffic types without degrading network performance by balancing the conflicting requirements between UEs and MTC devices. When devices and UEs coexist in the same network, a useful technique called Dynamic Radio Resource Allo-cation Strategy (DRRAS) was presented in [24] to dynamically modify the power levels of the devices. The goal of DRRAS is to maximize MTC device power consumption while upholding the necessary UE quality of service (QoS). The author [12] uses the packet multiplexing technique for fixed machines. The outcomes showed that this tactic might considerably raise machine traffic data rates, enhancing the network's overall effectiveness. Despite these developments, the majority of research has been on scheduling in the time domain, which works better in situations where there are only a few hundred devices on the network. However, standard time-domain scheduling loses effectiveness as the load in a cell increases, as in the case of thousands of connected devices. Distinguishing between MTC traffic and conventional H2H traffic becomes increasingly challenging in high-load scenarios, which may result in resource waste. For instance, if MTC devices utilize very little bandwidth, resources assigned to them might be wasted, whereas UEs—which normally require higher band-width—might not be able to access the resources they need. This study offers a novel method for integrating MTC and IoT data flow in cellular networks to overcome these issues. It is feasible to increase the efficiency and dependability of cellular networks in the face of expanding IoT use by creating new scheduling algorithms and resource management strategies that take into consideration the special qualities of MTC traffic. This method not only improves the functionality of current networks but also sets the stage for the next generation of cellular technologies, which will have to handle an even higher number of devices that are connected and have different communication needs

METHODOLOGY

As mobile technology has evolved, cellular networks have been inherently broadband systems, meaning they are dedicated to high data rate communication. In contrast, Machine-Type Communication (MTC) and Internet of Things (IoT) devices produce very small data packets which require lower bandwidth to function effectively. It is inefficient and also wastes a lot of resources since assigning a whole PRB to every machine or IoT device would be an overhead. This inefficiency is especially problematic considering the number of connected devices is increasing, putting stress on the network. Considering this situation, a ground-breaking approach, the Packets Collection and Forwarding (PCF) solution, has been designed. PCF essentially employs an intermediate device known as a PCF Node, which buffers and aggregates the small data packets produced by MTC and Internet of Things (IoT) devices. The data packets are instead offloaded in PCF Node before being transmitted to the cellular tower (eNodeB) as represented in Figure 2. The PCF Node is purposefully deployed in environments like containers with potentially several sensors J.

These small batches of data sent to PCF Node are based on information captured from the sensors, which do not send data all the way to the cellular network but rather deliver data to PCF Node. Now, as soon as the small packets arrive at the PCF Node, the small packets will get buffered up at the PCF Node and aggregated before sending to the eNodeB. It makes it possible to transmit multiple small packets together as a single packet of much larger size, which leads to a more efficient usage of the available bandwidth. The Net can greatly reduce the number of PRBs for MTC and IoT communication using the PCF approach. Furthermore, it can easily release valuable spectrum resources while increasing the overall efficacy of the network. As illustrated in Fig. On the other hand, as illustrated on Fig. 1, IoT devices and machines send their data to PCF Node, which would aggregate this data and exchange it with eNodeB. By accommodating this high MTC and IoT traffic through these means, the cellular network can retain an optimal performance and resource usage due to the fact that this MTC traffic is a main driver in the construction of a proper fenced and benefiting roaming architecture.

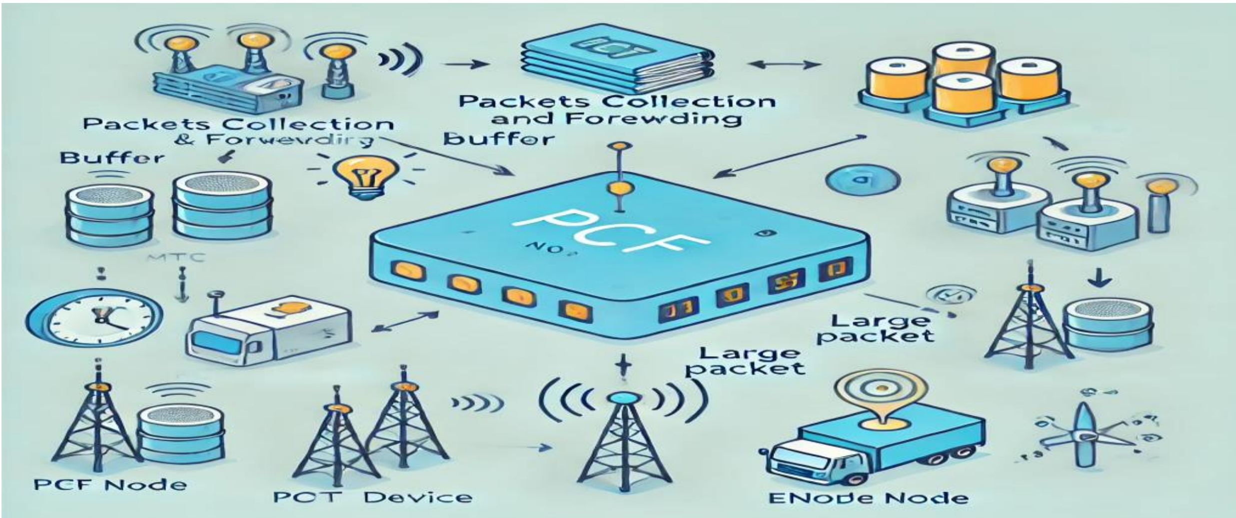

Figure 2.
Packet collection and forwarding [1]

IoT/MTC Devices: These are the devices that generate small data packets. PCF Node: Intermediate to collect buffer, will aggregate input packets Collect multiple small packets from IoT devices and merge them into big packets. eNodeB: The bundled data packet is forwarded to eNodeB (cellular tower) for transmission via the cell network. The PCF Node in this diagram acts as a buffer and aggregator for multiple IoT/MTC devices before submitting a packet into the network. IoT and MTC devices generate small packets, which are preserved in a buffer in the intermediary PCF Node. In specific, the Transport Block Size (TBS) number is a crucial component then, which dictating how much data can be sent over the network in a single transmission, hence it is essential to strategically establish the size of this buffer. The TBS calibrated buffer size calibration of this system guarantees that successful compaction happens to generate big, appropriately packed, packets for transmission, by several little packets. One important role of this accumulation process is to fully utilize the Physical Resource blocks (PRBs) that have been assigned. Packet relay bases, also known as PRBs, are the basic components for resource allocation in LTE and other advanced cellular networks.

Each PRB has a fixed capacity. The transmission of individual little packets will waste a considerable amount of the physical resource block (PRB), which may lead to the inefficient utilization of the available spectrum and even congestion in high-density network scenarios. It aggregates multiple small data packets into one large packet to increase the amount of data carried by each physical resource block (PRB) using a PCF technique. This enhances the overall performance of the network and reduces unnecessary use of resources. Only until the buffer in the PCF Node fills up, does the big packet is still combined and is sent to the eNodeB, i.e. the Base station which is responsible for handling the communication between the user equipment and the core network. The smaller fresh packets that do arrive are still collected and stored in the buffer and sent on when its their turn to cycle through transmission. This ongoing process ensures that large amounts of reliable and significant IoT and MTC data is conveyed to the core network infrastructure. But sensitive or urgent data management is another vital aspect that needs to be considered in this process. These data packets may experience unacceptably long waiting periods, making the information outdated or unusable, since they are stored in the buffer until the full memory is utilized. For instance, real-time monitoring systems in industrial automation or health care relieve instantaneous data transfer to function properly. In some cases, delayed communication may significantly impair patient care quality or operational efficiency. To address this challenge, the system integrates the buffering accumulation approach with a dynamic timing mechanism. Specifically, when the first packet arrives at the buffer a timer is triggered. Afterward, the system allows packets to queue up until either some rat-deterrent timer expires (the predetermine timer) or the buffer is filled to its last byte (the system fill). Whenever one of these situations occurs, the corresponding data is instantly packed into a large packet and transmitted to eNodeB. Then the timer is reset, and the process is repeated for incoming packets as in figure below.

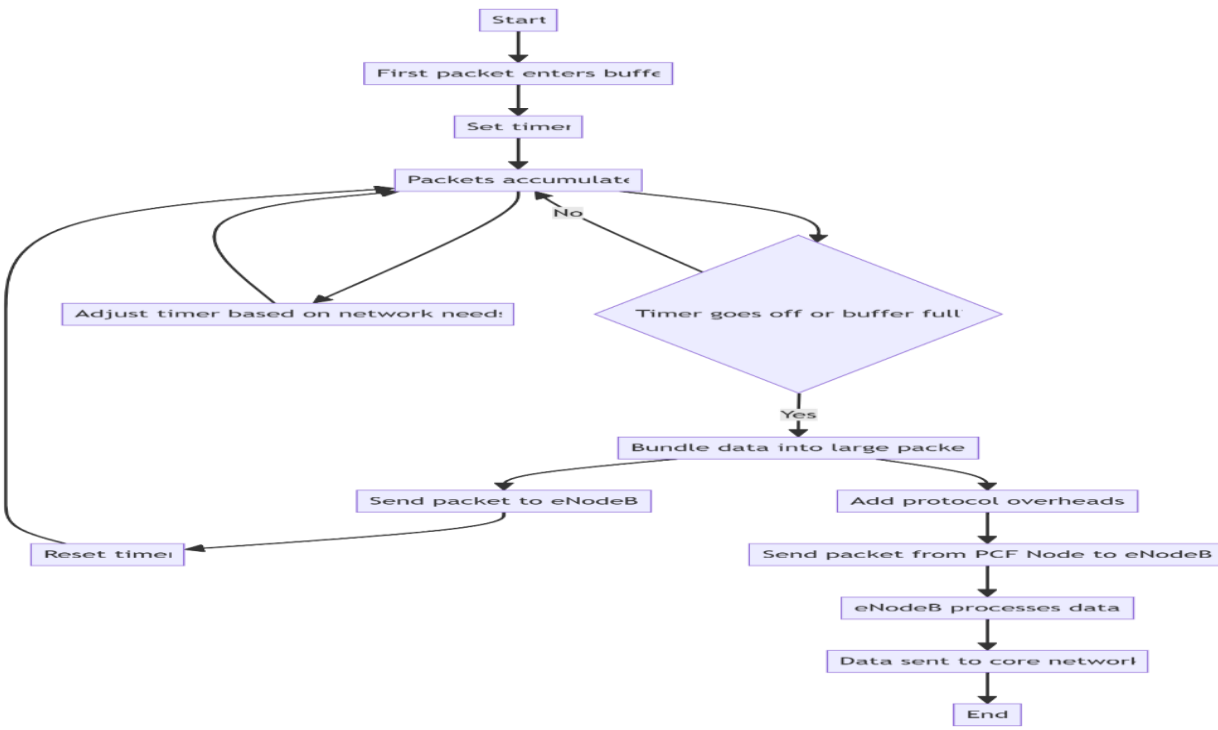

Figure 3:
PCF flow chart

All is still combined until the PCF Node buffer is full, the large packet will be sent to eNodeB, the Base station is responsible for communication with the user equipment and the core network. If a smaller fresh packet is most of all the packets still on the network, the buffer collects it and waits for it to be sent on, when it's time to cycle through transmitting. Such a continuous flow of small, reliable, and large IoT data from the edge subsets to the core network structures. This process though involves another important aspect of sensitive or urgent data management. Since these data packets get stored in the buffer until the complete memory is consumed, these packets can wait for unacceptably long periods, increasing the chance of the packets becoming obsolete or useless. For example, systems like real-time monitoring in industrial automation or health care depend on instantaneous data transfer for their operation. In some settings, delayed communication can substantially diminish the quality of patient care or the efficiency of operations. To tackle this problem, the system combines the buffering accumulation method with a dynamic timing system. In particular, whenever the first packet arrives at the buffer a timer is started. Next, packets are free to back up until such time as some rat-evicting timer passes (the predetermine timer), or the buffer is completely full (the system fills). It occurs whenever one of these situations happen, at this instance all the relevant data is packed into a huge packet and sent to eNodeB. The timer value resets, and the process is repeated for incoming packets. To secure data integrity and adequate routing, varying degrees of protocol overhead is imposed on various stages of the communication stack in the accumulation process.

This information typically comprises source and destination addresses, error-checking codes, sequencing information, etc., which are packaged in the form of Headers or trailers bundled as overheads. While it does add some overhead, overheads are essential for reliable and organized network communication. Once the big packet is fully constructed with all required overheads, it is sent from the PCF Node to the eNodeB. The eNodeB will then transmit the data to the relevant places in the core network, ensuring that the information is received by the rightful people at that same time. This structured and efficient data processing method ensures that cellular networks manage a high volume of IoT and MTC traffic with significantly improved performance and scalability. By far the best way to integrate MTC and Internet of Things data traffic in the existing cellular networks is the Packets Collection and Forwarding (PCF) methodology with some intelligent buffering and timing techniques. Its capabilities successfully provide the bridge between the high-speed characteristics of cellular networks and the low-speed demands of IoT devices in the fast-paced world of interconnected technologies, ensuring efficient, trustworthy, and scalable connectivity.

TRANSITION PROBABILITIES

The odds that a tiny packet will arrive in the buffer are known as PAT probabilities. For instance, when there is no packet in the buffer, packet arrival is certain, hence the value of t_0 = 1 (t_0 is the packet arrival probability). However, s_0 = 0 represents the packet departure probability, meaning that every time a packet arrives in the buffer, or a cumulative number of packets departs from the buffer. Like this, when there are already one, two, three, four, or five packets in the buffer, respectively, t_1, t_2, t_3, and t_4 are the probability of the second, third, fourth, and fifth packet arriving in the buffer. In a similar manner, the probability of large packets forwarded to eNodeB are represented by s_1, s_2, s_3, and s_4. Separate calculations are made for the transition probability in Scenario-1 and Scenario-2. Two PRBs are assigned to the system in the first scenario, while four PRBs are assigned to the system in the second. Furthermore, the simulation probabilities (A-posteriori probabilities) are verified using an analytical model as indicated in eq (2).

$$= \begin{cases} 1, & n = 0 \\ 1 - \sum_{j=0}^{n-1} \frac{(\lambda T_{max})^j e^{-\lambda T_{max}}}{j!}, & 1 \leq n < r \text{..............} \quad (2) \\ 0, & n \geq r \end{cases}$$

The chance of a packet arriving with none in the buffer is denoted by t_0 in equation (2).

RESULTS AND DISCUSSION

The findings showed that a small number of machines will result in a low load and a smaller value of t_1. The load determines the packet arrival rate; a low load results in a low packet arrival rate; a high load causes the packet arrival rate to increase as well, increasing the value of t_1 for the following sensor and machines. The value of t_1 rises as the number of machines increases, as Fig. 2 illustrates. With a value of 0.78 for t_1, the probability of the second packet arriving is 78%. Conversely, the chance of departure s_1 is equal to 0.22, or 22%. As shown in Figure 4, When the load is low, there's a greater chance that the next packet will come; when the load is high, there's a greater chance that the packet collection and forwarding process will start.

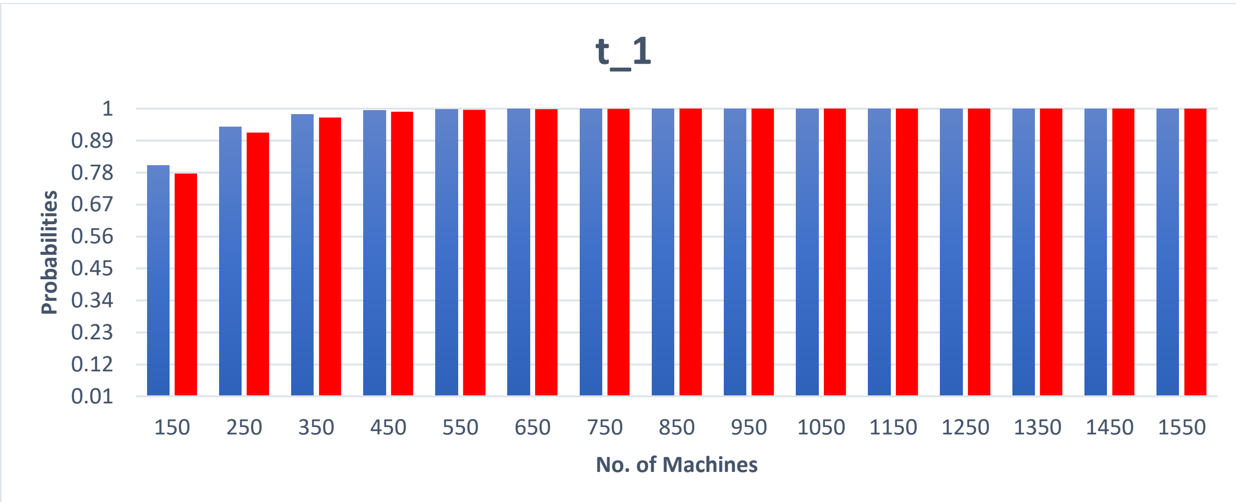

Figure 4. Comparison probability t_1 (Scenario-1, 3 PRBs)

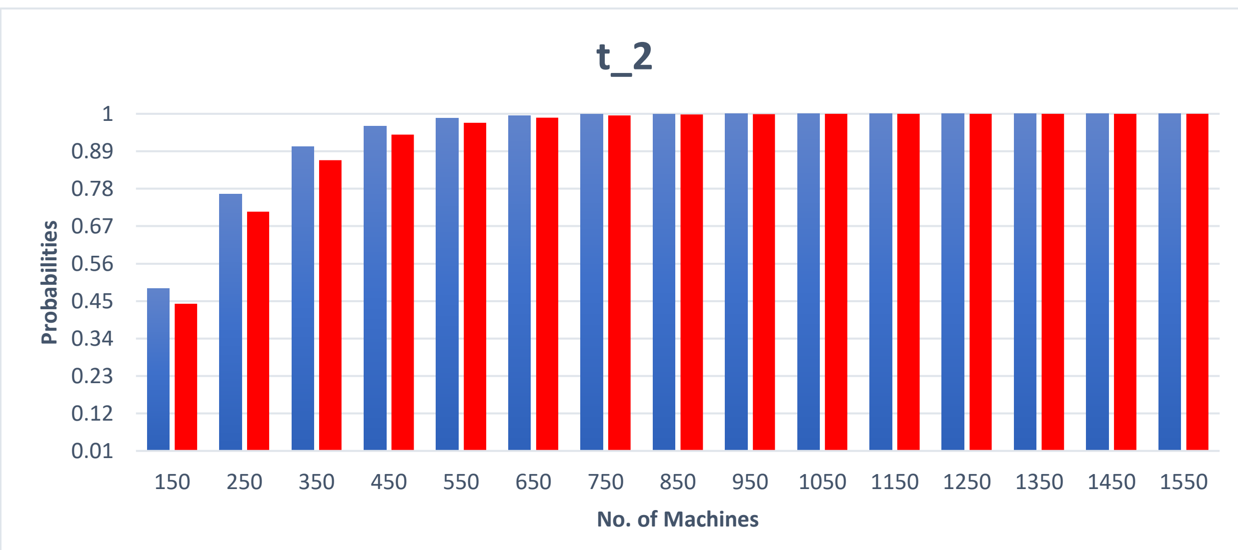

Figure 5.
Comparison probability t_2 (Scenario-1, 3PRBs)

The likelihood of the third packet arriving, t_2, is displayed in Fig. 5. At low load, the departure probability, or s_2, will rise to 0.55, indicating a 55% chance that the PCF process will begin, while t_2 is 0.45, indicating a 45% chance that the third packet will arrive in the buffer. The probabilities t_1, t_2, and t_3 are established in Scenario-2, where the intermediary node is assigned four PRBs, as seen in Figures 6, 5, and 6. The likelihood of the second packet arriving is denoted by t_1 in Fig. 4. When there are 200 machines, t_1 is equal to 0.78, and s_1 (the probability of an accumulated large packet) is equal to 0.22 for the same computers. The findings indicated that as the number of machines increases, so does the value of t_1.

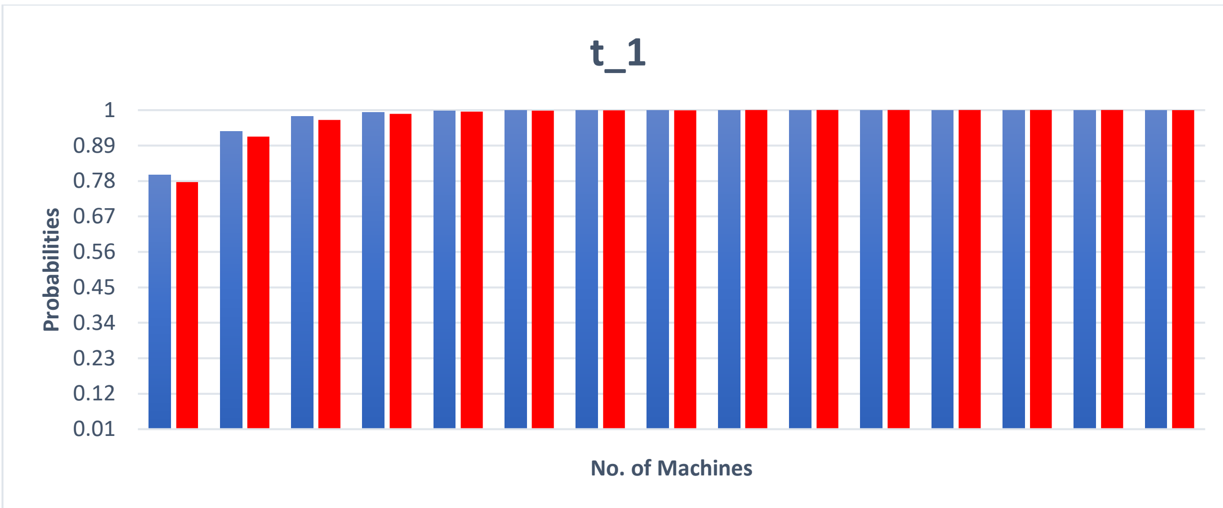

Figure 6.
Comparison probability t_1 (Scenario-2, 4 PRBs)

Similarly, the probability of the third and fourth packet arrivals are represented by t_2 and t_3 in Figures 7 and 8, respectively. In a similar vein, the departure probabilities for three and four packets in the buffer are represented by s_2 and s_3.

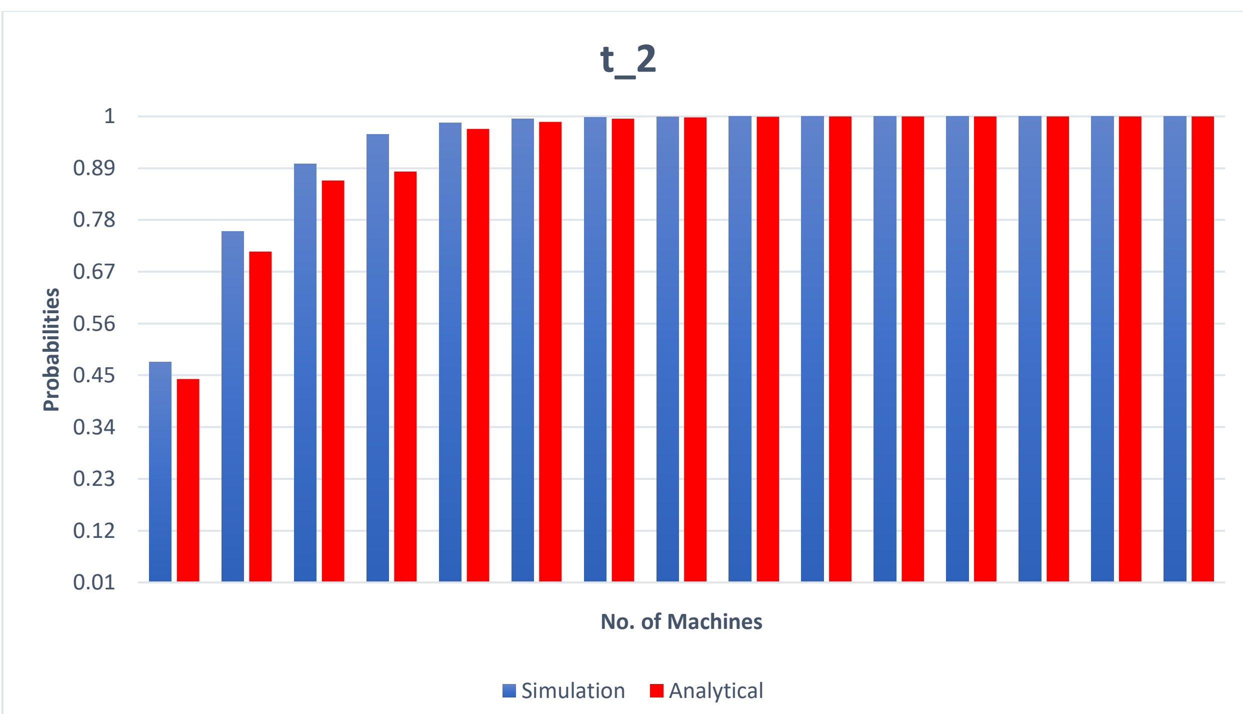

Figure 7. Comparison probability t_2 (Scenario-2, 4PRBs)

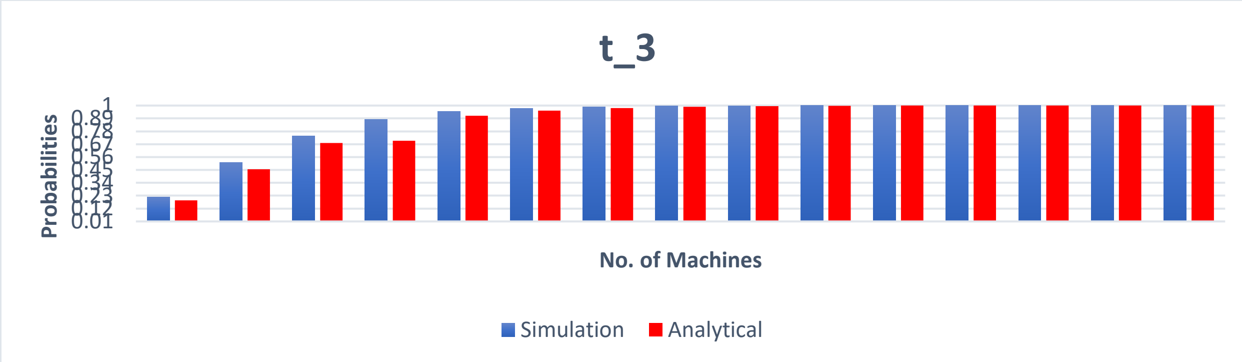

Figure 8:
Comparison probability t_3 (Scenario-2, 4 PRBs)

CONCLUSION

In this research, the PCF technique is presented, where machine and IoT-generated short data packets are temporarily held in memory. Another method for managing tiny packets in memory is the timer technique. These small packets wait until the timer expires or the memory is filled. In mobile networks, this approach can significantly increase spectral efficiency. Additionally, the findings show that an increase in the number of machines overloads the mobile network, causing congestion that prevents the system from providing the necessary services.

DECLARATIONS

Acknowledgement: We appreciate the generous support from all the supervisors and their different affiliations.
Funding: No funding body in the public, private, or nonprofit sectors provided a particular grant for this research.
Availability of data and material: In the approach, the data sources for the variables are stated.
Authors' contributions: Each author contributed equally to the creation of this work. However, Muhammad Ahmad Shahid took the lead in the research itself, as well as in its design, analysis, and manuscript preparation.
Conflicts of Interests: The authors declare no conflict of interest.
Consent to Participate: Yes
Consent for publication and Ethical approval: Because this study does not include human or animal data, ethical approval is not required for publication. All authors have given their consent.

REFERENCES

Khan, A. (2020). Resource Management in Mobile Networks for Machine-to-Machine Communication. University of Engineering & Technology Peshawar (Pakistan)
F. Z. Md, M.. M. Fouda, N. Kato, A. Takeuchi, N. Iwasaki and Y. Nozaki, "Toward intelligent machine-to-machine communications in smar grid," IEEE Communication s Magzine, vol. 49, no. 4, pp. 60-65, 2011.
A. Farhan, S. N. K. Marwat, Y. Zaki, Y. Mehmood and C. Gorg, "Mahine-to-machine sensor data multiplexing using LTE-Advanced relay node for logistics," In Dynamics in Logistics, pp. 247257, 2016.
M. Chen, J. Wan and F. Li, "Machine-to-Machine Communications: Architectures, Standards and Applications," KSII Transactions on Internet and Information Systems, vol. 6, no. 2, p. 480–497, Feb. 2012.

Eldred, Christopher, M. Kenney, E. Kenji, K. J. Murray and J. Zysman, 2019.
4G 5G World, [Online]. Available: http://4g5gworld.com/operator. [Accessed 3 Aug. 2011].
Laner, M. N. Nikaein, P. Svoboda, M. Popovic, D. Drajic and S. Krco, "Traffic models for machine-to-machine (M2M) communications: types and applications," In Machine-to-machine (M2M) Communications, pp. 133-154, 2015.
Alsharif, H. Mohammed, R. Nordin, M. M. Shakir and A. M. Ramly, "Small Cells Integration with the Macro-Cell Under LTE Cellular Networks and Potential Extension for 5G," Journal of Electrical Engineering & Technology, 2019.
H. Holma and A. Toskala, LTE for UMTS Evolution to LTE-Advanced, 2nd ed., The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom: John Wiley and Sons, 2011.
W. Jeanette, "LTE-advanced 3GPP," June 2013.
H. Mazar, An analysis of regulatory frameworks for wireless communications, societal concerns and risk: the case of Radio Frequency (RF) allocation and licensing., Universal-Publishers, 2009.
Khan, Ahmad, et al. "Packet Aggregation in Mobile Networks for IoT Traffic." 2019 IEEE 6th International Conference on Engineering Technologies and Applied Sciences (ICETAS). IEEE, 2019.
F. Saleh., "Radio Frequency Cell Site Engineering Made Easy," 2019.
P. Orim, N. Ventura and J. Mwangama, "Priority-based Random-Access Scheme for Massive Machine Type Communication," in Priority-based Random-Access Scheme for Massive Machine Type Communication, Zimbali, KwaZulu-Natal North Coast, South Africa, Sept. 2019.
Marwat, Safdar Nawaz Khan, et al. "Mobile Wi-Fi based scheduling of cyber-physical systems in healthcare." *Electronics* 9.2 (2020): 247.
Y. Liu, M. Derakhshani and S. Lambotharan, "Dual Connectivity in Backhaul-Limited Massive-MIMO HetNets: User Association and Power Allocation," in IEEE Global Communications Conference, Singapore, 4-8 Dec. 2017.
Y. Mehmood, T. Pötsch**,** S. N. K. Marwat, F. Ahmad, C. Goerg and I. Rashid, "Impact of Machine-to-Machine Traffic on LTE Data Traffic Performance," in *Dynamics in Logistics*, Springer International Publishing, ISBN 978-3-319-23511-0, 2016, pp. 259-269.
Yang, Zhaohui, W. Xu, H. Xu, J. Shi and M. Chen, "Energy efficient non-orthogonal multiple access for machine-to-machine communications," IEEE Communications Letters, vol. 21, no. 4, pp.817-820, 2016.
Han, Bin, M. A. Habibi and H. D. Schott, "Optimal resource dedication in grouped random access for massive Machine-Type Communications," In 2017 IEEE Conference on Standards for Communications and Networking (CSCN), pp. 72-77, 2017.
Mohd, K. Tauheed, N. Nicole and Y. J. Ahmad, "Multi-Modal Data Fusion in Enhancing Human-Machine Interaction for Robotic Applications," A Survey." arXiv preprint arXiv, p. 2202.07732, (2022)..
Sodhro, H. Ali, I. A. Ali, v. d. . B. Jaap and N. George , "Intelligent authentication of 5G healthcare devices: A survey."," (2022): 100610..
M. A. Hassan, F. A. Shahzad, S. S., B. S. and G. T., "Integration of blockchain technology and federated learning in vehicular (iot) networks: A comprehensive survey," Sensors, vol. 22(12) 4394..
Khan, Ahmad and Mehmood Yasir, Resource Management For Machine Type Communication And Internet Of Things In Mobile Networks, J. Engg. and Appl. Sci. Vol.38 No,2 July December 2019.
Solyman, A. A. Ahmed Amin Ahmed, and K. Yahya, "Evolution of wireless communication networks: from 1G to 6G and future perspective," International Journal of Electrical & Computer Engineering, (2088-8708) 12.4 (2022).
[Online]. Available: https://www.ericsson.com/en/reports-and-papers/mobility-report/dataforecasts/mobile-traffic-forecast. [Accessed 04 February 2025].
Marwat, Safdar Nawaz Khan, et al. "Method for handling massive IoT traffic in 5G networks." Sensors 18.11 (2018): 3966.

Ashraf, Abrar, Irfan ud Din, and Ahmad Khan. "Bioelectric Signal Acquisition and Design of Portable ECG for Internet of Medical Things_Application." *Journal of Innovative Computing and Emerging Technologies* 4.2 (2024).

Masood, Fahad, et al. "A hybrid CNN-LSTM random forest model for dysgraphia classification from hand-written characters with uniform/normal distribution." *Applied Sciences* 13.7 (2023): 4275.

Fatima, Areej, et al. "Improving Car Price Predictions by Identifying Key Features." *Spectrum of engineering sciences* 2.5 (2024): 18-172.

Muhammad Younas, Shahbaz Ahmad, Dr. Ahmad Khan, & Nasir Khan. (2025). Blockchain-Assisted Framework for Improving the Taxation System of Pakistan. Dialogue Social Science Review (DSSR), 3(2), 117–134

Muhammad Toseef, Ahmad Khan, Khalil Ullah, Shahbaz Ahmad, Ibrar Hussain, & Said Khalid Shah. (2025). Enhancing Breast Cancer Diagnosis Through Virtual Biopsy and Machine Learning. *Dialogue Social Science Review (DSSR)*, *3*(2), 103–116