International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 11
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 November 2023*

A Study to Enhance Cellular Network Efficiency through Wi-Fi Offloading

[1]Kavita Chetram Kore, [2]Dr. Priya Vij

[1,2] Department of Computer Science and Engineering, Kalinga University, Naya Raipur, Chhattisgarh, India

Abstract

Cellular network congestion is on the rise due to the fast increase in mobile data consumption caused by things like the proliferation of smartphones, streaming videos, cloud apps, and Internet of Things (IoT) devices. In heavily crowded urban locations in particular, this congestion leads to worse service quality, slower data rates, higher latency, and an overall worse user experience. One important tactic for overcoming these issues is Wi-Fi offloading, which involves moving mobile data traffic from cellular networks to Wi-Fi infrastructure. This improves network efficiency. The study considers various city topologies, movement speeds, and Wi-Fi access point technical features to determine the fraction of street users that can be offloaded to Wi-Fi access points. We demonstrate that the number of users on the street that can be transferred to Wi-Fi is significantly impacted by how fast they move, the range of the access points, and the time it takes to connect to the access points. Several test runs have shown that more Wi-Fi access points greatly enhance offloading efficiency, which in turn reduces the stress on cellular networks. Wi-Fi range also matters a lot, albeit the benefits start to dwindle as coverage from several access points starts to blend. Offloading rates are unaffected by changes in urban density, however connectivity is severely affected by changes in user movement speed and login delays. Insights gained from these results might help telecom carriers optimize Wi-Fi offloading solutions for use in urban areas, which in turn improves network performance.

Keywords: Cellular networks, Wireless, Urban, Offloading, User

I.INTRODUCTION

An integral part of today's digital infrastructure, cellular networks have altered the way people interact with one another, get information, and do business. Voice conversations, video streaming, social media interactions, cloud computing, and other data-intensive activities are made possible by these networks, which provide seamless communication across numerous devices. Network congestion is a new and unexpected problem for cellular networks brought about by the ever-increasing number of mobile users and linked devices. When there is a greater demand for network resources than there is capacity, cellular network congestion happens. This leads to slower data rates, higher latency, call drops, and worse service quality. This problem is more common in more populated cities since there are more users trying to use the network at once, which puts a pressure on the capacity. Telecommunications companies, government agencies, and IT companies have made alleviating congestion a major goal in response to the exponential growth of mobile data use. Conventional methods of alleviating congestion have included allocating more spectrum and building up existing networks; however, new approaches are being investigated to improve efficiency and guarantee uninterrupted access, including Wi-Fi offloading, network optimization, and next-generation wireless technologies.

The exponential growth of mobile data traffic is the main factor leading to cellular network congestion. A major factor in the dramatic increase in data consumption over the last decade has been the broad use of mobile devices such as smartphones, tablets, and Internet of Things (IoT) devices. Users increasingly depend on mobile networks for services that need a lot of bandwidth, such as HD video streaming, real-time gaming, video conferencing, and cloud storage. Video content accounts for the highest percentage of data use on platforms like YouTube, Netflix, and TikTok, which dominate mobile traffic. Mobile networks are experiencing congestion, particularly during peak hours, due to the huge demand for high-quality streaming, which includes 4K and 8K video. The ever-present multimedia material transmission by social media apps like Twitter, Instagram, and Facebook further adds to the strain on cellular infrastructure. The increasing reliance on mobile data has outstripped the increase of network capacity, leading to bottlenecks that impact both the user experience and the dependability of services.

When mobile traffic is not evenly distributed, it can lead to network congestion. Even though cellular networks can manage fluctuating data demands, they can become severely congested during unexpected spikes in consumption, which

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 11
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 November 2023*

are typically caused by certain events. An example of this would be the simultaneous attempts by a high number of mobile users to access the network at huge public events like concerts, sporting events, and festivals. Because of the nearby cellular towers being overwhelmed, connections may be delayed or even interrupted due to this unexpected surge in demand. On a regular basis, during peak hours, thousands of people use cellular networks for things like communication, navigation, and entertainment, which causes congestion in places like transit hubs, office districts, and highly populated residential regions. Predicting and managing these unpredictable traffic patterns while maintaining consistent service quality across multiple locations and time periods is a problem for network operators.

In order to transfer data from customers to service providers, cellular networks employ a mix of licensed airwaves, base stations, and backhaul technologies. But there's a limited amount of spectrum available, and getting more licenses is a hassle and a cost. Consequently, operators need to make the most of what they have in order to meet the increasing needs of traffic. Increasing network capacity through the traditional means, such erecting more cell towers or enhancing existing base stations, necessitates substantial capital expenditures and governmental clearances. Space constraints, zoning restrictions, and environmental concerns are further obstacles to the installation of new infrastructure in cities. The rising density of users and connected devices poses a continuous challenge to the network's capacity to offer flawless connection, regardless of the number of additional towers that are added.

Congestion on networks has serious consequences for both consumers and companies. Slow web browsing, buffering when watching videos, lost calls, and delayed messages are just a few of the annoying things that individual customers face as a result of congestion. Situations like virtual meetings, online schooling, and telemedicine consultations—where dependable connectivity is crucial—are especially troublesome when these problems occur. The inefficiencies caused by congestion also affect businesses that depend on mobile networks for customer care, digital transactions, and various operational tasks. In order to handle transactions, manage customer relationships, and provide smooth user experiences, cloud-based businesses, e-commerce platforms, and financial services rely on reliable and fast internet connections. Revenue loss, decreased productivity, and poor customer satisfaction can all come from any kind of connection disruption. Dedicated network access, private 5G installations, or Wi-Fi-based connection are some of the alternative options that enterprises may need to engage in in heavily populated locations to guarantee service delivery without interruption.

The problem of congestion is likely to change when cellular networks upgrade to 5G and other next-generation technology. 5G networks bring new challenges to network management and resource allocation, but they also offer faster speeds, reduced latency, and more capacity. Installing tiny cells, edge computing capabilities, and sophisticated spectrum utilization techniques are just a few of the infrastructure enhancements that will be necessary for 5G rollout. To go from where they are now to where they need to be in terms of network capacity, telecom operators will need to put effective congestion management methods in place. Network optimization is a great way to reduce congestion since it uses methods like data compression, load balancing, and traffic prioritization. Improved efficiency and less congestion are outcomes of operators' ability to dynamically allocate network resources in response to user needs and real-time demand.

Need for Wi-Fi Offloading

Cellular networks are experiencing unprecedented levels of congestion, which is causing slower speeds, network failures, and worsening user experiences. This is due to the exponential rise of mobile data traffic and the rising demand for high-speed, continuous access. Mobile network operators (MNOs) are facing increasing challenges in keeping up with the data demands of both consumers and businesses. This is especially true in densely populated urban areas, where the combination of high mobile usage and population densities puts a tremendous strain on the cellular infrastructure. The proliferation of data-intensive applications like video conferencing, cloud computing, real-time gaming, social networking, and high-definition video streaming has made this problem much worse. Cellular networks are finding it harder and harder to keep up with the exponential growth in data consumption caused by new technologies like the Internet of Things (IoT), smart cities, and apps powered by artificial intelligence. In light of these difficulties, mobile network operators are looking for new ways to improve service quality and reduce network congestion; Wi-Fi offloading is one of the best options currently available. Offloading mobile data traffic from cellular networks to Wi-Fi networks is known as Wi-Fi offloading. This helps to improve network efficiency and reduce the strain on cellular infrastructure.

Cellular networks may run more effectively and with less interference when MNOs use Wi-Fi hotspots in places like parks, homes, businesses, and transit hubs to offload some of their network traffic. This method optimizes network

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 11
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 November 2023*

resources, which enhances user experience and leads to faster data rates, lower latency, and improved connection for mobile users. When millions of people use mobile networks at once, congestion and poor service quality are commonplace in metropolitan areas, making Wi-Fi offloading an absolute necessity. Space limits, high prices, and regulatory constraints make the deployment of new cellular towers to boost network capacity impossible in many places. On the other hand, Wi-Fi networks offer a practical and economical alternative to cellular network congestion because of their flexible deployment options. Wi-Fi offloading is a scalable and practical approach for controlling mobile traffic, especially with the proliferation of public Wi-Fi hotspots and home and business Wi-Fi networks.

Wi-Fi offloading is even more crucial since, in contrast to cellular networks, which depend on licensed frequency bands allotted by regulatory bodies, Wi-Fi networks use unlicensed spectrum, which means they don't need expensive spectrum licensing. A cost-effective approach for increasing connectivity, Wi-Fi offloading allows telecom carriers to extend their network capacity without incurring major investments. Further, by transferring mobile data to Wi-Fi networks, the burden on cellular towers is decreased, leading to better service quality for consumers who still utilize the cellular network. This is especially helpful during times of heavy network traffic, when customers face slower speeds and more delay.

Mobile carriers may keep their networks balanced and efficient by shifting certain traffic to Wi-Fi. This way, important data and voice services won't be affected. The capacity to offer a smooth and fast connection experience is a major benefit of Wi-Fi offloading, particularly in interior areas where cellular connections could be poor or inconsistent. Dropped calls and sluggish data rates are common complaints from those living in highly populated metropolitan areas, buildings with thick walls, or facilities located underground. By utilizing Wi-Fi offloading, users in such settings may migrate to a more dependable connection, which improves overall connectivity and guarantees that online services will be accessible without interruption. Additionally, Wi-Fi offloading is even more successful at managing massive amounts of mobile data because to the incorporation of latest Wi-Fi technologies like Wi-Fi 6 and Wi-Fi 7, which have substantially increased network performance. Specifically, Wi-Fi 6 is a great option for dumping cellular data traffic because it has better efficiency in densely populated regions, faster speeds, more capacity, and reduced latency.

The effect of mobile data usage on device battery life is another fundamental reason propelling the necessity for Wi-Fi offloading. Using cellular networks only for data transmission can lead to increased power consumption for mobile devices. This is because there's an ongoing requirement to find and maintain a solid connection, which can be particularly taxing in places with weak or crowded signals. In contrast, devices can save electricity while still having a reliable internet connection when using Wi-Fi because it often uses less power. This means that Wi-Fi offloading helps mobile users save power while simultaneously improving network speed. When adopting Wi-Fi offloading, it is crucial to also think about security. There are security concerns with using public Wi-Fi networks, including the possibility of data collection, illegal access, and cyberattacks, despite the fact that they offer a practical option for mobile connection. The security of Wi-Fi offloading has been addressed by mobile carriers and technology suppliers through the implementation of different protocols. These protocols include authentication procedures, encryption, and Virtual Private Network (VPN) solutions. Users may now effortlessly switch between cellular and Wi-Fi networks without having to manually authenticate themselves, all thanks to the widespread usage of Hotspot 2.0 and Passpoint technologies.

With the arrival of 5G and subsequent generations, Wi-Fi offloading appears to have a bright future. 5G networks have a lot of potential, including vast connection, extremely low latency, and high speeds, but they also have a lot of problems, such as limited spectrum, expensive equipment, and complicated implementation. Here, Wi-Fi offloading is going to be vital for 5G networks to fill in the gaps left by under-or nonexistent 5G infrastructure by boosting capacity and coverage. Users will be able to seamlessly transition between networks in response to current traffic circumstances, signal strength, and data needs, thanks to the anticipated more efficient and integrated connectivity ecosystem that will result from the convergence of Wi-Fi and cellular networks. Smart traffic routing, automatic network optimization, and predictive congestion management are all possible thanks to the incorporation of AI and ML into network management, which will further improve Wi-Fi offloading. As cellular networks are already under tremendous stress from the exponential growth of mobile data consumption, Wi-Fi offloading is more important than ever.

Telecom providers may reduce congestion, boost service quality, and enrich user experience by offloading mobile traffic to Wi-Fi networks. Thanks to improvements in Wi-Fi technology and the proliferation of both public and private Wi-Fi networks, Wi-Fi offloading has emerged as a viable

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 11
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 November 2023*

and extensible method for controlling mobile data traffic. Saving money, improving energy economy, improving indoor connection, and increasing security through contemporary encryption methods are just a few of the many advantages of Wi-Fi offloading. As wireless communication continues to expand, the combination of Wi-Fi and cellular networks will play a critical role in creating the future of mobile connectivity, assuring dependable, high-speed, and efficient internet access for consumers globally. Telecom providers may strengthen their network infrastructure to handle the increasing needs of digital communication by embracing new ideas and investing in next-gen wireless technology. This will allow them to make the most of Wi-Fi offloading.

II.REVIEW OF LITERATURE

Majumder, Bhaswar & Venkatesh, T. (2022) A modern networking paradigm known as mobile data offloading redirects some cellular data traffic to WiFi's unlicensed spectrum. Here, we provide a new method of data offloading that is based on the minority game (MG) theory, which is based on exponential learning. An suitable offloading condition for our proposed MG-based distributed data offloading method has been derived by comparing the performance of cellular and WiFi services with regard to the supplied load. We analyze the performance of the MG algorithm through comprehensive simulation by changing various essential factors, such as the pricing parameter β, the cellular offered throughput (Sc), and the temperature coefficient of the algorithm (γ), in order to assess its effectiveness. An efficient methodology for adjusting the price parameter β in relation to the offered load, called the Target price scheme, is also introduced. This model takes into account the dynamic traffic conditions using a reverse engineering technique. We have made arrangements for our algorithm to be used in a setting with many entry points. We have investigated the actions of several node classes in a diverse population using a networking algorithm based on MG. Our proposed approach has been tested in an IEEE 802.11ax environment using comprehensive NS3-based simulations. We have examined the impact of MIMO, QoS, the transport layer, and unsaturated traffic conditions.

Zhou, Huan et al., (2018) Mobile data traffic has been expanding at an exponential rate, putting a strain on mobile network operators, as more and more people use their smartphones, iPads, and other electronic tablets to access a variety of multimedia services. One viable solution to this major problem in mobile networks is mobile data offloading, which involves managing data traffic via the use of complementary technologies such as small cell networks and WiFi networks. New methods for mobile data offloading are detailed in this article. Data offloading through small cell networks, data offloading through WiFi networks, data offloading through opportunistic mobile networks, and data offloading through heterogeneous networks are the four main categories into which the current mobile data offloading technologies fall, according to the diversity of data offloading initiators. Along with that, we present a comprehensive taxonomy of the associated mobile data offloading technologies by analyzing the benefits and drawbacks of different offloading solutions for various mobile network issues. Lastly, we present an overview of some preliminary research concerns and obstacles that may serve as benchmarks for further studies.

Yu, Haoran et al., (2017) Cellular networks have seen unprecedented energy consumption due to the meteoric rise in mobile data traffic, which has also caused mobile network operators to incur massive operational expenditures. Using supplementary technologies, like Wi-Fi, to redirect traffic away from cellular networks is an encouraging way to tackle this issue in 5G systems. Both operator-initiated and user-initiated mobile data offloading have recently seen technological and economic advancements, which are covered in this article. When mobile carriers engage in operator-initiated offloading, they transfer cellular data traffic to Wi-Fi networks that are either owned by the mobile carriers themselves, their residential users, or by third parties. Users, rather than mobile network providers, take the lead in determining how to unload traffic in user-initiated offloading. Various data offloading models are classified according to our taxonomy. We go over the technical and economic obstacles, and then we outline the algorithms and processes that we developed to overcome them. Lastly, we highlight a few unanswered questions that require more research.

Ahn, Chang-Woo & Chung, Sang-Hwa. (2017) The proliferation of smartphone apps has led to a dramatic increase in the amount of data sent across mobile networks. One way to expand the reach and capacity of cellular networks is via femtocells. However, interference issues have hindered its wider adoption because to its usage of the same frequency ranges as macrocells. In this study, we present a plan to use software-defined networking (SDN) technology to transfer traffic from WiFi networks to femtocells. As part of the suggested offloading strategy, a terminal can keep running sessions even after offloading thanks to software-defined networking (SDN) technology and centralized control of SDN-based equipment. In order to decrease the burden on the femtocells while maintaining throughput-based quality of service (QoS), we also provide an association control mechanism and an offloading target selection technique that are based on available bandwidth estimation. By utilizing the suggested target selection strategy, experimental findings on a real testbed shown that the proposed offloading scheme guarantees QoS after offloading, offers seamless connection, and decreases the femtocell load by up to 46%. Additionally, in a low-traffic scenario, we found that the suggested target selection method offloads 28% more traffic to WiFi networks than received signal strength indicator-based target selection.

Mehmeti, Fidan & Spyropoulos, Thrasyvoulos. (2016) In order to address the growing data demand and caused congestion, operators have lately turned to Wi-Fi offloading. In addition, researchers have proposed delaying offloading: in the event that there is no Wi-Fi connection, (part) of the traffic can be postponed until either a specified time or when WiFi becomes available, whichever comes first. However, the advantages of delayed offloading are still up for debate. The results of two recent experimental investigations were highly contradictory, and it is still unclear how these benefits vary depending on factors like user traffic load, network characteristics (such as Wi-Fi availability), and so on. Here, we present a queueing analytic model for delayed offloading, and we find out how important metrics like mean delay and offloading efficiency are for two distinct service disciplines (First Come, First Served and Processor Sharing) depending on the user's patience and critical network parameters. We use a variety of actual circumstances and genuine data trails to evaluate the correctness of our results. At last, we demonstrate, using these expressions, how the user may maximize her own benefits by solving versions of a limited optimization problem, which allows her to optimally set deadlines.

Chen, Xianfu et al., (2015) After introducing the topic, this paper quickly reviews the current state of the art in wireless traffic offloading methods. To illustrate this point, we present a case study of an online reinforcement learning framework that addresses the issue of traffic offloading in a stochastic heterogeneous cellular network (HCN). This type of network allows for the transfer of time-varying traffic to neighboring tiny cells. While preserving the Quality-of-Service (QoS) experienced by mobile customers, our goal is to decrease the overall discounted energy consumption of the HCN. Energy consumption is governed for each cell (macro or tiny) by its system load, which is associated with system loads in other cells by sharing a same frequency band. Our approach involves using a discrete-time Markov decision process (DTMDP) to represent the energy-aware traffic offloading problem in these HCNs. Without being aware of the DTMDP information beforehand, the network controller optimizes the traffic offloading strategy based on traffic observations and traffic offloading actions. Having a model-free learning framework is crucial, particularly in cases when the state space is large. A QC-learning, or centralized Q-learning with compact state representation technique, was developed to address the curse of dimensionality. In addition, a decentralized QC-learning variant is created on the principle that macro base stations (BSs) can autonomously oversee the actions of local small-cell BSs by utilizing the global network status data collected by the network controller. The usefulness of the generated centralized and decentralized QC-learning algorithms in managing the tradeoff between energy savings and QoS satisfaction is demonstrated through simulations.

Lee, Jong-Hyouk et al., (2014) There has been a meteoric rise in mobile Internet traffic due to the proliferation of mobile devices. Flattening mobile network topologies is one solution to this expansion, but IP mobility support protocols will need to change to keep up. The authors provide an IP mobility support protocol that offers selective data offloading and circumvents the constraints of current protocols by using distributed mobility anchors instead of a single mobility anchor. By comparing and contrasting qualitatively and doing simulations, they showcase the key aspects and strengths of their methodology.

Lee, Joohyun et al., (2012) The explosion of smart portable devices and apps that are heavy users of data transfer capacity has put cellular networks under extreme strain. Transferring data from cellular networks to WiFi is a realistic and economical option. Delay WiFi offloading is a new strategy that has been shown in both theory and practice to greatly reduce cellular capacity consumption by boosting the likelihood of encountering WiFi access points (APs) and delaying user data transmissions. The effectiveness of WiFi offloading in reducing mobile data explosion is heavily dependent on the financial incentives offered to both consumers and carriers to implement and utilize delayed offloading, despite the technique's enormous potential. Here, using a two-stage sequential game between a monopolistic supplier and consumers as a model, we investigate the potential monetary benefits of delayed WiFi offloading. We also present detailed numerical findings that were calculated using a set of parameters derived from the actual traces and Cisco's 2015 traffic statistics forecast. Our analytical and numerical findings incorporate a wide range of real-world situations and parameters, including user demand and willingness to pay for traffic, the spatial-temporal relationship between price and traffic, and different pricing

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 11
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 November 2023*

and delay tolerance strategies. In comparison to on-the-spot WiFi offloading, we show that delayed WiFi offloading offers significant economic advantages, with provider income increasing by 21% to 152% and consumers' surplus increasing by 73% to 319%.

III.EXPERIMENTAL SETUP

The model utilized in this study is derived from computer simulations of a city with a road system. A number of housing complexes are located in inaccessible regions between the roadways. Within apartment buildings, Wi-Fi connection points are dispersed at random. The model's output is a swarm of randomly moving users. They will automatically link up as soon as they come within range of a wireless network. It keeps constant tabs on the number of people logged into a Wi-Fi hotspot. Finding out what the average proportion of users are connected to the Wi-Fi access point is made possible in this method. Modifying the model's variables allows one to examine the impact on the user's Wi-Fi connection time.

For this reason, we incorporate five factors that influence Wi-Fi offloading efficiency into our model. Data on the density of Wi-Fi hotspots per square kilometer is first included. This variable has an impact on coverage, which in turn affects the likelihood that a user may send data over Wi-Fi instead of cellular connections. Second, we factor in the urban area's density, which is the quantity of roads, buildings, and users per square kilometer. In the third place, we factor in the login delay, which is the time it takes to establish a connection to a wireless network. The usability of Wi-Fi for data offloading decreases as the login delay increases. In the fourth place, we factor in the speed of roaming users, which is the rate at which a user is traveling throughout the geographical space. An increase in velocity leads to a decrease in efficiency since more logins are required to access Wi-Fi stations. Last but not least, we factor in the Wi-Fi access points' range, which varies greatly among networks and protocols.

Accurate modeling of mobile data off-loading is necessary for this investigation. Our interest in the consequences of different city topologies makes agent-based modeling an ideal tool for this type of research, which occurs when a system's spatial properties are crucial. The ability to freely modify variables in the agent-based model is what makes NetLogo such a useful tool for us.

Model description

Each of the 100 x 100 patches in the NetLogo model represents a 10 by 10 meter area. In this road model, the spaces between the grid cells stand in for various types of structures. Using the approach employed in Wilensky's NetLogo Traffic Grid model (2003), one may modify the distance between roadways and the size of buildings.

Wi-Fi access points and users are both created as agents during the model's init phase. Road users are placed at random locations based on the number. The placement of Wi-Fi access sites within constructed areas is also completely at random. No connection can be established to a Wi-Fi access point from the street if its range and the size of the building are such that this is the case.

At the beginning of the model, customers will have the option to stand motionless or move randomly. Users are able to connect to Wi-Fi networks the moment they are physically near an access point. The user tries to reconnect to additional Wi-Fi hotspots when the connection drops because they are no longer within range. Once the model is started, the tick, which is the operational section of the script, is executed. One second is considered a tick in this investigation.

IV.RESULTS AND DISCUSSION

We modify one model parameter while maintaining the others at their initial levels in order to examine the influence of each conceptual model variable on the efficiency of Wi-Fi offloading. Because the locations of Wi-Fi access points and roads are completely at random, we execute 10 iterations of each test to reduce the impact of these factors. To automate the process of running the model with various settings, we use the BehaviorSpace function in NetLogo.

The findings demonstrate that 25% of mobile data is offloaded over Wi-Fi when there are 100 access sites per square km. A density of 300 Wi-Fi access points/km^{2}makes this proportion 60%. This means that telecom providers in heavily populated areas can greatly benefit from a limited number of Wi-Fi access points, as shown in Figure 1.

After that, we look at Figure 2 to see how the range of the Wi-Fi access points relates to the quantity of mobile data that may be offloaded over Wi-Fi. Data offloadable amounts are strongly affected by range, according to the results. An increase in Wi-Fi access point range from 30 to 40 meters results in a 33% to almost 55% increase in the number of users connected. The growth of linked users slows down only when the range goes over 50 meters, at which time the coverage of the access points begins to overlap.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 11
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 November 2023*

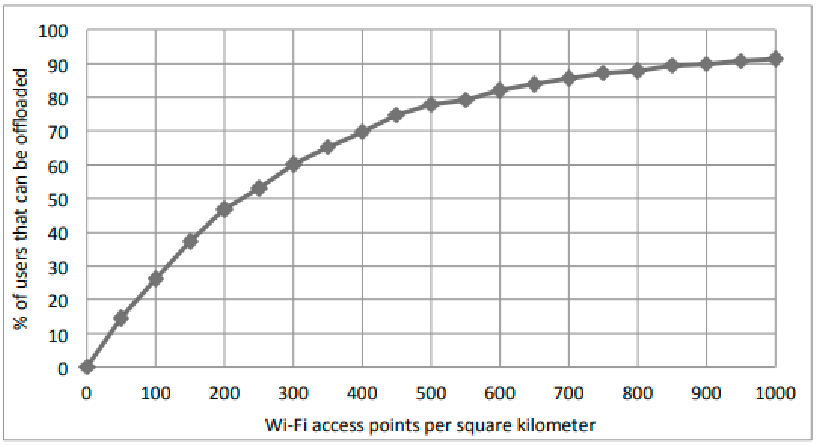

Figure 1: Impact of available Wi-Fi access points on the offloadable user

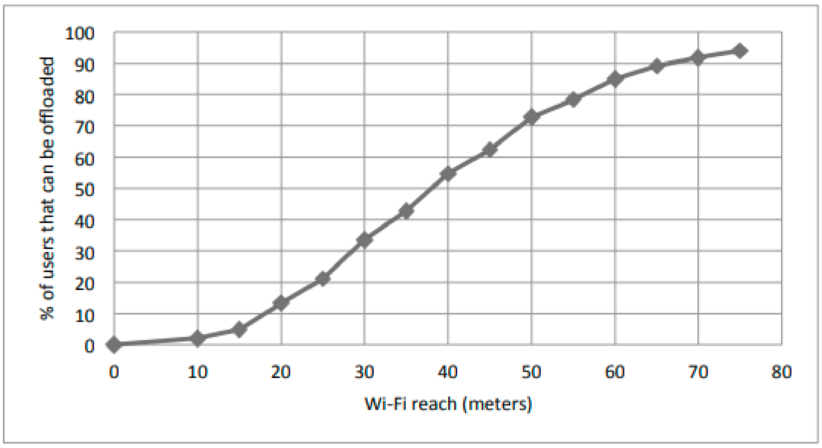

Figure 2: Impact of Wi-Fi coverage on the offloadable user

We then investigate, using density of urban area—that is, number of roads per square kilometer—how this affects the number of connected users via Wi-Fi, see Figure 3. We discover that the number of connected users via Wi-Fi scarcely changes if the number of roads rises from 6 to 16 per square kilometer, implying that the model's conclusions are generally applicable to several city topographies.

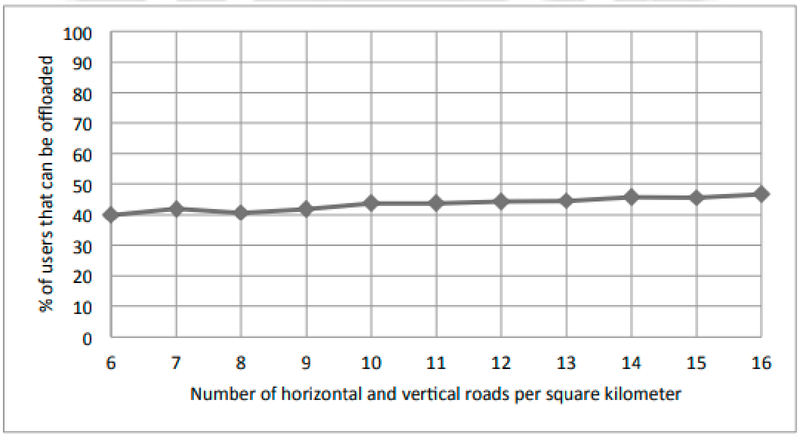

Figure 3: Impact of urban layout on offloadable user load

Finally, Figure 4 shows the link between user movement speed and mobile data offload efficacy. A significant component is the time it takes to connect to a Wi-Fi network during the login process. On average, 40% of users are connected by Wi-Fi, with a 4-second login latency and a 1-meter-per-second movement speed. On average, 9% fewer users were connected as the speed approached 14 m/s. The efficacy is greatly affected by the speed of movement.

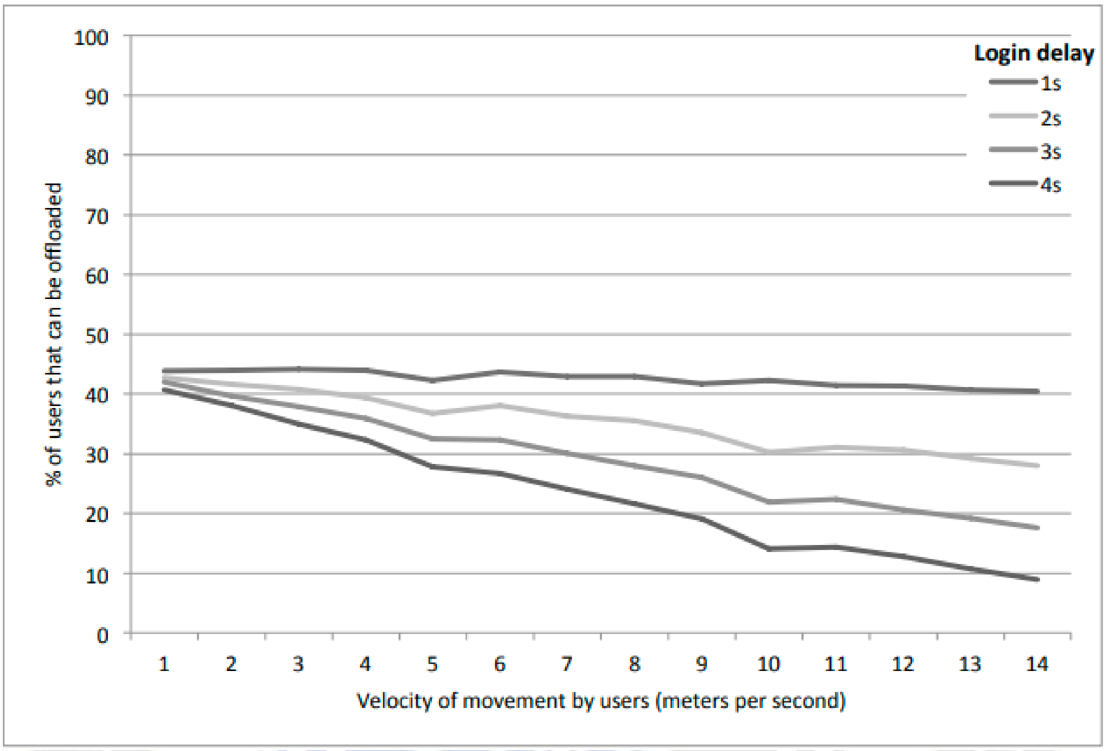

Figure 4: Impact of travel speed and login time on the offloadable user %

V.CONCLUSION

This study's findings show that Wi-Fi offloading can greatly reduce the load on cellular networks in city settings; however, the effectiveness of this technique is highly dependent on factors like the density and reach of Wi-Fi access points as well as the speed with which users move around. More Wi-Fi access points per square kilometer means more people connected, which means more mobile data offloaded from cellular networks. The range of Wi-Fi access points also plays a significant role; offloading is more affected by expanding coverage, but the effect levels out at a certain point. It is important to manage login delays and optimize access point locations in congested regions since offloading efficiency is significantly affected by variables like urban density and user movement speed. In sum, the research sheds light on how urban Wi-Fi networks should be planned and gives telecom providers actionable advice for improving their networks via offloading.

REFERENCES: -

[1] B. Majumder and T. Venkatesh, "Mobile data offloading based on minority game theoretic framework," *Wireless Networks*, vol. 28, no. 18, pp. 1–16, 2022.

[2] V. Shilpa and R. Ranjan, "SDN Based Data Offloading and Load Balancing Techniques for Applications in 5G," *Int. J. Recent Technol. Eng. (IJRTE)*, vol. 8, no. 2, pp. 6353–6358, 2019, doi: 10.35940/ijrte.B2203.078219.

[3] H. Zhou, H. Wang, and X. Li, "A survey on mobile data offloading technologies," *IEEE Access*, vol. 20, no. 10, pp. 1–10, 2018.

[4] H. Yu, M. Cheung, G. Iosifidis, L. Gao, L. Tassiulas, and J. Huang, "Mobile data offloading for green wireless networks," *IEEE Wireless Commun.*, vol. 24, pp. 31–37, 2017, doi: 10.1109/MWC.2017.1600323.

[5] C.-W. Ahn and S.-H. Chung, "SDN-based mobile data offloading scheme using a femtocell and WiFi networks," *Mobile Inf. Syst.*, vol. 2017, no. 1, pp. 1–15, 2017, doi: 10.1155/2017/5308949.

[6] G. Aujla, R. Chaudhary, N. Kumar, J. Rodrigues, and A. Vinel, "Data offloading in 5G-enabled software-

defined vehicular networks: A Stackelberg-game-based approach," *IEEE Commun. Mag.*, vol. 55, no. 8, pp. 100–108, 2017, doi: 10.1109/MCOM.2017.1601224.

[7] F. Mehmeti and T. Spyropoulos, "Performance modeling, analysis, and optimization of delayed mobile data offloading for mobile users," *IEEE/ACM Trans. Netw.*, vol. 25, no. 1, pp. 1–15, 2016, doi: 10.1109/TNET.2016.2590320.

[8] Q. Chen, G. Yu, A. Maaref, G. Li, and A. Huang, "Rethinking mobile data offloading for LTE in unlicensed spectrum," *IEEE Trans. Wireless Commun.*, vol. 15, no. 7, pp. 1–10, 2016, doi: 10.1109/TWC.2016.2550038.

[9] X. Chen, J. Wu, Y. Cai, H. Zhang, and T. Chen, "Energy-efficiency oriented traffic offloading in wireless networks: A brief survey and a learning approach for heterogeneous cellular networks," *IEEE J. Sel. Areas Commun.*, vol. 33, no. 4, pp. 627–640, 2015.

[10] J. Jiang, S. Zhang, B. Li, and B. Li, "Maximized cellular traffic offloading via device-to-device content sharing," *IEEE J. Sel. Areas Commun.*, vol. 34, no. 1, pp. 82–91, 2015.

[11] J.-H. Lee, K. Singh, J.-M. Bonnin, and S. Pack, "Mobile data offloading: A host-based distributed mobility management approach," *IEEE Internet Comput.*, vol. 18, no. 1, pp. 20–29, 2014, doi: 10.1109/MIC.2013.126.

[12] M. V. Barbera, A. C. Viana, M. D. de Amorim, and J. Stefa, "Data offloading in social mobile networks through VIP delegation," *Ad Hoc Netw.*, vol. 19, no. 1, pp. 92–110, 2014.

[13] A. Aijaz, H. Aghvami, and M. Amani, "A survey on mobile data offloading: Technical and business perspectives," *IEEE Wireless Commun.*, vol. 20, no. 2, pp. 104–112, 2013.

[14] B. H. Jung, N. O. Song, and D. K. Sung, "A network-assisted user-centric WiFi-offloading model for maximizing per-user throughput in a heterogeneous network," *IEEE Trans. Veh. Technol.*, vol. 63, no. 4, pp. 1940–1945, 2013.

[15] J. Lee, Y. Yi, S. Chong, and Y. Jin, "Economics of WiFi offloading: Trading delay for cellular capacity," *IEEE Trans. Wireless Commun.*, vol. 13, 2012, doi: 10.1109/TWC.2014.010214.130949.

[16] B. Han, P. Hui, V. A. Kumar, M. V. Marathe, J. Shao, and A. Srinivasan, "Mobile data offloading through opportunistic communications and social participation," *IEEE Trans. Mobile Comput.*, vol. 11, no. 5, pp. 821–834, 2011.