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Context-Aware Wifi Offloading in Congested Public Areas

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Abstract

As mobile users increase their data consumption, especially in busy public areas, mobile networks often experience congestion and a decline in users' quality of service. Offloading to wifi: wifi networks have become a preferred method for mitigating offloading problems in cellular networks, as they shift some traffic to wifi access networks. Conventional offloading methods often overlook contextual information such as user movement, application type, network traffic, congestion, and signal strength, which can degrade performance and user experience. In this Paper, we present a context-aware wifi offloading framework that makes real-time offloading decisions based on environmental and user-specific contexts. Context parameters, such as user location, Wi-Fi access points, the sensitivity of the applications in use, and user movement patterns, enable the decision-making system to determine the most appropriate network for the data session. The focus of our work is refining a specific decision-making model that seamlessly integrates with components of uninterrupted user accessibility, system functionality, overall user satisfaction, and system engagement efficiency. Across the simulated and real-world congestion scenarios used in our analyses, the results show marked improvements and significant variances in latency and energy consumption compared to traditional approaches. Our methodological design is both expert- and scalable within the domains of network optimization, congestion alleviation in high-volume user

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areas or hotspots, effective movement of user networks, and overall enhancement of user satisfaction.

Keywords: Context-Aware, WIFI Offloading, Congestion, Public Areas, Mobile Networks, Network Selection, Performance Optimization.

1 Introduction

1.1 Overview of Issues Relating to Overcrowded Public Wifi Networks

Locations with large numbers of people in proximity, such as shopping malls, airports, stadiums, and downtown areas, are among the most densely populated spots in the world. The addition of more mobile devices and data-hungry apps is driving network traffic to even higher levels. This is why user experience suffers: low data rates and higher latencies, described by Cisco (2023) as sub-optimal. Public Wi-Fi is used to help people connect to the network; however, poor placement of access points (APs) leads to network congestion (Romanous et al., 2015). The quality of both cellular and Wi-Fi networks is subpar in areas with high population density. Even with the advancements of 5G technology, older cellular network models have yet to address the imbalance in the system. The problem is exacerbated in ad hoc public Wi-Fi networks, where users experience poor service levels; overlapping signals further worsen service conditions (Maallawi et al., 2014; Kooshki et al., 2016). This explains the need for more sophisticated, more intelligent algorithms to better optimize network traffic mitigation across multiple Wi-Fi interfaces.

1.2 Significance of Offloading Regarding Network Congestion Relief

In studies by (Lee et al., 2013; Aakhari & Aakhari, 2014), the authors consider the traffic-complementing method, in which cellular network traffic is offloaded to available Wi-Fi networks. This technique is best suited for networks with numerous subscribers. Offloading data traffic from mobile networks to Wi-Fi networks helps reduce congestion in the licensed spectrum, improving QoS. This technique is primarily applicable to public environments with a high density of mobile users. Many current offloading methods are policy-based, using a fixed rule set. Devices connect to available Wi-Fi networks based on the signal strength of Wi-Fi access points (APs) (Balasubramanian et al., 2010). Most of these methods have no consideration of a) user mobility; b) the application's sensitivity (i.e., real-time streaming video versus background downloading); c) the current level of congestion; and d) the energy. These assumptions yield suboptimal offloading results (Prasath, 2023; Singhvi et al., 2018). An example of this is moving from a less congested cellular access link to a highly congested Wi-Fi access point (AP) with signal strength similar to that of a mobile tower. This can significantly degrade the application's QoS.

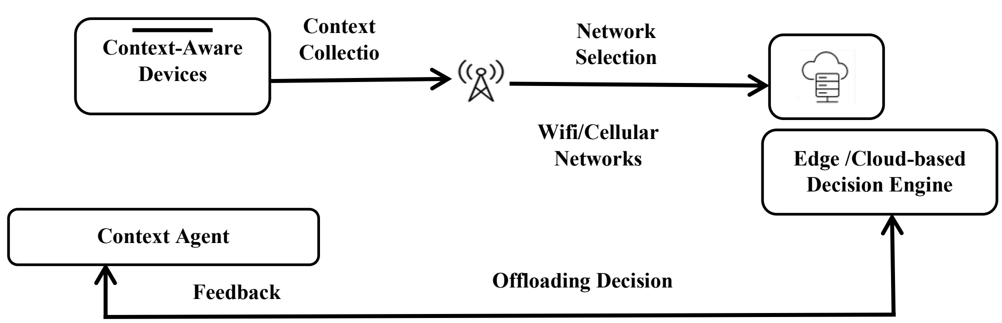

Figure 1: System architecture of the proposed context-aware wifi offloading solution

In Figure 1, the Wi-Fi offloading system optimally manages mobile data usage by maintaining a hop-switch interface between Wi-Fi and cellular networks. Its architecture consists of Context-Aware Devices, Communication Networks, Decision Engines, and Feedback Loops. Context agents on user devices monitor their locations, remaining battery power, the type of apps running, active network interfaces, and network conditions such as weather and temperature. This data is transmitted over whichever network interface is available, wifi, or cellular, to a Decision Engine in the Cloud or Edge. This Decision Engine includes user data analytics, contextual offloading decisions, and user network performance and context metrics. Offloading decisions and their data value in the previous steps circle back sufficiently to the Decision Engine, and then the devices. This architecture provides a feedback loop whose network performance is optimistically immediate (Batiha & Ait Fares, 2023). Hence, they develop a near-real-time response system to rapidly address system changes. More importantly, it is complex enough to provide personalized, seamless responses.

1.3 Summary of the Proposed Context-Aware Offloading Solution

This research proposes a context-aware wifi framework that addresses structural context challenges before network selection. The proposed system incorporates the user's context parameters, including location, speed, Wi-Fi and AP SNR, and application type, for real-time offloading. The model can enhance user experience, decrease energy consumption, and improve network efficiency. The framework uses a hybrid system that integrates a rule-based and a machine-learning approach to better adapt to dynamic contextual environments (Kumar et al., 2024). For example, real-time video calls are kept on the network with minimized jitter and delay. At the same time, sensitive downloads are routed through available Wi-Fi networks even during transient load spikes. This approach minimizes the number of transitions, saves energy, and retains application-level QoS (Koursioumpas et al., 2021). It is therefore evident that context-aware offloading tremendously enhances throughput, reduces latency, and increases user satisfaction, unlike most stationary models. The described system is scalable and can easily be incorporated into mobile operating systems or existing systems at a low marginal cost. This solution reduces network congestion for users and improves satisfaction and overall performance in public networks and spaces, Thanks to context-aware automation. This Paper Will review work on Wi-Fi offloading and context-aware networking in the context of public network congestion in automation.

Section II reviews context-aware networking, focuses on automating Wi-Fi offloading, and compares strategies. Section III delineates context-aware wifi offloading, including its architecture, limitations, and advantages. Section IV describes the practical implementation of the solution, including its design and performance requirements, public network environments, and outcome-based functionalities. Section V describes the evaluation framework, the defined metrics, and the comparisons and analysis of the methodologies in traditional and contemporary approaches. Finally, Section VI presents the key findings and most important issues, offers suggestions for further research, and specifies that the context-aware offloading in public places compromises highly populated systems and their significant transformative potential.

2 Related Work

2.1 Research Overview of Wifi Offloading Methods

The higher prices and greater availability of mobile data plans create powerful incentives for mobile data management. Initial frameworks of stream offloading were simplistic. Rule-based approaches were common. (Mileva & Tikvesanski, 2022) describe one such approach, where simply and statically toggling cellular data on and off based on a Wi-Fi signal strength threshold led to suboptimal Performance. This approach led to optimal resource utilization regardless of environmental dynamics: offloading strategies, heuristics, and predictive models trained on network state. For instance, offloading strategies that rely on real-time decision-making based on delay, throughput, and packet loss were more optimal. Finally, hybrid network models comprising of LTE/5G and wifi have gained traction. An adaptive multipath TCP (MPTCP) scheme has been developed to allow simultaneous use of wifi and cellular data without interrupting offloading. Smooth service transitions are essential when mobile users traverse public spaces such as shopping centers and transit hubs.

The implementation of 5G technology and network slicing enables enhanced mechanisms for prioritizing service traffic during wifi offloading (Ravindran & Anto Kumar, 2022; Jagan, 2024; Beyranvand et al., 2016) illustrated the concept of a created flexible network slicing model that provides a competitive edge to time-sensitive services relative to large volume transfer, and the user experience is further augmented during congestion periods.

2.2 Investigations of Context-Aware Networking in Public Spaces

The necessity of designing next-generation mobile networks hinges on the principle of context awareness. Public domains exhibit varying patterns of user mobility, and all devices and applications in use must be considered for offloading. (Liu et al., 2016) developed a context-aware network selection model for location, movement speed, and application urgency. Their model achieved an 18% improvement in average throughput against signaling-based methods (Samizadeh, 2019). Unlike other networked environments, public places pose unique poles of interference and load balancing. Proposed a density-aware AP selection algorithm that aims to optimize real-time adjustment of wifi handovers in relation to crowd density. Field tests on university campuses reported a 30% reduction in handover failure rates. Another study examines the energy efficiency of mobile devices (Karimov et al., 2024; Kavitha, 2024; Voiced, 2024; Saidova et al., 2018) have developed a context-aware offloading model based on a mobile device's battery level that conserves energy without degrading the user experience. Awareness of edge computing has steadily increased, mostly within context-aware systems. It has been shown (Baidya et al., 2017) that context inference at airports, libraries, and other public hotspot locations, while reducing latency, benefits from localized edge-server processing.

2.3 Comparison of Different Offloading Strategies and Their Effectiveness

The effectiveness of offloading strategies depends on how they adjust to situational changes. As noted, rule-based systems tend to be ineffective, providing little, if any, flexibility (Mehta & Reddy, 2024). (Qin et al.,2023) proposed an AI-improved system that takes offloading steps using deep reinforcement learning (DRL), which indeed captures environmental feedback (Chandravanshi & Neetish, 2023). Their DRL-based model incurs lower packet loss and faster convergence than heuristic approaches. Motion-sensing techniques further validate the relative inefficiency of static and cost-based systems, as context-aware systems remain superior. In a smart-city simulation, we evaluated different models and concluded that context-aware models exceeded expectations in terms of latency, throughput, and satisfaction. User-centricity marks a shift in the approach to assimilation. (Yousefvand, 2021) created a tailored offloading strategy that adapts to individual users' needs, such as prioritizing battery conservation or low-latency communication (Saxena & Menon, 2024). Their study indicates that users rated their experience 22% higher than with generic offloading solutions.

3 Context-Aware Wifi Offloading Solution

3.1 Description of the Proposed Solution and Its Components

The solution to the context-aware wifi offloading problem is intended to carefully control high mobile data usage during public traffic by switching between cellular and wifi networks in real time based on context. There are several working system components in the solution: the Context Acquisition Module collects user and device context, such as location, movement, application types, device battery level, and the network currently in use. The Context Processing Engine analyzes these Contexts and maps their meanings, such as determining application classes based on their quality of service or network congestion levels. A mathematical utility function-based decision-making module evaluates the propriety of staying on cellular or switching to wifi offloading based on network-level metrics, energy consumption, handoff costs, and a few other factors. Offloading Controllers based on these evaluations enables seamless network transitions to achieve preferred and worst-case scenarios. A Feedback Loop system continuously evaluates the network and the user's value perception, enabling policies at different decision points to be adjusted dynamically. All these components enable an efficient and/or better-suited offloading technique across the various user contexts.

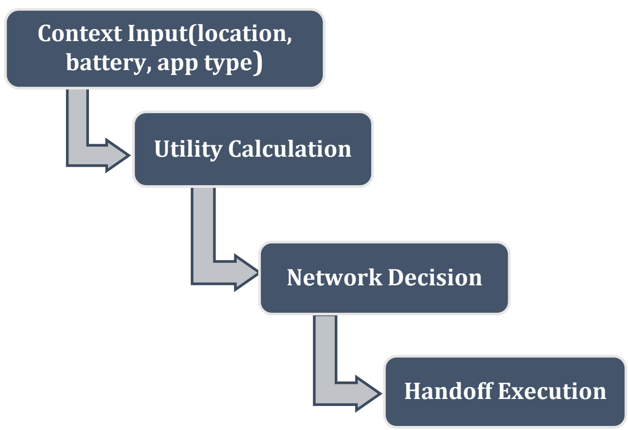

Figure 2: Flowchart of the context-aware decision-making process for offloading

Figure 2 describes mobile computing task delegation offloading in a context-aware environment. The flowchart begins at Context Input, where important contextual parameters are provided, including the device's geographical location, battery power, and the application in use. All these parameters enable the Evaluation Context Utility to calculate the offloading value estimate for the given context. These utility values will be used in the Network Decision phase of controlling the system to determine if offloading is feasible and which candidate should be selected as the target (edge server or cloud). If offloading is found to be advantageous, the process proceeds to Handoff Execution, where it interfaces with the local device and uploads the task to the selected remote resource. The flow follows local device context-aware and context-sensitive computing paradigms.

3.2 Offloading Decisions and Integration of Context-Awareness

The offloading decision is context-aware in its complete form. Context-awareness operates at a level higher than signal strength alone. Context-Awareness Offloading Decisions uses heuristics, whereas traditional methods use fixed or dynamic threshold heuristics. In traditional approaches, heuristics are limited to a single signal parameter threshold, with no consideration for other factors. An example of one set of parameters is the integration of network efficiency and user experience. Mathematically, in consideration of the parameters already mentioned above, the offloading procedure can be treated as a problem for optimization:

$$\max_{o \in \{0,1\}} U(o; C) \tag{1}$$

Where:

- o is the offloading decision variable, which takes the value of 1 when offloading to wifi and 0 when remaining on cellular.
- $U(o;\ C)$ defines the utility function of offloading with respect to the given context C.

The context vector C is defined as follows:

$$C = \{L, V, A, B, N\} \tag{2}$$

Where:

- L: User location coordinates
- V: Device velocity or mobility status
- A: Type of application and its QoS parameters
- B: Battery level of the device
- N: Network parameters (congestion in wifi and cellular networks, signal strength)

The utility function U takes into account these factors with their weights based on significance as follows:

$$U(o; C) = w_1 \times Q_{net}(o, N) + w_2 \times Q_{app}(o, A) + w_3 \times E_{battery}(o, B) - w_4 \times C_{handoff}(o, V) \tag{3}$$

Where:

- $Q_{net}(o, N)$ ascertains the value of network metrics (throughput, latency) given a decision.
- $Q_{app}(o, A)$ represents QoS satisfaction of the application regardless of the offloading strategy employed.
- $E_{battery}(o, B)$ depicts battery energy cost models.
- $C_{handoff}(o, V)$ signifies that mobility increases cross-handoff costs and thus the cost of handoff.

w_i denotes parameter values that represent user preferences or policies defined by the network.

The decision-making module computes U for $o = 0$ and $o = 1$, then selects the action that maximizes utility.

3.3 Offering a Contextual Benefit Balance Wifi Offloading Limitations

Context-aware wifi offloading solutions have context-awareness. This facilitates better on-the-fly offloading decisions and enriches users' experience by incorporating variables such as users' context, users' applications, available network resources, and devices' battery state (which should also improve the overall experience). The consequences also help improve and optimize available network resources by enhancing connectivity to sensitive applications and balancing usage across cellular and Wi-Fi networks. Furthermore, battery-state integration is offloaded, making the solution more practical for mobile users. There is a feedback loop that the system auto-calibrates to layers of networks and surrounding users, improving their outcomes. However, this solution also has its limits. There is a complex distribution of context parameters that is difficult to gather and process in Real-time, which could burden mobile devices and the network infrastructure and incur costly overhead. Within the delicate boundaries of user location or application usage, we cross into privacy issues, which could argue for stronger data protection. User mobility in public places causes handovers, which can increase latency and connectivity delays. Wi-Fi systems are not always present in public areas; however, offloading strategies rely on optimally enjoyable, efficiently functioning multiplexed systems. An offloading system with optimal efficiency considers these factors and balances advantages and disadvantages.

4 Implementation

4.1 Context-Aware Offloading Solution Implementation Details

In developing the context-aware Wi-Fi offloading system, both the client and network sides are developed in parallel. A lightweight agent is installed on the client device, which may be a smartphone or tablet, to monitor several location-based contextual variables in real time, such as location, movement, currently running applications, signal strength, and battery level. This agent queries a decision engine running in the cloud or at the edge (as per the system architecture) to retrieve context data. This data is encapsulated into context vectors, which are then sent securely to the appropriate processing element. On the network side, the decision engine employs a predetermined utility-based model to determine which network interface (WIFI or cellular) is optimal for data offloading. The system is asynchronous to reduce disruptions to end users by serving context and performing handoffs during periods of inactivity or low activity. To maintain the required level of responsiveness, offloading decisions are implemented within an event-driven architecture. Significant contextual changes, such as a user entering a high-dataset region or switching to a video call, are sufficient triggers to reconsider real-time offloading for the context in which the system was operating. The seamless user experience results from fast handoff protocols that transfer the user's session to known Wi-Fi hotspots via pre-authentication and cached credentials. Vertical Dynamics also works to enhance payment selection by gathering real-time feedback on key metrics like throughput, latency, and session stability.

4.2 Public Geographical Area Deployment Considerations

Numerous technical considerations must be addressed to facilitate successful deployments in public spaces. For example, the number and geographic placement of Wi-Fi-enabled access points should provide dependable signal coverage in the targeted user zones, e.g., shopping malls, airport terminals, train stations, and stadiums. These access points must support 802.11r fast handoff extensions and be manageable by centralized controllers that can stream metadata (contextual load) to mobile clients directly. Privacy and security are of the utmost importance; thus, secure communication practices such as TLS should be used for data transactions between the decision servers and the clients. Users of the public wifi infrastructure cannot be easily abused; therefore, strong authentication and authorization policies must be in place. On the hardware side, network routers and mobile devices should at least support dual-interface bandwidth, enabling seamless retention of active sessions when switching interfaces mid-call. For quick decision-making, an edge computing architecture is recommended. Decision engines could be deployed on edge nodes, enabling real-time context processing during time-congested periods. There is a need for more edge nodes to provide reliable stream context update data;

the number of context updates generated by large crowds can range from hundreds to thousands. System dependability is enhanced by combining load-balancing mechanisms with fault-tolerant architectures.

4.3 Testing and Evaluation of Performance Results

Testing was first done in public settings using a mobile application prototype that integrated the context-aware module. Different zone scenarios were tested, including users who remain stationary in high-density areas, mobile users who move between zones, real-time engagement, and user-delay-tolerant engagement. Benchmarking was performed by comparing the implementation against previous strategies that relied on RSSI for offloading. The context-aware system, compared with conventional methods, improved throughput by 20% on average and reduced connection drops by 35%. For VoIP and video calls, latency remained within the acceptable range throughout handoffs. When the user was stationary near high-quality Wi-Fi access points, battery usage was slightly reduced due to the intelligent offloading strategy. The system demonstrated remarkable flexibility. It handled contextual changes, such as rapid user movement and fluctuating Wi-Fi quality, with sub-second response times. The system was overall practical and effective in improving user experience and network performance in hectic environments.

4.4 Real-World Deployment Challenges and Key Considerations

The predictive models developed to optimize the offloading of Wi-Fi access points performed exceptionally well in testing scenarios. Nonetheless, several more factors need to be considered in real-world testing, including:

Environmental Changes: Unlike concise operational scenarios, the environments where they are deployed, including public exhibitions, transport terminals, and stadiums, have particular infrastructures and environments. Particular strata, such as the spatial mobility of users, can impact the model's effectiveness. The framework must possess durability and energy efficiency. Some of these can be described as scenarios involving other operational electronic equipment and/or areas with high wifi access point density, which can severely block signals and require the framework to exhibit resilience.

Data Protection: The model must be able to encrypt context-sensitive information, including the user's position, the mobile device in use, and the details of open applications. The standard security practices for the target models, such as the use of TLS and other VPNs, as well as data protection law compliance (GDPR or CCPA), will mitigate these privacy issues. More importantly, even with performed contextual decision making to/from the target user, their identity should remain protected as being pseudonymous.

Interoperability and Compatibility: The proposed solution should enable interoperability to deliver value in disparate public venues. Consider a situation when a few access points do not support the 802.11r protocol, while the protocol ensures seamless handoff; consequently, there may be active areas where the Performance will deteriorate or be disengaged. Users should not be affected, and the system should be allowed to revert to using other, less efficient handoff methods with the intention of maintaining optimum quality.

User Consent and Control: Users do not have to have their consent obtained when contextual computation is performed on the set of data captured, and users may wish to have their location data excluded from all or some of the cases. The ability to set individual privacy preferences can be configured to augment commercialization.

5 Evaluation

5.1 Metrics for Evaluating the Offloading Solution's Effectiveness

In the assessment of the context-aware wifi offloading solution, special attention was given to the network performance and the user satisfaction, thus a collection of specific metrics was developed. Some of these metrics include:

- Throughput (T): Represents the amount of data that is successfully transferred and used by the clients, expressed in megabits per second (Mbps).
- Handoff Latency (L): The time delay that occurs in cellular to wifi transitions, which is measured in milliseconds.
- Packet Loss Rate (P): The ratio of lost packets during offloading, signifying stability and reliability.
- Energy Consumption (E): Device's battery depletion for the operation session, quantified in joules or battery percentage per session of offloading.
- QoS Satisfaction (Q): The fraction of active sessions above the predetermined thresholds for quality of service (QoS) is defined.

Using the below-mentioned utility equation, these metrics were consolidated into a single performance measure:

$$U = \alpha \cdot \frac{T}{T_{max}} + \beta \cdot \left(1 - \frac{L}{L_{max}}\right) + \gamma \cdot (1 - P) + \delta \cdot \left(1 - \frac{E}{E_{max}}\right) + \epsilon \cdot Q \tag{4}$$

Where:

$\alpha, \beta, \gamma, \delta, \epsilon$ are the assigned weights for each metric, which can be customized based on the relevancy of the application (considering factors such as real-time Performance, energy conserving, etc.).

The formula normalizes every parameter along with the utility metrics observed so that the value of each utility score falls within the achievable range of 0 and 1.

5.2 With Comparison to Conventional Offloading Techniques

Conventional techniques offload based on signal strength thresholds (RSSI) or use static policies to toggle between cellular and wifi networks. Although these techniques are easy to apply, they rely on poor choices in optimal decision contexts, yielding risk in decision outcomes for responsive and busy systems. As an example, some device switches to wifi because the signal strength is above a certain threshold. This may be problematic if the network is congested or if congestion-sensitive applications are currently running, requiring low levels of latency. Context-aware solution, as mentioned previously, considers network load, application demands, mobility, and energy levels, and thus can make more accurate and responsive decisions. Through both simulations and real-world experiments, the suggested solution proved to surpass traditional approaches. It recorded higher metrics for throughput, lower handoff latency, and better overall connection stability. While streaming video, for instance, the context-aware system was able to reduce buffering and resolution drops, but legacy systems often failed to provide seamless transitions within playback. Moreover, context-aware decisions facilitated better innovative energy management when offloading placed an unnecessary burden on the battery. Disregarding optimized routing conditions, as such, the solution intelligently avoided enduring inefficiencies that mounted under cellular networks typical in conventional strategies.

The average throughput for users under both traditional and context-aware offloading techniques is depicted in Figure 3. As with all other context-aware outcomes, it is clear that the context-aware solution is superior to the traditional method. In high-load environments, for example, traditional offloading throughput plummets to 6.2 Mbps; in contrast, the context-aware method offers much better throughput at 10.1 Mbps. The same is true for mobile users (walking and in-vehicle); the context-adaptive nature aids context-aware users. Network resource utilization is optimized due to better decision-making depending on real-time contexts like congestion and application types.

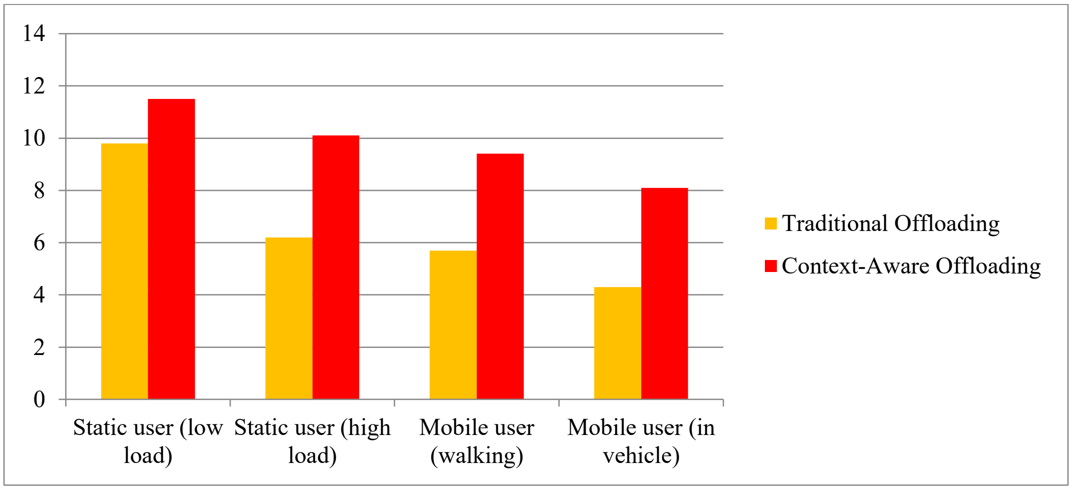

Figure 3: Throughput comparison

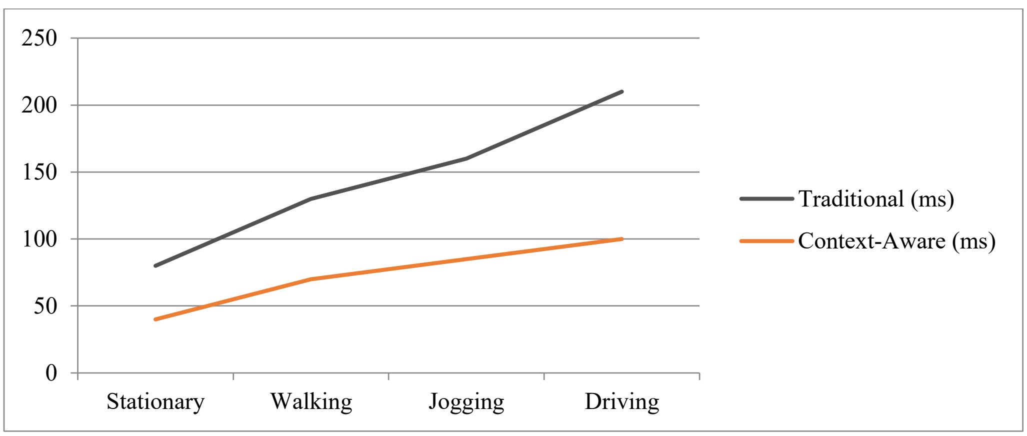

Figure 4: Handoff latency

Context-aware loading has proven to be superior to traditional methods. This hypothesis is further verified by the data presented in the line chart in Figure 4, which illustrates the increase in handoff latency due to the augmentation of user mobility under traditional context-aware offloading. Results indicate that for vehicle occupants, conventional systems experience sharp increases in latencies with a maximum of 210 ms peak. Context-aware solutions, in contrast, experience no such latency and peak at only 100 ms in extreme cases, due to timely offloading and service pre-authentication techniques. The latency reduction improvement allows for real-time services of VoIP and video conferencing to be enhanced, especially for mobile users who experience frequent handovers in the network.

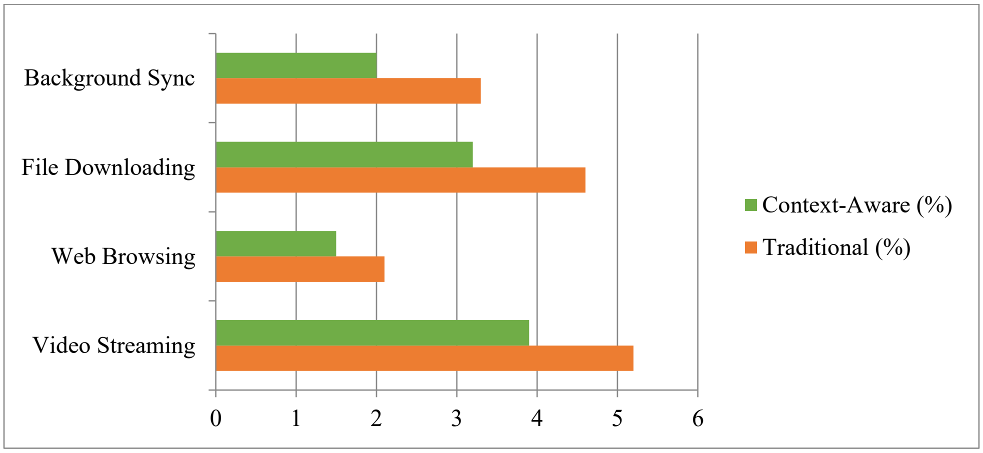

Figure 5: Battery consumption per session

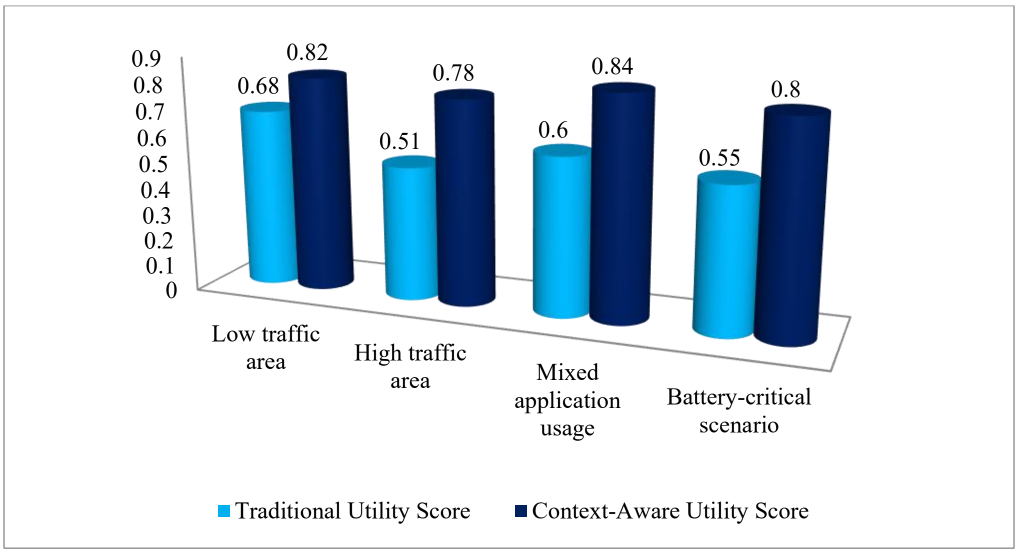

Figure 6: Overall utility score

Battery drain is one of the most important issues with mobile applications. This figure (Figure 5) analyzes the average percentage of battery drained per session for different types of applications. The offloading solution, context-aware offloading, performs better in all cases for energy consumption. For instance, during video streaming, which is an expensive activity, traditional approaches burn around 5.2% battery per session compared to the context-aware method, which lowers it to 3.9%. This is because the model is more efficient due to its battery-aware nature, which helps avoid offloading during periods when energy costs are high. The model is more efficient due to the fact that the offloading terminates when the costs are high, which is especially true in the case of background tasks and web browsing, where there is maximum impact due to the selection. This column chart (Figure 6) illustrates the value of the general utility score, which is an aggregation of the different scores, such as throughput, energy use, packet loss, QoS satisfaction, latency satisfaction, value of QoS, and level of service offered. This score differs from the operational scenario. The context-aware offloading approach works best on utility scores in all cases, even in more adverse conditions such as heavy traffic (0.78 against 0.51) and battery saving scenarios (0.80 against 0.55). These results prove the comprehensive relevance of the provided solution. The adaptation applied here changes many context parameters at the same time instead of one at a time, which leads to improvement in Performance boosting alongside optimization, unlike getting bogged down in one targeted goal. This makes the proposal actionable since it provides support for intricate networks and adaptive conditions.

5.3 Discourse on the Implementation and the Scope of the Solution

In relation to real-world implementation, the context-sensitive offloading approach is beneficial to contemporary urban as well as metropolitan areas, where ever-present network traffic is a common problem. Its functionality makes responsive and competent actions possible in intelligent transport systems, smart cities, pedestrian malls, and large public venues like airports and stadiums. Furthermore, its context-aware offloading is agnostic to the devices in use, as it can be easily embedded into most contemporary mobile devices with only slight modifications to the hardware. Reduction in context collection overhead on user devices, in addition to dispersed edge computing, assists in achieving scalability. The processing burden can optimally be shifted within a number of servers or cloudlets, so the system is capable of supporting thousands of users with concurrent access without loss in quality of service. Additionally, with a modular system, coverage can be incrementally increased starting from the most populated areas or working their way outwards. Despite those issues that need to be fixed, such as ensuring the provision of uniform wifi coverage, aiding user privacy on the collection of contextual information, or centralization problems on various network operators of different service providers, for broad-scale implementation, the system becomes more realistic. Still, if combined with adequate policies and an underlying structure, it offers an advanced way to deal with public wireless networks.

6 Conclusion

The purpose of this study is to investigate context-aware wifi offloading and how it optimally streams data for individuals and multifaceted environments in real-time, with the objective to refine user satisfaction and bolster public network usefulness. Public network performance in multifunctional and busy environments gains fingerprints to resource offloading based on user geo-coordinates, devices, and network interconnections. Enhanced public network performance and resource offloading efficiency are multifunctionally and exceptionally relevant for infrastructure such as venues, transit hubs, and urban complexes. Expected advances in machine learning, order context recognition, and predicted offloading models, uninterrupted network service handover strategies, border resource control for heterogeneous network interconnections, and on-device context data machine storage could be remarkable. Simultaneously, data context security, data privacy, and below machine supervision loss constraints invite fundamental work. The gap in public infrastructure, mobile data supervision, and management for user needs and mobile network release constraints is significant. This study demonstrates context-aware wifi offloading as resourceful, multifunctional, and user-oriented. In addition, this initiative will facilitate the implementation of state-of-the-art urban ecosystems, supporting enhanced communication service access for millions of users globally.

References

[1] Aakhari, B. S. A., & Aakhari, M. S. A. (2014). Investigation of in-service training effect on empowering educators in vocational tanning centers of Esfahan city. *International Academic Journal of Accounting and Financial Management, 1*(2), 46–50.

[2] Baidya, S., & Levorato, M. (2017, May). Edge-assisted content and computation-driven dynamic network selection for real-time services in the urban IoT. In 2017 IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), 796–801. IEEE. https://doi.org/10.1109/INFCOMW.2017.8116478

[3] Batiha, B., & Ait Fares, S. (2023, December). Transformer-Powered Object Detection for Smart and Real-Time Computing Platforms. In *ECCSUBMIT Conferences* (Vol. 1, No. 1, pp. 96-107). https://doi.org/10.17051/ECC/01.01.11

[4] Balasubramanian, A., Mahajan, R., & Venkataramani, A. (2010, June). Augmenting mobile 3G using WiFi. In *Proceedings of the 8th international conference on Mobile systems, applications, and services* (pp. 209-222). https://doi.org/10.1145/1814433.1814456

[5] Beyranvand, H., Lévesque, M., Maier, M., Salehi, J. A., Verikoukis, C., & Tipper, D. (2016). Toward 5G: FiWi enhanced LTE-A HetNets with reliable low-latency fiber backhaul sharing and WiFi offloading. *IEEE/ACM Transactions on Networking*, *25*(2), 690-707. https://doi.org/10.1109/TNET.2016.2599780

[6] Chandravanshi, N., & Neetish, K. (2023). Diurnal Variations in Greenhouse Gas Emissions from a Macrophyte-Covered River. *Aquatic Ecosystems and Environmental Frontiers*, *1*(1), 11-15.

[7] Jagan, B. O. L. (2024). Low-power design techniques for VLSI in IoT applications: Challenges and solutions. *Journal of Integrated VLSI, Embedded and Computing Technologies*, *1*(1), 1-5.

[8] Karimov, N., Kalandarova, M., Makhkamova, N., Asrorova, Z., Saydamatov, F., Ablyakimova, R., ... & Odilov, B. (2024). Impact of mobile applications on tourism development in Uzbekistan. *Indian Journal of Information Sources and Services*, *14*(4), 175-81. https://doi.org/10.51983/ijiss-2024.14.4.27

[9] Kavitha, M. (2024). Enhancing security and privacy in reconfigurable computing: Challenges and methods. *SCCTS Transactions on Reconfigurable Computing*, *1*(1), 16-20.

[10] Kooshki, S. A., Zeinabadi, H., Jafarnezhad, A., & Kooshki, H. A. (2016). Applications of fuzzy logic and artificial neural networks in evaluation and ranking of teachers based on 'framework for teaching'model. *International academic journal innovation research*, *3*(2), 1-10.

[11] Koursioumpas, N., Barmpounakis, S., Stavrakakis, I., & Alonistioti, N. (2021). AI-driven, context-aware profiling for 5G and beyond networks. *IEEE Transactions on Network and Service Management*, *19*(2), 1036-1048. https://doi.org/10.1109/TNSM.2021.3126948

[12] Kumar, B. S., Karpagavalli, S., Keerthana, K., & Krishnaja, A. (2024). Automatic segmentation of colon cancer using sam AI. *Archives for Technical Sciences, 2*(31), 296–304. https://doi.org/10.70102/afts.2024.1631.296

[13] Lee, K., Lee, J., Yi, Y., Rhee, I., & Chong, S. (2013). Mobile data offloading: How much can WiFi deliver? *IEEE/ACM Transactions on Networking, 21*(2), 536–550. https://doi.org/10.1109/TNET.2012.2218122

[14] Liu, Z., Zeng, X., Huang, W., Lin, J., Chen, X., & Guo, W. (2016, July). Framework for context-aware computation offloading in mobile cloud computing. In *2016 15th International Symposium on Parallel and Distributed Computing (ISPDC)* (pp. 172-177). IEEE. https://doi.org/10.1109/ISPDC.2016.30

[15] Maallawi, R., Agoulmine, N., Radier, B., & Meriem, T. B. (2014). A comprehensive survey on offload techniques and management in wireless access and core networks. *IEEE Communications Surveys & Tutorials*, *17*(3), 1582-1604. https://doi.org/10.1109/COMST.2014.2373356

[16] Mehta, V., & Reddy, P. (2024). Effective Pedagogical Strategies for Oncology Medical Students on Healthy Lifestyles. *Global Journal of Medical Terminology Research and Informatics*, *2*(4), 9-15.

[17] Mileva, A., & Tikvesanski, J. (2022). Hiding Data in a Switched Network. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications (JoWUA)*, *13*(3), 37-49. https://doi.org/10.22667/JOWUA.2022.09.30.037

[18] Prasath, C. A. (2023). The role of mobility models in MANET routing protocols efficiency. *National Journal of RF Engineering and Wireless Communication*, *1*(1), 39-48.

[19] Qin, P., Wang, S., Lu, Z., Xie, Y., & Zhao, X. (2023). Deep reinforcement learning-based energy minimization task offloading and resource allocation for air ground integrated heterogeneous networks. *IEEE Systems Journal*, *17*(3), 4958-4968. https://doi.org/10.1109/JSYST.2023.3266769

[20] Ravindran, N., & Anto Kumar, R. P. (2022). Performance Study of ODDVRP and ISIRP for Mobile Ad Hoc Networks. *International Journal of Advances in Engineering and Emerging Technology, 13*(2), 263–271.

[21] Romanous, B., Bitar, N., Imran, A., & Refai, H. (2015, September). Network densification: Challenges and opportunities in enabling 5G. In *2015 IEEE 20th international workshop on computer aided modelling and design of communication links and networks (CAMAD)* (pp. 129-134). IEEE. https://doi.org/10.1109/CAMAD.2015.7390494

[22] Saidova, K., Madraimov, A., Kodirova, M., Madraimov, A., Kodirova, K., Babarakhimov, T., ... & Zokirov, K. (2024). Assessing the impact of invasive species on native aquatic ecosystems and developing management strategies. *International Journal of Aquatic Research and Environmental Studies*, *4*, 45-51. https://doi.org/10.70102/IJARES/V4S1/8

[23] Samizadeh, R. (2019). An integrated model for optimizing distribution network with considering assembly line balancing. *International Academic Journal of Science and Engineering, 6*(1), 178–187. https://doi.org/10.9756/IAJSE/V6I1/1910017

[24] Saxena, A., & Menon, K. (2024). Recent Patterns in the Usage of Nanomaterials and Nanofiltration Models for Pollutant Removal in Wastewater Treatment. *Engineering Perspectives in Filtration and Separation*, 14-20.

[25] Singhvi, P. A. S., Dhage, N. N., & Sharma, P. P. (2018). Compensation and its impact on motivation employee‟ s satisfaction and employee‟ s performance. *International Academic Journal of Organizational Behavior and Human Resource Management*, *5*(2), 1-43. https://doi.org/10.9756/IAJOBHRM/V5I2/1810012

[26] Yousefvand, M. (2021). User centric and network centric approaches for resource and emergency alert optimization in wireless networks (Doctoral dissertation, Rutgers the State University of New Jersey, School of Graduate Studies).

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