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RESEARCH ARTICLE

An Improved 5G Mobility Handover Efficient by Creating a Digital Twin Network: A Review

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ABSTRACT - In the age of 5G, seamless mobility handovers are vital, especially in densely populated areas like Malaysia, to prevent disruptions and resource inefficiencies. A proposed solution involves a Digital Twin Network mirroring Malaysia's 5G infrastructure, integrating real-time data and user behaviors to optimize energy consumption during handovers. Emphasis is placed on energy-efficient protocols and algorithms to enhance network performance. The research follows the format of Systematic Literature Review (SLR). The algorithms predict and manage handovers proactively, enabling adaptive resource allocation for improved efficiency. The Digital Twin Network aims to significantly enhance mobility handover efficiency through predictive handovers and adaptive resource allocation, supported by energy-efficient protocols and edge computing for sustainability. This research offers a tailored solution to Malaysia's 5G mobility handover challenges, promising seamless connectivity and sustainability. It introduces a customized Digital Twin Network focusing on energy efficiency, evaluated against practical applications in information retrieval. Evaluation standards gauge effectiveness, supplemented by in-depth analysis of methods and performance metrics, concluding with insights, limitations, and recommendations for future research.

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1.0 INTRODUCTION

In the swiftly changing landscape of telecommunications, the emergence of 5G technology presents unparalleled opportunities for improved connectivity and mobility. As Malaysia moves forward in adopting advancements in wireless communication, optimizing the effectiveness of 5G mobility handovers becomes a top priority. This involves exploring the necessity of enhancing these handovers by introducing an innovative approach: the creation of a digital twin network specifically tailored to boost energy efficiency within the Malaysian context. The new fifth-generation wireless network (5G) is expected to deliver gigabit Internet speeds, increased capacity, and significantly reduced latency. Additionally, it is poised to simplify the installation of Internet of Things (IoT) devices [1]. In Malaysia, the provision of 5G services will be managed through Digital Nasional Berhad's Single Wholesale Network (SWN) [2]. As a government-owned entity, DNB will exclusively own, develop, and oversee the 5G infrastructure, while also offering 5G as a wholesale network service to various telecommunications providers, including Maxis, Celcom, Digi, U Mobile, Telekom Malaysia (TM), among others [3]. The significant growth in the number of users dependent on mobile devices such as smartphones, wireless data services enabled by mobile internet, and smart devices has sparked an examination of the 5G cellular network. These mobile devices operate on a fixed power source, namely, a battery. The limited power available for battery-operated wireless devices poses a notable obstacle to the advancement of more sophisticated gadgets like smartphones, which are highly sought after by consumers. Addressing this challenge involves the exploration of energy-efficient computer network architectures or environmentally friendly network solutions, often referred to as Green Networks [4]. The global adoption of Fifth Generation (5G) mobile communication technologies is well underway. Currently, 5G deployment is taking place in localized areas across nearly every continent, with a greater concentration of available networks in Europe and the USA [5]. Anticipations suggest that by 2025, 5G is expected to represent no less than 15 percent of the entire mobile communications market.

A digital twin network involves generating a virtual duplicate of the actual communication infrastructure, enabling continuous monitoring, analysis, and optimization. This method provides a holistic insight into network dynamics, making it possible to identify inefficiencies and implement specific improvements [6]. In the Malaysian scenario of 5G mobility handovers, where the need for dependable and energy-efficient connectivity is increasing, the utilization of digital twin technology presents significant possibilities. The shift to 5G networks holds the potential for notable enhancements in data speeds, minimal latency, and the ability to connect a wide range of devices [7]. Nevertheless, ensuring a smooth transition of devices between various network cells, a crucial element of mobility in wireless systems, demands meticulous attention. In the pursuit of an energy-efficient and seamlessly connected 5G ecosystem, the incorporation of a digital twin network emerges as a compelling solution. The 5G Digital Twin represents an innovative approach to testing and assurance, offering a software replica of the 5G physical network for continuous prototyping, testing, assurance, and

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self-optimization of the operational network. Consequently, there is a need for a virtual solution capable of constructing a digital model that accurately mirrors the 5G ecosystem by addressing the challenges mentioned above to meet 5G requirements. The Digital Twin (DT) can assess performance, predict the impact of environmental changes, and optimize 5G network processes and decision-making. In effect, the digital 5G model within the 5G DT will coexist with the physical 5G network, conducting operational forecasts and implementing optimal decisions into the operational network and its associated systems [8].

This investigation thoroughly examines the crucial factors, obstacles, and advantages linked to the development of a digital twin network aimed at improving the efficiency of 5G mobility handovers in Malaysia. By addressing these facets, the research seeks to contribute to the ongoing discussion on advancing the telecommunications landscape in the nation. The goal is to ensure that the integration of 5G technology seamlessly aligns with the objectives of energy efficiency and optimal connectivity. To effectively incorporate and deploy these technologies in the digitization process, a vital prerequisite is a dependable, high-performance, and exceptionally fast network connection utilizing cutting-edge networking technologies. Digital twin technology stands out as a primary pillar in the digital transformation process, allowing the creation of digital replicas of physical systems that offer numerous benefits, including real-time monitoring, heightened productivity, and increased efficiency.

The contributions of enhancing DT in 5G systems through the adoption of mobility handover are substantial and multifaceted. Implementing an efficient mobility handover method in 5G systems helps reduce energy consumption. Through accurately identifying and mitigating security threats, the system can avoid unnecessary resource-intensive processes triggered by ping-pong activities. This contributes to a more sustainable and eco-friendlier 5G network. Extensive research and empirical evidence support the chosen mobility handover method’s effectiveness in identifying and mitigating decision algorithm's in 5G systems. It has demonstrated superior performance compared to previous methods, making it a reliable choice. In conclusion, the adoption of DT method in 5G systems contributes significantly to mobility handover energy efficiency, network performance, security, and cost savings. The choice is justified by its proven effectiveness, scalability, real-time capabilities, and adaptive learning features, all of which collectively enhance the overall resilience and sustainability of 5G networks.

1.1 Core Issues for Investigation

The examination of improving the efficiency of 5G mobility handovers and crafting a digital twin network for energy-efficient wireless systems in Malaysia entails tackling various fundamental issues. These include technical hurdles, environmental factors, and the socio-economic repercussions of deploying advanced telecommunications solutions. As mentioned earlier, the energy consumption of mobile terminals constitutes a minor fraction of the overall energy usage. However, the severe battery constraints of these terminals, necessitating low power consumption solutions with outstanding energy efficiency, can pose challenges.

The international connection suffers from poor routing to major Internet networks, primarily due to insufficient coverage and limited port availability. Digital Nasional Berhad (DNB) faced challenges in acquiring a fixed fiber connection. The 5G landscape in this scenario is monopolized by a single provider, regardless of whether one subscribes to Maxis 5G, Celcom 5G, Digi 5G, or U Mobile 5G all operate on the identical 5G network, which is facilitated by Digital Nasional Berhad (DNB). Pertinent details about DNB include the absence of a fiber network and the lack of any base stations or 2G/3G/4G/5G networks [9]. DNB could rapidly extend 5G coverage across the entire country by utilizing the 700 MHz spectrum. However, an inherent drawback of the 700 MHz band, with its 80 MHz spectrum, is its potential limitation in delivering consistently high-speed Internet connections, particularly when the network accommodates a large user base, potentially reaching a million users. There is a concern that the 5G experience in Malaysia might resemble that of 3G and 4G, compounded by the unique challenge of having only one 5G network provider. Consequently, if users encounter inadequate 5G coverage or slow speeds, prompt improvements are unlikely. Unlike 3G and 4G, where there were multiple network providers, 5G offers the option of choosing from six different networks. Thorough exploration of these fundamental issues through this research can provide valuable insights for the development and implementation of energy-efficient, digitally optimized 5G networks within the framework of Malaysia's telecommunications landscape [10].

Examining Industry 4.0, characteristics like low latency, high bandwidth, increased capacity, exceptional reliability, improved mobility, and prolonged battery life have the potential to reshape use cases within the industry. In the realm of digital twins, 5G becomes crucial for scenarios demanding swift, secure, and reliable data transfer between locations. For instance, establishing an experimental 5G network could be excessively costly, particularly in developing nations where 4G deployment is still in progress. Given the frequent utilization of connected devices, mobile operators must vigilantly monitor their network security infrastructure, traffic patterns, and capacity requirements to prevent potential disruptions from incoming and outgoing handovers.

1.2 Problem Statement

As Malaysia speeds up its adoption of 5G technology to address the growing need for high-speed connectivity, the effectiveness of mobility handovers in the wireless network becomes a critical challenge. Smooth transitions of devices between different network cells are essential for maintaining a reliable and uninterrupted user experience. However, the existing framework faces significant obstacles in ensuring optimal handover efficiency, resulting in higher network congestion, energy consumption, and latency. Additionally, given the importance of aligning technological progress with sustainable practices, the energy efficiency of wireless systems becomes a pressing issue. Current 5G networks consume a considerable amount of energy, requiring a shift in design and operation to meet environmental goals. In this context, the incorporation of a digital twin network emerges as a potential solution, offering real-time monitoring, analysis, and optimization capabilities [11]. The current challenge involves improving the efficiency of 5G mobility handovers and addressing the increasing energy requirements of wireless systems in Malaysia. The deficiencies in existing handover processes contribute to issues such as network congestion, latency, and inefficient resource allocation. Furthermore, the environmental consequences of elevated energy consumption underscore the necessity for innovative approaches to both design and management [12].

Figure 1. Digital twin and 5G network (https://www.interlakemecalux.com/blog/digital-twin)

It is crucial to tackle these challenges to establish an advanced and sustainable wireless ecosystem in Malaysia as seen in Figure 1. This involves ensuring effective 5G mobility handovers and reducing the environmental impact of wireless communication systems, see Figure 2.

The paper is organized into sections; Section 1 introduction, Section 2 literatures, Section 3 methodology, Section 4 result, Section 5 discussion and finally conclusion significance and contribution.

2.0 RELATED WORKS

As reported by [13], In the context of inward mobility within layered macrocell networks, a handover decision algorithm has been developed to manage scenarios where User Equipment (UE) is located within the boundary of a femtocell, surrounded by multiple macrocells and femtocells. The main goal of this algorithm is to address the challenge of inconsistent power transmission between macrocell and femtocell base stations. It does so by implementing a windowing function that uses measured Received Signal Strength (RSS) values from individual base stations to smooth out rapid fluctuations in RSS. The RSS measurements are divided into Reference Symbol Received Power (RSRP) and Reference Symbol Received Quality (RSRQ). The algorithm establishes a windowing function based on RSRP measurements for both the serving and target cells at time 't' after a handover-triggering event. The UE then determines if the filtered RSS from the femtocell base station exceeds a predefined threshold. It also checks whether a specific combination parameter surpasses the sum of the fluctuation margin and the macrocell's filtered RSS, or if the RSS from the femtocell base station falls below the sum of the fluctuation margin and the macrocell's filtered RSS. If these conditions are met, the UE connects to the femtocell [14]. Alternatively, The UE evaluates whether the adjusted RSS within the femtocell at a specific time surpasses the combined value of the fluctuation margin and the filtered RSS from the serving macrocell. If it doesn't, the UE checks if the modified RSS at the femtocell is lower than the sum of the serving macrocell's RSRP, the femtocell's RSRP, a predefined RSRP threshold, and the hysteresis margin. If either of these conditions is met, the UE re-establishes its connection with the macrocell. If neither condition is satisfied, the handover decision process concludes. The variables used in the algorithm and the details of the windowing function are further elaborated. This approach offers significant benefits in managing inward mobility within the two-tier macrocell-femtocell network. It effectively addresses the issue of uneven signal strength differences between serving and target base stations and provides a means to balance the risk of handover failure against the likelihood of successful handovers by optimizing the weighting value. The algorithm was rigorously tested across various performance metrics and validated accordingly. It's worth noting that the algorithm was designed with the assumption of a single macrocell and a single femtocell, not accounting for scenarios where the UE might choose from multiple femtocell base stations [15]. There is a need for the creation of an RSS-driven handover decision algorithm that considers scenarios involving multiple femtocell base stations. This requirement arises from the prevalence of installations where buildings may house several femtocell base stations. Additionally, the basic single macro-femto model does not incorporate factors such as user equipment velocities

(UEV), interfering stages, available bandwidth, and access restrictions. Consequently, the algorithm lacks compatibility with the intricate deployment scenarios encountered in practical applications.

According to [16], The strategy based on Route Loss and Received Signal Strength involves using a proposed algorithm to manage incoming mobility, specifically when transitioning from a macrocell to a femtocell. This decision relies mainly on evaluating the Received Signal Strength (RSS) and route loss. This approach is similar to algorithms discussed in previous studies and is applicable in scenarios with only one macrocell and one femtocell. It employs a window function, directly tied to the assessment of Reference Signal Received Power (RSRP) at both macrocell and femtocell base stations. These steps occur after a handover has been initiated by a pre-defined handover-triggering event. The User Equipment (UE) first checks if the filtered RSRP exceeds a set RSRP threshold. If it does, the algorithm moves to the next evaluation phase; if it does not, the UE remains connected to the serving macrocell. In the second phase, the algorithm determines whether the RSRP at the target femtocell exceeds the combined value of the macrocell's RSRP and the hysteresis margin. If this condition is met, the handover decision is finalized, and the handover is executed. If not, the algorithm then evaluates the UE's route loss in relation to both the serving and target base stations [17]. If the UE encounters significant path loss from its serving macrocell, it assesses which path loss is greater and initiates a handover to the target femtocell accordingly. This method effectively integrates path loss and RSS data, creating a robust metric that accounts for either path loss or signal strength during the handover decision process. It's important to note that this algorithm is designed specifically for situations involving a single macrocell and a single femtocell, which may not fully reflect real-world deployments. The method for calculating path loss and received signal power is not thoroughly explained. Despite undergoing performance evaluations, the algorithm remains vulnerable to frequent "ping-pong" handovers, particularly due to the highly variable nature of path loss criteria.

From [18], Intra-cell switching of femtocells, which considers challenges related to RSS and SINR, involves a handover decision algorithm focused on managing transitions within the same type of cell, particularly in environments with dense femtocell deployments. Intra-cell handovers refer to the process where User Equipment (UE) transitions within the same cell type, such as between different femtocells on the same channel. This approach is especially useful in situations where the UE experiences interference from multiple femtocells, regardless of whether it is covered by a macrocell or connected to another femtocell. The system evaluates the Signal to Noise and Interference Ratio (SINR) of the UE, comparing it to a predetermined SINR threshold to determine if an intra-cell handover is necessary. If the SINR is below this threshold, the handover process is initiated; if not, the handover decision is paused. After gathering all the Received Signal Strength (RSRP) measurements, the macrocell compiles a list of potential candidate cells for the handover. To be included in this list, the RSRP of each macrocell at time 't' must not exceed the sum of the RSRP of the corresponding eligible cell and the handover fluctuation margin. The handover decision process only concludes when this candidate cell list is empty. If the list is not empty, the macrocell carefully reviews its communication channels and operating bandwidth options before allocating any resources to the UE, thereby concluding the handover decision-making process [19]. The macrocell compares its current list of interfering femtocells with the previous list if it is not empty. If the comparison reveals an unfavorable outcome (indicating the presence of a new conflicting cell), the handover decision process is halted. If the result is negative (indicating an increase in overlapping cells), the macrocell identifies an unallocated channel and directs the femtocell to carry out an intra-cell handover. This process is then repeated to check for any further inconsistencies. Conversely, if the outcome remains positive, indicating no change in the list, the macrocell implements power regulation in the affected femtocell and reevaluates the list. This iterative process continues until a successful intra-cell handover is achieved. This approach is particularly effective in scenarios involving a single macrocell and multiple femtocell base stations, as it efficiently manages interference from neighboring cells and reduces the likelihood of unnecessary handovers [20]. However, this method could potentially prolong the overall handover process by adding extra delays due to the signaling operations involved in the handover decision step. Additionally, when reallocating interfering femtocells to different channels, there is concern about a possible increase in interference levels in nearby femtocell base stations or User Equipment (UEs).

According to [21], 5G represents the next evolution in mobile communication standards, surpassing the current 4G standards in response to global demand. The shift towards faster, higher-capacity broadband internet is a natural progression. Moreover, 5G is expected to generate significant revenue from the expansive opportunities within the Internet of Things (IoT), overcome challenges in delivering tailored services across various industries, and enable next-generation services that are not possible on 4G networks. Although there is substantial interest in 5G, research is still in its early stages, with no established standards or specifications yet. The 5G Digital Transformation (DT) is viewed as a driving force for new services, including technologies for city management, which could help developing nations address critical issues such as traffic control, water and sanitation management, and urban security [6]. In light of the ongoing global pandemic, the implementation of a 5G Digital Twin (DT) could enhance our understanding of the spread of COVID-19. By leveraging artificial intelligence (AI) within the 5G DT, it could predict potential epidemic hotspots. This would involve creating a DT with a three-dimensional model of the city and integrating the 5G network with various data sources, such as transit networks, street layouts, buildings, Internet of Things (IoT) data, human movement and activity patterns, and epidemiological data from current and past pandemic trends. Additionally, the DT could assess the overall performance of 5G-connected vehicles and enable the provision of tailored services [22]. Artificial intelligence is employed to forecast a vehicle's performance in various dynamic situations, identify potential issues, and implement improvements, thereby enhancing the safety of the driver's experience. However, before deploying this technology on public roads, extensive testing through simulations is essential. Femtocells, also known as home base stations, are small, cost-effective, low-power base stations that consumers install to improve indoor voice and data reception. These femtocells, when placed within homes, act as miniature base stations, enabling direct connection to the cellular network through the femtocell rather than the outdoor macrocell, which improves call quality [23].

As suggested by [20], Concerning the density of femtocell deployment, there is a simultaneous enhancement in Quality of Service (QoS) and a significant reduction in energy consumption per bit for User Equipment (UE). To fully harness the inherent superiority of femtocells in terms of improved QoS and decreased energy consumption, more advanced Handover (HO) decision algorithms are needed, especially in the context of LTE femtocells. Additionally, an energy-efficient HO decision policy for the LTE network encompassing both macrocells and femtocells is essential. This policy aims to minimize transmit power at the mobile terminals. Also, in the report of [21], Various levels of service are offered for different types or streams of data based on factors such as throughput, latency (delay), jitter (delay fluctuation), and packet errors or loss. The objective of this study is to introduce a fundamental Quality of Service (QoS) principle for the 5G LTE service. Similarly, [22] suggested that the research has employed WLAN models sourced from network simulators to establish wireless networks that are both energy-efficient and secure. The primary contributions of this study include the design and validation of energy models tailored for WLAN environments, utilizing real-world measurements. The research also provides guidelines to enhance the accuracy and efficiency of WLAN energy models, enabling successful modeling of large and intricate wireless networks. Additionally, the study investigated the impact of proposed adaptations to the energy efficient WTLS security protocol on the energy consumption of the IPSec protocol.

Figure 2. Flow of digital twin in 5G network

Hence, over the span of several decades, advancements have been made in wireless communication technology for mobile devices. While earlier technologies have become obsolete, there are significant differences in various wireless connection and data transmission methods that have evolved from one generation to the next, considering factors such as speed, range, and reliability. The growth of battery capacity has been comparatively slow in keeping pace with the rapid advancements in Internet technologies and mobile devices, highlighting the need for improvement as seen in Figure 1. The Digital Twin Network approach provides a comprehensive and dynamic viewpoint, laying the foundation for more robust and adaptable 5G networks in the future, see Figure 2.

3.0 METHODS AND MATERIAL

The research methodology employed in this study adopts a thorough and iterative strategy, integrating both quantitative and qualitative research methods from Figure 3. The objective is to network nadiral data, evaluate the efficacy of the digital twin network, and offer insights into the enhancement of 5G mobility handovers. The study will encompass practical components to explore the research issues.

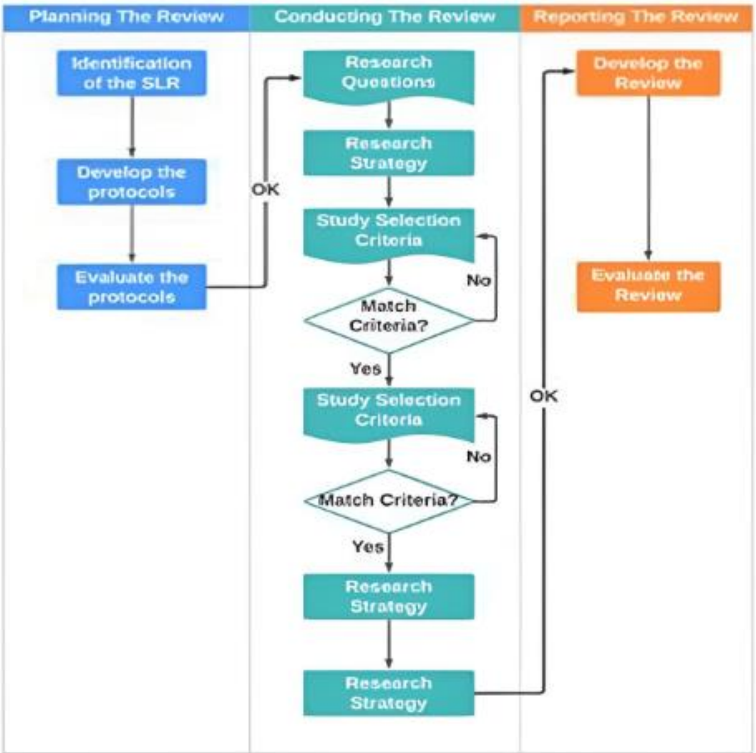

Figure 3. Methodology flow

3.1 Planning the Review

The review plan seeks feedback to refine the approach, ensuring that the review effectively addresses the chosen topic while contributing to the existing body of knowledge. This phase can effectively plan and structure the review, ensuring that it comprehensively covers the chosen topic while offering valuable insights to the readers.

A. Research Questions

The research questions review comprehensively explore the implications, challenges, and potential advancements related to leveraging digital twin networks for enhancing 5G mobility handover efficiency.

i. How does the implementation of digital twin networks impact the efficiency of 5G mobility handover processes?

The implementation of digital twin networks impacts the efficiency of 5G mobility handover processes by providing a virtual replica of the physical 5G network. This digital twin allows for proactive monitoring, predictive analysis, and optimization of handover procedures. By simulating and predicting network behavior, digital twin networks can help anticipate and address potential issues before they occur, leading to smoother and more efficient handover processes. In essence, digital twin networks enable better planning, real-time adjustments, and improved management of 5G mobility handover, ultimately enhancing the network's overall efficiency and performance.

ii. What are the specific challenges in 5G mobility handover that digital twin networks aim to address, and how do they mitigate these challenges?

The specific challenges in 5G mobility handover that digital twin networks aim to address include issues related to seamless transition between network cells, potential latency, and maintaining quality connections during movement. Digital twin networks tackle these challenges by creating virtual replicas of the real network, allowing for predictive analysis and proactive adjustments. By simulating various handover scenarios and predicting network behavior, digital twin networks can anticipate and mitigate potential disruptions, ensuring smoother transitions between network cells and minimizing the impact of latency, thus maintaining high-quality connections as devices move within the 5G network.

iii. How do digital twin networks compare to traditional methods of managing mobility handover in 5G networks offer better QoS, and what are the relative advantages and limitations of each approach?

Digital twin networks differ from traditional methods of managing mobility handover in 5G networks by offering a virtual replica of the network for predictive analysis and proactive adjustments. This contrasts with traditional methods that often rely on reactive responses to network conditions. The advantages of digital twin networks include the ability to anticipate and prevent potential disruptions, leading to smoother handover processes and improved network performance. However, traditional methods may have established protocols and may require less computational resources, but they might be less adept at predicting and preventing issues before they occur.

B. Review protocols

Review protocols typically involve a set of guidelines or procedures for conducting a systematic review of literature or research. These protocols outline the steps, criteria, and methodologies that will be employed throughout the review process. By adhering to review protocols, researchers ensure a structured and transparent approach to conducting systematic reviews, enhancing the rigor and reliability of the review process and its outcomes.

i. Searching keywords

Refine the list of keywords and test them in database searches to see which ones yield the most relevant results. By employing these strategies, a compilation of a comprehensive list of keywords that accurately represent our research topic will effectively guide the literature search.

To discover the most directly relevant articles in the literature, we employed the main alternatives and incorporated the "OR operator" and "AND operator," as illustrated in Table 1.

Table 1. Description of inclusion and exclusion criteria

S/N	Keywords
1	("Digital Twin” AND “5G network")
2	("Energy Efficiency” OR in AND “5G Systems” AND using OR “Digital Twin")
3	("Mobility handover” AND “5G network")
4	("Digital Twin” AND “5G network “OR “mobility handover”)
5	("Digital Twin” AND “5G network" AND “Energy Efficiency” AND “Mobility handover”)

ii. Literature Source

Initial review studies: To identify relevant publications, the databases utilized for this review encompassed Google Scholar, NCJ, Web of Science, Scopus, ACM Digital Library, Springer, Science Direct, and IEEE Explorer. These databases curate a comprehensive array of high-quality articles within our field, encompassing ISI and Scopus indexed articles. The robust search capabilities provided by these databases were leveraged to formulate the search term. Our search spanned the years 2020 to 2024 as summarized in Figure 4 for relevancy of each study using inclusion and exclusion criteria.

3.2 Conducting the review

We conducted the examination at this stage in alignment with the research inquiries, protocols, and keywords. In accordance with Table 2. (A) and Table 2. (B), this stage primarily centers on incorporating and excluding publications.

Table 2. (A) Description of inclusion criteria and Table 2. (B) Description of exclusion criteria

A. Inclusion Criteria
The criteria for inclusion in the review of "An Improved 5G Mobility Handover Efficiency by creating a Digital Twin Network" encompass factors and parameters that contribute to the assessment of enhanced mobility handover efficiency within the context of a digital twin network associated with 5G technology. • The research has relevance to 5G Systems. • The Digital Twin is directly relevant to the research.
B. Exclusion Criteria
The exclusion criteria for the review of "An Improved 5G Mobility Handover Efficiency by creating a Digital Twin Network" involve specific conditions or characteristics that would lead to the exclusion of certain studies or sources from the review. These criteria may include factors such as irrelevant methodologies, unrelated topics, outdated information, or insufficient relevance to the scope of the review. • Research’s that was unrelated to the domain of Energy Efficiency, Digital Twin in 5G Systems was excluded.

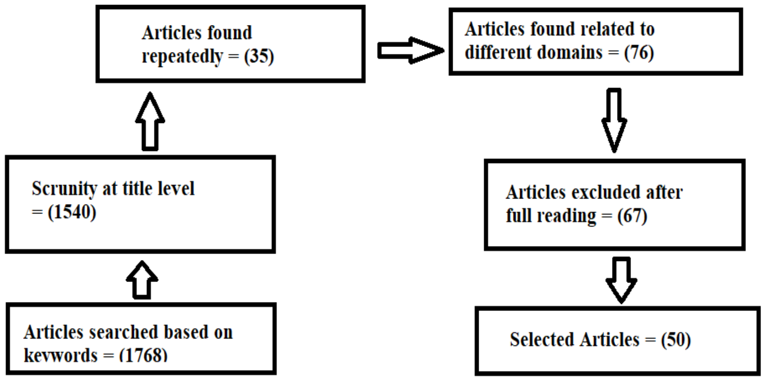

Figure 4. How relevant studies are identified

i. Study selection

A summary of an overview of the complete research selection process is shown in Figure 4. We searched the internet for 1768 articles in the process of finding relevant research. By employing screening using name, word, inclusion, and exclusion criteria, a small number of 142 publications were shortlisted. The inclusion and exclusion criteria are defined in Table 2. (A) and Table 2. (B). There were 76 entries that had previously appeared in other databases, along with 35 pieces from a variety of fields, such as music, the sciences, gaming, sociology, and other languages. Eventually, 67 things are removed from the list after careful examination. Table 2(A) and Table 2(B) detail the choosing criteria for the relevant articles based on keywords. Duplicate articles and articles that don't answer every query are removed. The number of selected articles for this research is 50 which were used for the relevant studies identification.

ii. Data extraction

The act of extracting data usually from unstructured or poorly organized sources for additional processing, storing, or processing is known as data extraction (or data migration).

iii. Information Synthesis

At this phase, some materials were combined to address the research questions. The strategy of narrative synthesis was utilized to address research inquiries. Therefore, we used tables and charts to describe our findings.

3.3 Reporting the review

Additionally, data from the original studies were used to address the three research issues that were mentioned in research questions.

4.0 RESULTS AND DISCUSSION

This section addresses 5G systems, including their current applications as well as some novel concepts for prospective future paths in network energy efficiency research for digital twins. Over the past 18 years, the Digital Twin network has significantly improved several network mitigation strategies. In addition, extensive research into 5G systems is being conducted to enhance the network of the digital twin. It displays the thorough arrangement of the selected studies' summary in Figure 4. A maximum of 50 articles were reviewed for this study. Table 3 shows that 15 studies focused on 5G network, 15 studies addressed the Digital Twin network, 10 studies focused on energy efficiency and 10 studies focused on mobility handover.

Table 3. RQ studies

RQ	Studies
5G networks	15
Digital twin	15
Energy efficiency	10
Mobility handover	10

Figure 5 illustrates the quantity of studies chosen annually. For instance, the number of related research projects rose to 18 in 2021 from just 8 in 2020.In 2022, there were 22 studies found; in 2023 and 2024, there were 45 and 11, respectively.

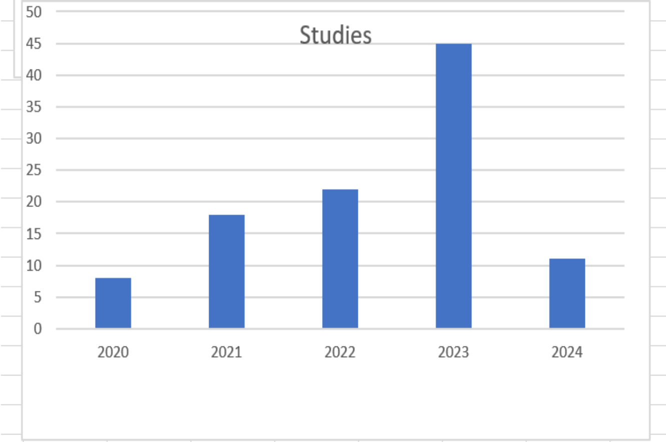

Figure 5. Quantity of studies chosen annually

A. In what ways does the deployment of digital twin networks influence the effectiveness of 5G mobility handover mechanisms?

The efficiency of 5G mobility handover procedures can benefit from the deployment of digital twin networks in several ways. By building virtual versions of actual systems or items, digital twin networks enable real-time analysis, optimization, and monitoring. Digital twin networks have the potential to improve the overall performance and efficiency of 5G mobility handovers [24]. By offering real-time insights, predictive analytics, dynamic resource allocation, defect detection, optimal parameters, and service customization, the use of digital twin networks improves the effectiveness of 5G mobile handover procedures as in Table 4. These features help to make the 5G network more resilient and responsive, which guarantees a smooth user experience when there are changes in mobility.

Table 4. Ways by which digital twin can enhance performance of 5G network

S/N	Performance	Significance
1	Predictive Analytics	Digital twins could forecast possible problems with mobility handovers by analysing past data. The network can anticipate handover requirements, its predictive feature, which optimizes resource allocation and lowers the likelihood of interruptions [25].
2	Real-time Monitoring	Real-time network conditions monitoring, such as traffic load, signal strength, and device movement patterns, is made possible by digital twin networks. Handovers are more effective because of the network's ability to dynamically adjust to changing conditions by ongoing monitoring [26].
3	Dynamic Resource Allocation	Digital twin networks can dynamically distribute resources according to demand by continually evaluating the condition of the network and associated devices. This guarantees the effective distribution of resources, reducing latency and enhancing the handover procedure [27].
4	Fault Detection and Remediation	Digital twin networks have the capability to promptly identify abnormalities or flaws in the system that might affect mobility handovers. The digital twin can suggest or carry out remedial techniques automatically if a problem has been found to preserve uninterrupted connectivity [28].
5	Optimized Handover Parameters	Digital twin networks can simulate various handover scenarios and optimize handover parameters, including target cell selection criteria, hysteresis values, and handover start thresholds. This optimization eliminates needless handovers and enhances decision-making during handovers [29].
6	Network Slicing for Customized Services	Network slicing may be implemented more easily with the help of digital twins, giving operators the ability to design virtual, specially tailored network segments that meet needs. By ensuring that vital services have the resources they require during handovers, this capacity improves overall efficiency [30].
7	Machine Learning and AI Integration	Artificial intelligence and machine learning techniques may be used by digital twin networks to enhance their comprehension of user behavior and network dynamics over time. Over time, this adaptive intelligence optimizes the process by assisting in the making of more informed judgments during handovers [31].

A virtual version of a real system, process, or item is called a "digital twin." To enable real-time monitoring, analysis, and simulation, a digital counterpart of the real-world entity must be created. Applications and sectors for which digital twins are employed include infrastructure, manufacturing, healthcare, and more. By building a virtual representation that closely mimics and interacts with the real environment, digital twins offer a potent foundation for enhancing productivity, creativity, and decision-making across a range of sectors. "5G" stands for fifth generation mobile networks, the most recent cellular technology standard [32]. 5G expands on the features of 4G (LTE), building on its strengths and adding several new developments to offer more application compatibility, lower latency, higher data rates, and enhanced device connection. The broad use of 5G networks, which are already being deployed, is predicted to fundamentally alter how people engage with technology, communicate, and obtain information. New technologies and use cases are expected to surface as 5G infrastructure keeps growing. The meaning of the term "mobility" varies according to the context in which it is employed. It may be applied to a variety of fields, including technology, and typically alludes to the capacity for mobility [6]. Mobility in the context of technology and telecommunications frequently refers to a user's capacity to access networks, services, or information when they are on the go. Users using mobile devices, such as tablets and smartphones, may stay connected to the internet and communicate no matter where they are by utilizing mobile or wireless connectivity. There are many facets to the idea of mobility, and how it is understood varies depending on the circumstance. When used in conjunction with technology, transportation, or human activities, it can improve mobility, accessibility, and interaction efficiency. A "handover" (sometimes called a "handoff") in the context of wireless communication and telecommunications is the act of moving an ongoing conversation or data session from one network cell or base station to another [33]. In a cellular network, handovers are necessary to ensure that a mobile device stay connected when it travels across various locations that are serviced by different cells. Ensuring a smooth transition without disrupting the data session or communication is the main objective. Maintaining a high-quality user experience requires efficient handovers, particularly in situations when users are moving quickly, such as while driving or using mobile devices while strolling. To streamline handover and reduce interruptions, cutting-edge technology like beamforming, numerous antennas, and clever algorithms are used [34].

B. What issues in 5G mobility handover are digital twin networks designed to tackle, and how do they alleviate these issues?

Utilizing real-time monitoring, modelling, and analytics capabilities, digital twin networks can effectively tackle difficulties associated with 5G mobility handovers, see Table 5. Hence, offering real-time insights, predictive analytics, dynamic resource allocation, defect detection, optimal parameters, and service customization, digital twin networks seek to improve the effectiveness of 5G mobility handovers. Together, these features make the 5G network more resilient and responsive and guarantee a smooth user experience when switching between mobile networks [35].

Table 5. Challenges and ways in which digital twin networks aim to mitigate them

S/N	Name	Challenge	Mitigation
1	Dynamic Network Conditions	When a mobile device travels, 5G networks operate in dynamic environments where network conditions, such interference and signal strength, can change quickly [36].	Digital twins are always keeping an eye on the current state of the network and forecasting any changes. Digital twin networks can dynamically optimize handover settings to adjust to changing situations by reviewing past data and running simulations [37].
2	Optimizing Handover Parameters	For smooth transitions without needless handovers, changeover parameters like hysteresis values and handover initiation thresholds must be tuned [38].	Digital twin networks improve parameters using machine learning algorithms and simulate different handover circumstances. The best configurations that strike a compromise between the necessity of prompt handovers and the avoidance of pointless handovers may be found using this simulation [39].
3	Resource Allocation	Maintaining quality of service during handovers requires efficient use of network resources, particularly in congested or highly mobile environments [40].	Digital twin networks flexibly distribute resources according to demand by utilizing real-time data. By doing this, latency and disturbances are reduced, and the network is guaranteed to allot enough resources to sustain continuous connections during handovers [41].
4	Fault Detection and Remediation	The dependability of handovers can be impacted by network abnormalities or problems, which can result in lost connections or poor performance [42].	Digital twin networks are always on the lookout for abnormalities or defects. The digital twin can identify problems and automatically or offer remediation measures to fix them and keep connectivity uninterrupted [43].

5	Predictive Analytics	It is difficult to forecast future handover needs and possible network problems in the absence of predictive skills [44].	Digital twin networks foresee changeover requirements using predictive analytics and historical data. The network can provide a seamless handover experience by anticipating future mobility events and detecting patterns and trends [45].
6	Customized Services with Network Slicing	It might be difficult to guarantee optimal performance for each service during handovers since different services may have different needs [46].	Using the idea of network slicing, digital twin networks generate virtual segments that are suited to certain service needs. This makes it possible to allocate resources in a tailored way during handovers, guaranteeing that vital services get the assistance they require [47].
7	Continuous Machine Learning and AI Integration	Constant intelligence is needed to adjust to changing network circumstances and user behavior [48].	AI and machine learning are used in digital twin networks to enable continuous data learning. The network can make wise judgments during handovers because to its adaptive intelligence, which gradually increases efficiency as it absorbs lessons from real-world situations [49].

The capacity of a system, apparatus, or procedure to fulfill its intended function with the least amount of energy usage is referred to as energy efficiency. It is an important factor in many areas, such as industry, technology, transportation, and infrastructure construction. Enhancing energy efficiency contributes to greenhouse gas emission reduction, resource optimization, and environmental sustainability. Increasing energy efficiency is a complex problem that calls for a mix of new technology, legislative initiatives, and behavioral adjustments [50]. In addition to lowering energy use, improvements in energy efficiency can have positive economic and environmental effects. The term "Quality of Service," or QoS, refers to the collection of guidelines and controls used to assess and guarantee the dependability and efficiency of a computer network or telecommunications service [51]. When many forms of data traffic such as audio, video, and data share the same network infrastructure, quality of service (QoS) becomes even more crucial. It aids in managing and prioritizing the flow of data to satisfy precise performance standards. A complete collection of guidelines, procedures, and policies known as quality of service is intended to provide dependable and predictable network performance. Hence, it is essential to ensure that networks satisfy the various needs of various users and applications, resulting in a reliable and fulfilling user experience.

C. How do digital twin networks compare to conventional methods of managing mobility handover in 5G networks, and what are the relative advantages and limitations of each approach?

In the framework of 5G networks, digital twin networks might not have been widely implemented or standardized. Nonetheless, the table below offers a broad summary of how digital twin principles can affect mobility handover management in 5G networks and contrast with current approaches from Table 6. It is crucial to remember that several variables, including industry acceptability, technological maturity, and standardization, will affect the uptake and success of digital twin networks in 5G.

Table 6. Comparison of DT, 5G, and Mobility Handover

Traditional Methods of Managing Mobility Handover in 5G Networks			
S/N		Advantages	Limitations
1	Hard Handover	Easy to put into practice. Decision-making during handover is simpler.	Commotion during the transfer. Possibility of packet loss [52].
2	Soft Handover	Smooth transfer without affecting service. distributing the load among several base stations.	A rise in complexity. Increased overhead in signalling [53].
Digital Twin Networks in 5G			
To track, examine, and improve the behavior of real entities (such network elements), digital twin networks create virtual copies of those items.			
		Advantages	Limitations
		Real-time network and user device monitoring is made possible by digital twins [54].	Digital twin network implementation and management can be challenging, requiring advanced analytics and algorithms.

		Digital twins can anticipate possible problems and improve handover decisions by modelling various situations [55].	Processing and analysing data in real time requires a large amount of computer power.
		Continual optimization grounded in empirical data can result in more effective network administration [56].	It is essential to prevent unwanted access to digital twin data.
		Comparison	
		Digital twin networks	Traditional methods
1	Seamlessness	The goal of digital twin networks is to minimize service disruptions by optimizing handovers smoothly.	Handovers involving traditional procedures may encounter problems [57].
2	Effectiveness	Compared to conventional techniques, digital twin networks may be able to utilize resources more effectively by dynamically optimizing handovers utilizing real-time data.	
3	Intricacy	Because of the generation and maintenance of virtual duplicates, digital twin networks come with an extra layer of complexity.	In general, traditional procedures are easier to use [58].
4	Use of Resources	Considering user behavior and the constantly changing character of the network, digital twin systems possess the possibility to optimize resource use more efficiently.	
5	Safety	Since digital twins need a lot of data processing, there can be more security concerns.	Strong security measures are needed for traditional as well as digital twin techniques [59].
6	Adaptability	Compared to conventional techniques, digital twin networks are more dynamic in their ability to adjust to shifting network circumstances and user behavior.	

Similarly, this paper covers many Digital Twin strategies to enhance Energy Efficiency in 5G Systems. Moreover, 5G systems for energy efficiency employ digital twin methods to improve performance and efficiency. Digital Twin networks beat handover decision algorithms (HAD) with the help of Intrusion Detection methods. To construct an Energy Efficient network, twin networks, prevention, and detection were used [60]. The results of the research showed that the quality of Digital Twins created with these tactics is superior. 5G systems use radio link failure (RLF), mobility state detection (MSD), and time to trigger (TTT) technologies to locate and retrieve the network in an efficient manner. Included are core approaches that are developed from studies that are relevant to the study themes. The term DT in several scholarly publications is important for improving a network's energy efficiency across the board [61]. Digital Twins help with the iterative optimization of both models by integrating the data model and the physical model of the product. The iterative optimization of the models reduces the duration of the whole design process and lowers the possibility of additional expenses during rework. Eliminating energy waste by using less energy to accomplish the same task is known as energy efficiency [61, 62]. Energy efficiency has several benefits, such as reduced network energy consumption, a decline in the need for imported energy, and a reduction in the energy consumption of base stations and the network. While solar solutions also help achieve these objectives, increasing energy efficiency is the most practical and cost-effective way to reduce internet consumption. There are several opportunities to improve efficiency in a few economic sectors, including the building, transportation, and energy sectors.

4.1 Discussion

Highlighting the advantages of digital twin networks in the context of 5G mobility handover, such as their ability to simulate and optimize network behavior, predict handover scenarios, and facilitate proactive adjustments to enhance overall efficiency. Addressing specific challenges related to 5G mobility handover and how digital twin networks offer potential solutions, including mitigating latency issues, managing handover complexities, and ensuring seamless connectivity for mobile users. Comparing and contrasting the effectiveness of digital twin networks with traditional methods of managing mobility handover in 5G networks, potentially showcasing the advantages and limitations of both approaches. Discussing practical use cases and scenarios where the implementation of digital twin networks has shown promise in improving 5G mobility handover efficiency, possibly citing examples of specific network configurations or deployment environments. Then exploring the broader implications of leveraging digital twin networks on overall network performance, reliability, and user experience, including considerations for scalability and adaptability in dynamic 5G environments. Identifying areas for further research and development, such as the need for empirical validation, security considerations, integration with emerging technologies, and potential standardization efforts within the telecommunications industry. In summary, the discussion likely delves into the advantages of digital twin networks, their application in addressing 5G mobility handover challenges, comparisons with traditional methods, practical use cases, implications for network performance, and future research opportunities within this domain. It is also advised that researchers concentrating on the topic of Energy Efficiency in 5G Systems make more use of these methods by adjusting parameter settings to get the optimal result. To achieve energy efficiency, this concept will expand the use of digital twins from Figure 6.

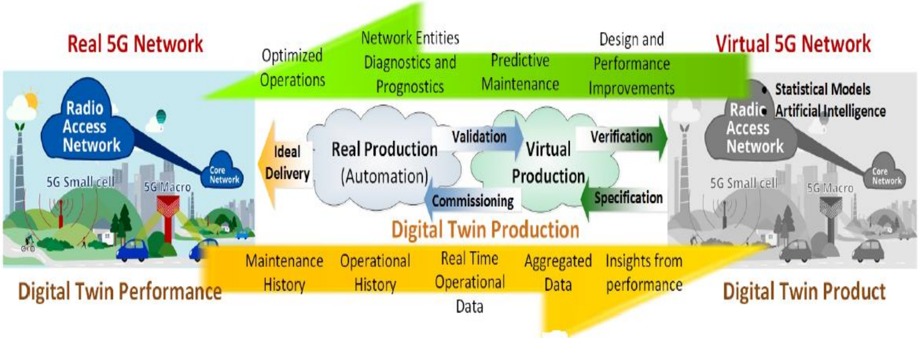

Figure 6. 5G and DT

4.2 Hypothesis

The successful implementation of a digital twin network tailored for Malaysia's 5G infrastructure will significantly enhance mobility handover efficiency and contribute to the development of energy-efficient wireless systems. The key hypothesis include:

a. Optimized Digital Twin Network Design
If a digital twin network is designed and implemented effectively to replicate and simulate the dynamic nature of 5G wireless systems in Malaysia, Then, the real-time monitoring and analysis capabilities of the digital twin will lead to optimized network configurations, reducing handover latency and enhancing overall efficiency

b. Dynamic Traffic Management
Once the digital twin network incorporates intelligent algorithms for dynamic traffic management during 5G mobility handovers. Then, it will lead to improved spectral efficiency, reduced network congestion, and an enhanced quality of service for end-users.

c. Energy Consumption Reduction
The digital twin network is strategically employed to monitor and optimize energy consumption patterns within the 5G infrastructure; hence, it will result in a substantial reduction in energy consumption during mobility handovers, contributing to a more sustainable and environmentally friendly wireless ecosystem.

d. Enhanced Security and Reliability
Since the digital twin network is integrated with robust security protocols and reliability mechanisms, Then, it will mitigate security vulnerabilities and enhance the overall reliability of 5G mobility handovers, fostering trust among users and stakeholders.

e. Cost-Effective Implementation
If the implementation of a digital twin network is cost-effective and aligns with the economic considerations of telecommunication providers and end-users, Then, it will result in a positive cost-benefit ratio, encouraging widespread adoption and investment in the deployment of energy-efficient 5G networks.

f. Regulatory Alignment and Support
If there is alignment between the digital twin network implementation and the regulatory model in Malaysia, later, it will facilitate a smoother integration process and create an enabling environment for the optimization of 5G mobility handovers.

Lastly, the hypothesis of this research sets the foundation for the research model that seeks to validate these propositions through empirical studies, simulations, and practical implementations. The goal is to provide evidence-based insights into the effectiveness of a digital twin network in enhancing 5G mobility handover efficiency and promoting energy-efficient wireless systems in the Malaysian context. To develop energy-efficient protocols and mechanisms within the digital twin by achieving a sustainable and environmentally friendly wireless communication ecosystem leads to integrating robust security protocols and reliability mechanisms into the digital twin network that will address potential vulnerabilities during 5G mobility handovers.

4.3 Contribution

Significantly, this research introduces the concept of a Digital Twin Network tailored to Malaysia's 5G infrastructure, aiming to significantly improve mobility handover efficiency. By leveraging real-time data, environmental factors, and user behaviors, the network optimizes energy consumption during handovers, thus reducing disruptions and resource wastage. The research emphasizes predictive handovers facilitated by systematic literature review (SLR) algorithms. This proactive approach enables the network to anticipate and manage handovers in advance, leading to smoother transitions and better user experiences. Through adaptive resource allocation mechanisms, the Digital Twin Network optimizes resource usage during handovers, thereby enhancing overall network efficiency. This contributes to improved network performance and sustainability. The integration of energy-efficient protocols and edge computing techniques promotes sustainability by reducing energy consumption and carbon footprint. This focus on sustainability aligns with global efforts to minimize the environmental impact of telecommunications infrastructure. Through specifically addressing the challenges of 5G mobility handovers in Malaysia, the research provides a localized and contextually relevant solution. This tailored approach ensures that the proposed Digital Twin Network meets the unique requirements and demands of the Malaysian telecommunications landscape. The contribution of this topic lies in its comprehensive review and proposal of a Digital Twin Network as a strategic solution to enhance 5G mobility handover efficiency, with a particular focus on energy efficiency, sustainability, and localized optimization for Malaysia.

4.4 Significance of Study

Similarly, through accomplishing the goal, this research aims to provide valuable insights, methodologies, and practical solutions for the seamless integration of a digital twin network. This integration seeks to enhance 5G mobility handover efficiency and promote the development of energy-efficient wireless systems in Malaysia. Businesses and developers can anticipate and comprehend how to optimize their existing infrastructure and integrate other technologies to generate additional value by leveraging digital twins. These technological applications facilitate the adoption and deployment of various technologies, enabling enterprises and developers to efficiently use their existing infrastructure and integrate other technologies for added value. Digital twins offer numerous advantages, including streamlined corporate processes, heightened productivity, and faster innovation at reduced costs. Due to these multifaceted benefits, digital twins emerge as a suitable solution for addressing challenges in various fields, such as industry and education. They enable the creation of digital replicas of physical systems, delivering advantages like real-time monitoring, enhanced production, and increased efficiency. 5G Digital Transformation (DT) is recognized as a catalyst for emerging services, including city management technologies. These technologies have the potential to assist less developed nations in managing critical challenges like traffic control, water and sanitation management, and urban security. DT supports the transition from traditional network designs, reliant on physical deployment, to digital/virtual network designs, encompassing testing and validation stages. Acknowledging the relevance of this research to policy areas, governments can proactively shape regulatory and technological landscapes that foster innovation, sustainability, and economic development within the telecommunications sector.

The introduction of 5G networks marks a period of unparalleled connectivity, offering improved data rates, reduced latency, and extensive device connectivity. Nevertheless, ensuring the smooth mobility of devices across diverse wireless networks, especially in densely populated urban regions such as Malaysia, presents considerable challenges. This study seeks to enhance the effectiveness of 5G mobility handovers by suggesting the creation and execution of a Digital Twin Network specifically designed to suit the distinctive features of the wireless landscape in Malaysia. The objective of this research is to provide valuable insights and practical solutions for optimizing the efficiency of 5G mobility handovers, placing emphasis on energy-efficient wireless systems within the Malaysian context.

4.5 Novel theories, new findings and knowledge

The study makes significant contributions to the field by introducing novel insights and knowledge that enhance the current understanding of the subject matter. This includes the introduction of a dynamic Digital Twin Network model, surpassing static representations, by integrating real-time data analytics, machine learning algorithms, and edge computing. This dynamic modelling is designed to adapt to the changing dynamics of the Malaysian wireless landscape, offering unprecedented insights into the behavior of 5G networks across different conditions. The research underscores the importance of developing and validating machine learning algorithms that not only predict handovers but also proactively optimize handover decisions based on historical patterns, user behaviors, and environmental factors. This proactive approach aims to create a more adaptive and anticipatory handover process, ultimately reducing latency and enhancing the overall efficiency of the 5G network. Additionally, the study proposes and evaluates novel energy-efficient protocols tailored specifically for mobility handovers in 5G networks. The investigation delves into how these protocols intelligently manage energy resources during handovers, potentially extending the battery life of IoT devices and mitigating the environmental impact of wireless communication. The research also explores the introduction of innovative adaptive resource allocation strategies within the Digital Twin Network, ensuring optimal resource utilization during handovers. This involves the implementation of self-optimizing algorithms that dynamically adjust resource allocations based on real-time demand and traffic patterns. Furthermore, the study suggests that extending the research to analyze the socioeconomic impact of upgraded 5G mobility handovers in Malaysia could provide insights into how improvements in connectivity efficiency contribute to economic growth, job creation, and societal advancements. An examination of the regulatory and policy implications of implementing advanced mobility handover technologies is also proposed, leading to recommendations for regulatory models that support the deployment of energy-efficient and optimized 5G networks. While these areas may not introduce entirely novel theories, the research findings within these domains have the potential to contribute significant advancements and deepen the understanding of the complexities associated with upgrading 5G mobility handover efficiency within the context of Malaysia's wireless systems.

4.6 Impact Statement on research deliverables like Society, Academia, Government, Industry and Environment

a. Society: Enhanced Connectivity and Quality of Life. The research aims to significantly improve the efficiency of 5G mobility handovers, leading to enhanced connectivity and a superior quality of life for society. Users will experience seamless transitions between wireless networks, reducing disruptions and improving overall connectivity experiences.

b. Inclusive Connectivity: The optimized 5G mobility handovers will contribute to more inclusive connectivity, ensuring that individuals in diverse socioeconomic backgrounds and geographical locations across Malaysia can benefit from improved and reliable wireless communication.

c. Academia: Advancements in Digital Twin Modelling. The research introduces advancements in the field of digital twin modelling for wireless systems, providing academia with new methodologies and insights into creating dynamic and adaptive network representations.

d. Contributions to Wireless Communication Research. Research deliverables will include academic publications, presenting new findings and methodologies that contribute to the broader field of wireless communication, particularly in the context of 5G mobility.

e. Government: Informed Policy Decisions. Findings from the research will inform policy decisions related to 5G infrastructure and connectivity in Malaysia. The government can use the insights to formulate and update policies that foster the deployment of energy-efficiency and optimized 5G networks.

f. Socioeconomic Development: The improved connectivity resulting from optimized 5G mobility handovers can contribute to socioeconomic development, empowering communities, and supporting the government's digital transformation initiatives.

g. Industry: Technological Innovation. Industry stakeholders, including telecommunication providers and technology companies, will benefit from innovative solutions for 5G mobility handovers. The proposed Digital Twin Network model, along with energy-efficient protocols, can be implemented to enhance the efficiency of wireless systems.

h. Competitive Edge: Companies in the telecommunications sector can gain a competitive edge by adopting research insights and implementing cutting-edge solutions, positioning themselves as leaders in the rapidly evolving landscape of 5G technology.

i. Environment: Energy-Efficient Wireless Systems: The research focuses on designing energy-efficient protocols and adaptive resource allocation strategies, contributing to a reduction in the overall energy consumption of wireless networks. This has positive environmental implications, aligning with global sustainability goals.

j. Resilience Against DDoS Attacks: The integration of edge computing for DDoS resilience enhances the security of wireless systems, mitigating potential environmental impacts associated with cyber threats and attacks on critical infrastructure.

In summary, it is expected to have a far-reaching impact across the Quintuple Helix, fostering societal inclusion, advancing academic knowledge, guiding government policies, driving industry innovation, and promoting environmentally sustainable practices in wireless communication.

5.0 CONCLUSIONS

The effectiveness of digital twin networks in simulating and optimizing 5G network handover processes, leading to improved overall efficiency and performance. The review's support for the adoption of digital twin technology to address challenges related to mobility handover within 5G networks, potentially highlighting specific use cases or scenarios where this technology excels as seen in Table 6. The potential impact and benefits of deploying digital twin networks in 5G environments, such as reduced latency, enhanced reliability, and seamless handover experiences for users and connected devices as seen in Table 5. Conducting empirical studies to validate the theoretical benefits of digital twin networks in real-world 5G mobility handover scenarios potentially through field trials or scaled simulations. From Table 4, we investigated the security implications of digital twin networks within 5G environments and developing strategies, it ensures the reliability and resilience of these systems in the face of potential cyber threats or disruptions. Also, there is need for contributing to the standardization efforts within the telecommunications industry to ensure the interoperability of digital twin networks across diverse 5G infrastructures and deployments. There are research methods to address scalability challenges and resource management issues associated with deploying digital twin networks at scale within complex 5G network environments.

Recommendations for future research and implementation strategies to further leverage digital twin networks for optimizing mobility handover processes within 5G networks by potentially identifying areas for continued exploration or development. In essence, it is likely to underscores the significance of digital twin networks in improving 5G mobility handover efficiency and may offer insights into the future implications and advancements in this area. These future areas of work aim to advance the understanding and practical implementation of digital twin networks for optimizing 5G mobility handover efficiency, contributing to the ongoing evolution and enhancement of 5G network capabilities.

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AUTHORS CONTRIBUTION

Umar (Experimentation; Data analysis coordination)

Kamaluddeen (Writing - menu draft)

Aliza (Manuscript arrangement)

Abdussalam (Research design; Study organization)

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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