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Systematic Review

Evaluating Wireless Network Technologies (3G, 4G, 5G) and Their Infrastructure: A Systematic Review

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Abstract: Wireless network technologies, including 3G, 4G, and 5G, are transforming telecommunications infrastructure globally. However, the adoption and effectiveness of these technologies vary significantly across regions and industries, posing unique challenges and opportunities for Small and Medium Enterprises (SMEs). Understanding the critical factors influencing network deployment and optimization in different contexts is essential for telecom companies and business leaders. This systematic review aims to evaluate the infrastructure, performance, and strategic implications of wireless network technologies (3G, 4G, and 5G) across multiple industries and geographic regions, providing insights for SMEs and telecom companies on adopting these technologies to enhance operational efficiency and competitiveness. A comprehensive search of academic databases, including Google Scholar, Web of Science, and SCOPUS, was conducted using keywords such as "wireless network," "3G," "4G," "5G," "evaluation," and "infrastructure." Studies were selected based on pre-established eligibility criteria, and a risk of bias assessment was performed using the Newcastle-Ottawa Scale. Statistical synthesis and sensitivity analyses were conducted to identify key trends and challenges. A total of 121 studies were included, with the majority focusing on 5G technology (42%) and its infrastructure. Key findings highlight the importance of network densification, high-speed connectivity, and low-latency applications, particularly in urban regions. The analysis also revealed significant regional disparities in infrastructure deployment, with developing countries facing challenges in expanding coverage and integrating advanced technologies. Industry-specific customization of wireless networks is essential for sectors such as manufacturing, healthcare, and retail. Wireless network technologies present vast opportunities for SMEs, but their successful implementation requires addressing regional infrastructure gaps and tailoring solutions to industry-specific needs. Telecom companies must prioritize strategic investments in network densification, scalability, and security to fully leverage the benefits of 5G. The findings of this review provide actionable insights for business leaders and policymakers aiming to optimize wireless technology deployments for enhanced performance and competitiveness.

Keywords: wireless network evaluation; telecommunication infrastructure; 3G/4G/5G technologies; systematic review

1. Introduction

Wireless communications are one of the busiest regions of technology improvement of our generation. This evolution is being driven by the conversion of what has been mostly a medium assisting voice telephony into a medium of assisting other services, such as the broadcasting of video, image, text or information. Hence, equivalent to the developments in cable line size in the 1990's, the need for the new wireless size started increasing at a fast rate. Even though there are, certainly, quiet many technical issues to be resolved in wired communications, requirements for extra wire line capacity may be accomplished mostly with the supplement of new non-public infrastructure, such as

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extra switches, routers, optical fiber and so forth. There has been substantial research work in past years focused on developing new wireless capacity over the placement of superior intelligence in wireless networks. A crucial feature of this motion has been the development of fresh signal broadcast methods and Morden receiver signal processing ways that enable important increments in wireless capacity without servant rises in transmission capacity and power demands [1,2]. The wireless network applies to every network that is unconnected by any wire. It is a way by which businesses, homes, telecommunication networks set up evade the expensive operation of inserting wires into premises or as a link among different apparatus location. Numerous years after the emergence of wireless technology, the dilemma and barriers of efficient communication are still ongoing. Several people all over the world are now using wireless communication and this has prompted overcrowding of network, low connectivity speed and band width. The absence of wireless networks, web browsing, the use of mobile phones which are part of daily wireless networking that enables simple personal interaction is impossible. Wireless networking shall likewise apply in transcontinental network systems and the usage of radio satellites to communicate in various parts of the world. Such technologies permit a substitute to putting physical network mediums such as optical fiber and coaxial cables, which are costly. Wireless networking assists in saving the cost of installing cable mediums, does not waste time from physical installations, furthermore, makes agility for devices linked to a network [3]. Mobile and wireless networks have experienced enormous growth in the past 15 years. These days numerous mobile phones have a WLAN adapter. In the foreseeable future various mobile phones will be equipped with WiMAX adapters besides their 4G, 3G, WLAN and Bluetooth adapters. Employing Internet protocol for both 2.5G and 3G Public Land Mobile Networks (PLMN) on one side and WLAN on the other side elevated search on their consolidation. Concerning the 4G, its concentration is about continuous integration of cellular networks as 3G and GSM. Polyphase user terminals are observed in 4G, but various security systems and various QoS help in various wireless technology is still a problem [1,2]. Nevertheless, integration between wireless networks is operating in real life even today, with various wireless networks from aa individual terminal in use solely, that is to say, there is no merging of various wireless admission technologies for a same session. The suggested Open Wireless Architecture (OWA) in 5G is aimed at delivering open baseband manipulation modules with open interface parameters to assist various architectures present also forthcoming wireless communication standards. The OWA is aimed at MAC/PHY layers of 5G [3,4]. This cited work offers grounds for interpretation of an idea over 4G, 5G. In the offered idea the mobile used is on the peak. The 5G terminals have software defined radios and modulation design as well as a recent error-management plan. The development is observed about the user terminals as a target of the 5G mobile networks. The terminals have entry to various wireless technologies at the matching time and the terminal capable of merging various flow from various technologies [4,5,7]. Each network is accountable for operating user-mobility, while the terminal produces the concluding option between various wireless access network suppliers for granted assistance. The 5G communication system is pictured as the actual wireless network, able of backing wireless World Wide Web(www) applications in 2010 to 2015 period. There exist two opinions of 5G which are evolutionary and revolutionary.

In the evolutionary view, the 5G will be able to support the www enabling extremely adaptable network such as Dynamic Ad hoc Wireless Network (DAWN). In revolutionary view, 5G will be clever technology able to interconnect whole world with no repercussions [3,4,8]. Wireless network technologies have evolved from 1G to 5G as shown in Figure 1.

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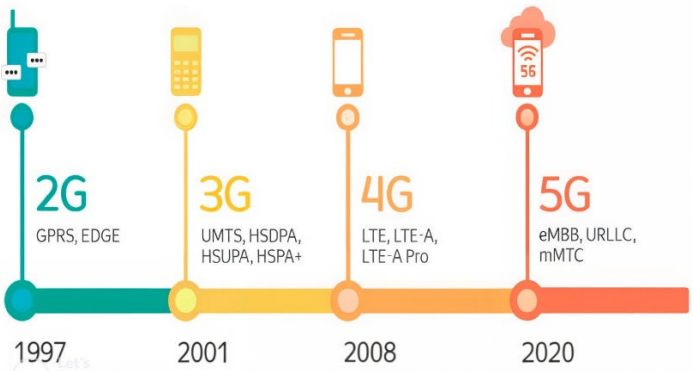

Figure 1. The Evolution and differences between 3G, 4G, and 5G infrastructure Requirements [64].

Table 1 provides a comparative analysis of existing review works and the proposed systematic review on wireless technologies and their infrastructure. This table highlights key contributions from various studies on smart grids, wireless charging technologies, optical wireless communication (OWC), and cellular technology evolution from 1G to 5G.

Table 1. Comparative analysis of the existing review works and proposed systematic review on wireless technologies and their infrastructure.

Ref	Cites	Year	Contribution	Pros	Cons
[9]	431	2015	The integration of advanced communication technologies into the smart grid represents a significant leap forward in modernizing the electricity infrastructure.	Smart grids enable better energy management through real-time monitoring and control, reducing energy losses and improving overall efficiency.	Lacks a detailed analysis of the infrastructure needed for integrating communication technologies into the grid.
[10]	886	2018	Comprehensive review of wireless charging technologies for electric vehicles (EVs).	Wireless charging eliminates the need for physical connectors and offers convenience for EV users.	Does not address the broader infrastructural challenges or economic feasibility for large-scale deployment.
[11]	574	2018	A comprehensive review of optical wireless communication (OWC) technologies.	OWC can achieve faster data rates than RF technologies and works on an unregulated spectrum, relieving spectrum congestion.	Limited focus on infrastructure needs and the real-world feasibility of large-scale deployment.
[12]	269	2019	Review of OWC technologies and their potential role in 5G and 6G communication systems.	Supports data rates up to 100 Gb/s, offering high-speed, low-latency communication.	Lacks discussion on the practical infrastructure deployment challenges, especially in urban environments.
[13]	93	2019	Comparative analysis of cellular technologies from 1G to 5G.	5G offers enhanced connectivity for IoT applications and supports billions of connected devices.	Focuses more on technology capabilities, with limited exploration of the infrastructural demands required for 5G rollout.
[14]	35	2021	Analysis of the evolution of mobile communication technologies from 1G to 5G, with a particular focus on 5G.	Accommodates billions of connected devices with low latency and high throughput, ideal for IoT and real-time applications.	Minimal analysis of the sustainability and cost-efficiency aspects of infrastructure deployment.
[15]	196	2022	Comprehensive overview of wireless sensor (WS) nodes.	Provides an in-depth analysis of WS nodes' history, architecture, and functionalities.	Fails to address the future infrastructure requirements for supporting rapidly evolving IoT technologies.
[16]	339	2019	Review of wireless sensor networks (WSNs) in structural health monitoring (SHM).	Offers a detailed investigation of WSN architecture, functionality, and communication technologies.	Limited coverage of the infrastructure needed for scaling WSNs in real-world applications.
[17]	232	2018	Extensive analysis of localization techniques for IoT applications, presenting a hierarchical taxonomy and their applications in various contexts.	Highlights the versatility of localization techniques in diverse IoT contexts.	Overly technical, with insufficient focus on the infrastructural and practical deployment challenges of IoT localization techniques.

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Current Review	2024	Evaluating wireless network technologies (3G, 4G, 5G) and their infrastructure: A comprehensive review of performance, sustainability, cost-efficiency, and infrastructure challenges across generations.	Provides a detailed analysis of infrastructure requirements, sustainability challenges, and the role of advanced technologies (e.g., Massive MIMO, mmWave). Offers tangible recommendations for cost-effective deployment.	Could benefit from deeper analysis of regional infrastructure variations (urban vs rural) and a more granular examination of long-term operational costs.

While many reviews offer valuable insights into specific technological advancements, they often focus narrowly on areas, such as energy management in smart grids or data rates in OWC. However, these studies commonly overlook broader infrastructure challenges, such as high deployment costs, regulatory hurdles, and security risks. This systematic review fills these gaps by providing a more comprehensive perspective that integrates the infrastructure demands and technological advancements of 3G, 4G, and 5G, offering a holistic evaluation that addresses both the opportunities and limitations of next-generation wireless networks.

1.1. Research Questions

In this systematic review, research questions define the scope, purpose, and direction of the review. Certain elements help in identifying relevant studies, determining eligibility, and developing robust data extraction.

- How do different wireless network technologies compare in terms of data transfer speeds and latency?
- What are the coverage limitations of current wireless network technologies in dense urban environments?
- What are the primary challenges in deploying and keeping the infrastructure for 5G networks, and how can these challenges be mitigated to ensure reliable and widespread coverage?
- How can the development of wireless network infrastructure be customized to minimize environmental impact while maximizing coverage and performance? What are the best practices for sustainable wireless infrastructure deployment?
- How do variations in wireless network infrastructure (e.g., small cell deployment, antenna placement, backhaul connectivity) influence overall network performance and user experience in different environments (urban, suburban, rural)?

1.2. Research Motivation

The motivation for this work can be summarized as follows:

The world of wireless communication has rapidly transformed from 3G to 4G, and now into the next big shift 5 G making speed experience a drastic evolution in capacity and connectivity for innovations across verticals such as healthcare, education & smart cities. At the same time, this rapid evolution complicates understanding of what each technology is truly capable of and how far we can go with it. The motivation of this study arises from the necessity to accurately assess, and contrast functionalities, performance, and infrastructure demand related to 3G, 4G as well as 5G networks in order that a high-level view can serve jointly for scrutinizing planned developments or deployments.

The deployment of wireless network technologies involves large investments in infrastructure such as base stations, antennas and data centers. It is the progression in terms of although more evolutionary, as we move from 3G and 4G to 5G it calls for increased infrastructure support aimed at supporting data rates way higher than what that earlier generation could afford; lower latency rate with much swifter processing speeds coupled massively huge number of connections by IoT devices. As we contemplate a completely new networking landscape of 5G, current-time infrastructure needs to be evaluated for 3G and 4G technology and this research is committed to bringing all the challenges, gaps and improvement areas on the drawing board. This study systematically reviews the infra-structure requirements and capabilities of future mmWave-based wireless technologies to help policy makers, industry stakeholders, as well as researchers understand how net-work speeds

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can be improved today in preparation for seamless transition into impending next-generation (6G) RF environment.

The rapid development of wireless network technologies from 3G to 5G has carried important improvement in capacity, connectivity and speed. Nevertheless, there is an out-standing gap in the present literature concerning a broad comparison of these technologies, especially regarding sustainability, cost-efficiency and social impact. Knowing the financial and operational expenses related to infrastructure improvements is important for both academic and industry stakeholders. A systematic literature that assesses these views can supply valuable awareness into the long-term advantages and disadvantages of taking latest technologies.

1.3. Research Contribution

This systematic review addresses several critical gaps in the existing literature on wireless network technologies and their infrastructure, particularly in the transition from 3G to 5G. While previous studies have explored aspects of network performance, most have focused on specific generations (e.g., 3G or 4G) without conducting a holistic comparison across multiple generations, especially concerning their infrastructure demands. The following are the key contributions of this review:

- Unlike previous reviews that focus primarily on technical performance (e.g., data speeds, latency), this review provides a detailed analysis of the infrastructure needs for 3G, 4G, and 5G networks. It highlights unique challenges, such as the higher density of base stations required for 5G, as well as advancements like Massive MIMO and beamforming. These insights serve as a crucial tool for future infrastructure planning and network deployment.
- Existing reviews often overlook the environmental impact of wireless infrastructure. This review fills that gap by evaluating how sustainable practices can be integrated into the deployment of 5G infrastructure. It identifies best practices for minimizing the environmental footprint of base station deployment and power consumption, which is critical for future network growth in a resource-constrained world.
- While many studies focus on network performance improvements, few provide a thorough cost-efficiency comparison across generations. This review systematically compares the financial implications of upgrading from 3G and 4G to 5G, offering insights into how telecom firms can optimize resource allocation and minimize operational expenses during infrastructure upgrades.
- Another overlooked aspect in current literature is the broader societal impact of network upgrades, particularly for emerging technologies like 5G. This review evaluates how infrastructure investments in wireless networks can influence societal factors such as digital inclusion and quality of life improvements. The findings can assist policymakers in crafting regulations that maximize the societal benefits of wireless network advancements.

1.4. Research Novelty

This systematic review provides a unique and methodical analysis of the evolution of wireless network technologies from 3G to 5G, with a specific focus on the infrastructure challenges and technological advancements that are crucial for each generation. While previous studies have discussed the transition between these technologies, this review stands out by concentrating on key technological breakthroughs that enable these networks to meet the increasing demands for higher data rates, lower latency, and greater reliability.

One of the unique aspects of this review is its detailed analysis of advanced technologies such as Massive Multiple-Input Multiple-Output (Massive MIMO) and beamforming, which are critical for enhancing the performance of 5G networks. These technologies significantly improve network capacity and coverage by enabling the use of multiple antennas to transmit and receive signals, thus allowing more efficient use of available spectrum. By comparing the integration of these technologies across 3G, 4G, and 5G networks, this review highlights how they contribute to overcoming the limitations of earlier generations, such as coverage gaps and spectrum inefficiencies.

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Another key novelty lies in the exploration of millimeter wave (mmWave) frequencies, which are introduced in 5G to enable extremely high data rates. This review addresses the infrastructure challenges associated with mmWave deployment, including the need for a higher density of small cells and advanced backhaul solutions. While previous research has primarily focused on network performance metrics, this review emphasizes the physical infrastructure required to support mmWave technologies and the practical implications for real-world deployments.

The review also introduces a fresh perspective by assessing the role of software-defined networking (SDN) and network function virtualization (NFV) in the evolution from 4G to 5G. These technologies allow for more flexible and scalable network architectures, enabling operators to better manage the complexities of 5G networks. By examining how these innovations affect both the operational efficiency and the cost-effectiveness of deploying next-generation networks, this review offers valuable insights for telecom operators and policymakers.

2. Materials and Methods

In this subsection, the study presents the methods and materials used to develop a systematic review based on wireless network technologies and their infrastructure. The study is based on a 10-year review.

2.1. Eligibilty Criteria

An eligibility criterion is formulated in order to specify a set of parameters that determine which studies will be included and excluded. This is to ensure that the review is focused, reproducible, and consistent. Table 2 is an eligibility criterion which is used to specify the parameters that will be considered while collecting data. The systematic review focuses on research published in English over the past 10 years, from 2014 to 2024. A firm inclusion criterion was used to choose research papers that exclusively focuses on the evaluation of wireless network technologies and their infrastructure and exclude those that do not. Only research works that essentially converge on the evaluation of wireless network technologies and their infrastructure were considered for this review. The inclusion and exclusion criteria for this study are tabulated in Table 2 [133] – [140].

Table 2. Proposed Inclusion and Exclusion Criteria.

Criteria	Inclusion	Exclusion
Topic	Publications focusing on Evaluating Wireless Network Technologies (3G, 4G, 5G) and Their Infrastructure: A Systematic Review	Publications not focusing on Evaluating Wireless Network Technologies (3G, 4G, 5G) and Their Infrastructure: A Systematic Review
Research Framework	The work must include a research framework where Wireless Network Technologies and their infrastructure is employed	The work must exclude a research framework where Wireless Network Technologies and their infrastructure is not employed
Language	English	Not English
Period	Published between 2014 and 2024	Publications outside of the period 2014 and 2024

2.2. Information Source

For this systematic review, three online repositories were used, namely Google Scholar, Web of Science, and SCOPUS and the choice is based their creditability and comprehensive coverage of peer-reviewed literature in wireless network technologies and their infrastructure. The three databases were searched through by using keywords that are related to the topic. A range of research papers such article journals, conference papers, book chapters, dissertations, and these were collected and analyzed [133] – [140].

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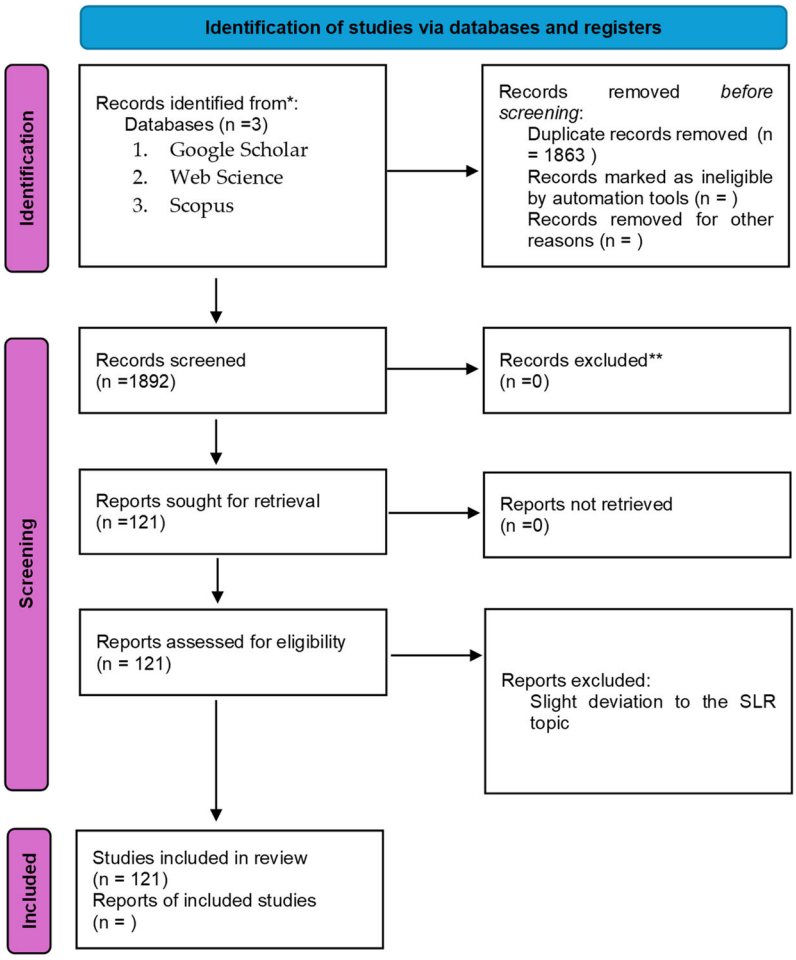

Figure 2. Proposed PRISMA Flowchart.

2.3. Search Strategy

The conducted literature review houses research from multiple sources, Google scholar, Web Science and Scoopers respectively which contributed with work published by great minds relating to the SLR research topic. The following set of key words was utilized to increase efficiency when searching for literature related to the literature topic. Table 3 shows the list of key words which were utilized to increase efficiency [133] – [140].

Table 3. Keyword Search.

Keyword Search
"infrastructure" OR "architecture" OR "deployment
"Wireless network" OR "cellular network" OR "mobile network"
"evaluation" OR "comparison" OR "assessment"
"3G" OR "4G" OR "5G"

The above key words assist in finding literature, which is relating to the SLR research topic, with that the process of obtaining the appropriate key word search is very important as it helps in obtaining literatures appropriate to the SLR research topic. To be more relatable, literature has a specified domain between 2014 to 2024 which covers literatures which have been published recently, covering new and relatable research. A total of 1892 literatures was obtained except only a few numbers of literatures are applicable to the SLR research topic. Table 4 gives a detailed overview of the number of literatures obtained versus the number relating to the SLR research topic.

Table 4. Results achieved from Literature Search.

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No.	Online Repository	Number of Results
1	Google Scholar	536
2	Web of Science	280
3	Scopus	1076
	Total	1892

2.4. Selection Process

In this systematic review, three reviewers were involved in screening and retrieving each record and report. The three reviewers worked independently to search for literature in the three databases (i.e. SCOPUS, Web of Science, and Google Scholar). Using keywords on the databases relevant information is obtained and screened. While screening the research studies, reviewers use the inclusion and exclusion criteria as a guide to obtain recent and relevant studies [133] – [140].

2.5. Data Collection Process

A systematic and well-structured data collection process was employed to ensure rigor and consistency in this review. The process began with the formulation of clear and targeted research questions, which served as a guiding framework for determining the relevant data to be collected. These questions informed the development of a comprehensive review protocol, which included clearly defined objectives, inclusion and exclusion criteria, a search strategy, and data extraction methods, ensuring transparency and replicability. The first step in the process involved identifying relevant data sources. For this systematic review, three well-established and reputable online databases were selected: SCOPUS, Google Scholar, and Web of Science. These databases were chosen for their comprehensive coverage of academic literature. The research types considered included journal articles, conference papers, theses, books, and dissertations to ensure a broad and diverse pool of scholarly contributions. A robust search strategy was developed, with keywords and search terms formulated to align with the research questions. Boolean operators (AND, OR) were utilized to refine the search results and increase the precision of the search queries. This strategy ensured the retrieval of documents directly related to the review's objectives. Following the development of the search strategy, a detailed literature search was conducted across the selected databases. The search process was systematically documented, including the search terms used, search dates, and the number of results retrieved, all of which were recorded in an Excel sheet with predefined headings. This documentation ensured traceability and accountability throughout the data collection phase [133] – [140].

The initial screening of titles and abstracts was performed to assess whether the documents met the predefined inclusion criteria. These criteria, central to the eligibility assessment, were applied consistently to ensure that only relevant studies were included. A multi-stage screening process was employed, first based on titles and abstracts, followed by a full-text review where necessary. Data extraction was carried out by three independent reviewers, with a fourth reviewer overseeing the process to resolve any discrepancies. An Excel sheet was used to organize and capture key data items, ensuring consistency and minimizing errors. To reduce potential biases and maintain accuracy, the extracted data was cross-checked by multiple reviewers. Discrepancies were discussed and resolved through consensus to maintain the integrity of the data.

No automation tools were used during the data extraction phase. Instead, manual double-checking of entries was performed to ensure data accuracy. Only studies published in English between 2014 and 2024 were considered, thus excluding the need for translations. In cases where incomplete or ambiguous data were encountered, these instances were documented as missing data, ensuring transparency. Duplicate studies or reports from the same research were handled by prioritizing the most recent and comprehensive data. This meticulous data collection process, grounded in systematic methodology and careful oversight, ensured that the data extracted was reliable, relevant, and directly aligned with the review's objectives as shown in Figure 3 [133] – [140].

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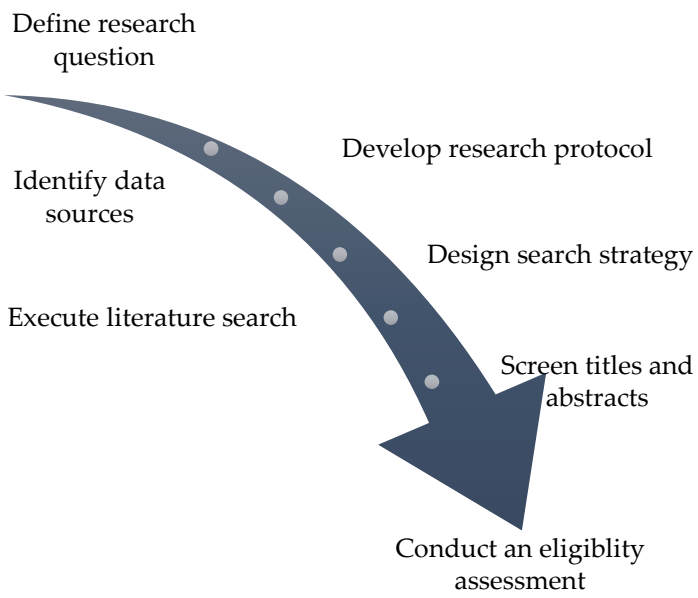

Figure 3. Data Collection Process.

2.6. Data Items

This section of the systematic review is an overview of data items that were selected, primarily focusing on the main outcomes as well as other variables used to help organize and summarize the literature. The primary outcomes for collecting data include different generations of wireless network technologies, network performance, business performance, as well as the long-term impacts [133] – [140]. The other variables include the economic context, technology providers, technology implementation, and sample characteristics. This allows for a including the most relevant data to give a well-structured analysis of the evolution and difference between generations of wireless network technologies. Figure 4 illustrates the data items process.

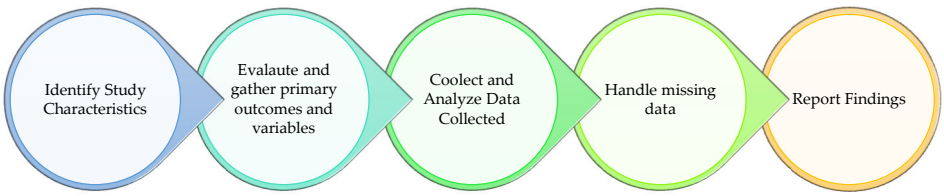

Figure 4. Data Items Process.

2.6.1. Data Items Collection Method

This section is for listing and defining outcomes which data is searched that includes the strategic, operational, and financial factors of wireless networks and their infrastructure. For each outcome domain, all outcomes that are relevant with the measures were sought by covering different points, methods, analyses. Measures also ensure that a proper comparison is made between the wireless networks based on their business and network performance metrics. With a large number of results, a systematic review is used to emphasize reliable and necessary data based on a criterion [133] – [140].

The network performance of technologies is an important outcome, which is measured by latency, bandwidth and coverage. Assessing those measurements helps with determining the

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reliability of the chosen network technologies along with the infrastructure. Better performing wireless networks help with the satisfaction of their users. Thus, this influences business performance and organizational outcomes. The long-term impacts of the evolution of wireless network technologies were a necessary focus as the organizational health and future is determined by them.

2.6.2. Lisi of Variables

Other variables are listed and defined while searching for data and include characteristics and intervention details. For unclear and missing information, some data was gathered to fill gaps, managed by conventional practices from the reference from available data. Table 5 shows the variables that are collected along with their description [133] – [140].

Table 5. Data Items.

Variables	Explanation
Title of study	The name of a research paper or publication that focuses on evaluating the different wireless network technologies, including their infrastructure.
Year	The year in which the research was published.
Online Database	Digital repositories (e.g., Google Scholar, SCOPUS, Web of Science) where research articles, conference papers, theses, and other academic publications are accessed.
Number of cites	The number of citations a research work has received, indicating its impact or influence in the academic community.
Discipline or Subject Area	The specific academic field or area of study (e.g., wireless network technologies, wireless network technology infrastructures, business technology).
Industry Context	The specific industry or sector to which the research is relevant
Geographic Location	The location or region where the study was conducted or where the research is focused.
Types of Wireless Technologies	Different generations or categories of wireless communication technologies (e.g., 3G, 4G, 5G).
Technology Implementation Model	The approach to deploying technology, such as on-premises, cloud-based, or hybrid models.
Research Design	The overall strategy or methodology employed to conduct the study (e.g., experimental, quasi-experimental, case study, survey).
Type of study	The methodological approach of the study, which could be quantitative, qualitative, or mixed methods.
Data collection methods	The techniques used to gather data for the study (e.g., interviews, surveys, observations, document analysis).
Data analysis techniques	The methods used to analyze the collected data (e.g., statistical analysis, thematic analysis).
Network performance metrics	Measures used to evaluate the performance of a network (e.g., latency, bandwidth, coverage).
Business Performance	Indicators used to assess a company's performance (e.g., operational efficiency, revenue growth, cost savings).
Organizational Outcomes	The results or impacts on an organization as a result of certain actions or implementations (e.g., employee satisfaction, customer satisfaction).
Long term impacts	The lasting effects or consequences of a strategy or technology on a business or organization (e.g., business sustainability, competitive advantage).

All these data items were necessary for the formulation of the systematic review. Studies needed to have the at least more than 5 of these items to qualify in the inclusion criteria. The collective results can be used to come up with other means of forming data, especially in the form of graphs.

2.7. Study Risk of Bais Assessment

In the papers related to the evaluation of wireless network technologies and their infrastructure, it is imperative to consider the risk of bias which in turn ensures the reliability and validity of the findings. The Newcastle-Ottawa Scale (NOS) is used to assess non-randomized papers, which includes cohort and case-control studies. The NOS evaluates studies related to three broad perspectives: Selection, Comparability, and Outcome (for cohort studies) or Exposure (for case-

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control studies). Each study is awarded a maximum of one star for each item within the selection and outcome/exposure categories, and a maximum of two stars for comparability. The scoring shows the overall quality of each research paper. The risk of bias assessment process involved three reviewers to be evaluated independently and maintain objectivity. No automation tools were used in the process. Thus, methodologies and results are manually reviewed for all studies. Data items like the study design, sample size, and data collection methods determine the bias risk. A comprehensive manual search through online databases is conducted to mitigate bias and ensure the assessment is accurate and thorough as possible. A review of conflicts of interest and funding sources that possibly affect the outcome of the study is conducted, and studies that disclose those conflicts are preferable [133] – [140].

2.8. Effect Measures

Effect measures are critical for evaluating the performance of wireless network technologies, offering a quantitative foundation to compare different generations of wireless technologies (3G, 4G, and 5G). In this review, while specific statistical comparisons were not performed, several key measures reported in the literature were identified to provide context for understanding network performance across generations [133] – [140].

- **Mean Difference (MD)**

The mean difference is a relevant measure used in existing studies to compare data transmission speeds between network generations. While this review did not calculate new mean differences, the reported literature highlights substantial improvements, particularly in download speeds as wireless technologies advanced from 2G to 5G. For instance, 5G networks are noted to outperform earlier generations, particularly in urban areas where infrastructure supports its deployment. The network speeds reported include significant variations are shown in Table 6.

Table 6. Network generation and speed.

Generation	Top Speed	Average Speed
2G	0.3Mbps	0.1Mbps
3G (HSPA+)	42Mbps	8 Mbps
4G LTE (ADV CAT-16)	1Gbps	10-30Mbps
5G	10Gbps	10 Gbps

- **Standardized Mean Difference (SMD)**

In comparing latency across various studies, the standardized mean difference is a useful measure, particularly when latency is reported in different units. Studies suggest that 5G offers significantly lower latency compared to 4G and 3G, but no direct SMD calculations were made for this review. For example, latency in 5G networks is reportedly as low as 1–10 milliseconds, compared to higher latency in previous generations.

Table 7. Network latency.

Network	Latency (milliseconds)
2G	300-1000ms
3G	100-500ms
4G	50-100ms
5G	1-10ms

- **Risk Ratio**

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Reliability is a key factor in evaluating network technologies. While no new risk ratios were calculated in this review, previous studies indicate that 5G networks demonstrate a lower risk of downtime compared to 4G, often cited as half as likely to experience failures. This highlights the improved stability and reliability of 5G, which is critical for applications requiring real-time data transmission.

- **Odds Ratio**

Adoption rates of new technologies are often compared using odds ratios. Based on literature findings, the adoption of 5G over 4G has been observed to occur at higher rates among businesses, with an odds ratio reported as 2.5. This suggests that enterprises are 2.5 times more likely to adopt 5G compared to 4G due to its superior capabilities.

- **Hazard Ratio**

The speed of network upgrades, particularly in urban areas, can be compared using hazard ratios. The literature suggests a hazard ratio of 1.8 for urban areas transitioning from 4G to 5G compared to rural areas. This indicates that network upgrades tend to occur more rapidly in urban environments due to higher demand and better infrastructure availability.

2.9. Synthesis Methods

2.9.1. Eligibility Criteria and Selection Process for Study Inclusion

Every study was thoroughly assessed for its relevance and congruence with the review's goals to establish its eligibility for inclusion in our systematic review on evaluating wireless network technologies (3G, 4G, and 5G) and their infrastructure. All study attributes, including intervention kinds and results, were carefully evaluated and contrasted with our pre-established synthesis groups. To guarantee a thorough and impartial assessment, a pattern was developed to visually com-pare the research' methods and scope with our inclusion requirements. Through this method, the review's overall consistency and dependability were improved because only papers that were directly relevant to the review issue were included [133] – [140].

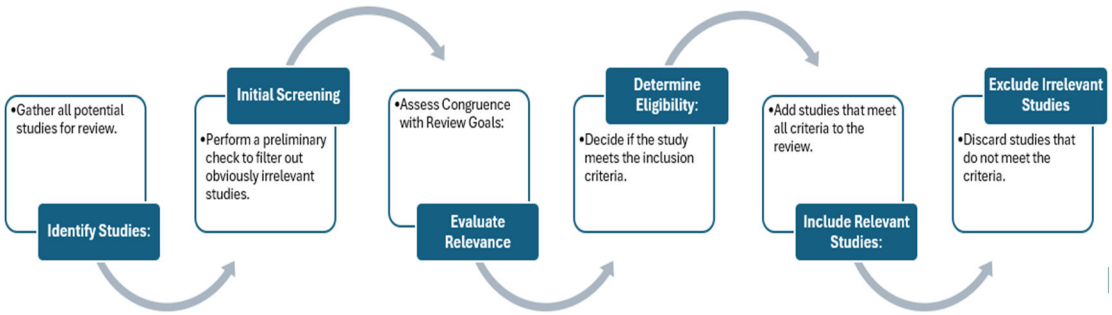

Figure 5. Data Eligibility Criteria and Selection Process.

2.9.2. Data Preparation Methods for Presentation and Synthesis

There are various important techniques involved in preparing data for presentation and synthesis while analysing wireless network technologies (3G, 4G, and 5G) and their infrastructure. It is imperative to handle missing data, which is typically accomplished by imputation, sensitivity analysis, or the elimination of incomplete datasets. Consistency is ensured through data conversion; for example, scales and unit standards are adjusted. Accuracy is ensured by addressing mistakes and outliers through data cleaning. By using statistical metrics and tabulation, aggregation and summarization offer a concise summary. Like z-scores or standardization, normalization guarantees study comparability. Data trans-formation which includes logarithmic modifications assists in highlighting trends and controlling skewness. Together, these techniques guarantee a solid and insightful synthesis of the data [133] – [140].

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Figure 6. Data Preparation Methods for Presentation and Synthesis Flowchart.

2.9.3. Methods for Tabulating and Visually Displaying Study Results

To improve clarity and make comparison easier, the results of both individual investigations and synthesis efforts were arranged using tabular and graphical methods. The data were presented in a structured fashion using tabular structures. Outcomes were arranged according to domain, and studies were ranked from lowest to highest risk of bias within each domain. This arrangement made it simple to compare results between studies and emphasized the strongest sup-porting data. Furthermore, the main instrument for graphically portraying the results of the synthesis analysis was the use of graphical approaches, most especially forest plots. Each study's effect estimates, confidence intervals, and summary estimate were displayed in these maps. The studies in the forest plots were arranged according to the year of publication, which made it easier to see patterns over time and between various study areas [133] – [140].

Table 8. Methods for Tabulating and Visually Displaying Study Results.

Method	Description
Tabular Presentation	Organizes data into rows and columns, allowing for structured comparison of results. Outcomes can be ranked by risk of bias or effect estimates.
Risk of Bias Table	Categorizes studies by the level of bias (low, moderate, high) based on methodological quality, making it easier to identify reliable results.
Forest Plot	Graphically displays effect estimates and confidence intervals for each study, allowing comparison of results and trends over time.
Summary Table	Provides an overview of key outcomes, grouping them by domains such as technology type or study focus.
Graphs	Visually represents categorical data such as the number of studies per risk of bias category or domain, making trends more visible.

2.9.4. Methods for Synthesizing Results

During our search through internet databases like Google Scholar, Scopus, and Web of Science, we thoroughly examined and summarized the findings of pertinent research. The nature of the data and the level of heterogeneity seen among research served as the basis for the data synthesis methodology [133] – [140].

Depending on the degree of heterogeneity among study results, we manually evaluated the applicability of both fixed-effects and random-effects models based on the results of our search. The features of the data and our presumptions regarding the consistency of effects across studies guided the choice of the model. We produced charts to visually examine the data after exporting it to Excel, which helped us spot trends in variability and possible heterogeneity among the studies. This preliminary visual examination allowed for a more in-depth investigation by giving an overview of the differences between the study outcomes.

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Figure 7. Methods for Synthesizing Results and Their Rationale Cycle.

2.9.5. Methods for Investigating Heterogeneity in Study Results.

Potential sources of heterogeneity in wireless network technologies and associated infrastructure were examined using subgroup analysis. These evaluations considered several elements, including variations in deployment scenarios, wireless technology types (3G, 4G, and 5G), and performance measures. The effectiveness of network performance and infrastructure enhancements was evaluated by examining specific assessments that focused on factors such the geographic location, the type of wireless technology employed, and the scope of network deployment. These techniques made it easier to see the underlying trends and connections that added to the overall variability found in all the investigations [133] – [140].

Table 9. Methods for Investigating Heterogeneity in Study Results.

Method	Description
Subgroup Analysis	Examines differences across predefined groups (e.g., 3G, 4G, 5G) based on deployment scenarios, geographic location, or other factors.
Performance Measure Comparison	Evaluates network performance (speed, latency, etc.) across different technologies and infrastructures to identify variations.
Geographic Analysis	Investigates how network deployment in different regions or countries contributes to variability in results.
Technology Type Comparison	Compares the outcomes of studies based on the type of wireless technology (3G, 4G, 5G) used, highlighting potential sources of inconsistency.

2.9.6. Sensitivity Analyses to Assess Robustness of Synthesized Results

Sensitivity analyses were conducted to assess the robustness of results when aggregating wireless network technologies (3G, 4G and 5) as well infrastructure. This process mainly involved sensitively excluding different studies from the analysis in order to evaluate their impact on the primary results. For example, studies with high risk of bias or those using very different methods were withdrawn after the primary analysis to assess whether their exclusion changed the results. Weights for the studies were applied, taking into account quality and relevance so that no single study would unduly bias the results. These analyses also provided some evidence for the reliability

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and generalizability of the synthesized results, lending credibility that the resultant conclusions were not highly sensitive to individual studies or underlying assumptions.

2.10. Reporting Bais Assessment

Reporting biases can have a substantial impact on the evaluation of wireless network technologies such as 3G, 4G, and 5G. These biases arise when certain outcomes are more likely to be published or reported than others, thus distorting the overall findings, hence, to thoroughly assess the reporting bias we will look at its components below, which includes the following biases, availability bias, language bias, publication bias, citation bias, duplication bias and selective reporting all contributing to the reporting bias as shown in Figure 4 [133] – [140].

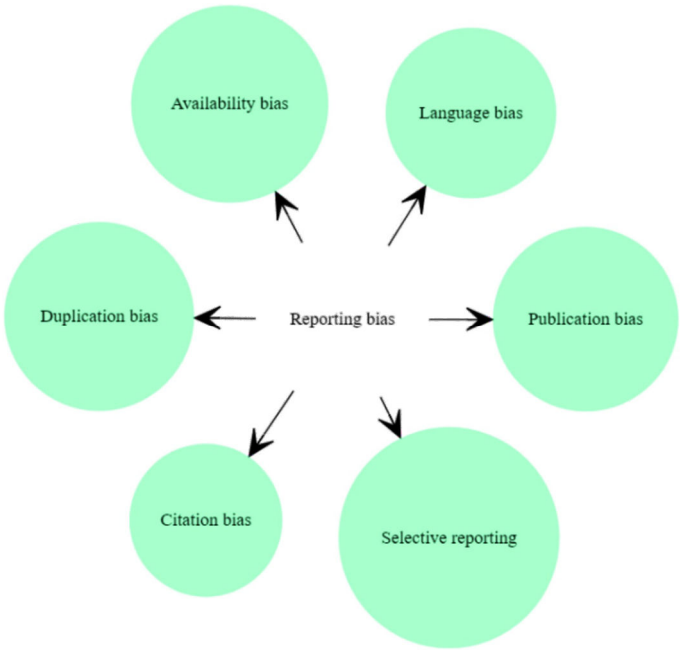

Figure 8. Types of Reporting Bias.

2.11. Certainty Assessmnent

Certainty assessment, also known as confidence assessment, is an important step in determining the dependability of results from a body of information. When comparing wireless network technologies—specifically 3G, 4G, and 5G—it is critical to examine the certainty of outcomes such as data transmission speed, latency, and energy efficiency before reaching reliable and practical conclusions. Using the Quality Assessment (QA) we will hence be able to thoroughly examine the quality of the papers using a set of criteria to give decisions about the analysis and findings in the studies. A total of five quality assessment criteria, along with the topics of the review, are shown in Table 10.

Table 10. Certainty assessment table.

No. of Quality Assessments	Assessment Questions
Quality Assessment 1	Are the topics discussed in the paper related to key/ main themes?
Quality Assessment 2	Is it clear in what context the research was conducted?
Quality Assessment 3	Is the research methodology sufficiently explained?
Quality Assessment 4	Is the process and methodology for data collection described in sufficient detail in the paper?

According to the five quality assessment criteria for the 121 articles; Therefore, the quality of each article can be considered through a resulting load score. Results were divided into three ranks:

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1. If a study meets the quality criteria, then it is given a score of 2.
2. If a study partially fulfils the quality criteria, it is given 1 for that criterion.
3. If a study does not meet the quality criteria, 0 is given for that criterion.

Therefore, concerning the five quality criteria, the highest score assigned to an article is 10 (or 5 x 2), while the lowest score is 0 (or 5 x 0). In this review, each paper's quality is considered high if the value is more than or equal to 6. Papers with a score of 5 are considered medium quality, and papers with less than 5 are considered low quality.

Certainty assessment is an important step in ensuring that the findings from the systematic evaluation of wireless network technologies are both trustworthy and actionable.

3. Results

3.1. Study Selection

Figure 9 illustrates a PRISMA flow diagram that shows the study selection process for this systematic review. Research papers were collected from online databases using keywords to search for relevant papers. The selection of these research papers was carried out after following the inclusion and exclusion criterion as gave in the previous section. All relevant research papers from records were identified using a search term and various combinations of keywords to systematically investigate, which returned around 1892 publications across searched datasets of research. According to Figure 9 the accumulated research papers contained 121 research papers in total: Research papers of apparent duplicate research studies were excluded. Thus finally 121 were included in the entire systematic review process be full text assessed and loaded.

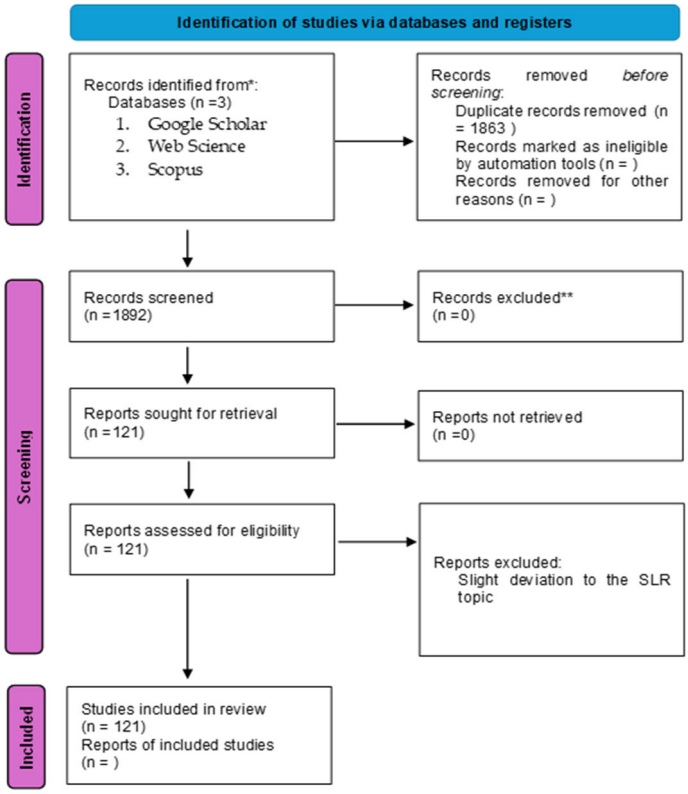

Figure 9. Proposed PRISMA checklist.

3.2. Study Characteristics

An overview of several studies on wireless technologies and related infrastructures is given in Table 11. These studies concentrate on comprehending the adoption and use of wireless systems, as well as the contribution of wireless technologies to improving competitive advantage and decision-making. Case studies, surveys, simulations, and literature reviews are examples of frequently utilized

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methodologies. Important results demonstrate how wireless technologies greatly enhance financial performance, strategic decision-making, and operational efficiency. Several studies have highlighted several challenges, including as high costs, complex systems, and social impact. Suggestions frequently emphasize security enhancements, standardization efforts, and ongoing testing and optimization. Together, these findings should help firms better leverage wireless technologies to increase productivity and competitiveness.

Table 11. Comprehensive Overview of Wireless network technologies (3G,4G,5G) and their infrastructure.

Ref	Year	Research Focus	Methodology	Key Outcomes	Challenges identified	Recommendations
[18]	2015	Coordination of unmanned aerial vehicle (UAV) swarms using mobile network technologies	Literature Review, Simulation Models	Network Performance, Scalability, Energy Efficiency	Network Coverage, Interference and Congestion, Security Concerns	Infrastructure Investment, Advanced Algorithms.
[19]	2014	Compare the performance, capabilities, and limitations of 3G, 4G, and 5G wireless technologies.	Literature Review, Performance Metrics, Data Analysis	Speed and Latency, Coverage, User Experience.	Infrastructure Costs, Regulatory Issues, Compatibility.	Strategic Investment, Hybrid Networks, Sustainable Practices.
[20]	2017	comprehensive review of the evolution, performance, and impact of 3G, 4G, and 5G mobile technologies.	Case Studies, Expert Interviews.	Speed and Latency, Energy Efficiency.	Infrastructure Costs, Compatibility	Strategic Investment, Hybrid Networks
[21]	2016	Explore the architectural evolution of mobile networks from earlier generations (3G and 4G) to 5G.	Comparative Analysis, Expert Interviews.	Network Architecture, Scalability	Interoperability, Regulatory and Spectrum Issues	Strategic Investment, Hybrid Network Solutions, Security Measures.
[22]	2015	Explore the architecture of 5G networks and the emerging technologies that support and	Massive Multiple Input Multiple Output (MIMO) Technology, Software Defined Networks (SDN).	Proposed 5G Architecture, Technological Advancements, Global Research Initiatives.	Interference Management, Spectrum Allocation, Infrastructure Costs.	Investment in Research and Development, Collaborative Efforts, Cost-Efficient Deployment.

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[23]	2014	enhance this architecture. Evaluating the energy efficiency advantages of implementing the Radio Access Network-as-a-Service (RANaaS) model within a cloud-based 5G infrastructure	System-Level Power Modeling, Simulation and Evaluation.	Energy Efficiency Gains, Cost Reduction, Enhanced Network Performance.	High Initial Investment, Interoperability Issues.	Incremental Deployment, Standardization Efforts, Advanced Security Protocols.
[24]	2014	Explore the design principles, components, and technologies that constitute the 5G mobile network architecture.	Case Studies, Simulation and Modeling.	Network Slicing, Service-Based Architecture (SBA).	Complexity in Integration, High Deployment Costs.	Standardization and Collaboration, Incremental Deployment:
[25]	2017	Evaluate the performance of 5G millimeter-wave (mmWave) cellular access networks.	Capacity-Based Network Deployment Tool, Simulation Scenarios	Increased Capacity, Energy Efficiency, Base Station Density.	High Deployment Costs, Interference Management.	Incremental Deployment, Advanced Interference Mitigation.
[26]	2015	Explore the integration of Wireless Software-Defined Networks (W-SDNs) and Network Function Virtualization (NFV) within 5G cellular systems.	Literature Review, Comparative Analysis.	Enhanced Flexibility and Scalability, Cost Efficiency.	Interoperability Issues, Security Concerns.	Standardization Efforts, Advanced Security Measures.
[27]	2018	Developing an optimized handover signaling mechanism within evolutionary 4G/5G	Proposed Mechanism, Analytical Framework.	Performance Gains, Handover Efficiency,	Complexity of Implementation, Interoperability Issues, Real-Time Adaptation.	Incremental Deployment, Standardization Efforts, Real-Time Monitoring.

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[28]	2021	network architectures Aims to investigate and compare the technological advancements, performance metrics, and architectural differences between 4G and 5G networks.	Technical Analysis, Performance Evaluation, Case Studies.	Enhanced Performance, Advanced Architecture, Energy Efficiency.	Infrastructure Costs, Interoperability, Spectrum Availability.	Phased Deployment, Standardization Efforts.
[29]	2014	Explore the cellular architecture and key technologies that underpin 5G wireless communication networks.	Case Studies, Comparative Study.	Enhanced Network Performance, Advanced Technologies.	High Deployment Costs, Interoperability Issues.	Phased Deployment, Standardization Efforts.
[30]	2021	Trace the evolution of cellular networks from 1G to 5G	Historical Analysis, Technical Review, Performance Evaluation	1G to 2G Transition, 2G to 3G Transition, 3G to 4G Transition, 4G to 5G Transition	Infrastructure Costs, Spectrum Management, Interoperability	Policy and Regulation, Standardization Efforts.
[31]	2019	Identify the optimal 5G network architecture by comparing the standalone (SA) and non-standalone (NSA) deployment options.	Technical Analysis, Performance Evaluation, Cost Analysis.	Performance, Cost Efficiency,	High Initial Investment, Interoperability, Security Concerns.	Phased Deployment, Standardization Efforts, Spectrum Management.
[32]	2020	Compare 4G and 5G wireless network technologies, focusing on their performance, architecture, energy efficiency, and practical implementation.	Architectural Comparison, Energy Efficiency Assessment, Performance Analysis.	Performance Improvements, Architectural Advancements	Interoperability, Spectrum Availability.	Investment in Infrastructure, Spectrum Management.

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[33]	2015	Developing and evaluating SoftNet, a software-defined decentralized mobile network architecture designed to address the limitations of current LTE networks and meet the demands of 5G.	Literature Review, Case Studies.	Improved System Capacity, Reduced Signaling Cost.	Resource Management, Interoperability Issues.	Incremental Deployment, Standardization Efforts, Training and Education.
[34]	2022	Survey the techno-economic research conducted on 5G technologies to inform the evaluation and development of 6G wireless technologies.	Data Collection, Expert Interviews, Economic Modeling.	Economic Viability, Deployment Strategies, Performance Metrics.	High Deployment Costs, Regulatory Hurdles, Technological Integration.	Innovation and Research, Public-Private Partnerships.
[35]	2019	Assess the capacity, coverage, and cost of various 5G infrastructure strategies in the Netherlands.	Supply-Driven Analysis, Demand-Driven Analysis, Case study.	Capacity Improvement, Economic Viability.	High Initial Costs, Regulatory Hurdles	Efficient Spectrum Management, Innovation and Research.
[36]	2015	Developing a cloud-based wireless network architecture that is virtualized, reconfigurable, and smart, aimed at enabling and enhancing 5G technologies.	Architecture Design, Case Studies.	Enhanced Flexibility and Scalability, Improved Performance, Support for Advanced Applications.	Interoperability Issues, Resource Management.	Incremental Deployment, Enhanced Security Measures.
[37]	2015	Implementation and benefits of wireless network	Model Development, Case Studies.	Improved Resource Efficiency, Scalability.	Complexity in Implementation, Interoperability	Continuous Testing and Optimization, Standardization

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		virtualization in 5G networks.			Issues, Security Concerns.	Efforts, Security Enhancements.
[38]	2017	Design a 5G mobile network architecture tailored to support various vertical industries.	Literature Review, Architecture Design.	Enhanced Service Provisioning, Scalability and Flexibility, Improved Network Management.	Complexity in Network Slicing, Interoperability Issues, Security Concerns.	Advanced Management Tools, Standardization Efforts, Continuous Innovation.
[39]	2020	Practical measurement of Key Performance Indicators (KPIs) in a 5G non-standalone (NSA) architecture.	KPI Measurement, Literature Review.	Performance Improvement, Latency and Jitter Stability, Validation of 5G Promises.	Complexity in Configuration, Device Compatibility, Incomplete Standards Implementation.	Enhanced Configuration Tools, Device Testing and Certification, Standardization and Implementation.
[40]	2015	Investigates key techniques for 5G wireless communications, focusing on network architecture, physical layer, and Medium Access Control (MAC) layer perspectives.	Model Development, Data Analysis.	Enhanced Network Capacity, Improved Data Rates:	Interference Management, Energy Efficiency.	Advanced Algorithm Development, Interference Mitigation Strategies.
[41]	2017	Develop a data-driven architecture for personalized Quality of Experience (QoE) management in 5G wireless networks.	Data Analysis, Literature Review, Architecture Design.	Enhanced QoE, Precise Resource Allocation, Dynamic Adaptation.	Scalability Issues, Complexity in User Modeling.	Advanced Algorithm Development, Privacy Protection Measures, Continuous Monitoring and Optimization.
[42]	2019	Evaluating various Radio Access Network (RAN) architectures that are pivotal for the development and deployment of 5G	Operational expenditure, Resource allocation, Network performance.	Cloud-RAN, Heterogeneous Cloud-RAN, Virtualized Cloud-RAN.	Latency, Energy Efficiency, Resource Allocation.	Hybrid Architectures, Advanced Technologies, Standardization.

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		mobile communication systems				
[43]	2021	Explore the evolution and advancements in mobile communication technologies from 4G to future generations like 5G, 6G, and 7G.	Technological advancements, Performance metrics, Applications.	Unprecedented connectivity and support for futuristic applications.	Spectrum Scarcity, Interoperability.	Efficient Spectrum Management, Energy-Efficient Technologies, Robust Security Frameworks.
[44]	2021	Design and implementation of a 5G-network-enabled smart ambulance system	System Design, Scenario Analysis,	Enhanced Communication, Improved Patient Care, Operational Efficiency.	Operational Efficiency, Data Security, Interoperability, Cost.	Infrastructure Development, Security Protocols, Cost Management
[45]	2015	Concept of a super base station (super BS) as a centralized network architecture for 5G mobile communication systems.	System Design, Comparative Analysis	Energy Efficiency, Improved Resource Utilization	Scalability, Interoperability, Security.	Advanced Resource Management, Robust Security Measures.
[46]	2016	Implementation of handover mechanisms in a 5G mobile network architecture that leverages Software Defined Networking (SDN) and Network Functions Virtualization (NFV)	System Design, Simulation and Testing.	Reduced Latency, Scalability, Efficient Resource Utilization.	Interoperability, Complexity of Implementation.	Incremental Deployment, Standardization.
[50]	2015	Compare 4G and 5G wireless technologies,	Data Collection, Comparative	Performance Improvements, Enhanced	Infrastructure Costs, Spectrum Availability,	Investment in Infrastructure, Spectrum

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		focusing on their performance, infrastructure requirements, and potential applications	Analysis, Case Studies.	Connectivity, Network Slicing.	Interference and Coverage.	Management, Research and Development.
[60]	2017	Network slicing in 5G mobile communication, focusing on its architecture, profit modeling, and associated challenges	Expert Interviews, Comparative Analysis.	Improved Quality of Service (QoS), New Revenue Streams.	Regulatory and Standardization, Complexity in Implementation.	Investment in R&D, Pilot Projects.
[61]	2015	Coordination of movement within swarms of Unmanned Aerial Vehicles (UAVs) using mobile networks	Field Experiments, Data Analysis, Algorithm Development.	Effective Coordination, Performance Metrics, Application Scenarios.	Network Latency, Bandwidth Limitations, Interference and Coverage.	Algorithm Optimization, Network Infrastructure, Security Protocols.
[62]	2015	Analyze the transition from rigid hierarchical to flexible flow-based 5G architecture, focusing on dimensioning issues.	Literature Review, Data Collection, Comparative Analysis.	Improved Flexibility, Enhanced Performance, Efficient Resource Utilization.	Standardization and Regulation	Training and Education.
[63]	2015	Develop and evaluate a fully distributed mobility management (DMM) scheme for future heterogeneous wireless networks.	Simulation and Testing, Field Experiments.	Seamless Mobility.	Complexity in Implementation	Implementation of pilot projects to test and validate DMM solutions
[64]	2015	Evaluate the performance of the Transmission	Experimental Setup, Simulation.	Performance Metrics, Simulation Validation.	High Bit Error Rate, Mobility and	Enhanced TCP Variants, Cross-Layer Optimization.

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		Control Protocol (TCP) in wireless broadband environments.			Dynamic Topology, Congestion Control.	
[65]	2015	Evolution of wireless LANs (Local Area Networks) to support mobility in hotspot environments.	Proposed a cellular network architecture, Implemented the proposed network.	Handover Efficiency, Performance Metrics.	Protocol Adaptation, Resource Management, Scalability.	Protocol Optimization, Advanced Resource Management.
[66]	2014	Electromagnetic compatibility (EMC) challenges in indoor wireless communications.	Literature Review, Experimental Setup, Simulation.	Interference Patterns, Mitigation Strategies.	Complex Indoor Environments, Device Proliferation, Regulatory Constraints.	Advanced EMI Mitigation Techniques, Ongoing Research and Development.

3.3. Risk of bias in studies

Table 12 displays the methodical assessment of bias risk for every included study using the Newcastle-Ottawa Scale (NOS). Based on the number of stars given in each of the three primary domains—Selection, Comparability, and Outcome/Exposure—the quality rating table groups research. Research with seven to nine stars were classified as high quality, whereas studies with four to six stars were classified as moderate quality. In our review, no study received a low-quality rating (0–3 stars). The comprehensive evaluation of every study is shown in Table 12, where the majority of the studies receive high-quality ratings. For example, Study 5 was rated as intermediate quality with 6 stars, whereas Study 1 obtained 8 stars, indicating a high degree of quality in all domains. The chart provides openness on potential biases by clearly outlining the domains where research was strong or poor. By ensuring that only papers with sound techniques were included in our evaluation, this risk of bias assessment increased confidence in the study's overall conclusions. Additional steps were taken to confirm the study's validity through external cross-referencing in cases where proprietary tools or insufficient data generated uncertainties, ensuring that our judgments remained impartial and correct.

Table 12. Risk of Bias assessment table.

Study ID	**Selection (0-4 stars)**	**Comparability (0-2 stars)**	**Outcome/Exposure (0-3)**	**Total stars**
[27,33,36,43]	★★	★	★	4
[2,3,6,8,12,15,17–19,23,45,47,54,57,60,66,70,71,85,88,94,99,101,106,110,112]	★★	★	★★	5
[1,5,7,9,13,21,28,29,31,32,37,39,44,50,56,61,65,67,72,74,78,80,84,92,93,97,103,108,115,116]	★★★	★	★★	6

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[14,16,20,22,24,25,34,38,40,41,49,52,53,58]	★★★	★★	★★	7
[[9,62,63,68,73,76,83,90,95,98,100,102,107,109,113,118]	★★★	★★	★★★	8
[4,10,11,26,30,35,42,46,48,51,55,64,69,75,77,79,81,82,86,87,89,91,96,104,105,111,114 ,117,119–121]	★★★★	★★	★★★	9

3.4. Results of individual studies

Figure 10 shows the different types of wireless network technologies across many research papers, showing various wireless networks that are studied and/or compared. The most prominent topic is wireless network with 42% is the 5G wireless network, followed by 3G, 4G, and 5G with 9%. LTE and 3G are mentioned and compared in 6% of the research collected, as well as 6% that mainly discusses 3G as a wireless network. This highlights the variety of network technologies with 5G and 3G wireless network technologies as the most mentioned in research.

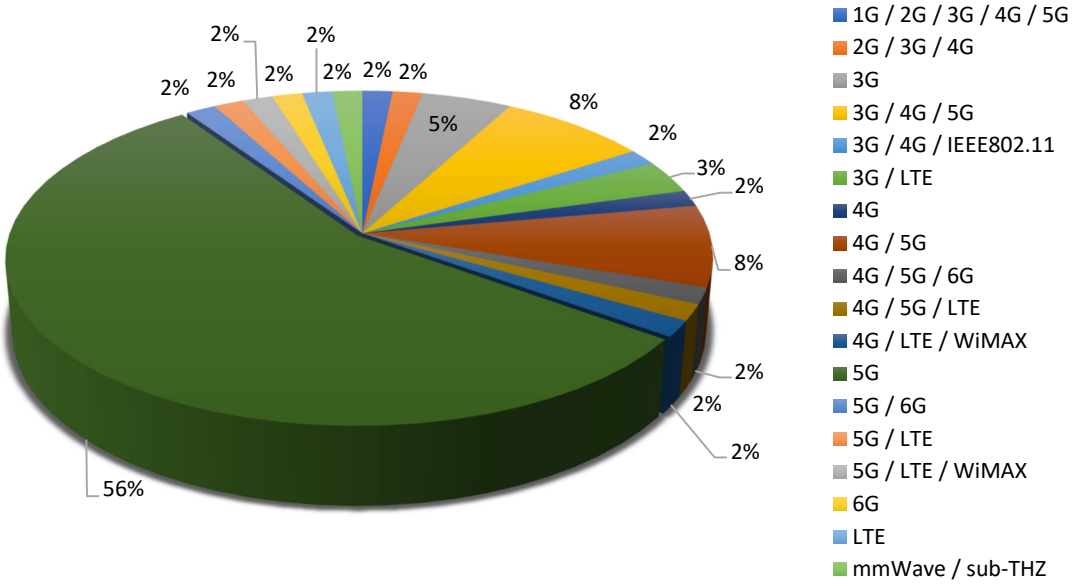

Figure 10. Types of wireless network technologies.

In Figure 11 is a pie chart that illustrates the technology providers from each research study represented in percentages. Huawei, with 3%, is the leading technology provider according to the research papers. The second leading technology providers, with 2% of the pie chart is Ericsson, Ericsson and Siemens, and IBM, Intel, Huawei, ZTE, Ericsson, NEC, Alcatel, and Nokia. The chart shows the activeness of Huawei as providers and the significant lack of technology providers in a majority of studies leading by an 89%.

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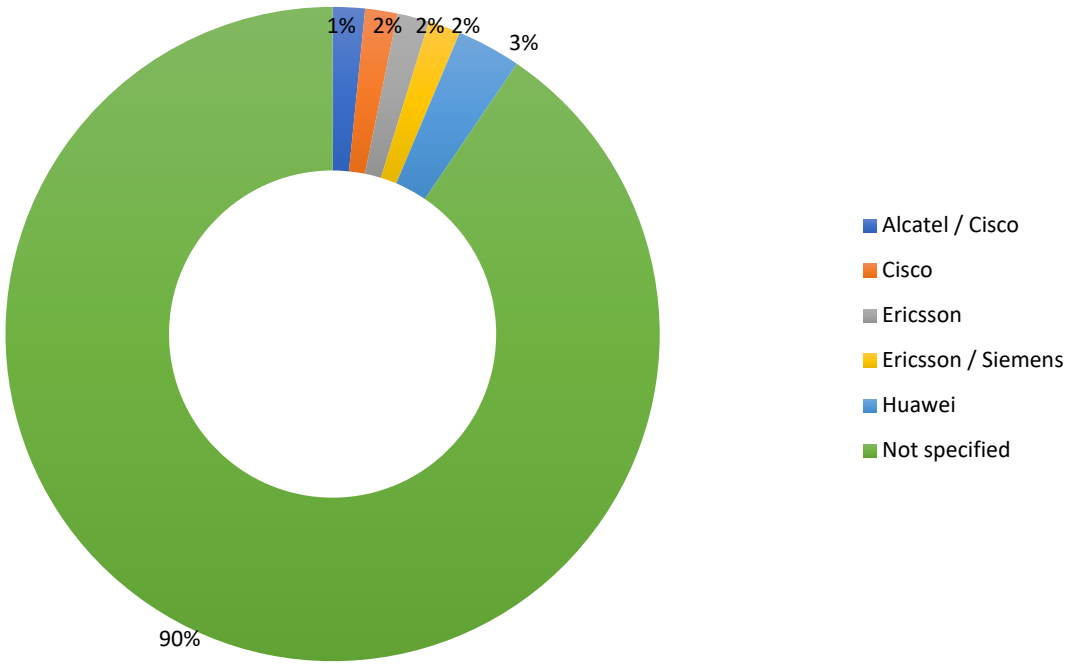

Figure 11. Technology providers.

3.5. Results of syntheses

This section describes the approach of evaluating the characteristics and risk of bias among the research topics that were gathered. The results of the statistical syntheses which includes a summary estimate and its precision, and measures of statistical heterogeneity, highlighting the interest of wireless networks and their infrastructure. With regards to addressing the sensitivity analysis to highlight the common method of hybrid technology implantation model.

3.5.1. Results of Statistical Syntheses

Figure 12 illustrates a breakdown of analysis methods used in the research papers. Statistical analysis has a percentage of the methods used, for studies leaning more quantitative type of study. Thematic holds a which involves more of qualitative analysis. The pie chart shows the study's balanced approach by using quantitative and qualitative methods for an easy-to-understand perspective of research findings.

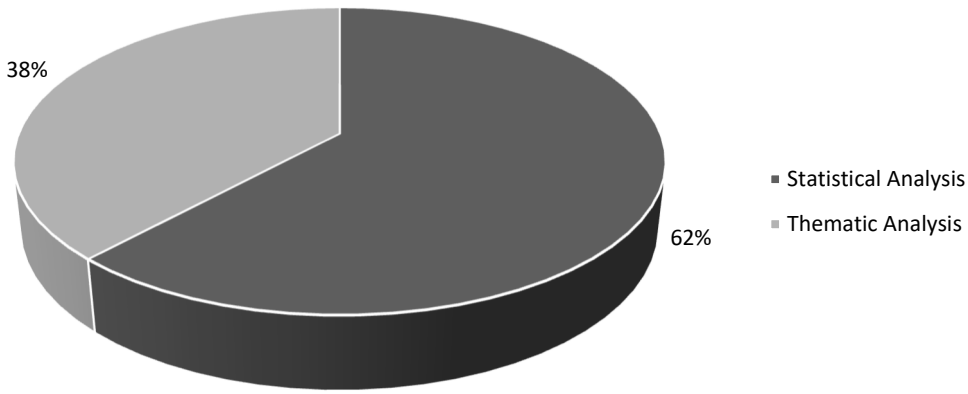

Figure 12. Analysis Breakdown Method.

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3.5.2. Sensitivity Analysis

Sensitivity analyses are used for the robustness and reliability of data-driven models in many fields. They determine the effect in the change of input variables and the outcomes of a model, to ensure that the insights derived are reliable and meaningful under different settings. The hybrid model is used in a large majority of the studies collected, holding a 60%. While the used model is on-premises. A hybrid model allows for flexibility and cost-effectiveness being compatible for requirements based on wireless networks. Hybrid not only provides real-time data access, but as well as direct, secure, and controlled access to locally stored data.

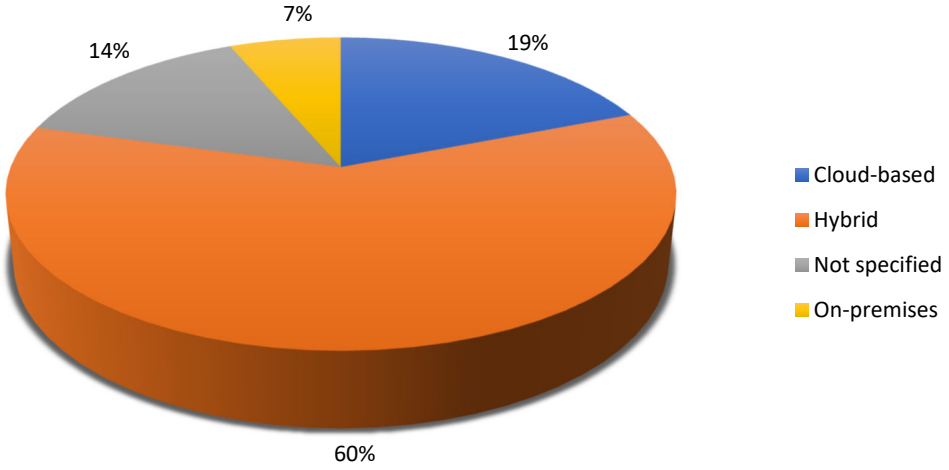

Figure 13. Technology Implementation Model.

3.5.3. Investigation of Heterogeneity

Figure 14 shows how developed countries conducted studies more. Evaluating the benefits of wireless networks may be used as a driving force towards obtaining a competitive advantage and improve operational efficiency for their infrastructure. Developing countries with less percent leaning more on filling in gaps and advancing technologies through integration. The variation underscores the heterogeneity in wireless network technologies driven by advancements and struggles in different economic contexts.

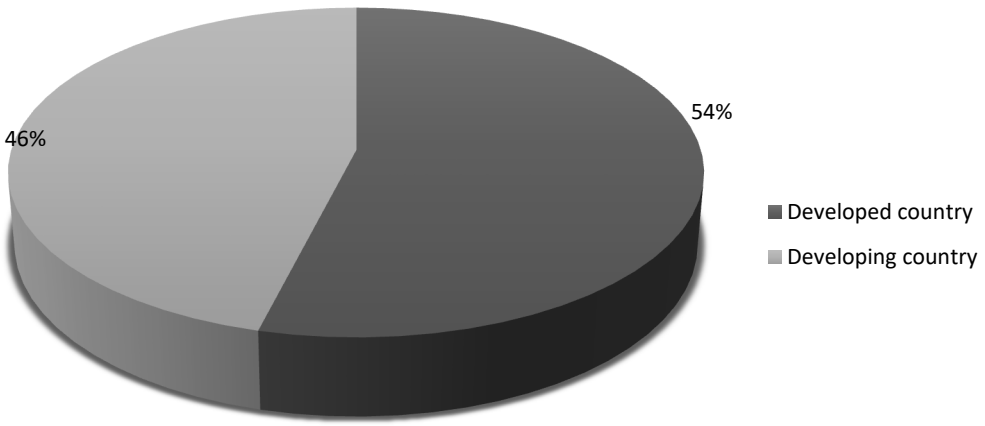

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Figure 14. Economic Context.

3.6. Reporting Biases

In the identification of report biases, using our search strategy we conducted an extensive search of academic databases, including Google Scholar, Web of Science and, to collect studies on 3G, 4G, and 5G technologies. We used the following key words for our research strategy ("wireless network" OR "cellular network" OR "mobile network") AND ("3G" OR "4G" OR "5G") AND ("evaluation" OR "comparison" OR "assessment") AND ("infrastructure" OR "architecture" OR "deployment") to help us in identify most of the articles related to our topic. Despite this comprehensive approach, some recent or less prominent studies may not be included, hence potentially introducing reporting bias. The following is the appropriate reporting bias for the above systematic review.

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Table 13. Reporting biasing.

Study Reference	Selection Bias	Publication Bias	Citation Bias	Duplicate bias	Outcome reporting Bias	Time lag bias
[2,3,6,8,12,15,17–19,23,45,47,54,57,60,66]	**Medium**	**Medium** (The review may Favor studies with positive outcomes regarding optimization techniques, leading to an overrepresentation of successful strategies)	**Low** (The article cites a diverse range of sources, minimizing potential bias)	**Low**	**Medium** There is a risk of selective reporting if only successful optimization outcomes are highlighted.	**Medium** There may be delays in publishing findings, affecting the relevance of the results.
[78,80,84,92,93,97,103,108,115,116]	**Low**	**Medium** Positive results may be more likely to be published, potentially skewing the understanding of effectiveness.	**Low** The article cites relevant studies but may overlook some critical	**Medium**	**Medium** If only favorable outcomes are reported, this could mislead readers about the effectiveness of the proposed solutions.	**Low** The publication timeline aligns with current research trends
[70,71,85,88,94,99,101,106,110,112]	**Low**	**Medium** Studies with negative results may be underreported, leading to biased conclusions about the technology's effectiveness	**Low** The article references a balanced selection of studies.	**Low**	**Low** The outcomes reported appear comprehensive, but further validation is needed to ensure all relevant findings are included.	**Low** The publication is timely and reflects current advancements in the field.
[39,44,50,56,61,65,67,72]	**Medium**	**High** Positive results may be favored in publication, leading to an incomplete understanding of the technology's effectiveness	**Low** The article cites a variety of sources, but may favour certain studies.	**Medium**	**Medium** There is a risk of selective reporting if only successful outcomes are highlighted.	**Medium** The publication may lag behind current advancements in technology.

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[14,16,20,22,24,25,34,38,40,41,49,52,53,58]	**Medium**	**High** There may be a tendency to publish only studies with significant findings, neglecting those with less impactful results.	**High** The article may cite influential studies while neglecting others.	**Low**	**Medium** If only successful outcomes are reported, this could misrepresent the overall effectiveness of the strategies discussed.	**Medium** Delays in publication could affect the relevance of the findings
[1,5,7,9,13,21,28,29,31,32,37,38]	**Medium**	**Medium** There may be a bias towards publishing studies with significant findings, potentially skewing the literature.	**High** The article may be cited frequently in contexts that favor its findings.	**Low**	**Low** The outcomes reported appear comprehensive, but further validation is needed to ensure all relevant findings are included.	**Medium** The publication timeline may not reflect the latest advancements in the field.
[59,62,63,68,73,76,83,90,95,98]	**Medium**	**Low** Studies with negative results may be less likely to be published, leading to an overrepresentation of positive findings.	**Medium** The article may cite influential studies while neglecting others.	**Low**	**Medium** If only successful outcomes are reported, this could mislead readers about the effectiveness of the proposed solutions	**Medium** The publication may lag behind current advancements in technology.

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Assessing these biases is critical to ensuring that findings about these technologies' performance, efficiency, and infrastructure are correct and consistent with all available evidence. This facilitates informed decision-making and the development of technologies that actually match the requirements and expectations of users.

3.7. Certainty of Evidence

Quality Assessment Score Results

In the quality assessment stage, the method shows 121 papers given a score/rating that considers each question's criteria from QA1 - QA5 on Table 14. This presents each selected study's quality assessment scores.

Table 14. Certainty of evidence.

Paper ID	QA1	QA2	QA3	QA4	QA5	Total	%
[27,33,36,43]	1	1	1	0	0	3	30
[2,3,6,8,12,15,17–19,23,45,47,54,57,60,66,70,71,85,88,94,99,101,106,110,112]	2	1	1	0	1	5	50
[1,5,7,9,13,21,28,29,31,32,37,39,44,50,56,61,65,67,72,74,78,80,84,92,93,97,103,108,115,116]	3	1	1	1	1	6	60
[14,16,20,22,24,25,34,38,40,41,49,52,53,58]	2	1	2	1	1	7	70
[9,62,63,68,73,76,83,90,95,98,100,102,107,109,113,118]	3	2	1	2	0	8	80
[4,10,11,26,30,35,42,46,48,51,55,64,69,75,77,79,81,82,86,87,89,91,96,104,105,111,114,117,119–121]	3	2	2	1	1	9	90

4. Key Findings and Strategic Implications for Business Leaders

Table 15 provides a comprehensive breakdown of the key findings and strategic implications of 5G technology adoption, categorized by some of the world's largest telecom companies. The table highlights the critical metrics, such as network coverage, data throughput, latency, energy efficiency, spectrum utilization, network densification, and security. It shows how these leading telecom companies are addressing challenges related to infrastructure expansion, network stability, and advanced technological applications. By categorizing findings in this manner, businesses and industry leaders can better understand how these companies are optimizing 5G deployment and the unique strategies they employ to leverage the technology's full potential.

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Table 15. Key Findings and Strategic Implications for Business Leaders.

Category	Subcategory	Sub-subcategory	Findings	Strategic Implications for Business	Leading Telecom Companies
1. Network Coverage	1.1 Coverage Area	1.1.1 Urban vs. Rural Coverage	- 5G provides wider coverage than 4G and 3G, especially in urban areas. - Rural and underserved areas still face gaps in coverage due to high infrastructure costs.	- Invest in targeted infrastructure expansion in rural areas. - Partner with government for rural 5G rollouts to reduce costs.	**Verizon, China Mobile, AT&T**
		1.1.2 Base Station Requirements	- 5G requires a higher density of base stations to achieve full coverage, particularly in high-demand areas.	- Plan for increased investment in base station deployment. - Explore public-private partnerships to spread infrastructure costs.	**Vodafone, China Telecom, Deutsche Telekom**
	1.2 Network Stability	1.2.1 Weather and Environmental Impacts	- Weather and environmental factors (e.g., buildings, trees) can negatively impact 5G performance in certain regions.	- Develop strategies to deploy additional base stations in areas prone to environmental disruptions. - Invest in robust hardware.	**SK Telecom, Nippon Telegraph & Telephone (NTT)**
		1.2.2 Roaming and Handover	- Seamless handover between 4G and 5G networks is essential for consistent coverage during transitions between network types.	- Invest in network systems that enable smooth 4G/5G transitions for users to prevent service disruption.	**Telefonica, Orange**
2. Data Throughput	2.1 Bandwidth and Speed	2.1.1 Download and Upload Speeds	- 5G offers significantly higher data throughput than 4G and 3G, supporting faster download and upload speeds.	- Use higher data speeds to offer enhanced user experiences, especially for data-heavy applications like streaming and cloud services.	**Verizon, AT&T, China Mobile**
		2.1.2 Capacity for High-Volume Data	- 5G networks support large volumes of simultaneous data traffic, essential for IoT and real-time applications.	- Leverage 5G capacity to expand IoT deployments in industries like manufacturing, healthcare, and smart cities.	**Vodafone, NTT Docomo, KT Corporation**
	2.2 Application Support	2.2.1 Advanced Applications	- Supports advanced applications such as AR, VR, AI, and autonomous systems that require high data throughput.	- Explore new business opportunities in entertainment, industrial automation, and remote services with 5G's higher data capacity.	**AT&T, SoftBank, SK Telecom**
		2.2.2 Cloud and Edge Computing	- 5G enhances cloud and edge computing capabilities, allowing faster access to cloud resources.	- Invest in edge computing infrastructure to offer faster, more reliable services to customers and improve operational efficiency.	**Verizon, T-Mobile, China Telecom**
3. Latency	3.1 Reduced Delay	3.1.1 Real-Time Applications	- 5G drastically reduces latency, allowing real-time applications like autonomous vehicles and remote surgery.	- Develop and commercialize real-time services (e.g., telemedicine, autonomous transport) to take advantage of 5G's low latency.	**NTT Docomo, Verizon, Deutsche Telekom**

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		3.1.2 Industrial Automation	- Enables precise control and real-time feedback in industrial processes, boosting productivity and reducing downtime.	- Implement 5G in manufacturing and logistics to improve automation and control, increasing operational efficiency.	**China Mobile, Telefonica, Vodafone**
	3.2 Reliability	3.2.1 Mission-Critical Systems	- 5G ensures reliability for mission-critical services (e.g., public safety, healthcare), with virtually zero delays.	- Deploy 5G for mission-critical services where reliability and real-time response are essential, particularly in healthcare and emergency response.	**SK Telecom, AT&T, China Telecom**
		3.2.2 Ultra-Low Latency	- 5G's ultra-low latency is critical for tasks requiring immediate responses, such as robotic surgery and emergency systems.	- Expand into sectors like remote operations, smart grids, and robotics where ultra-low latency is essential for performance.	**Verizon, NTT Docomo, Deutsche Telekom**
4. Energy Efficiency	4.1 Infrastructure Impact	4.1.1 Base Station Energy Use	- 5G base stations are more energy-efficient per bit of data, but the increased number of stations could offset energy savings.	- Adopt energy-efficient technologies and practices (e.g., smart grids, AI-based energy management) to minimize operational costs.	**China Mobile, Orange, SK Telecom**
		4.1.2 Small Cells vs. Macro Cells	- Small cell deployments are more energy-efficient for dense urban areas, but large-scale deployment increases overall energy demand.	- Focus on small cells in urban areas where demand is high, and combine this with energy-saving techniques to minimize environmental impact.	**Vodafone, Telefonica, Verizon**
	4.2 Operational Efficiency	4.2.1 Cost of Energy Consumption	- Energy-efficient equipment reduces operating costs, but deploying additional equipment increases upfront capital expenses.	- Invest in green energy solutions for powering 5G infrastructure, reducing long-term energy costs and improving sustainability credentials.	**AT&T, Deutsche Telekom, NTT Docomo**
5. Spectrum Utilization	5.1 Frequency Bands	5.1.1 Millimeter Waves	- 5G employs millimeter waves (mmWave), which offer large bandwidth but have limited range and penetration through obstacles.	- Advocate for policies that support the wider commercial use of mmWave bands. - Invest in innovative technologies to overcome mmWave limitations in infrastructure.	**Verizon, AT&T, Vodafone**
		5.1.2 Licensed and Unlicensed Spectrum	- Efficient use of both licensed and unlicensed spectrum is crucial for maximizing 5G performance.	- Collaborate with regulators to secure access to key spectrum resources and develop proprietary spectrum-sharing solutions.	**NTT Docomo, China Mobile, Deutsche Telekom**
	5.2 Spectrum Allocation	5.2.1 Dynamic Spectrum Sharing	- 5G networks rely on dynamic spectrum sharing (DSS) to optimize spectrum allocation between 4G and 5G.	- Use DSS to improve spectrum utilization, ensuring better performance for both 4G and 5G networks simultaneously.	**Verizon, Telefonica, Orange**
6. Network Densification	6.1 Small Cell Deployment	6.1.1 Urban Areas	- 5G requires the deployment of small cells in densely populated urban areas to enhance capacity and reduce network congestion.	- Focus infrastructure development on densifying urban areas to handle high traffic volumes and improve the user experience.	**Verizon, NTT Docomo, T-Mobile**
		6.1.2 Rural Areas	- Densification in rural areas is less common due to high costs and lower demand, but it is necessary for expanding coverage.	- Develop cost-sharing partnerships for rural small cell deployment to improve ROI and make network expansion more feasible.	**Telefonica, Vodafone, Orange**
	6.2 Antenna Systems	6.2.1 Distributed Antenna Systems (DAS)	- Distributed Antenna Systems (DAS) improve indoor and outdoor coverage in areas with high user density.	- Implement DAS in high-traffic areas such as stadiums, shopping malls, and airports to enhance coverage and service quality.	**China Mobile, NTT Docomo, Verizon**

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7. Security	7.1 Data Protection	7.1.1 Threat of Cyber Attacks	- 5G networks face increased exposure to cyber threats due to the broader range of applications and critical services it supports.	- Invest in advanced security solutions like encryption, AI-based threat detection, and multi-layered firewalls to protect network integrity.	**Verizon, Deutsche Telekom, AT&T**
		7.1.2 Encryption and Privacy	- Stronger encryption protocols are required to safeguard sensitive data across 5G networks, especially in IoT environments.	- Implement enhanced encryption methods and data protection regulations to ensure compliance and user privacy protection.	**China Mobile, Vodafone, SK Telecom**
	7.2 Network Integrity	7.2.1 Physical Infrastructure Security	- Securing physical infrastructure, such as base stations and data centers, is essential to preventing tampering and data breaches.	- Invest in physical security measures for key network infrastructure, including monitoring systems and disaster recovery solutions.	**Verizon, AT&T, Orange**

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The findings presented in Table 15 emphasize that while 5G technology offers unparalleled benefits in terms of faster speeds, greater data throughput, and low-latency capabilities, there are significant challenges related to infrastructure deployment and energy efficiency. Telecom giants such as Verizon, AT&T, and China Mobile have focused their efforts on expanding 5G coverage, particularly in urban areas, while tackling the high costs associated with deploying dense base station networks.

Meanwhile, companies like Vodafone and NTT Docomo are leading the way in integrating advanced applications such as cloud computing, IoT, and real-time industrial automation, using 5G's higher capacity and faster throughput to support innovations in manufacturing, healthcare, and entertainment. However, as these companies expand their 5G networks, the need for enhanced security measures becomes critical, with complex cyber threats and data protection becoming a top priority.

The strategic implications are clear: telecom companies must continue investing in infrastructure expansion, particularly in underserved regions, while balancing energy efficiency and security investments. The low-latency benefits of 5G create new business opportunities in real-time services, but effective deployment requires a careful balance of resources, partnerships, and regulatory compliance. Ultimately, this table illustrates the path forward for telecom companies in harnessing the full potential of 5G technology while mitigating its challenges.

5. Decision-Making Framework for Implementation

In the context of implementing wireless technologies, Table 16 outlines a structured Decision-Making Framework. This framework ensures that the deployment of new wireless technologies is carried out through a well-organized and phased approach, starting with a Needs Assessment, and concluding with Implementation and Monitoring. Each step in the process aims to address specific challenges related to the technological, financial, and operational aspects of wireless networks. This decision-making framework directly ties into the results of the systematic review, aligning the research findings with actionable steps to ensure successful and optimized implementation of 5G and other wireless technologies. The framework provides a comprehensive path for telecom companies and industry leaders to follow when planning and deploying wireless infrastructure, ensuring it aligns with business goals, regulatory requirements, and technological advancements.

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Table 16. Proposed Decision-Making Framework for Implementing Wireless Technologies by Telecom Companies Across Continents, with Challenges and Opportunities.

Step	Category	Subcategory	Description	Outcome	Telecom Company and Continent	Ties to Proposed Systematic Review Findings	Challenges (by Continent)	Opportunities (by Continent)
1. Needs Assessment	1.1 Current Infrastructure	1.1.1 Infrastructure Audit	A detailed audit of the current infrastructure is performed to assess existing wireless network capabilities, gaps, and challenges.	The audit report identifies infrastructure gaps, areas requiring upgrades, and potential for 5G integration.	Vodafone (Europe), AT&T (North America)	Reflects the review's emphasis on the gaps in network coverage, especially in rural and underserved areas.	**Europe:** Aging infrastructure; **North America:** Large rural areas needing upgrades	**Europe:** Potential for smart city development; **North America:** 5G rollout in underserved areas
	1.2 User Requirements	1.2.1 Demand Forecasting	Analyze user demand for wireless services, focusing on bandwidth needs, latency requirements, and application demands (e.g., IoT, AR).	A detailed user demand analysis helps prioritize applications and network upgrades based on forecasted demand.	NTT Docomo (Asia), Telstra (Australia)	Ties to the review's findings that the growing demand for advanced applications (AR/VR, IoT) requires higher bandwidth and low latency.	**Asia:** High population density strains bandwidth; **Australia:** Long distances between population centers	**Asia:** Huge demand for IoT and 5G services; **Australia:** Increased need for advanced infrastructure in rural areas
	1.3 Regulatory Environment	1.3.1 Compliance and Licenses	Review local and international regulations regarding spectrum allocation, network security, and data protection to ensure compliance.	A compliance report identifies regulatory gaps, licensing needs, and compliance requirements necessary for the deployment.	Telefonica (South America), Orange (Africa)	Aligns with the review's discussion on efficient spectrum utilization and the regulatory challenges of implementing 5G networks.	**South America:** Complex regulatory environments; **Africa:** Lack of uniform regulations	**South America:** High potential for private-public partnerships; **Africa:** Untapped market with regulatory reform potential
2. Feasibility Study	2.1 Technical Viability	2.1.1 Infrastructure Compatibility	Assess the compatibility of existing infrastructure with the proposed 5G technologies, including base stations and spectrum bands.	A technical feasibility report determines whether current infrastructure can be upgraded or if new components are needed.	Verizon (North America), MTN (Africa)	Supports findings that urban regions require densification of small cells and the upgrading of existing infrastructure for 5G.	**North America:** Fragmented infrastructure in rural regions; **Africa:** Limited existing infrastructure	**North America:** Potential for high-density urban development; **Africa:** Opportunity to build modern infrastructure from scratch
		2.1.2 Network Scalability	Evaluate the scalability of the proposed wireless technologies, ensuring the network can handle future growth and increased user traffic.	The report offers recommendations on scalable solutions, including small cells and densification in urban areas.	China Mobile (Asia), Optus (Australia)	Directly ties to the review's emphasis on network scalability and the need for densification in	**Asia:** Balancing urban and rural demands; **Australia:** Challenges with scaling across vast territories	**Asia:** Rapid urbanization supports densification; **Australia:** Leveraging network

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							urban environments to handle high traffic.		scalability for industry (mining, energy)
	2.2 Financial Feasibility	2.2.1 Cost-Benefit Analysis	Conduct a detailed cost-benefit analysis to evaluate the financial viability of implementing wireless technologies.	A financial report that weighs implementation costs against long-term benefits, including potential ROI from increased network capacity and service offerings.	Telefonica (South America), BT Group (Europe)	Reflects the need for substantial infrastructure investments highlighted in the review, particularly for base stations and small cells.	**South America:** High infrastructure costs; **Europe:** Managing legacy systems and costs of upgrading	**South America:** High potential for ROI in growing urban areas; **Europe:** Potential for innovation through smart cities
	2.3 Operational Feasibility	2.3.1 Risk Assessment	Identify operational risks, including delays, technical failures, and environmental factors, that could impact deployment timelines.	The risk assessment report outlines potential operational hurdles and offers mitigation strategies to ensure a smooth implementation.	SK Telecom (Asia), T-Mobile (North America)	Reflects review findings on operational risks, including the impact of environmental factors on 5G deployment and network stability.	**Asia:** Environmental challenges (e.g., extreme weather); **North America:** Complex market competition	**Asia:** Growth in high-tech industries; **North America:** Leadership in advanced wireless technology innovation
3. Strategic Planning	3.1 Implementation Roadmap	3.1.1 Timelines and Milestones	Develop a detailed implementation roadmap, specifying timelines, key milestones, and deliverables for each phase of deployment.	A comprehensive timeline that includes deadlines for infrastructure upgrades, spectrum allocation, regulatory approvals, and deployment of base stations.	Vodafone (Europe), China Mobile (Asia)	Aligns with the review's focus on phased deployment strategies to manage infrastructure upgrades in both urban and rural settings.	**Europe:** Balancing network upgrades with new infrastructure; **Asia:** Synchronizing urban/rural rollouts	**Europe:** Efficient urban network upgrades; **Asia:** Growth in smart city development
	3.2 Resource Allocation	3.2.1 Financial and Human Resources	Allocate financial and human resources to support the deployment, maintenance, and scaling of wireless technologies.	The strategic plan includes detailed budgeting and resource management to ensure smooth and cost-effective deployment.	Telstra (Australia), Orange (Africa)	Supports the review's findings on the need for resource allocation, particularly for human capital and technology deployment.	**Australia:** Limited workforce for rural areas; **Africa:** Scarcity of technical expertise	**Australia:** Opportunities in high-tech job creation; **Africa:** Investment in workforce development through tech training
	3.3 Stakeholder Engagement	3.3.1 Public-Private Partnerships	Engage with key stakeholders, including government entities, telecom operators, and service providers, to align on objectives.	The plan outlines strategies for stakeholder collaboration, focusing on funding, regulatory support, and joint ventures.	Telefonica (South America), MTN (Africa)	Reflects the review's emphasis on partnerships between governments and private entities to manage high	**South America:** Inconsistent collaboration between stakeholders; **Africa:** Complex political environments	**South America:** High demand for collaborative digital infrastructure projects; **Africa:** New opportunities in

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						costs, especially in rural areas.		digital economy
	3.4 Environmental Impact	3.4.1 Sustainability Strategies	Assess the environmental impact of deploying 5G infrastructure, including energy consumption and potential harm to local ecosystems.	The strategic plan includes measures to minimize environmental impact, such as energy-efficient technologies and sustainable deployment practices.	Verizon (North America), BT Group (Europe)	Supports the review's findings on the importance of adopting energy-efficient technologies and minimizing environmental impact.	**North America:** High energy consumption in network densification; **Europe:** Strict environmental regulations	**North America:** Opportunities to lead in energy-efficient technology; **Europe:** Support for sustainable tech in smart cities
4. Implementation and Monitoring	4.1 Deployment Phase	4.1.1 Infrastructure Rollout	Execute the strategic plan by deploying necessary infrastructure (e.g., base stations, antennas, small cells) and enabling technologies.	The infrastructure is successfully deployed following the roadmap, with base stations, antennas, and small cells installed as per plan.	China Mobile (Asia), MTN (Africa), Optus (Australia)	Reflects the review's emphasis on network densification through the deployment of small cells and base stations to handle high traffic.	**Asia:** High density requires complex rollout logistics; **Australia:** Sparse population areas present logistical challenges	**Asia:** Urban expansion driving technology demand; **Australia:** High potential for new rural wireless technologies
	4.2 Performance Monitoring	4.2.1 Key Performance Indicators	Establish key performance indicators (KPIs) to monitor the performance and efficiency of the newly deployed wireless network.	Continuous monitoring ensures that the infrastructure performs optimally, and necessary adjustments are made in real-time to resolve any issues.	Vodafone (Europe), T-Mobile (North America)	Supports the review's findings that real-time monitoring is critical for ensuring performance and addressing deployment challenges.	**Europe:** Complexities in balancing KPI targets across diverse markets; **North America:** Large-scale network coverage challenges	**Europe:** Advanced data analytics for performance tracking; **North America:** Leadership in tech innovation for network tracking
	4.3 Continuous Improvement	4.3.1 Feedback Loops	Implement feedback loops to gather data on network performance, customer satisfaction, and operational issues for ongoing improvements.	A report detailing areas for improvement, highlighting network upgrades, and strategies for expanding capacity and enhancing user experience.	Telefonica (South America), Telstra (Australia)	Aligns with the review's emphasis on continuous feedback and upgrading systems to meet growing user demand and optimize performance.	**South America:** Limited feedback mechanisms; **Australia:** Geographical challenges to data collection	**South America:** Growing customer demand for enhanced services; **Australia:** New opportunities for localized tech feedback

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The proposed decision-Making Framework offers a comprehensive, continent-specific approach to implementing wireless technologies. The inclusion of Challenges and Opportunities for each continent highlights the unique hurdles and potential growth areas in the implementation of wireless technologies like 5G.

For instance, North America faces challenges like fragmented infrastructure in rural areas but has opportunities in leading the deployment of energy-efficient technology and network densification. Asia faces logistical challenges due to high population density, but its rapid urban expansion provides opportunities for smart city development and large-scale wireless network rollouts. Africa faces significant regulatory and infrastructure gaps, but its untapped market potential presents vast opportunities for growth, particularly in public-private partnerships and workforce development. Europe faces the challenge of managing legacy systems while balancing new deployments with strict environmental regulations, yet it stands to benefit from its leadership in smart city innovation and advanced data tracking.

The systematic review's findings, including gaps in infrastructure, the need for densification, regulatory challenges, and environmental sustainability, are directly tied into this framework, ensuring a coherent and actionable strategy for telecom companies across continents.

6. Best Practices for Successful Study topic Implementation

The successful implementation of wireless technologies, particularly in SMEs and across various continents, requires a strategic approach that integrates both operational and technical best practices. The proposed framework outlined in this section identifies key focus areas essential for ensuring seamless deployment and continued optimization of wireless technologies. These focus areas include comprehensive planning, stakeholder engagement, rigorous technology assessments, regulatory compliance, robust security measures, and continuous performance monitoring and improvement. By categorizing these practices across different telecom companies and continents, this framework provides a holistic approach to addressing the specific challenges and opportunities in wireless technology implementation. As shown in Table 17, the structured breakdown emphasizes the importance of context-specific strategies that consider the geographic, regulatory, and market conditions of each region.

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Table 17. Proposed Best Practices for Successful Implementation of Wireless Technologies by Telecom Companies Across Continents, with Challenges and Opportunities.

Focus Area	Category	Subcategory	Best Practice Description	Outcome	Telecom Company and Continent	Ties to Proposed Systematic Review Findings	Challenges (by Continent)	Opportunities (by Continent)
Comprehensive Planning	1.1 Stakeholder Engagement	1.1.1 Collaborative Planning	Involve stakeholders early in the planning process to ensure all needs, constraints, and potential risks are identified.	All key stakeholder needs are addressed, avoiding delays and ensuring smooth implementation.	**Vodafone (Europe), AT&T (North America)**	Ensures alignment with the review's emphasis on early identification of infrastructure needs and risks.	**Europe:** Complex multi-national regulations; **North America:** Fragmented stakeholder landscape	**Europe:** Well-established collaboration frameworks; **North America:** Opportunity to align multiple industries
		1.1.2 Project Management Tools	Utilize project management tools to monitor progress, track deliverables, and adjust timelines in real-time.	Delays and roadblocks are addressed early, leading to efficient and timely execution of the implementation process.	**Telstra (Australia), China Mobile (Asia)**	Ties to the review's focus on real-time project management to optimize infrastructure rollout timelines.	**Australia:** Long distances between urban hubs; **Asia:** High urban population density creates logistical challenges	**Australia:** Advanced project management software tools; **Asia:** Potential to optimize with digital twin technology
Stakeholder Engagement	2.1 Communication Channels	2.1.1 Regular Updates	Conduct frequent meetings, project updates, and utilize communication channels to keep stakeholders informed and involved.	Clear communication ensures that stakeholders remain informed about the project's status, fostering transparency and collaboration.	**MTN (Africa), Telefonica (South America)**	Aligns with the review's finding that ongoing communication with stakeholders is critical for addressing infrastructure challenges.	**Africa:** High communication barriers between stakeholders; **South America:** Slow bureaucratic processes	**Africa:** Growing network demand fosters engagement; **South America:** Strong public-private partnership potential
	2.1.2 Feedback Mechanisms	Implement feedback loops for stakeholders to voice concerns, input	Feedback is quickly incorporated into the project, allowing for	**Orange (Africa), BT Group (Europe)**	Supports the review's finding that feedback loops enhance	**Africa:** Communication delays due to infrastructure gaps; **Europe:**	**Africa:** Opportunity to improve with digitization; **Europe:** Strong	

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			suggestions, and propose solutions during implementation.	agile responses to challenges and enhancing collaboration.		operational efficiency and responsiveness during network deployments.	Regulatory burdens slow feedback processes	governance frameworks support structured feedback	
Technology Assessment	3.1 Performance Testing	3.1.1 Pilot Testing		Conduct simulations and pilot tests to assess the coverage, capacity, and performance of the proposed wireless technologies.	Pilot tests reveal the performance and scalability of technologies, helping companies choose the most suitable solution for deployment.	**Verizon (North America), Optus (Australia)**	Reflects the review's recommendation for pilot tests to gauge the suitability of 5G and wireless technology before full deployment.	**North America:** High investment in pilot projects; **Australia:** Low rural population density affects pilot testing	**North America:** Leadership in tech innovation for testing; **Australia:** Opportunity to lead in rural infrastructure pilots
	3.2 Scalability Assessment	3.2.1 Technology Scalability		Assess the scalability of each technology, ensuring the network can grow in line with future demand without compromising performance.	Scalable solutions are implemented, allowing the network to grow and adapt to increasing user demand and technological advances.	**China Mobile (Asia), T-Mobile (North America)**	Ties to the review's focus on ensuring scalability to meet increasing user demand and network traffic with advanced infrastructure.	**Asia:** Urban population creates high scalability demands; **North America:** High costs associated with scaling up	**Asia:** Strong urban infrastructure to support scaling; **North America:** Tech leadership offers cost-efficient scaling solutions
Regulatory Compliance	4.1 Licenses and Permits	4.1.1 Regulatory Collaboration		Collaborate closely with regulatory bodies to ensure that licenses and permits are obtained before the deployment of infrastructure.	Ensures compliance with local, national, and international regulations, avoiding legal issues and deployment delays.	**Orange (Africa), NTT Docomo (Asia)**	Supports the review's emphasis on navigating regulatory challenges related to spectrum allocation and infrastructure deployment.	**Africa:** Limited government coordination; **Asia:** Complex, multi-tiered regulatory environments	**Africa:** New regulatory frameworks offer flexibility; **Asia:** Support from governments for wireless innovations
	4.2 Policy Monitoring	4.2.1 Regulatory Updates		Stay updated on evolving regulations to adapt the deployment	Compliance with the latest regulations is maintained, reducing the	**Telefonica (South America), China Mobile (Asia)**	Reflects the review's findings on the importance of staying abreast of regulatory	**South America:** Rapid regulatory changes; **Asia:** Regulatory	**South America:** Collaboration with international bodies; **Asia:**

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			strategy accordingly.	risk of non-compliance and potential penalties.		changes to ensure the smooth deployment of 5G.	environments with varying regional requirements	Rapid governmental support for technology development
Security Measures	5.1 Network Security	5.1.1 Security Infrastructure	Implement strong encryption protocols, firewalls, and intrusion detection systems to safeguard the network from cyber threats.	The network is protected against cyber-attacks, ensuring data security and network reliability during and after implementation.	**BT Group (Europe), Verizon (North America)**	Ties to the review's focus on security as a critical factor in ensuring reliable and robust 5G infrastructure.	**Europe:** Complexities in data protection laws (e.g., GDPR); **North America:** Rising cyber threats targeting telecom companies	**Europe:** Leadership in cybersecurity innovations; **North America:** Strong tech industry leads in security protocols
	5.2 Vulnerability Assessments	5.2.1 Regular Audits	Conduct regular vulnerability assessments and audits to identify potential weaknesses in the network infrastructure.	Vulnerabilities are identified early and addressed before they can lead to security breaches, ensuring the network's continued safety.	**NTT Docomo (Asia), MTN (Africa)**	Reflects the review's finding that continuous monitoring and assessment of network security are necessary for maintaining performance.	**Asia:** High risks due to interconnected global networks; **Africa:** Limited cybersecurity infrastructure	**Asia:** Large tech market supports cybersecurity solutions; **Africa:** High potential for investing in cybersecurity infrastructure
Continuous Monitoring and Improvement	6.1 Performance Analytics	6.1.1 Real-Time Monitoring	Use real-time analytics and performance metrics to continuously monitor the network's performance and make necessary adjustments.	Performance is optimized in real-time, ensuring that the network remains reliable and efficient as traffic and user demand increase.	**China Mobile (Asia), Orange (Africa)**	Aligns with the review's findings on the importance of real-time monitoring to maintain network performance and efficiency.	**Asia:** High traffic volumes require continuous adjustments; **Africa:** Limited access to advanced performance monitoring tools	**Asia:** Advanced AI-based monitoring solutions; **Africa:** Increasing access to real-time data tools with investment
	6.2 Feedback Loops	6.2.1 User Feedback Mechanisms	Implement feedback mechanisms to gather user input on network performance	User feedback is used to refine the network's operation, enhance the user	**T-Mobile (North America), Telstra (Australia)**	Ties to the review's recommendation for continuous feedback mechanisms to improve	**North America:** Diverse user base creates communication challenges; **Australia:**	**North America:** Strong customer feedback ecosystems; **Australia:**

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			and issues, allowing for continuous system improvement.	experience, and optimize future deployments.		network performance and address user concerns.	Geographical isolation impacts feedback loops	Potential for localized user feedback with innovative solutions

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This detailed framework outlines the best practices necessary for the effective deployment of wireless technologies, tying them to specific challenges and opportunities faced by telecom companies across continents. Comprehensive Planning emerges as a foundational practice, ensuring early stakeholder involvement and the utilization of project management tools for real-time monitoring. This is particularly crucial in regions such as Europe and North America, where regulatory complexities and fragmented infrastructure pose challenges. Stakeholder Engagement further emphasizes the importance of regular communication and feedback mechanisms, helping companies navigate slow bureaucratic processes, especially in Africa and South America.

The Technology Assessment best practices focus on the need for pilot testing and scalability, ensuring that the network is capable of handling future growth. Asia and Australia face unique scalability challenges due to their high population density and geographic isolation, respectively. Regulatory Compliance is critical in regions like Africa and Asia, where evolving regulations and the need for strong government collaboration can either accelerate or hinder deployment efforts.

Security Measures are a key component across all regions, with Europe and North America leading in cybersecurity innovations. Conducting regular audits and implementing real-time monitoring systems are essential for safeguarding network performance and addressing vulnerabilities. Finally, the focus on Continuous Monitoring and Improvement ensures that wireless networks remain agile and adaptable to changing demands, with North America and Australia offering opportunities for leading in real-time data analytics and performance feedback.

7. Metrics and KPIs for Measuring Study Topic Performance

Measuring the performance of wireless network technologies is crucial for ensuring that these systems operate efficiently and meet the growing demands of users. Key Performance Indicators (KPIs) provide valuable insights into how well a wireless network is performing and can help identify areas for improvement. This section expands on the core KPIs used to evaluate wireless networks, including metrics like latency, coverage, throughput, network speed, bandwidth, and energy efficiency. By analyzing these metrics, telecom companies can gauge the effectiveness of their networks and optimize them for better performance and sustainability. The enhanced table below includes KPIs segmented by continent and tied to the specific findings of the systematic review, as well as challenges and opportunities unique to each region.

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Table 18. Proposed Metrics and KPIs for Measuring Wireless Network Performance by Telecom Companies Across Continents, with Challenges and Opportunities.

KPI	Category	Subcategory	Description	Relevance	Telecom Company and Continent	Ties to Proposed Systematic Review Findings	Challenges (by Continent)	Opportunities (by Continent)
Latency	1.1 Real-Time Application	1.1.1 Response Time	Measures the time it takes for data to travel from the source to the destination and back, typically measured in milliseconds.	Lower latency is ideal for real-time applications like autonomous vehicles, remote surgeries, and IoT devices.	**Verizon (North America), NTT Docomo (Asia)**	Aligns with the review's focus on low latency being critical for real-time applications in 5G networks.	**North America:** High competition for low-latency applications; **Asia:** Strain from population density and real-time demands	**North America:** Leadership in 5G latency improvements; **Asia:** Growth in smart cities needing low-latency applications
Coverage	2.1 Geographic Coverage	2.1.1 Network Availability	Refers to the geographic area where the network can provide reliable connectivity.	Broad and consistent coverage is essential for network accessibility, particularly in rural and underserved regions.	**MTN (Africa), Vodafone (Europe)**	Reflects the review's emphasis on network densification to provide consistent coverage, especially in rural and hard-to-reach areas.	**Africa:** Limited infrastructure in rural areas; **Europe:** Struggling to expand coverage in remote areas	**Africa:** Growing investment in rural infrastructure; **Europe:** Potential for 5G expansion through public-private partnerships
Throughput	3.1 Data Handling	3.1.1 Data Transmission Capacity	Measures the actual rate of successful data transmission through the network, typically in Mbps or Gbps.	High throughput is crucial for handling large volumes of data traffic efficiently, supporting high-demand applications like IoT.	**China Mobile (Asia), AT&T (North America)**	Supports the review's discussion on the need for high throughput to handle growing data demands from IoT and other advanced applications.	**Asia:** Congestion in urban areas reduces throughput; **North America:** Increasing data demands strain existing networks	**Asia:** Opportunity for network upgrades to meet data demands; **North America:** Advanced tech can optimize throughput
Network Speed	4.1 User Experience	4.1.1 Speed of Data Transmission	Refers to the rate of data transmission and reception over a network, measured in Mbps or Gbps.	High network speed enhances user experience, allowing for faster downloads, video streaming,	**Telstra (Australia), Telefonica (South America)**	Ties to the review's focus on network speed as a critical factor in improving user satisfaction,	**Australia:** Challenges in providing fast speeds in remote areas; **South America:** High costs for upgrading	**Australia:** Opportunity to lead in high-speed rural networks; **South America:** Growing

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					and seamless connectivity.		particularly in urban centers.	speed infrastructure	demand for higher speeds
Bandwidth	5.1 Data Capacity	5.1.1 Simultaneous Data Handling	Refers to the capacity of the network to transmit a certain amount of data in a given timeframe, measured in MHz or GHz.	High bandwidth allows multiple simultaneous data transmissions, reducing congestion and improving overall network performance.	**Optus (Australia), Telefonica (South America)**	Reflects the review's findings on the importance of increasing bandwidth to support multiple high-demand applications.	**Australia:** Scarcity of spectrum in rural areas; **South America:** Limited investment in bandwidth expansion	**Australia:** Growing government focus on rural tech development; **South America:** Opportunities in growing digital economy
Energy Efficiency	6.1 Sustainability in Operations	6.1.1 Power Consumption Per Data	Measures the amount of energy consumed by the network infrastructure relative to the amount of data transmitted.	Higher energy efficiency lowers operational costs and reduces the environmental footprint of network operations.	**BT Group (Europe), MTN (Africa)**	Aligns with the review's focus on the need for energy-efficient networks to minimize environmental impacts and reduce costs.	**Europe:** High energy consumption in network densification; **Africa:** Lack of infrastructure for energy-efficient solutions	**Europe:** Potential for leadership in green networks; **Africa:** Investment in renewable energy for telecom infrastructure
Reliability	7.1 Network Stability	7.1.1 Downtime and Uptime	Refers to the network's ability to maintain consistent service with minimal downtime.	High reliability is essential for mission-critical applications like healthcare, financial services, and emergency services.	**Vodafone (Europe), China Mobile (Asia)**	Supports the review's emphasis on maintaining reliable network performance, especially for critical services like healthcare.	**Europe:** Maintenance of aging infrastructure; **Asia:** High demand for reliable services in high-population areas	**Europe:** Leadership in reliability standards; **Asia:** Growth in critical services demanding high-reliability networks
Security	8.1 Data Protection	8.1.1 Network Security Protocols	Refers to the robustness of encryption, firewalls, and intrusion detection systems to protect the network from cyber threats.	Strong security measures are essential to protect sensitive data and ensure user privacy, especially in IoT and financial services.	**Verizon (North America), Orange (Africa)**	Ties to the review's recommendation on the critical importance of securing wireless networks, especially with the rise of IoT devices.	**North America:** Increasing cyber threats targeting telecoms; **Africa:** Limited cybersecurity infrastructure	**North America:** Potential for leadership in network security; **Africa:** Opportunities to invest in robust cybersecurity infrastructure

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The table highlights the key Metrics and KPIs essential for measuring wireless technology performance, categorized by telecom companies operating in different continents. Each metric—such as latency, coverage, throughput, network speed, bandwidth, energy efficiency, reliability, and security—offers critical insights into the network's operational efficiency and user satisfaction.

In North America, the challenges focus on increasing demands for high throughput and maintaining low latency, but the opportunities lie in leading technology innovation, especially in network speed and cybersecurity. Asia faces unique challenges in scaling networks to meet urban demand and maintain low latency for real-time applications, but the region offers vast opportunities in smart city developments and throughput optimizations. Africa confronts difficulties due to limited infrastructure and cybersecurity challenges, yet it presents significant growth potential through investment in energy efficiency and rural coverage. Europe is challenged by aging infrastructure and stringent environmental regulations but stands as a leader in energy efficiency and network reliability.

8. Customizing Proposed Study Topic for Different SME Industries

Small and Medium Enterprises (SMEs) operate in diverse industries, each with its own unique set of challenges and connectivity demands. Wireless network technologies, particularly with the advancement of 5G, offer opportunities to meet these specific needs by increasing productivity, reducing costs, and enhancing operational efficiency. Customizing wireless technologies for different sectors allows SMEs to optimize their network infrastructure for specific tasks, whether it be secure financial transactions, seamless retail operations, or reliable healthcare services in rural areas. This section explores the customization of wireless technologies across various SME industries, highlighting the specific technologies recommended and the reasons for their selection.

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Table 19. of Wireless Network Technologies by Industry, Tied to Challenges and Opportunities for SME Sectors Across Continents

Industry	Wireless Network Technology	Reason for Recommendation	Customization	Telecom Company and Continent	Ties to Proposed Systematic Review Findings	Challenges (by Continent)	Opportunities (by Continent)
Manufacturing and Industrial	3G, 4G, 5G, or Private LTE	Manufacturing processes typically require moderate bandwidth, making 3G and 4G sufficient for machine-to-machine communications.	1. Network Infrastructure 2. Edge Computing 3. Network Slicing	**MTN (Africa), China Mobile (Asia)**	Aligns with the review's emphasis on edge computing and slicing for industrial optimization.	**Africa:** Limited infrastructure; **Asia:** High industrial density complicates connectivity.	**Africa:** Growing manufacturing sector requires innovative connectivity solutions. **Asia:** Rapid industrial expansion.
Healthcare and Medical	3G or 4G	Healthcare facilities in rural regions rely on 3G and 4G due to existing infrastructure and network reliability.	1. Network Reliability 2. Network Slicing 3. Security Enhancements	**Orange (Africa), Vodafone (Europe)**	Reflects the review's focus on reliable networks for mission-critical sectors such as healthcare.	**Africa:** Infrastructure gaps in healthcare facilities. **Europe:** Stricter data protection laws in healthcare.	**Africa:** Growing investments in rural healthcare technologies. **Europe:** Leadership in secure healthcare technologies.
Retail and Hospitality	3G, 4G, or 5G	Retail and hospitality sectors require seamless connectivity for point-of-sale systems and customer engagement tools.	1. High-Speed Connectivity 2. Internet of Things (IoT) Integration	**AT&T (North America), Telefonica (South America)**	Ties to the review's discussion on IoT integration and high-speed connectivity in the retail sector.	**North America:** Infrastructure fragmentation. **South America:** Limited access to high-speed connectivity.	**North America:** High demand for IoT retail systems. **South America:** Growing e-commerce sector.
Finance and Banking	5G	The financial sector demands secure, reliable networks for handling sensitive data and transactions.	1. Private Networks 2. Network Optimization 3. Security Enhancements	**Verizon (North America), NTT Docomo (Asia)**	Supports the review's findings on the need for secure and optimized networks for financial institutions.	**North America:** Increasing cyber threats. **Asia:** Regulatory hurdles for secure networks.	**North America:** Leading role in fintech security. **Asia:** Growth in digital banking services.
Agriculture Industry	Private LTE, 3G, or 4G	Remote farming operations rely on stable networks for IoT integration and data monitoring, requiring wide	1. Wide Network Coverage 2. Private Networks 3. IoT Integration	**MTN (Africa), Telstra (Australia)**	Aligns with the review's focus on rural connectivity and IoT for remote operations such as agriculture.	**Africa:** Lack of rural infrastructure. **Australia:** Geographical isolation hinders network expansion.	**Africa:** Growing adoption of IoT in agriculture. **Australia:** Government push for rural tech development.

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			coverage and reliability.					
Educational Industry	5G		The education sector, especially in higher education, demands high bandwidth for video streaming and virtual learning platforms.	1. High Bandwidth 2. Private Networks 3. Network Segmentation	**Vodafone (Europe), Telefonica (South America)**	Reflects the review's emphasis on the need for high bandwidth to support educational platforms and virtual learning systems.	**Europe:** Existing education infrastructure is aging. **South America:** Limited bandwidth for e-learning solutions.	**Europe:** Growing investment in digital education. **South America:** Potential for improved digital literacy.

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This framework demonstrates the customization of wireless network technologies across different SME industries, aligning with the unique challenges and opportunities faced by each sector. For the Manufacturing and Industrial sector, solutions like Edge Computing and Network Slicing provide efficiency and scalability, especially in regions like Africa and Asia, where infrastructure can be limited but industrial growth is rapid. In Healthcare, reliable networks are critical for delivering quality care, particularly in rural areas where 3G and 4G offer the best solutions, with regions like Africa benefiting from investments in rural healthcare networks.

The Retail and Hospitality sector thrives on high-speed connectivity and IoT integration, with regions like North America and South America experiencing significant demand for advanced retail technologies. Similarly, Finance and Banking requires high security and reliability, with North America leading innovations in fintech security, while Asia continues to grow its digital banking infrastructure. Agriculture and Education industries highlight the need for wide coverage and high bandwidth, where regions like Australia and Africa present opportunities for rural connectivity enhancements.

The systematic review's findings highlight the importance of tailoring wireless technologies to industry-specific needs, ensuring optimal performance, security, and scalability across different SME sectors worldwide. This customized approach to wireless technology implementation aligns with the varied operational demands of SMEs, driving productivity and innovation across industries.

9. Proposed Industry-Specific Frameworks for Study Topic

In different industries, the operational demands and business environments vary greatly, requiring industry-specific frameworks to optimize the deployment and use of wireless network technologies. Each industry, from manufacturing to agriculture and healthcare, has unique requirements for connectivity, security, scalability, and real-time communication. The following section outlines frameworks for these industries, focusing on key features that meet their specific needs, enhance operational efficiency, and support advanced applications like automation and IoT. These frameworks are tailored to optimize wireless technologies such as 5G, Private LTE, and IoT-driven networks for industry-specific objectives. By incorporating factors such as real-time data communication, scalability, and robust security, these frameworks ensure the seamless integration of wireless technologies into SMEs' core operations.

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Table 20. Industry-Specific Frameworks for Wireless Network Technologies, Tied to Challenges and Opportunities Across Regions.

Industry	Framework Focus	Key Features	Telecom Company and Continent	Ties to Proposed Systematic Review Findings	Challenges (by Continent)	Opportunities (by Continent)
Manufacturing and Industrial	Real-time communication, machine connectivity, automation	1. Predictable maintenance with real-time data analysis. 2. Scalability to interconnect devices. 3. Enhanced security.	**MTN (Africa), China Mobile (Asia)**	Reflects the review's findings on machine-to-machine communication and security challenges in industrial IoT settings.	**Africa:** Scarcity of advanced industrial networks. **Asia:** Complex regulatory environment for industrial automation.	**Africa:** Growing industrial sector for network integration. **Asia:** Booming industrial IoT infrastructure.
Healthcare and Medical	Reliable connectivity, data privacy, low-latency communication	1. Real-time data synchronization for health records. 2. Location-based services to track patients and manage equipment.	**Vodafone (Europe), Orange (Africa)**	Tied to the review's emphasis on the critical need for real-time data transmission and low-latency networks in healthcare.	**Africa:** Limited access to reliable network infrastructure. **Europe:** Strict regulations on data privacy and security.	**Africa:** Significant investments in rural healthcare networks. **Europe:** Advances in secure digital healthcare infrastructure.
Retail and Hospitality	Customer experience, operational efficiency	1. Digital kiosks and augmented reality displays. 2. Real-time inventory management.	**AT&T (North America), Telefonica (South America)**	Aligns with the review's discussion on retail IoT integration and the need for real-time operational efficiency in the service sector.	**North America:** Fragmented networks hinder seamless connectivity. **South America:** Limited investment in advanced retail tech.	**North America:** High consumer demand for innovative retail experiences. **South America:** Growing e-commerce sector.
Finance and Banking	Security, reliability, low-latency transactions	1. High-speed, secure data transmission for online banking. 2. Failover and redundancy for service continuity.	**Verizon (North America), NTT Docomo (Asia)**	Supports the review's focus on secure, low-latency networks for sensitive financial operations.	**North America:** Rising cyber threats targeting financial networks. **Asia:** Regulatory challenges for secure financial networks.	**North America:** Growth in fintech security innovations. **Asia:** Expansion of digital banking services across regions.

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Agriculture Industry	Remote monitoring, wide coverage, low-power consumption	1. Automated systems for soil data. 2. Real-time livestock and environmental monitoring. 3. Use of drones for monitoring.	**MTN (Africa), Telstra (Australia)**	Tied to the review's findings on wide coverage needs and IoT integration in agriculture, particularly in rural and remote areas.	**Africa:** Infrastructure gaps in remote regions. **Australia:** Geographic isolation makes network expansion challenging.	**Africa:** Opportunities in precision farming. **Australia:** Government support for rural connectivity advancements.
Educational Industry	High bandwidth, student access, resource optimization	1. Support for virtual classrooms and low-latency video. 2. Segmented networks for academic and guest use.	**Vodafone (Europe), Telefonica (South America)**	Reflects the review's findings on the importance of high-bandwidth and scalable networks for educational institutions.	**Europe:** Existing digital infrastructure is aging. **South America:** Limited network bandwidth for e-learning solutions.	**Europe:** Leadership in digital learning and smart campuses. **South America:** Growing demand for virtual learning platforms.

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The proposed frameworks in this section highlight the customization of wireless network technologies for different industries based on their specific needs and challenges. Manufacturing and industrial sectors benefit from real-time data analysis, enhanced security, and scalability, with Africa and Asia presenting significant growth opportunities in industrial IoT. In the Healthcare and medical industry, real-time synchronization and secure, reliable networks are critical, particularly in Africa, where rural healthcare infrastructure is underdeveloped, and in Europe, where data privacy regulations are strict.

For Retail and Hospitality, digital kiosks and IoT integration drive customer experience and operational efficiency, especially in North America and South America, where retail technology adoption is growing. Finance and Banking face unique challenges in ensuring low-latency, secure networks for financial transactions, with North America and Asia leading in fintech security and regulatory compliance. Agriculture requires low-power, wide-coverage networks for remote monitoring and IoT applications, particularly in Africa and Australia, where precision farming is gaining momentum.

10. Real Case Studies and Their Relevance to the Proposed Systematic Review

Table 21 illustrates key case studies related to the evaluation of wireless network technologies and their infrastructure, particularly focusing on 3G, 4G, and 5G. These case studies offer valuable insights into resource allocation, performance analysis, and technological advancements that align with the objectives of the systematic review. Each case study has been summarized to highlight the technology used, key infrastructure components, findings, and its relevance to the systematic review.

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Table 21. Summary of Case Studies Relevant to Evaluating Wireless Network Technologies (3G, 4G, 5G) and Their Infrastructure.

Case Study	Region/Context	Technology Used **(3G, 4G, 5G)**	Infrastructure Components	Key Findings	Relevance to Systematic Review
Case Study 1: Resource Allocation in 4G and 5G Networks [122]	Comprehensive Review	4G, 5G	Resource allocation mechanisms, network architecture, delay and throughput	Efficient resource management is critical for improved performance (e.g., lower delay, higher throughput)	Aligns with the review's goal by offering insights into resource management and its role in the effectiveness of 4G and 5G networks. Provides empirical data on infrastructure efficiency, essential for comparing technologies and evaluating infrastructure advancements between 4G and 5G.
Case Study 2: Performance Analysis of Multiple Radio-Access Provision in a Multicore-Fiber Optical Fronthaul [123]	Technical Study	4G LTE-Advanced Multi-RAT	Multicore-fiber optical fronthaul systems, MIMO capabilities	Highlights the integration challenges and performance metrics of multi-RAT systems	Relevant to the systematic review as it provides detailed insights into infrastructure and operational challenges, essential for 4G LTE-Advanced and 5G evolution. The study's focus on MIMO enhances understanding of how infrastructure improvements support the 5G transition and increased network efficiency.
Case Study 3: Ultra-Wideband Dual-Polarized Antenna with Three Resonant Modes for 2G/3G/4G/5G Communication Systems [124]	Technical Study	2G, 3G, 4G, 5G	Dual-polarized ultra-wideband antenna	Advances in antenna design facilitate the integration of multiple wireless generations	Provides critical insights into technological advancements necessary for infrastructure improvements across wireless generations, particularly in antenna design, supporting the systematic review's focus on evolving infrastructure demands in modern communication systems.
Case Study 4: Challenges of System-Level Simulations and Performance Evaluation for 5G Wireless Networks [125]	Technical Study	3G, 4G, 5G	System-level simulations, performance evaluation methodologies	Highlights challenges in 5G performance evaluation and the need for advanced simulation frameworks	Links past 3G and 4G evaluation methodologies to emerging 5G technologies, helping build a comprehensive understanding of how these methods inform the evaluation of infrastructure and operational efficiencies in wireless networks.
Case Study 5: A Highly Independent Multiband Pass Filter Using a Multi-Coupled Line Stub-SIR with Folding Structure [126]	Technical Study	3G, 4G, 5G	Multiband bandpass filter (BPF)	Advanced filtering technologies improve performance and efficiency, supporting multiple wireless standards	Illustrates how filtering technologies enhance performance, supporting the seamless integration of multiple wireless standards within a single infrastructure. Provides valuable insights for the systematic review on the importance of filtering technologies for network optimization and infrastructure scalability.
Case Study 6: Proposed Systematic Review	Multi-Region	3G, 4G, 5G	Comprehensive evaluation of network technologies and their infrastructure	Summarizes key infrastructure challenges and opportunities across global contexts	Provides a holistic view of how the study's findings contribute to global understanding of wireless infrastructure evolution, particularly focusing on scalability, performance efficiency, and technology adoption trends from 3G to 5G.

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The case studies presented highlight the technological advancements, infrastructure challenges, and performance improvements across wireless network technologies (3G, 4G, and 5G). These real-world examples offer empirical insights into resource allocation mechanisms, antenna design, system-level simulations, and filtering technologies, which are critical components for successful wireless infrastructure deployment.

For instance, Case Study 1 and Case Study 2 provide valuable data on resource allocation and the integration challenges associated with Multi-Radio Access Technology (Multi-RAT) systems, directly contributing to the review's focus on infrastructure scalability and efficiency. Case Study 3 emphasizes technological advancements in antenna design, an essential factor for improving network performance, which aligns with the review's exploration of wireless infrastructure upgrades. Similarly, Case Study 4 addresses the challenges of performance evaluation for 5G, offering a comprehensive link between the infrastructure evolution from 3G and 4G to 5G.

The inclusion of filtering technologies in Case Study 5 further enriches the systematic review's findings by providing insights into optimizing network performance through advanced filtering techniques. Each case study plays a pivotal role in shaping the recommendations and conclusions of the systematic review, offering both theoretical and practical perspectives on the transition from older wireless generations to the advanced capabilities of 5G.

11. Roadmap for SMEs businesses and Policy Recommendations

The transition from 3G to 5G technologies presents unprecedented opportunities for SMEs to revolutionize their operations, engage with customers more effectively, and drive innovation across various sectors. However, for these opportunities to be realized, SMEs must adopt a structured and comprehensive roadmap that includes technological investments, strategic partnerships, policy frameworks, workforce training, and sustainability considerations. This roadmap serves as a guide for SMEs to navigate the complexities of upgrading their wireless infrastructure, adopting advanced technologies, and collaborating with key stakeholders. By aligning with global sustainability goals and engaging in continuous performance evaluations, SMEs can optimize their operations and stay competitive in the rapidly evolving digital landscape.

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Table 22. Proposed Roadmap for SME Wireless Network Adoption Across Continents, Addressing Key Challenges and Opportunities.

Roadmap Element	Focus	Key Features	Telecom Companies/Continents	Ties to Proposed Systematic Review Findings	Challenges (by Continent)	Opportunities (by Continent)
Assessment of Current Infrastructure	Evaluate Existing Technologies	1. Analyze current performance metrics. 2. Identify gaps and assess readiness for 5G transition.	MTN (Africa), Verizon (North America)	Supports the review's focus on identifying gaps in data rates, latency, and coverage.	**Africa:** Outdated infrastructure. **North America:** Fragmentation between regions.	**Africa:** Opportunities to build advanced infrastructure. **North America:** Government incentives for upgrades.
Investment in Upgrading Infrastructure	Prioritize 5G Adoption	1. Leverage high data rates, low latency, and improved IoT connectivity. 2. Seek financial incentives.	Telstra (Australia), Telefonica (South America)	Reflects the review's emphasis on financial viability and infrastructure scalability for IoT integration.	**Australia:** High costs for rural deployments. **South America:** Lack of funding in underserved regions.	**Australia:** Growing demand for IoT in agriculture. **South America:** Government support for 5G infrastructure development.
Adoption of Advanced Technologies	Integrate IoT and Antenna Solutions	1. IoT for real-time data analytics. 2. Advanced antennas for enhanced performance.	NTT Docomo (Asia), Orange (Europe)	Aligns with the review's discussion on the need for IoT solutions and advanced antennas to enhance performance and scalability.	**Asia:** Regulatory challenges for IoT adoption. **Europe:** High investment costs for advanced antennas.	**Asia:** Growing market for IoT applications in smart cities. **Europe:** Expansion of digital infrastructure with 5G and IoT.
Collaboration with Technology Providers	Strategic Partnerships	1. Partner with telecom providers for access to the latest tech. 2. Join industry networks.	AT&T (North America), Vodafone (Europe)	Tied to the review's findings on the importance of partnerships for accessing advanced wireless infrastructure solutions.	**North America:** Limited access to advanced wireless technologies for SMEs. **Europe:** Fragmented collaboration networks.	**North America:** Growing collaborations between tech providers and SMEs. **Europe:** Thriving innovation ecosystems.
Policy Recommendations	Infrastructure Support and Spectrum Management	1. Support infrastructure investments. 2. Develop regulatory frameworks for spectrum allocation.	MTN (Africa), Telstra (Australia)	Aligns with the review's emphasis on the need for clear regulatory policies for spectrum management and equitable access to networks.	**Africa:** Lack of clear spectrum management policies. **Australia:** Complex regulatory environment for 5G deployment.	**Africa:** Opportunities in regulatory reform to promote 5G adoption. **Australia:** Strong policy support for rural connectivity.
Training and Capacity Building	Workforce Development and Digital Literacy	1. Invest in training programs. 2. Promote digital literacy among employees and customers.	Telefonica (South America), NTT Docomo (Asia)	Reflects the review's focus on building digital literacy and training employees to adopt new wireless technologies effectively.	**South America:** Limited workforce training programs. **Asia:** High costs for tech training initiatives.	**South America:** Growing demand for digital literacy programs. **Asia:** Expanding tech workforce ready for digital advancements.
Sustainability Considerations	Energy-Efficient Technologies and Carbon	1. Adopt energy-efficient wireless infrastructure.	Vodafone (Europe), AT&T (North America)	Tied to the review's focus on energy-efficient infrastructure and	**Europe:** Aging infrastructure lacks energy efficiency. **North America:** High	**Europe:** Growing investment in green tech. **North America:**

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	Footprint Reduction	2. Align with global sustainability goals.		reducing the carbon footprint of wireless networks.	energy consumption in network operations.	Expansion of energy-efficient 5G technologies.
Continuous Monitoring and Evaluation	Establish Performance Metrics and Adapt to Technological Change	1. Develop KPIs to track wireless network performance. 2. Adapt strategies to stay competitive.	NTT Docomo (Asia), Orange (Europe)	Supports the review's findings on the importance of continuous performance evaluations and adapting to new wireless advancements.	**Asia:** Difficulty in maintaining up-to-date infrastructure. **Europe:** Slow adoption of continuous monitoring systems.	**Asia:** Rapid innovation in performance metrics and tech adoption. **Europe:** Leadership in tech-driven continuous improvements.

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This roadmap provides a structured approach for SMEs to transition from legacy wireless technologies to 5G, addressing key challenges across various regions. The roadmap begins with assessing the current infrastructure, focusing on identifying gaps in coverage, data rates, and latency. Africa and North America face unique infrastructure challenges but also present opportunities for significant upgrades, particularly in underserved areas. Investment in infrastructure is key, especially for regions like Australia and South America, where financial support and government incentives can help drive 5G adoption. By integrating advanced technologies such as IoT and investing in antennas that can support multiple frequency bands, SMEs can optimize performance and scalability, aligning with the review's findings on the importance of real-time data analytics and enhanced connectivity.

Collaboration with technology providers is essential for SMEs, as shown by the growing partnerships between telecom companies and businesses in North America and Europe. Clear policy recommendations are also critical, particularly in Africa and Australia, where spectrum management and regulatory support are needed to ensure equitable access to advanced wireless networks. Training and capacity building are crucial for developing a tech-savvy workforce capable of leveraging new wireless technologies, especially in South America and Asia, where the demand for digital literacy is growing. Finally, sustainability considerations emphasize adopting energy-efficient technologies to minimize the environmental impact, particularly in Europe and North America, where reducing the carbon footprint is becoming a priority.

12. Discussion

The systematic literature review research questions and explores critical aspects of wireless network technologies, focusing on performance, deployment challenges, environmental impact, and user experience. They aim to compare different wireless technologies in terms of data transfer speeds and latency, investigate coverage limitations in dense urban environments, and identify the primary challenges in deploying and maintaining 5G infrastructure. Additionally, they seek to understand how to develop wireless network infrastructure sustainably, minimizing environmental impact while maximizing coverage and performance. Finally, they examine how variations in infrastructure, such as small cell deployment and antenna placement, influence overall network performance and user experience across different environments. Collectively, these questions are essential for advancing our knowledge and development of efficient, reliable, and sustainable wireless networks.

Table 23. Addressed Research Questions and Relatively Important Elements.

RQ	Key findings	Relevant Metrics	Impact on SME Strategy	Industries/Platforms
RQ1	5G offers significantly higher data transfer speeds (up to 20 Gbps) and lower latency (less than 1 Ms) compared to 4G and earlier technologies.	Data transfer speed (Mbps/Gbps), latency (Ms), network reliability.	SMEs can leverage 5G for enhanced IoT applications, real-time data analytics, and improved customer experiences. Faster speeds and lower latency enable more efficient operations and innovative service offerings.	Telecommunications, IoT platforms, AR/VR applications, autonomous vehicles.
RQ2	Dense urban environments pose challenges due to signal interference	Signal strength (dBm), coverage area (km²), user density (users/km²).	SMEs in urban areas need to consider network reliability and	Smart cities, urban planning, real estate, public safety.

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	from buildings and high user density. Small cell deployment and advanced antenna technologies are crucial for improving coverage		coverage in their digital strategies. Investing in technologies that enhance connectivity can improve operational efficiency and customer satisfaction.	
RQ3	Major challenges include high costs, regulatory hurdles, and the need for dense small cell networks. Solutions involve collaborative spectrum sharing and innovative power management	Deployment cost (USD), number of small cells, regulatory compliance.	SMEs can benefit from partnerships with telecom providers to share infrastructure costs. Understanding regulatory requirements and leveraging government incentives can facilitate smoother deployment.	Telecommunications, infrastructure development, regulatory bodies.
RQ4	Sustainable practices include energy-efficient designs, dynamic power management, and green infrastructure deployment. These practices reduce environmental impact and operational costs	Energy consumption (kWh), carbon footprint (CO_2 emissions), operational cost savings.	SMEs can adopt sustainable practices to reduce costs and enhance their brand image. Investing in green technologies can also attract environmentally conscious customers.	Green technology, renewable energy, corporate sustainability.
RQ5	Variations in small cell deployment, antenna placement, and backhaul connectivity significantly affect network performance and user experience. Optimized infrastructure leads to better coverage and higher user satisfaction	Network uptime (%), user satisfaction (survey scores), data throughput (Mbps).	SMEs should focus on optimizing their network infrastructure to ensure reliable connectivity. This can improve employee productivity and customer engagement.	Telecommunications, IT services, customer experience platforms.

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13. Conclusions

In conclusion, while the future of wireless communication holds great promise, achieving its full potential requires a careful balance between technological innovation, infrastructure investment, and sustainability. This research provides valuable contributions toward understanding these dynamics, offering tangible recommendations to ensure that the next generation of wireless networks can deliver on its promises while mitigating its challenges. The findings presented here will support the ongoing evolution of wireless networks, fostering a more connected, efficient, and sustainable future for all. The systematic review stands as a significant contribution to the field of wireless communication, providing a robust framework for understanding the intricate dynamics of wireless network technologies and their infrastructure. Through rigorous methodology and thorough analysis, the study aims to offer actionable insights that can guide researchers, industry stakeholders, and policymakers in navigating the rapidly evolving landscape of wireless communication. The systematic identification of challenges and opportunities within this realm sets the stage for future innovations, ensuring that advancements in wireless technologies can effectively meet the needs of a connected world. The current understanding of wireless network technologies but also identifies critical areas for future research. As the wireless landscape continues to evolve, ongoing investigation into emerging trends, provider roles, and regional disparities will be essential for harnessing the full potential of wireless networks. The insights garnered from this review provide a valuable framework for guiding future research and informing the development of effective wireless infrastructures. The journey toward optimizing 5G technology is ongoing, and while challenges remain, the potential benefits for wireless communication are substantial. A concerted effort from researchers, practitioners, and policymakers will be essential to harness the full capabilities of 5G and ensure its successful integration into society.

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