The Impact of 5G Networks on Smart Mobility and Intelligent Transportation Systems in Saudi Arabia

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Abstract- The fast development of fifth-generation (5G) wireless technology is creating new opportunities for smart mobility and intelligent transportation systems (ITS). In Saudi Arabia, continuous efforts to improve digital systems and develop smart cities have made 5G a major force in updating transportation systems. This research looks at how 5G networks affect the growth and functioning of smart mobility and intelligent transportation systems in Saudi Arabia. The study uses a thorough and detailed research method to look at how 5G technology helps with managing traffic in real time, communication between vehicles and everything around them, connected and self-driving cars, and smart public transport systems. It gathers information from academic papers, industry reports, and real examples to understand these benefits. The results show that 5G greatly increases how fast data can be sent, lowers the delay in communication, and makes the system more dependable, which helps traffic move more smoothly, makes roads safer, and gives users a better experience. The study also points out some difficulties, like the high cost of building infrastructure, the risk of cyber-attacks, and the lack of readiness in handling regulations. The study shows that good governance, careful planning, and ongoing investment are necessary to fully benefit from 5G-powered intelligent transportation systems in Saudi Arabia.

Keywords- 5G Networks; Smart Mobility; Intelligent Transportation Systems; Connected Vehicles; Autonomous Transportation; Smart Cities; Traffic Management; Digital Infrastructure; Saudi Arabia

I. INTRODUCTION

Transportation systems around the world are changing a lot because digital communication technologies are constantly improving. Among these technologies, fifth-generation (5G) wireless networks are a major improvement. They are able to connect a large number of devices simultaneously, have a lower delay, transfer data quickly, and are more reliable. Because of these features, 5G is a crucial technology for intelligent transportation and mobility systems that rely on constant, real-time data sharing to function properly.

Smart mobility means using digital tools and data to make transportation systems better in terms of how well they work, how safe they are, how easy they are to use, and how friendly they are to the environment. Intelligent transportation systems are a key part of smart mobility. They use communication networks, sensors, vehicles, and control systems to watch over and handle traffic conditions. Applications like real-time traffic monitoring, adaptive traffic signals, smart parking systems, connected cars, and self-driving vehicles all need quick and dependable communication systems to work properly. However, traditional wireless technologies like 4G LTE and Dedicated Short-Range Communications (DSRC) often have trouble meeting the strict performance needs of modern transportation systems, especially in busy city areas and on fast-moving roads.

In recent years, Saudi Arabia has seen fast-growing cities, a stronger economy, and more people moving into the country, which has made the transportation systems work harder to keep up. Big cities like Riyadh, Jeddah, and Dammam have problems with heavy traffic, unsafe roads, high fuel use, and harm to the environment. At the same time, traveling long distances by road is very important in the country because of its large size and the fact that people depend a lot on roads for transportation. These factors show that we need smarter and more advanced ways to move people and goods, going beyond the usual methods of managing traffic.

The rollout of 5G networks throughout Saudi Arabia creates a solid technological base for building advanced smart transportation systems. One of the

biggest things 5G brings to transportation is its support for communication between vehicles and everything around them, like other vehicles, pedestrians, and infrastructure. V2X allows cars to talk to each other, to things around the road, to people walking, and to traffic control centers in real time. This ongoing sharing of information helps with features like avoiding collisions, making better route choices in real time, working together while driving, and giving drivers a clearer understanding of their surroundings. In a situation where road safety is still a big problem, these abilities could help lower the number of accidents and make traffic move more smoothly.

Besides helping connected cars, 5G networks are very important for building self-driving and semi-self-driving transportation systems. Autonomous driving systems need fast data handling and almost immediate communication between cars, sensors, and control systems. 5G's very low delay and strong reliability make it good for making important safety decisions. Even though self-driving cars are still new and not widely used yet, test programs and special projects show that using 5G for automated driving is becoming more important in today's transportation systems. Public transportation systems also get advantages from using 5G technology. Smart buses, metros, and trains can use real-time internet connections to better plan their schedules, keep track of how well they're working, and give passengers exact updates about their trips. Tools like predictive maintenance, real-time tracking, and combined ticketing systems help improve how well a business runs and make the experience better for users. In Saudi Arabia, where big investments are being made in new public transport systems, using 5G technology can help create better, faster, and more convenient ways for people to move around.

Even though 5G-enabled intelligent transportation systems have a lot of promise, there are several challenges when it comes to putting them into use. High costs to set up infrastructure, worries about keeping data safe and private, and the need for rules that everyone follows can make it hard for things to be used on a big scale. Putting together new digital tools with the old transportation systems needs thoughtful planning and teamwork from many different groups. In this context, the study looks at how 5G networks affect smart mobility and intelligent transportation

systems in Saudi Arabia. The study looks into how 5G technology improves transportation by making it faster, safer, and better overall, and also finds out the main difficulties and possible future chances for getting 5G used effectively.

II. LITERATURE REVIEW

2.1 Overview of 5G Technology

Fifth-generation mobile communication technology, known as 5G, marks a big change in the ability of wireless networks to connect and transfer data compared to earlier generations. Unlike 4G networks, which mainly focused on faster data speeds, 5G is built to handle very low delays, dependable connections, and support for a huge number of connected devices. These features make it especially good for uses that need quick communication and fast system reactions, like intelligent transportation systems (ITS).

Some research shows that 5G networks can send data really fast, even up to a gigabit per second, and they can also make the delay between sending and receiving data very small, just one millisecond. This performance allows devices to share data almost instantly when they are connected. Researchers say that 5G is not just a small improvement, but a big base for digital systems that helps with advanced tech like edge computing, network slicing, and ultra-reliable low-latency communication. These features are very important for transportation uses because any delays or problems with communication can directly impact safety and how well the system works.

5G is the primary communication system that connects cars, road equipment, sensors, and control hubs in the transportation sector. The ability of 5G to manage a large amount of data while maintaining reliable connections is frequently cited in the literature as a reason why it is crucial for future mobility systems.

2.2 Smart Mobility and Intelligent Transportation Systems

Smart mobility means using digital tools, communication systems, and data analysis in transportation to make it more efficient, safer, easier to use, and better for the environment. Intelligent transportation systems serve as the technological base

for smart mobility by gathering, handling, and sharing traffic information as it happens.

According to studies, Intelligent Transportation Systems (ITS) are utilized for managing traffic jams, electronically collecting tolls, assisting with parking, adjusting traffic lights in response to real-time conditions, managing traffic lights, and providing drivers with up-to-date travel information. These apps work by keeping vehicles, road systems, and traffic control centers in constant contact with each other. Early implementations of ITS used technologies like Dedicated Short-Range Communications (DSRC) and 4G LTE to support their operations. However, the literature points out that these technologies have some limits when it comes to scaling up, delay in performance, and dependable operation, especially in busy city areas.

Recent studies are starting to see 5G as a good answer to these problems. 5G allows for quicker data transfer and reduced delays, which helps support modern intelligent transportation systems features like shared driving, instant danger identification, and changing traffic management. Researchers say that adding 5G to Intelligent Transport Systems makes the system work better and allows for transportation services that were hard to do on a large scale before.

2.3 5G and Vehicle-to-Everything (V2X) Communication

Vehicle-to-everything (V2X) communication is a topic that has been widely talked about in the research on transportation systems that use 5G technology. V2X involves communication among vehicles (V2V), between vehicles and the road infrastructure (V2I), between vehicles and pedestrians (V2P), and between vehicles and the internet network (V2N).

The main goal of V2X communication is to make driving safer and traffic flow smoother by sharing information instantly between vehicles and other road systems. Research shows that using 5G for car-to-everything communication works better than older ways of sending messages between vehicles and other objects. Improved reliability and lower delay help cars send important details like speed, location, sudden stops, and dangerous road conditions almost right away. This feature helps with safety functions like avoiding crashes, warning about sudden stops, and assisting with changing lanes.

In places where people rely a lot on cars, like Saudi Arabia, studies show that V2X communication can greatly help lower the number of accidents and make traffic move more smoothly. Even though there aren't many studies specifically about Saudi Arabia, research from the region and around the world shows that having 5G coverage everywhere helps make it easier to use large-scale vehicle-to-everything technology.

2.4 5G-Enabled Connected and Autonomous Vehicles

Connected and autonomous vehicles are a big step forward in today's transportation systems. The literature highlights that being connected is very important for autonomous driving, because cars need to keep sending and receiving information from sensors, the road system, and control centers to drive safely. The communication system required to handle these operations that require a lot of data and quick response times is provided by 5G networks.

Edge computing must be integrated into 5G networks, according to experts. By handling data close to the vehicle, edge computing reduces communication delays and speeds up the system's response time. Studies and experiments show that self-driving cars that use 5G technology are better at moving around, avoiding obstacles, and communicating with other vehicles and traffic. Even though fully self-driving cars are still being made, studies show that semi-autonomous and connected vehicles are already using fast and quick communication systems.

In countries that are still developing, like Saudi Arabia, studies show that having good infrastructure, strong rules in place, and people's willingness to accept new technologies are key for successfully using self-driving vehicles.

2.5 Smart Traffic Management and Public Transportation

Another important use of smart traffic management is mentioned in the literature. Traffic jams are still a big problem in cities that are growing quickly, which shows how important it is to have smart systems that can watch and manage traffic as it happens. Research indicates that traffic systems using 5G can gather information from cars, sensors, and cameras to make traffic lights work better and deal with accidents more swiftly.

Public transportation systems also benefit from using 5G technology. Studies show that these technologies can be used in different ways, such as following the movement of vehicles, figuring out when parts might need fixing, giving passengers up-to-date information, and setting up payment systems that work well. Fast internet connections help operations run more smoothly and services stay more reliable, which also improves the overall travel experience for passengers.

2.6 Concerns and Unfinished Research in Cybersecurity

Even though 5G-enabled intelligent transportation systems offer many advantages, studies often mention worries about security and keeping personal data safe. Better connections make it easier for cyber threats to attack, especially in transportation systems where safety is very important. Researchers stress the importance of strong cybersecurity systems, safe ways to send messages, and clear rules for managing data.

The literature also points out that there aren't enough studies that look specifically at how 5G affects transportation systems in real-world settings in emerging countries. This study looks at the Saudi Arabian situation and offers information that is useful for both government officials and people involved in transportation.

III. RESEARCH METHODOLOGY

3.1 Research Design

This study uses a qualitative and analytical approach to look at how fifth-generation (5G) networks are affecting smart mobility and intelligent transportation systems in Saudi Arabia. A qualitative approach works best because the study is about learning how technology is used, the bigger effects on systems, and the difficulties in making it happen, instead of just checking if a single number or idea is correct. The analytical design allows for a clear and organized assessment of current ideas, models, and actual applications in 5G-powered transportation systems.

The study is meant to describe and explore things in detail. It tries to find out how 5G technology is being used in transportation, including any patterns, connections, and new developments. This method helps to understand how complex communication networks affect transportation systems in a particular country.

3.2 Research Objectives

The method used is based on these research goals:

- To look at how 5G network features help make smart mobility and intelligent transportation systems possible.
- To look into how 5G technology affects the way traffic is managed and how safe the roads become.
- To look into how 5G technology can be used in systems that connect and control self-driving cars.
- To figure out the main difficulties in setting up transportation systems that use 5G technology.
- Suggest smart ways to properly set up and use smart mobility systems.

These goals help set up a clear plan for gathering and reviewing the data. -

3.3 Data Sources

This study uses only secondary data sources, which are suitable for a research focus on technology and policy. The information comes from scholarly articles published in academic journals that discuss 5G networks, smart mobility, and intelligent transportation systems. Besides that, recent technological advances are also picked up from conference papers, industry reports, and technical white papers that are published by organizations in the telecommunications and transportation fields. Government documents, rules, and public policy reports about digital infrastructure and transportation are also checked. Some real-world examples of transportation projects that use 5G technology are included to help you better understand how it works in different situations. Using several data sources helps check the information from different angles, which makes the results more trustworthy.

3.4 Literature Selection Criteria

To make sure the information was relevant and good quality; certain rules were followed to decide which articles to include and which to leave out. Only studies written in English from the past ten years were included, making sure they are up-to-date and relevant to current technology and situations. The chosen articles are about 5G technology, smart mobility,

intelligent transportation systems, or other related digital infrastructure subjects.

Publications that don't have solid research methods, old studies, or sources that aren't connected to transportation uses were not included. This careful way of choosing sources makes sure the analysis comes from trustworthy and top-quality academic and professional materials.

3.5 Data Analysis Method

The study uses thematic content analysis as the main way to analyze the data. This method is good for finding common themes and patterns in different types of data. The important information from the chosen sources was carefully looked at and organized into groups based on the goals of the study.

The analysis process started with getting to know the data, finding main ideas about what 5G can do and how it's used in transportation, and understanding how the technology's features connect to different results in mobility. The analysis's clarity and uniformity are enhanced by this organized approach

3.6 Validity, Reliability, and Ethical Considerations

Validity and reliability are important to make sure the results of qualitative research are trustworthy. This study makes its findings more reliable by using several trusted sources of existing data, such as articles from respected academic journals, reports from industry organizations, and official policy documents. Looking at results from different sources helps check each other and lowers the chance of unfair or one-sided conclusions. Reliability is ensured because the research used clear rules for choosing which studies to include and kept the same way of analyzing information all through the process, making it easy to understand and repeat.

There are no ethical concerns regarding human participants in this study because it only makes use of secondary data. All sources are properly cited, and academic honesty is kept by honoring intellectual property rights and preventing plagiarism.

IV.   . DISCUSSION AND FINDINGS

4.1 Overview of Key Findings

Looking at studies from academic sources, industry reports, and real-life examples, it shows that fifth-generation (5G) networks greatly help improve smart mobility and intelligent transportation systems (ITS). The results show that the main features of 5G—like very fast response times, strong data speed, and dependable connections—help improve how well and quickly modern transportation systems work.

The results are covered in four main areas: how well traffic is managed, making roads safer, the development of connected and self-driving vehicles, and improving public transport systems. These dimensions match the framework we used in this study and show the main ways 5G helps achieve smart transportation results.

4.2 Impact of 5G on Traffic Management Efficiency

One of the biggest findings from the analysis is that traffic management is working better now. Research shows that 5G technology lets transportation officials track traffic as it happens by gathering information from vehicles, sensors on the roadside, and security cameras. Having access to good, real-time data helps control traffic signals better, manage lanes more flexibly, and quickly spot any problems on the road.

Compared to regular traffic management systems, 5G-based systems react quicker to traffic jams and accidents. Ultra-low latency lets traffic control centers make quick changes to traffic signals and routing plans right away. Because of this, traffic moves more easily, people spend less time driving, and they use less fuel. These results are especially important for quickly growing cities, where traffic causes a lot of stress on roads and transportation systems. The results also show that using advanced analytics and artificial intelligence together with 5G networks can be really helpful. Predictive traffic management systems use real-time data to help officials see traffic jams coming before they happen, so they can act before the problem gets worse. This smart approach helps build transportation systems that perform better and can deal with problems more efficiently.

4.3 Road Safety Enhancement through 5G Connectivity

According to the analysis, vehicles can quickly share important safety information, such as alerts about sudden braking, warnings about possible crashes, and notices about unsafe road conditions, by utilizing 5G to support vehicle-to-everything (V2X)

communication. Smart transportation systems that use 5G technology show big benefits when it comes to keeping roads safe. It is important for safety systems because 5G communication works well and has very little delay. This is very important because even small delays can cause big problems. According to research, the use of 5G in safety systems enables motorists to maintain a higher level of awareness and respond more rapidly, thereby decreasing the likelihood of collisions. These benefits are particularly useful in fast-moving highway settings and busy city areas. Emergency response systems work better when vehicles, traffic control centers, and emergency services can communicate and work together more quickly and efficiently.

The findings show that 5G helps prevent accidents and also makes it easier to respond quickly after an accident, which lowers how bad and harmful road accidents can be.

4.4 Autonomous and Connected Mobility

The findings also demonstrate the significance of 5G in facilitating the proper operation of connected and self-driving automobiles. Computers, roads, and automobiles must constantly communicate. This makes it easier for drivers to move together smoothly, stay safe, and avoid obstacles. According to the analysis, these functions are supported by 5G's fast, reliable communication and good edge computing capabilities. Autos that are completely self-driving are still being tested, but those that are connected to 5G networks or have driver assistance already perform better. Adaptive cruise control, lane assistance, and real-time route optimization all benefit from improved internet connections and faster data processing. Studies also show that using 5G along with edge computing reduces communication delays and makes the system more dependable. The integration of various technologies is regarded as an essential component in the development of smart transportation systems for the future.

4.5 The User Experience and Public Transportation

Another important finding is how 5G technology contributes to the enhancement of public transportation systems. A fast internet connection makes it possible to track vehicles in real time, predicts when maintenance is needed, and gives accurate passenger information. There are fewer issues with day-to-day operations for transportation companies, and customers receive more consistent service as a result.

From the passenger's point of view, getting real-time information about when a vehicle will arrive, any changes to the route, and any service issues helps them feel more satisfied and better prepared for their trip. The results show that using 5G in public transportation helps more people use shared mobility options, which in turn helps reduce traffic and the effect on the environment.

4.6 Discussion of Implementation Challenges

Even though there are good results from the analysis, it also shows that there are some difficulties with 5G-powered smart mobility systems. High costs for setting up infrastructure are still a big problem, especially when trying to cover large areas. As transportation systems become more connected and rely on more data, the risk of cybersecurity threats and data privacy issues also goes up.

Adding 5G technology to current transportation systems needs thoughtful planning, teamwork between organizations, and being ready with the right rules and regulations. The results show that just having better technology isn't enough on its own; it also needs good rules and teamwork from different groups.

V. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study looked at how fifth-generation (5G) networks are affecting smart mobility and intelligent transportation systems (ITS) in Saudi Arabia. The analysis shows that 5G is a key technology that supports modern transportation systems because it offers very fast data transfer, strong connectivity, and almost no delay. These technical features help with instant communication and making decisions based on data, which are important for advanced intelligent transportation systems.

The results show that 5G greatly helps manage traffic better by allowing real-time tracking, adjusting traffic signals as needed, and quickly handling accidents or issues. Better communication between cars, roads, and traffic control centers helps make traffic move more

smoothly, reduces traffic jams, and saves fuel. Road safety improves because of 5G technology that allows vehicles to communicate with everything around them, such as other cars, pedestrians, and traffic lights. This helps give warnings about dangers quickly, avoid crashes, and make emergency responses faster and more effective.

The study also points out that 5G is becoming more important in helping with connected and self-driving vehicles. Right now, fully self-driving cars are still mostly being tested, but vehicles that are connected or semi-autonomous are already showing better results. This is because they can share information more quickly and have less delay in communication. Public transportation systems also gain a lot from using 5G technology. This includes tracking vehicles in real time, predicting when parts might need repair, and giving passengers better and more timely information. These improvements help make the system run more smoothly and make the experience better for people using it.

Even though these benefits exist, the study points out some difficulties that could stop the plan from being used widely. High costs to set up infrastructure, dangers from cyber-attacks and worries about keeping data private, plus the need for rules that everyone agrees on, are still big problems. These challenges show that just having better technology isn't enough on its own. You also need good rules and leadership in place, along with careful planning for the future.

5.2 Recommendations

Based on what was found in this study, there are several suggestions made to help make sure that 5G-powered smart mobility and intelligent transportation systems work well in Saudi Arabia. First, government officials and telecom companies should focus on setting up 5G networks in busy city areas and along important roads, where smart transportation tools can make the biggest difference. Focused placement can help get the most value while keeping infrastructure expenses under control. Second, it's important to create strong rules for keeping information safe and secure, because connected transportation systems have more chances of being attacked or having data leaks. Having clear rules for handling data, safe ways to share information, and ongoing checks on systems are important for keeping important operations safe and

keeping people's confidence. Third, there needs to be a good system of rules and organizations in place to help transportation officials, tech companies, and government leaders work together smoothly. Creating common rules for vehicle-to-everything (V2X) communication and making different systems work together will help things grow bigger and last longer over time. In addition, public transportation companies should use 5G technology for things like tracking buses in real time, fixing problems before they happen, and giving passengers up-to-date information to make their trips better and more reliable. Finally, it's important to support pilot projects and ongoing performance checks to try out new technologies, find any problems that come up during implementation, and use these insights to guide future policies and how money is spent.

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