# PROGRAM GOVERNANCE AND DEPLOYMENT CHALLENGES OF FTTH AND 5G BACKHAUL NETWORKS IN SAUDI SMART CITIES: EVIDENCE FROM RIYADH AND NEOM

## DESAFIOS DE GOVERNANÇA E IMPLANTAÇÃO DE REDES FTTH E 5G EM CIDADES INTELIGENTES DA ARÁBIA SAUDITA: EVIDÊNCIAS DE RIAD E NEOM

**Muhammad Bilal Yousaf***
*Prime Gate for Telecommunications and IT, Riyadh, Kingdom of Saudi Arabia
Orcid: https://orcid.org/0009-0005-4119-4643
laxmi@westernglobaluniversity.us

The authors declare that there is no conflict of interest

## Abstract

The accelerated advancement of digital communication systems has emerged as a major trigger in developing smart cities across various parts of the globe. The programs of digital transformation in Riyadh, Kingdom of Saudi Arabia, as well as developing cognitive cities in NEOM, demonstrate a strong commitment towards developing futuristic communication systems in line with. The underlying foundation of such programs centers upon FTTH, 5G backhaul, along with overall IoT communication systems, as part of such smart city frameworks. This paper refers to the technological foundation as well as the strategic significance of the integration between the technologies of FTTx, 5G backhaul networks, and IoT connections, in the developing Smart City environment in Saudi Arabia. Furthermore, it looks into the infrastructural options related to the technological platform: FTTx access network, wireless backhaul network, as well as IoT communication protocols connecting massive devices. Architectural paradigms to transfer data among IoT devices, network cores, and cloud computing platforms. It talks about the main use cases associated with intelligent cities. It covers important use cases for smart cities, intelligent transportation management, energy management for the city itself, public safety management for citizens, healthcare management for citizens, and environmental sustainability within the city. Apart from this, the paper also covers the economy and the regulatory framework through discussions on relevant partnerships between the government and private organizations, national broadband plans, and the use of the radio frequency spectrum for further enabling the city's overall digitization.It also critically discusses challenges it might face in terms of scalability,

## Resumo

*O avanço acelerado dos sistemas de comunicação digital emergiu como um importante catalisador para o desenvolvimento de cidades inteligentes em diversas partes do mundo. Os programas de transformação digital em Riade, Reino da Arábia Saudita, bem como o desenvolvimento de cidades cognitivas em NEOM, demonstram um forte compromisso com o desenvolvimento de sistemas de comunicação futuristas. A base fundamental desses programas centra-se em FTTH, backhaul 5G, juntamente com sistemas de comunicação IoT em geral, como parte dessas estruturas de cidades inteligentes. Este artigo aborda a base tecnológica, bem como a importância estratégica da integração entre as tecnologias FTTx, redes backhaul 5G e conexões IoT, no ambiente de Cidades Inteligentes em desenvolvimento na Arábia Saudita. Além disso, analisa as opções de infraestrutura relacionadas à plataforma tecnológica: rede de acesso FTTx, rede backhaul sem fio, bem como protocolos de comunicação IoT que conectam dispositivos massivos. Paradigmas arquitetônicos para transferência de dados entre dispositivos IoT, núcleos de rede e plataformas de computação em nuvem. Aborda os principais casos de uso associados a cidades inteligentes. Este artigo aborda importantes casos de uso para cidades inteligentes, gestão inteligente de transportes, gestão energética da própria cidade, gestão da segurança pública para os cidadãos, gestão da saúde para os cidadãos e sustentabilidade ambiental na cidade. Além disso, o artigo também aborda a economia e o quadro regulatório por meio de discussões sobre parcerias relevantes entre o governo e organizações privadas, planos nacionais de banda larga e o uso do espectro de*

security, data privacy, and long-term sustainability, through mitigation techniques that include network slicing, edge computing, and security in the Internet of Things. Finally, this paper aims to illustrate and discuss how the well-planned deployment of FTTH, 5G, and IoT technologies in Saudi Arabia will give an impetus to the development of data-oriented and sustainable smart cities to take the leadership position in the world.

**Keywords:** FTTH Infrastructure. Smart Cities. Network Scalability. Interoperability Challenges. Large-Scale Infrastructure Programs.

*radiofrequência para impulsionar ainda mais a digitalização da cidade. Discute criticamente os desafios que podem surgir em termos de escalabilidade, segurança, privacidade de dados e sustentabilidade a longo prazo, por meio de técnicas de mitigação que incluem fatiamento de rede, computação de borda e segurança na Internet das Coisas. Finalmente, este artigo visa ilustrar e discutir como a implantação bem planejada das tecnologias FTTH, 5G e IoT na Arábia Saudita impulsionará o desenvolvimento de cidades inteligentes orientadas a dados e sustentáveis, para que a cidade assuma a liderança mundial.*

***Palavras-chave:*** *Infraestrutura FTTH. Cidades Inteligentes. Escalabilidade de Rede. Desafios de Interoperabilidade. Programas de Infraestrutura de Grande Escala.*

# 1 INTRODUCTION

Smart cities are a reflection of the latest innovations in urban development studies, wherein the development of physical architecture is accompanied by the incorporation of cutting-edge information technologies. Smart cities are distinguished from traditional ones based on the incorporation of cutting-edge information technologies that ensure the betterment of the quality of life as well as the utilization of resources. At the core of the recent innovations in urban development studies is the incorporation of cutting-edge communication. Among the cutting-edge infrastructures in communication are Fiber to the Home (FTTH) technology, 5G network technology, and Internet of Things (IOT) technology.However, in order to solve these complexities, urban issues like those concerning traffic congestion, the rapid increase in urban energy consumption and degradation, as well as those concerning urban safety, smart city technologies are deployed in order to solve urban issues through smart urban technologies that focus on the efficient integration of urban gadgets and services through digitalization in order to deliver urban needs through efficient urban digital communication platforms in which urban fibers and urban 5G play significant roles in order to allow IoT to deploy all of its capabilities in order to allow smart urbanization through the capabilities that allow all urban gadgets - even Billions of them - to communicate with others in real-time.Saudi

Arabia has clearly emerged as a shining example of a country that is very serious about its smart city development as a whole. As a part of the initiative, this country has clearly dedicated itself to ensuring the development of a non-oil economy, a position of leadership in terms of innovation, and a better quality of life. Digital transformation has clearly been recognized as a very important component of. Huge investments have been made in the development of emerging technologies such as artificial intelligence, cloud computing, and big data analytics. Next-generation communication infrastructures have also seen huge investments.Flagship projects like NEOM and Digital Transformation in Riyadh represent some of the major aspects of Saudi Arabia's commitment to establishing competitive and digital-based cities. This is because they are seen as some of the most ambitious plans towards building a smart city around the world, with its futuristic vision of producing electricity through clean and sustainable energy sources like renewable energy." (The future of energy, n.d.) This is seen as an ambitious plan towards establishing a number of 'cognitive cities' and embedding various aspects of 'connectivity,' 'AI,' 'autonomous systems,' and 'IoT platforms' through this initiative. (NEOM launches infrastructure work for the world's leading cognitive cities, 2020) This requires an exceptional and adaptable communication plan to handle large amounts of information and applications. Similarly, in developing smart cities in Riyadh, there are plans to deliver improvements in terms of mobility, security, and service, as well as environmental sustainability through smart technologies. (Riyadh Strategy Report 2024, n.d.) Moreover, smart traffic management systems, smart street light systems, digital government services, and various other services are dependent on high-end broadband and wireless networks. (Smart City Services, n.d.) Therefore, in terms of delivering high-end bandwidth services to consumers and entities, there are plans to deliver high-end services through FTTH broadband services with its 5G backhaul networks in smart city development activities in Riyadh. (stc group marks major leap in nationwide fiber and 5G rollout, accelerating Saudi Arabia's digital future, 2025) Moreover, IoT networks are required in delivering wireless connectivity to various infrastructure in cities, including energy and waste. (Nikpour et al., 2023)For a smart city implementation to succeed in Saudi Arabia, there needs to be a consideration of not just the effectiveness of employing a particular technology but also attaining various levels of connectivity. FTTH will provide a platform that will increase the reliability of fixed broadband as well as data

connectivity. Similarly, 5G backhaul will create an additional platform that will increase the reliability of fixed broadband, along with mobile broadband services that have the added advantage of low-latency connectivity, necessary for a variety of very high-speed IoT services that will need to be deployed over a large area. IoT will enable interaction between the physical world and the digital world through connectivity, allowing data processing that creates smart insights.Despite such great opportunities identified with FTTH, 5G technologies, and IoT technologies, there are many challenges identified pertaining to the development of 5G technologies along with FTTH and IoT technologies. Some of these challenges include high costs that are to be incurred while developing the infrastructure for FTTH technologies to be deployed in smart cities, costs of development that are to be incurred while carrying out the network planning to be done with 5G technologies to be deployed in smart cities, etc. (Saudi Arabia 5G Technology Market Performance Trends &Growth Forecast Report 2030, 2025) Although reference is given to the very important role of spectrum policy in smart cities, there are also clear indications of numerous challenges associated with spectrum policy as well. Out of these challenges, there can also be identified challenges pertaining to the high deployment costs of spectrum policy in smart cities, etc. This present paper aims to discuss the technologies, deployment plans, and strategic considerations behind the deployment of FTTH access networks, 5G backhaul networks, as well as IoT communication infrastructures in the context of the smart city development plan in Saudi Arabia. This present study further discusses how technologies in FTTH networks, 5G communication infrastructures, as well as IoT communication technologies, are included in the emerging smart cities in Saudi Arabia, including Riyadh, NEOM, and other smart city development initiatives within the Saudi Arabian context. This present study further aims to highlight a host of issues pertaining to smart city development in the context of Saudi Arabia's plan. Accordingly, it may be understood that this present study aims to provide insights into how communication infrastructures are leveraged to ensure the development of sustainable smart cities in Saudi Arabia.

## 2 TECHNOLOGICAL FOUNDATIONS

### 2.1 Fiber-to-the-Home (FTTH)

FTTH simply implies the deployment of fiber optical connections to homes and establishments to enable large throughput and minimum latency. It acts as the backbone of current information and communication technologies. (The 5G Fixed Wireless Access growth in KSA, 2023) It promises more speed in comparison to copper-based technologies. (Saudi Arabia's High-Speed Internet Revolution: Fiber Booms, 5G Soars, and Satellites Race to Connect the Kingdom, 2024)

The advantages of FTTH are:

- "Gig infrastructure" to enable high speeds needed by data-intensive applications such as video service providers, cloud computing service providers, and providers of their own
- Future scalability – Optical fibers are scalable with high bandwidth capacity and negligible additional costs. (Geravand et al., 2025)
- Less signal loss during long-distance transmission compared to conventional media. (Petrovich et al., 2025)With regards to this case in Saudi Arabia, government-driven efforts in enhancing broadband access, especially in unconnected areas, have significantly contributed to the increase in broadband access in the nation. (5G and other innovative technologies to encourage ICT growth in Saudi Arabia, 2020) The players, like Dawiyat, contributed to the increase in broadband access under the FTTH through their efforts in covering millions of homes across the nation. (Dawiyat Integrated installs 25K fibre optic cables in some Saudi cities, 2020)

FTTH acts as the access layer for both institutions and residences as well, giving them the needed base that can support different smart services. (STC Expands FTTH Network to 600,000 New Locations in Saudi Arabia, 2013)

## 2.2 5G backhaul networks

This is a tremendous leap from a 4G network to a 5G network and is capable of enabling:

• Enhanced Mobile Broadband (eMBB) for high throughput.

• Massive Machine-Type Communications (mMTC) – to be specially developed for

• Ultra-Reliability Low-Latency Communications (URLLC) for various missions 5G backhaul can be described as a connection found in a network that connects the core network to the 5th generation radio access network itself. This connection has been an integral part in creating an effective connection that will be efficient for a 5G network in meeting both its data rate and latency demands in an effective manner. (Yang, 2025) The backhaul network used in smart cities is the interconnectivity between the various DWNs and processing centers or data centers. It provides connectivity for: Real-time video surveillance and public safety solutions. Smart Traffic Management & Smart Vehicle Operation.

• Distributed sensor networks with high reliability requirements. Similarly, in the case of Saudi Arabia, the telecommunication firms like Saudi Telecom Company (STC), Zain KSA, Mobily, and others have been growing their 5G technology base quickly and growing in the large geographical zones like Riyadh, NEOM, and others. (Saudi Arabia's Telecommunication Services Market 2025–2029: Strategic Capital Allocation in a 5G-Driven Digital Transformation, 2025) The 5G backhaul not only provides high-speed connectivity, but it also supports solutions such as network slicing, which will play a key role in smart city solutions. (E& UAE Launches 5G Slicing for Businesses, Nokia STC Network Slicing PoC Over GPON and More, 2025)

## 2.3 Connectivity of IoT

Internet of Things:

In plain words, the 'Internet of Things' is an IoT ecosystem that includes an interrelated group of devices, persons, physical objects, and digital objects, each

containing sensing devices, actors, objects, services, information sources, and communication devices that can be interconnected in the use of the possibility to collect, exchange,

• Transportation and traffic networks

•Observe environmental conditions: air quality, weather, and waste management

• Public Safety and Emergency Response

Energy Management and Smart Grids

They are also applied in the following:

• Healthcare monitoring systems

IoT systems often use multiple forms of network connectivity.

• Low-Power Wide Area Networks - LPWAN intended for battery-powered NB-IoT or LTE-M-cellular IoT on 5G for :

• Short-range wireless: Wi-Fi/Bluetooth for local clusters.

For example, smart cities require a heterogeneous approach: wide area networks are combined with high-speed wireless systems.

*2.3.1 Saudi Arabia's and smart city strategy*

It was one about digital transformation, about a diversified economy, and improvement in the quality of life in this country for the year 2030. The infOTEstructure-the biggest investment in digital transformation-will actually develop a competitive city on the world scene.

**Figure 1**

*Saudi Arabia's and Smart City Strategy*
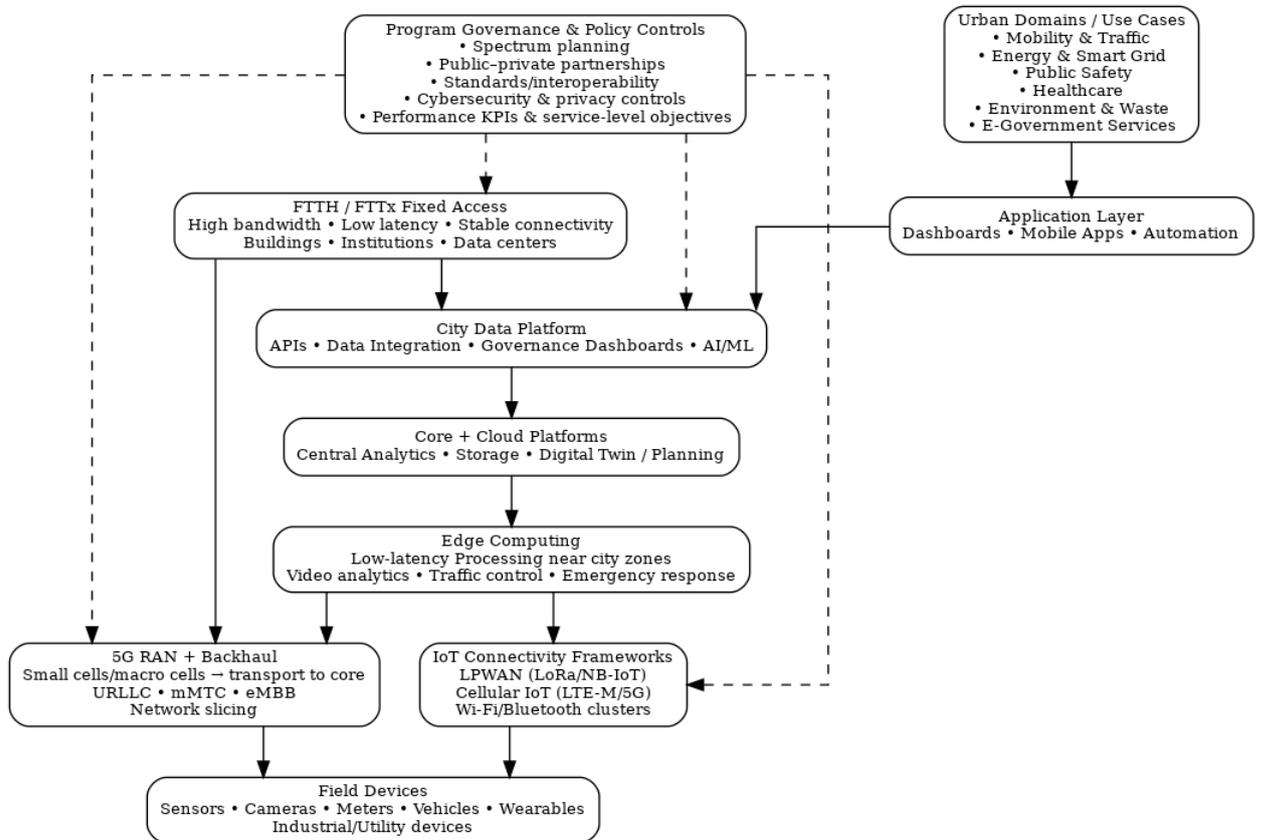


## 3 SMART CITY INITIATIVES IN RIYADH

Being the capital city with the largest population in the Kingdom of Saudi Arabia, there are numerous projects put in place within the digital framework in handling traffic management systems within the city of Riyadh. Development in artificial intelligence lighting also features, along with integrated services and electronic government systems. Digital City in Riyadh is a technological park developed to act as a pioneering step in IT development.

On the local front, multilateral cooperation is well on track, especially with local and international organizations like Tata Communications with Zain KSA to integrate intelligent street lighting, waste management initiatives, connected workplaces, and IoT technologies within Riyadh City. Such a specific organization of efforts reflects the potential of 5G technology and IoT capabilities to change the lives of citizens for good.

## 3.1 NEOM and cognitive cities

NEOM will be one of the largest smart cities in the world and a role model for an urban environment where cognition plays an important role in connecting with AI, robotics, and other connected environments and networks around the world. STC is tasked with providing all 5G and IoT infrastructures to NEOM. NEOM's cognitive cities will be empowered to share and analyze information with residents and:

• Smart Homes and Buildings

Autonomous Transportation Networks

• Pubic safety systems

Industrial IoT Applications

Thus, highly developed 5G technologies are integrated in an attempt to make functions like these possible much sooner, up to ten times faster than those of 4G, and with near-zero latency to power mission-critical IoT applications.

## 4 INFRASTRUCTURE INTEGRATION & ARCHITECTURAL CONSIDERATIONS

### 4.1 Riyadh smart city initiatives

The same said host of events regarding smart cities must be at the forefront of advancing this interest of the kingdom in smart cities in particular. As it is a capital and the biggest metropolitan in Saudi Arabia, it has undertaken various initiatives in regards to its journey towards digital transformation in forms of efficiency, mobility, sustainability, and service delivery in a manner that it fits well in regards to achieving goals in utilizing advanced forms of communication technologies like FTTH, 5G, IoT, etc.Among the significant areas of strategic priority in the smart city vision of Riyadh lies intelligent traffic management. Through the integration of connected sensors, intelligent traffic lights, and even data analytics in intelligent sensors, the authorities in Riyadh are enabled to properly address and monitor the extent of congestion in order to enhance travel time. (Adaptive Traffic Light Management for Mobility and Accessibility in Smart

Cities, 2025) Supporting the vision of intelligent and more efficient techniques lies intelligent lighting. It involves the utilization of IoT lights to reduce costs by matching lighting with the density of the surrounding environment. (Leveraging advanced digital technologies for smart city development in Saudi Arabia: opportunities, challenges, and strategic pathways, 2023, pp. 1-12)At the same time, Riyadh has been doing an impressive job in integrating public services through the help of electronic governance technologies as well. This enables citizens as well as resident communities to make use of any government services they might require through an easy-to-use platform, aiming at further transparency in services as well as efficiency in governance processes as a whole. (Saudi Arabia ranks 4th and Riyadh 3rd globally in digital services, 2025) This has a special demand for fiber-optic technology to be employed as a secure medium of communication through data networks, which are free from any kind of disconnections or interruptions in services. (Saudi Arabia Fiber Optics Market Value To Hit USD 1,390.0 Million By 2033, Expanding At 8.10% CAGR, 2025)In the same vein, the initiative by the government to create the "Digital City" in Riyadh provides an iconic sense of the city's dedication to fostering an environment for the nurturing of innovations and technology-based growth. As one of the best technology parks in the land, the "Digital City" houses information technology companies, centers for research and startups, and multinational technology corporations. (Digital City (Riyadh), 2024) Collaboration for innovations creates an enabling environment through the prevalence of the highest fiber connectivity and comprehensive data infrastructure for the promotion of cloud computing and software development. (Saudi Arabia ICT New Data Center Strategy to Accelerate AI and Cloud Expansion, 2025)These partnerships will add more power and energy to the smart city system in Riyadh. Partnerships with companies that specialize in smart city solutions, such as Tata Communications and Zain KSA, also show that global expertise is a driving factor in smart city solutions. These partnerships will lead to smart city solutions in terms of street lighting, waste management, smart workplaces, and IoT solutions in Riyadh. (KSA, 2022) The combination of 5G networks, along with IoT solutions, is a step towards creating more convenient and efficient solutions in people's day-to-day lives, as well as in enhancing efficiency in smart cities. (Yang, 2025)

## 4.2 NEOM and cognitive cities

One of the most ambitious projects in developing a smart city and a regional development of any kind globally, NEOM has thus been seen and designed to be a futuristic urban system with a presence of intelligence and a high level of sustainability within its system. It will represent a system of cognitive cities with a high presence of artificial intelligence, robotics, and connectivity. Amongst various other smart cities, NEOM has the differentiation of having not just been retrofitted with a high presence of intelligence, but having had its presence and creation from its very inception. (NEOM launches infrastructure work for the world's leading cognitive cities, 2020)The connectivity infrastructure of NEOM will also prove a key enabler to this vision. In this context, Saudi Telecom Company has signed a contract for the deployment of cutting-edge 5G and IoT infrastructure solutions within the region, including the introduction of a base-layer digital infrastructure that will facilitate the enablement of future services. (NEOM launches infrastructure work for the world's leading cognitive cities, 2020) The proposed infrastructure will enable the use of ultra-high-speed data transmission, massive connectivity, and ultra-low latency, as mandated by real-time analytics and mission-critical applications. (Yang, 2025)NEOM cities shall be continuously collecting, exchanging, and analyzing data between residents, infrastructure, and urban systems. Also, this data-driven approach shall allow proactive management of cities in many ways:

• Smart home and smart buildings, through which the monitoring and optimization of various factors such as consumption, security access, and surroundings is controlled automatically. - Autonomous transport network means connected vehicles, smart roadways, and AI-enabled coordination of transportation. • Advanced Public Safety Solutions: facilitated by real-time monitoring, predictions, and automation of response actions. Industrial IoT Services – including support for smart manufacturing, logistics management, and predictive asset management.It is expected that the deployment of high-end 5th Generation Networks across the territory of NEOM will ensure that the speed of the connected devices will be ten times more than what can be readily achieved today by the conventional 4th Generation Networks, while at the same time providing ultra-low latency times for the connected devices (Yang, 2023), thereby creating an epitome for smart cities of the future across the globe using 5th Generation Networks as the solution

for high-speed IoT networks while traditional wired networks will be the solution used for the traditional backhaul networks within the territory of NEOM itself. Consequently, in a brief recapitulation, it can now be seen that within this context, the Riyadh scenario, as well as that of NEOM, represents a validation of the construct that in the well-articulated plan that has come to be referred to as Vision 2030, smart cities are a crucial part of that scheme through the applications of the latest advanced connections, or what can also be referred to as infrastructure, in the creation of cities that are not only sustainable, cogitated, smart, but also globally competitive. (NEOM launches infrastructure work for the world's leading cognitive cities, 2020)

## 4.3 Challenges and solutions

Although the technologies in question—namely FTTH, 5G backhaul, and IoT connectivities—create the technological foundation for smart cities to be built upon, the deployment of such technologies presents various technical, operational, and governance-related challenges. These challenges have to be addressed in such a manner as to ensure the viability, sustainability, as well as both social acceptability and security related to smart city implementations. (Yang et al., 2022) This section presents some of the most pressing smart city-related technological challenges: scalability, as well as coverage-security/privacy.

## 4.4 Scalability and coverage

**Figure 2**

*Key Deployment Challenges*
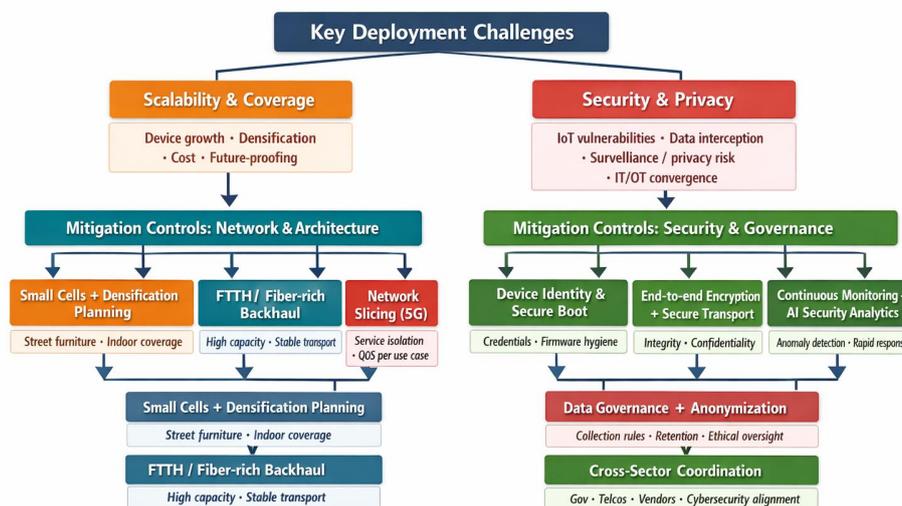


One of the defining factors of a smart city is the scale on which a tremendous number of devices maintain a state of connectivity. Cities such as Riyadh and NEOM have the potential to accommodate millions of such smart devices. (NEOM ties up with STC for developing world's leading cognitive cities, 2020) This range of devices extends from mobile phones and sensors to cars, smart utilities, industrial devices, and city infrastructure. Therefore, this has raised a number of scalability issues. (Kumar et al., 2023)

**Challenges:** A major problem occurs in terms of network densification. For a high-density deployment of a cellular network, as well as 5G, numerous macro cells and small cells are necessary. Moreover, indoor solutions are required. Other issues in terms of deployment come with high-rise buildings and complicated 5G deployment regulations within a densely populated metropolitan area. Besides those challenges, time and costs are associated with FTTH and 5G backhaul's deployment using numerous fiber-optic cables. (Ghadialy, 2024) Moreover, scalability issues will be exacerbated further by the fact that some areas will have more frequent flow, such as business areas, stations,

sporting venues, and business hubs, where demand will exceed normal usage many times over. (Overcoming Scalability Challenges in Smart City Projects: A Case Study, 2022) Another issue that should be highlighted is future-proofing. It should be noted that smart cities will require long-term planning, in the sense that the infrastructure deployed will have to take into account the potential exponential increases in device density, data volumes, and sophistication that could be expected in the future. (Romualdo-Suzuki & Finkelstein, 2020)

**Solutions**: To address scalability and coverage issues, a smart city needs to implement a multi-layered architecture. With FTTH and 5G backhaul, a smart city can achieve flexible traffic distribution capacity. This is mainly based on the needs of FTTH, which has virtually limitless capacity for applications such as high-density fixed environments. (Browning et al., 2017)The deployment of small cells is another important strategy for enhancing coverage and capacity in areas with high user density and is normally deployed on street furniture and public infrastructure. This will serve to enhance and relieve some of the demand on macro cells. The deployment of these cells is normally done using a form of backhaul called fiber backhaul, thus highlighting the significance of FTTH. (Small Cell Backhaul Market Size & Share [2035], n.d.) Network slicing will provide a further option for scalability with the advent of 5G technology; this will enable the sharing of physical resources between various virtual networks. This will ensure optimum performance of slices with respect to various services or scenarios they will support. (Network Slicing in Virtualized 5G Core with VNF Sharing, 2023)

From the planning point of view for the future, geospatial analytics and AI-driven tools for intelligent network planning can help identify areas for coverage, traffic prediction, and efficient infrastructure planning. In the case of greenfield cities such as NEOM, these tools can be used for designing the networks almost from scratch to ensure that losses and inequalities in coverage can be addressed uniformly. (Afroosheh & Askari, 2024)Finally, the use of open standards helps ensure that smart city networks can be upgraded incrementally as technology improves, allowing the integration of technologies without the need to replace existing infrastructures. This idea follows perfectly the sustainability strategy laid out to ensure economic efficiency in the future. (Al-Khouri & Al-Khouri, 2023)

**4.5 Security and privacy**

**Figure 3**

*Key Deployment Challenges*
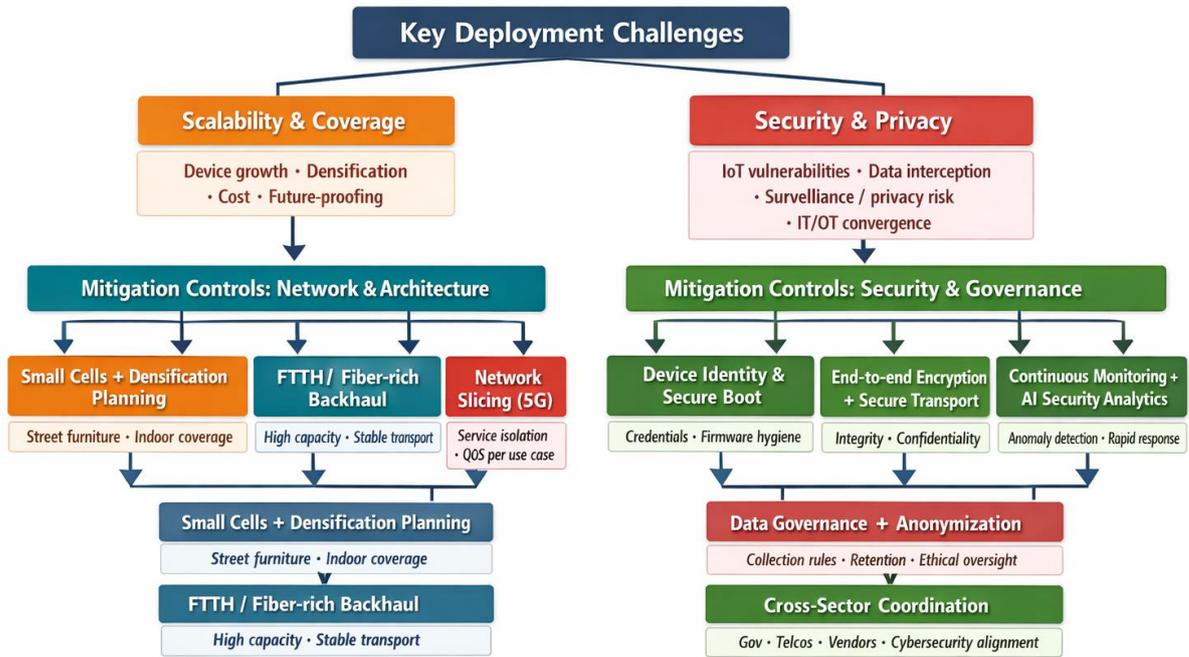


With smart cities becoming more technological and data-intensive, the issue of security and privacy becomes an area of great challenge in the future. Furthermore, the IoT environment increases the vulnerability to attacks since it entails various devices with limited computing abilities. Therefore, the impact of a cyberattack in smart cities could be significant in the sense that it would threaten crucial services as well as sensitive information. (The Rising Demand for Smart Cities Cybersecurity Professionals in the Middle East, 2025).

*4.5.1 Challenges*

A major concern in security threats in IoT systems is device authentication and identity management. Generally, most IoT systems are deployed in large numbers and

often operate over a long period with little maintenance. Weak authentication processes, default credentials, and obsolete device firmware are some of the risks. (Top IoT Security Challenges and Strategies for Protection, 2023)Another significant security issue to address relates to data transmission security. There will always be data transmission between different smart city-based applications and devices. Thus, without sufficient encryption of data being transmitted, the problem of intercepted and manipulated data can prove to be quite significant. Not to mention that this problem becomes even more severe in the case of mission-critical smart city applications. (Cybersecurity Implications for Smart Cities and Connected Infrastructure, 2025).

The challenges related to privacy issues stem from handling large amounts of collected and processed personal or behavioral data. The smart cameras, mobility trackers, and smart public infrastructures provide large amounts of data that could potentially uncover various details about a person's movement, behavior, and identities if managed inappropriately due to inadequate data management. (Protecting Personal Data in Smart Cities: The Role of Privacy Tech, 2023)

Further, the integration of information technologies (IT) and operational technologies (OT) in smart cities creates a blurring of security boundaries, as industrial internet of things (IoT) systems managing services like utilities and transport need to be made secure against cyber threats that could affect safety. (Mosteiro-Sanchez et al., 2022).

### 4.6 Solutions

Overcoming security and privacy issues demands that we implement security in depth across all architectural layers. At the device level, implementing secure boot processors, hardware security modules, along with proper device credentials, ensures that we allow proper or enhanced device connections to the network.For transmitting data, end-to-end encryption and secure communication have to be established. 5G is known to have vastly improved security features compared to earlier generations. New 5G features include improvements to authentication, integrity, and isolation. In this way, when fiber is used as a backhaul option, a secure environment is established for transmitting data. (5G Security: Everything You Should Know For a Secure Network, 2023)At the platform

level, the implementation of security management with monitoring can facilitate the early detection of abnormalities or cyber threats. AI-driven security analytics need to be able to recognize unusual patterns or behaviors so that the response can be swift. (Koli et al., 2025)The protection of individual rights to privacy necessitates well-structured data governance systems that outline rules of collection, storage, processing, and sharing of data. Data anonymization and other related measures aim to cater to the need for protecting individual information while promoting the importance of extracting valuable analytics from it. Additionally, it is important to adhere to various regulations set to promote public trust in smart cities' systems. (Trust, Privacy and Security for Smart Cities, 2023)

Lastly, cross-sector cooperation and collaboration with various actors in the sector, including government entities, telecom service providers, vendors, and tech and cybersecurity experts, would be crucial. For instance, in Saudi Arabia, developing a harmonized smart city security strategy with national cybersecurity strategies would facilitate a cohesive and strengthened security mechanism. (National Cybersecurity Strategy, n.d.)

## 5 CONCLUSION

With continuous investments in Fiber to the Home and Fifth-Generation technologies to enable backhaul and IoT connectivity, for example, the Kingdom is believed to have taken up an educated approach, one that is anticipatory in nature, to the reformation of its urban landscape in line with the goals and objectives espoused Initiative, as its smart urbanization capabilities make use of such technological capabilities to transcend the boundaries and possibilities of traditional urbanization possibilities and models.

For this, we consider two examples of smart city projects in Riyadh and NEOM. FTTH will be logically required to deploy high-capacity, low-latency connectivity, which is crucial for fixed broadband access, enterprise environments, and public sector applications. Similarly, 5G backhaul would be needed to extend the same amount of resources towards mobile users, autonomous environments, and IoT infrastructure. (Telecom, 2025) This way, all environments will be able to receive seamless connectivity

without discrimination based on their differences. IoT supports various interconnectivity levels and further enhances the system through IoT-based connectivity that allows for real-time sensing, monitoring, and support in various key areas of a city requiring strategic planning and monitoring, with a need for improvement: transportation, energy, public safety, healthcare, and sustainability are just a few examples. (Alanazi, 2023) The IoT enables city infrastructures since it connects edge computing and analytics platforms, hence allowing timely decision-making; the processing occurs as close to where the data is available as possible, which is critical for mission-critical situations. (Nduka, 2024, pp. 127-145)

In addition to the technological progress that these projects represent, it is the direct applications of these activities that will achieve the ambitious plans of the economy and society outlined by the government under the vision whose pillars are the economy and society. The economy has much to expect from this area since most of them promise foreign investments and high-skilled employment opportunities in areas like telecommunication services and related emerging fields that include artificial intelligence and cybersecurity. (Saudi Arabia - Information and Communications Technology, 2023)

However, to ensure the successful outcome of these intelligent city initiatives, it should be noted that the deployment of the infrastructure is just one aspect, and a lot more: governance, security measures, and sustainability strategies assume greater importance. Challenges associated with the success of these initiatives lie in handling issues associated with scalability, security measures, data privacy, and energy sustainability. (Mutambik, 2024) Saudi Arabia thus remains at an advantageous position compared to other potential competitors with its thrust on integrated planning, the use of private-public associations, and the need to update its regulatory framework itself. (Saudi Arabia's Giga-Projects, n.d.) Hence, in conclusion to the above paragraphs concerning the technological developments in Saudi Arabia in the fields of FTTH, 5G backhaul technologies, and IoT technologies, it may be asserted that the integration of these technologies in the Kingdom takes the position of the smart city to the highest echelon globally. (Emerging Technologies Adoption Readiness in Government Agencies 2025, n.d.) With the integration of technologies such as IoT within the corporate objectives across Saudi Arabia, a future-proof smart city environment is built to assure the sustainability of urban living in Saudi Arabia.

# REFERENCES

1. Digital Government Authority (Saudi Arabia). (2023). Digital Government Strategy 2023–2030.

2. Digital Government Authority (Saudi Arabia). (2024). Digital Transformation Measurement 2024.

3. Riyadh Municipality. (2025). Riyadh Municipality Digital Transformation Strategy (report/overview).

4. Royal Commission for Riyadh City. (2024). Riyadh City Strategy / Strategic Plan (smart city & digital transformation components).

5. NEOM. (2020). NEOM launches infrastructure work for the world's leading cognitive cities (press release).

6. Saudi Telecom Company (stc). (2020). Annual Report 2020.

7. Communications, Space & Technology Commission (CST). (2023). Spectrum Outlook 2021–2023.

8. International Telecommunication Union. (2020). How Saudi Arabia is opening access to ultra-fast broadband connections.

9. International Telecommunication Union. (2020). WSIS case story: Saudi Arabia ultra-fast broadband / FTTH national broadband plan.

10. GSMA. (2024). The Mobile Economy: Middle East & North Africa 2024.

11. GSMA Intelligence. (2024). IoT market forecast to 2030: Connections by region and vertical.

12. 5G Americas. (2020). Innovations in 5G Backhaul Technologies: IAB, HFC & Fiber (white paper).

13. 5G Americas. (2023). Transport Networks for 5G (white paper).

14. International Telecommunication Union Radiocommunication Sector (ITU-R). (2020). Report ITU-R M.2410: Requirements related to technical performance for IMT-2020 radio interface(s).

15. 3rd Generation Partnership Project (3GPP). (2022). TS 23.501: System architecture for the 5G System (5GS) (Release 17).

16. European Telecommunications Standards Institute (ETSI). (2023). ETSI White Paper No. 59: Enabling Multi-access Edge Computing in Internet-of-Things: how to deploy ETSI MEC and oneM2M.

17. oneM2M. (2023). Enabling Multi-access Edge Computing in the Internet of Things (WP59 overview/summary page).

18. Organisation for Economic Co-operation and Development (OECD). (2023). Data governance for smart cities (policy report).

19. National Institute of Standards and Technology (NIST). (2020). SP 800-207: Zero Trust Architecture.

20. National Institute of Standards and Technology (NIST). (2020). SP 800-53 Rev. 5: Security and Privacy Controls for Information Systems and Organizations.

**Authors' Contribution**

All authors contributed equally to the development of this article.

**Data availability**

All datasets relevant to this study's findings are fully available within the article.

**How to cite this article (APA)**

Yousaf, M. B. (2026). PROGRAM GOVERNANCE AND DEPLOYMENT CHALLENGES OF FTTH AND 5G BACKHAUL NETWORKS IN SAUDI SMART CITIES: EVIDENCE FROM RIYADH AND NEOM. *Veredas Do Direito*, 23(4), e234548. https://doi.org/10.18623/rvd.v23.n4.4548