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Conceptual Business Model Framework for AI-based Private 5G-IoT Networks

Laurence Banda [1]

[1]Wits Business School (WBS), University of the Witwatersrand, Johannesburg, 2050, South Africa

*Corresponding author: Laurence Banda, +27 834282216, laurencebandad@gmail.com

ABSTRACT: The fusion of fifth generation (5G) networks, Internet of Things (IoT) and artificial intelligence (AI), referred to as intelligent connectivity by most industry experts, can be seen as a crucial success factor for sustainable digitalization. Until recently, research into these key triad technologies has been conducted in isolation. One of the promising applications of intelligent connectivity is wireless private networks. This article presents a conceptual business model framework that can be adopted by AI-driven private 5G-IoT networks. These emerging and disruptive private networks will certainly change the mobile business landscape. Private network operators should therefore rethink and adapt their business models in order to remain economically competitive, create innovative mobile services and support sustainable practices.

KEYWORDS: 5G, Artificial Intelligence (AI), Business Model, Conceptual Framework, Internet of Things (IoT), Private Networks

1. Introduction

Fifth generation (5G) networks are being widely deployed around the world with the hope that these cutting-edge mobile systems will contribute to the sustainable digital transformation and economic prosperity of society [1]. With the introduction of more affordable devices and the expansion of commercial 5G mobile networks, customer and business interests in the market are increasing rapidly. Furthermore, the Internet of Things (IoT) and artificial intelligence (AI), which are revolutionizing our modern world through digitalization, have been enabled in large part by 5G networks [2].

IoT technologies pervasively connect natural and artificial objects and people across all network infrastructures [3]. Furthermore, IoT is considered a multidisciplinary field that encompasses numerous areas, including natural ecosystems, infrastructure, public services, social activities, technology, and the business and economic sectors [4]. The aim is to create innovative network architectures, applications and services based on smart IoT networks and smart sensors based on the 5G-IoT technology standard. 5G-IoT is therefore expected to generate massive amounts of sensor data, which requires machine learning (ML) to analyze and make intelligent decisions.

AI is a relatively new technical science that studies theories, techniques, tools and application systems that mimic and enhance human intelligence [5]. In particular, through massive data learning, machines mimic human thinking and behavior. AI is a remarkable technology with applications that cannot be fully covered by traditional methods as current solutions require advanced automation and optimization. Mobile networks in particular generate large amounts of data and make them amenable to machine learning (ML) optimization techniques. Therefore, the application of AI to networks actually refers to the use of AI/ML methods to develop supporting functions for network optimization, configuration and management operations.

The foundation of "intelligent connectivity," as some have termed it, is the combination of 5G, IoT and AI [2,6]. This is the beginning of an era characterized by ubiquitous hyper-connectivity and highly contextualized and personalized experiences. Almost every aspect of our everyday lives could be affected, including the way we work and interact with colleagues, as well as the way we

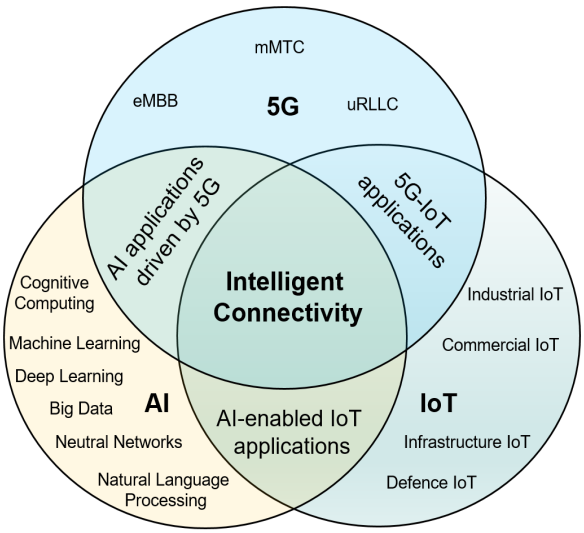

Figure 1: Fusion of 5G, IoT and AI for intelligent connectivity

consume digital entertainment [7]. Consequently, the convergence of 5G, IoT and AI will improve the quality of goods and services, lead to significant productivity gains and enable more effective use of global resources by both businesses and consumers. Key applications of intelligent connectivity include industrial IoT (iIoT), sustainable smart cities, Industry 4.0, and network security [2,6,7]. Figure 1 shows the fusion of 5G, IoT and AI for intelligent connectivity.

The 5th Generation Partnership Project (5GPP) has standardized private networks to provide specialized wireless connectivity with improved communication qualities, optimized services and tailored security features in specific locations [8]. These wireless local area networks are deployed in isolated and remote areas that are not adequately covered by traditional public cellular networks. 5G, IoT and AI are arguably the three most revolutionary technologies of the current decade. The three technologies were used independently until recently and each has exceeded our expectations. It should come as no surprise that adoption or integration of 5G, IoT, and AI is expected to increase as more businesses embrace the data trend. In addition, the combination of 5G, IoT and AI technologies has increased the number of network partners. To remain sustainable and profitable, AI-based private 5G-IoT network operators must therefore realign their business models.

This study contributes to the development of innovative business model solutions for novel triad technologies (5G, IoT and AI). In particular, the paper aims to contribute to research, development and innovation in AI-based private 5G-IoT networks by proposing a conceptual business model framework that can be adopted by operators of such networks. The article also presents some considerations for the cross-sector implementation of business models. Furthermore, the article is a continuation of our research publications on business models for 5G mobile network operators (MNOs) and private 5G-IoT networks [9,10]. The proposed business models are viewed from both a strategic and technology theoretical perspective. The rest of the article is structured as follows. Section II highlights related works from the literature. Section III discusses private 5G-IoT networks with AI capabilities. Section IV presents the proposed conceptual business model framework, while Section V discusses industrial applications of the proposed conceptual framework. Section VI concludes the article.

2. Related Work

Recent developments in 5G wireless networks, IoT and AI have led to attempts to review relevant literature. Specifically, [11] essentially conducted a techno-economic analysis of private 5G network architectures. To accelerate the achievement of return on investment (RoI) by private network operators and other third parties, the paper focuses primarily on cost elements associated with the network deployment of private 5G networks. However, the paper ignores other crucial elements of the AI-based private 5G IoT network value chain, such as the value proposition, customer interface and infrastructure management. In [10] new business models for private 5G-IoT networks were presented. The study first develops a conceptual framework for the private 5G-IoT network value chain and then describes several business models relevant to different use cases and vertical markets. Nevertheless, the authors' study did not address the AI component.

A theoretical framework for Internet of Everything (IoE) applications for creativity in the context of 5G and 6G ecosystems was introduced in [12]. The study discusses issues with the IoE-based business platform. This is particularly about creative, cross-domain business solutions that cover different application paradigms and business platforms. However, the authors of [12] did not identify the industry's vertical target customers. Business model options for 5G and future mobile network operators were discussed in [10,13]. The paper first outlines the limitations of current business models for mobile network operators, before presenting new business models for 5G and future networks that mobile network operators should consider when introducing such networks. There was more focus on traditional or public 5G networks, while less attention was paid to private 5G networks. A business model agenda for 5G and 6G players is discussed in [14]. The authors' work focuses on the telecommunications ecosystem and emphasizes the significant changes in business models brought about by 5G. In addition, potential future business models beyond 5G and 6G are identified and attention is drawn to the respective business opportunities of the players. However, important new technologies such as IoT and AI enabled by 5G and 6G networks were not taken into account.

This article differs from previous related works in that it exclusively addresses business models for AI-powered private 5G- IoT networks using a conceptual framework; it highlights some of the key concerns of private network operators related to certain AI-driven 5G-IoT business models; and it highlights some of the economic benefits and concerns associated with integrating 5G, IoT and AI technologies.

3. AI-based Private 5G-IoT Networks

The introduction of 5G operational networks, which are almost mature, is followed by the concept and architectural design of AI-powered private 5G-IoT networks. The GSMA estimates that around 65% of the world's population will have access to 5G and high-speed mobile internet connectivity by the end of 2025 [9]. Proper deployment of new technologies such as sensor-based and AI-powered IoT, integrated with the 5G Machine Type Communication (MTC) ecosystem and associated smart industries, will enable the growth of new smart industries and drive digitalization.

3.1. 5G-IoT-AI Integration

By integrating AI into 5G IoT networks, millions of simultaneous intelligent connections are expected across a range of smart devices, automated machines, connected homes, smart grids, and smart transportation systems [9]. The idea behind intelligent connectivity is to use 5G, IoT and AI together to accelerate technological advancement and open up new, disruptive digital services [7]. In the context of intelligent connectivity, artificial intelligence (AI) technologies will analyze, contextualize and present the digital data collected by the machines, devices and sensors of the 5G-IoT networks to users in a more meaningful and useful way [6]. This would facilitate the delivery of personalized experiences to users and improve decision-making, leading to richer and more satisfying interactions between individuals and their environment.

Intelligent connectivity aims to achieve several key goals, including enhanced communication reliability, higher data rates, multiple sensor connectivity, and incredibly low power consumption [15]. However, the integration of 5G, IoT and AI faces implementation challenges due to different platforms, including: device platform (e.g. radio frequency security and device battery life), application platform (e.g. centralization constraints), and the central network platform (e.g. enabling always-online services) [15]. By dividing the physical network infrastructure into multiple logical networks (slices), each with unique service requirements and performance standards, network slicing technologies can help resolve these issues [9,16].

3.2. The Concept of AI-driven 5G-IoT Networks

A private 5G network, also known as a non-public 5G network, is a local area network that provides dedicated wireless connectivity within a specific area. Its owner can manage the network independently and has complete control over all aspects of the network, including resource scheduling, security, and priority access [17]. Therefore, an AI-based private 5G-IoT network can be described as a non-public 5G network enabled by AI technologies and tailored to IoT-based vertical markets.

Private 5G networks can be deployed in either standalone (independent) or public network integrated (dependent) mode, depending on the availability of spectrum resources and infrastructure as well as the level of network management and access control. A standalone private 5G network is a network that is deployed as an isolated and independent system without relying on a public 5G network. Conversely, a private 5G network integrated into a public network is anchored in the public network and therefore has a lower level of customization, self-control and security compared to standalone mode [9,17]. Figure 2 shows typical private 5G networks supporting various vertical markets as illustrated in [18].

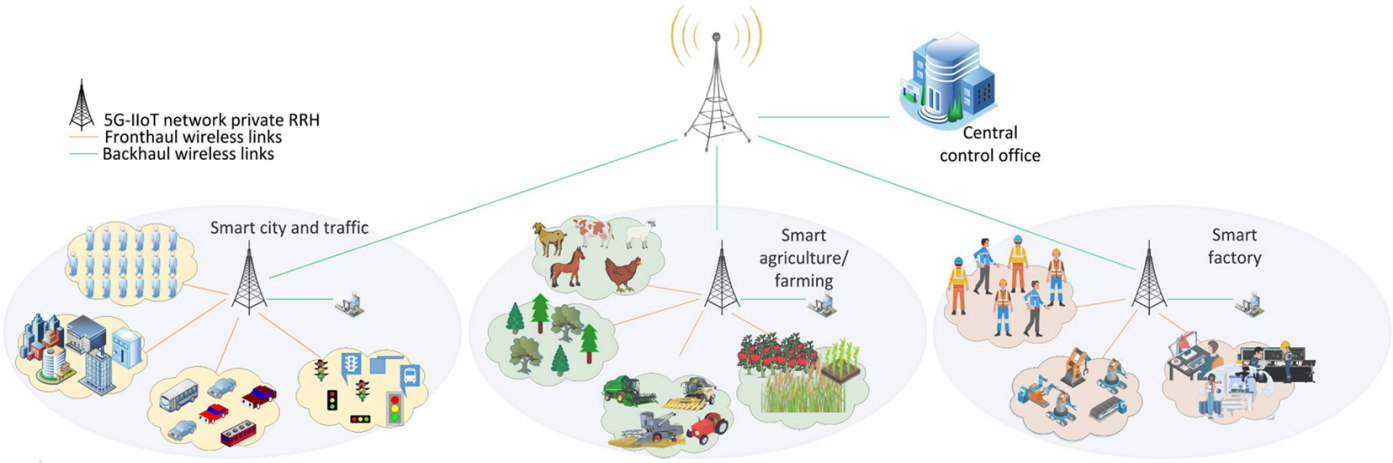

Figure 2: Private 5G networks [18]

4. Conceptual Business Model Framework

4.1. The Business Model Theoretical Concept

Since the mid-1990s, when the Internet first became widespread, the concept of business model (BM) has become increasingly popular and is now a key area of interest for researchers [19]. The term "business model" is widely used in academic literature and management practice, but there is no formal, accepted definition [19]. This is primarily because business models can be used in different research and practical fields [9]. A business model in the context of this study can be defined as follows:

The rationale for implementing the business plan of an AI-based private 5G-IoT network by leveraging interconnected elements such as customer relationships, value proposition, financial aspects and infrastructure management to create, deliver and capture value within the network ecosystem.

The present study adopts two distinct research perspectives to examine the business model concept. The first is a strategic perspective that focuses on the value proposition, creation, delivery, and capture activities within the AI-driven 5G-IoT value chain. The second perspective is technological in nature, wherein AI-driven 5G-IoT networks are considered as technological enablers for innovative business models aimed at private network operators [9]. Figure 3 illustrates the business model for AI-driven private 5G-IoT networks from both a strategic and technological perspective.

4.2. Proposed AI-based Private 5G-IoT Value Chain

Based on the business model ontology presented in [20], the relationships between the value chain components within the global market should be precisely defined in order to develop viable business models for AI-based private 5G-IoT networks. The following value chain components are proposed and shown in Figure 4.

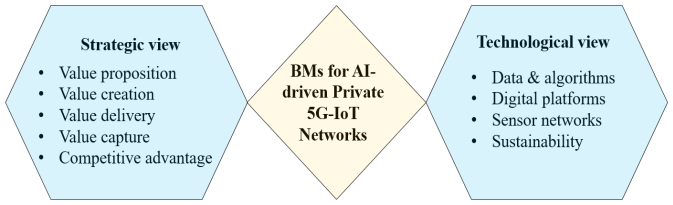

Figure 3: Strategic and technological views of AI-driven private 5G-IoT networks' business models

Who? Which target customer segments will benefit from the proposed value offered by the private network operator? This part of the value chain is about identifying the specific needs of these customers and offering tailored services to ensure their satisfaction. Customer segments include government and public institutions (such as public safety and smart cities), private companies (such as media and entertainment), industries (such as energy and healthcare), and individual consumers.

What? This value chain component explains the private network operator's value proposition for a specific customer group with the aim of generating added value for both the provider and the customer. These services include: enhanced mobile broadband (eMBB) applications such as ultra-high definition video; massive machine type communication (mMTC) applications such as smart factories; and ultra-reliable low latency communication (uRLLC) applications such as remote surgery.

How? This part of the value chain describes the technology design, network infrastructure and network resources available to the private network operator to provide the relevant services to intended customers. The following could be included in the "How?" component: AI-based key technologies for private 5G-IoT networks; sharing site infrastructure such as antennas, baseband resources, radio resources and tower space; spectrum sensing and acquisition such as mmWave band, sub-3GHz band and C-band; and collaboration with partner networks such as platform suppliers, device manufacturers and device providers.

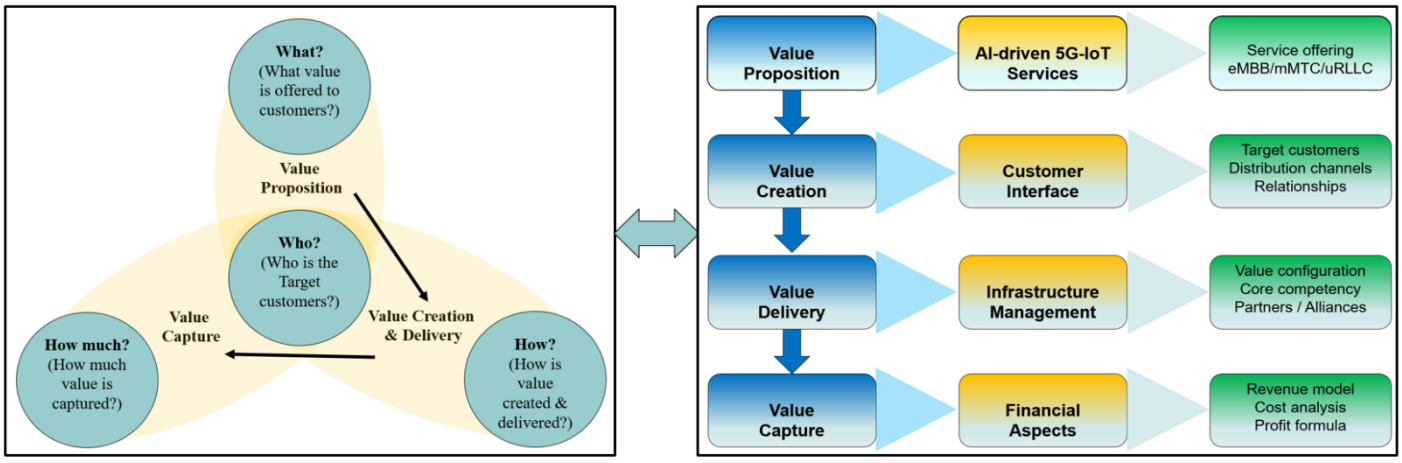

Figure 4: Relationships between value chain components of AI-based private 5G-IoT network

How much? This part of the value chain provides a blueprint for how an operator wants to maximize profits while minimizing costs within the AI-based 5G private IoT network ecosystem: How much value will the private network operator derive from the target customer segment? The "How much?" components include: revenue structures such as revenue streams, profit margins and return on investment (RoI); pricing strategies such as unit cost pricing and on-demand pricing; and cost structures such as deployment costs, capital investments and operational costs.

4.3. Proposed Conceptual Business Model Framework

A conceptual framework serves as an analytical tool that provides a preliminary theory of a phenomenon under study [21]. It establishes the connection between concepts by illustrating the theories that impact the research investigation, thereby providing a theoretical basis for designing and understanding the results [21]. Table 1 shows the ten components of the proposed conceptual business model framework for AI-based private 5G-IoT networks based on the business model canvas developed by [20].

Key partners: demonstrates the need for collaborative arrangements with external organizations to effectively deliver and monetize the proposed value.

Key activities: describes the activities and competencies required to implement the private network operator's business model.

Value proposition: provides a comprehensive overview of a range of products and services offered by a private network operator.

Customer segment: describes the customer segments to which a private network operator wants to offer value. These are the target groups of the value proposition.

Customer relationships: explains the type of connections that a private network operator establishes between itself and its various customer segments.

Key resources: these are the resources available to a private network operator to ensure that value is created and delivered in line with the operator's business objectives.

Distribution channels: describes various means that a private network operator can use to engage with its customers and offer them the value proposition.

Infrastructure management: describes the technology design, network infrastructure, and network resources available to the private network operator to deliver the relevant proposed value to intended customers.

Cost structure: sums up the monetary consequences of the resources used in the business model of a private network operator.

Revenue streams: describes the way a private network operator makes money through a variety of revenue flows.

5. Discussion of Industrial Applications of the Proposed Conceptual Framework

5.1. Sustainable Industry using AI-based Private 5G-IoT Networks, Business Models and Use Cases

Different business models can be used when implementing 5G cellular technologies for AI-driven private 5G-IoT network applications. The choice of business model is influenced by a number of factors, including the industrial sector, a specific use case, capital and operating costs, and the scalability of the network [9]. In addition to providing reliable services to key stakeholders, private 5G networks are fast, easy to manage, secure and can operate in remote or isolated locations. Table 2 summarizes typical business models, vertical industry target markets, key drivers and use cases for AI-based private 5G-IoT networks.

Furthermore, one of the key killer use cases identified in the recent COP28 climate agenda is the use of emerging digital technologies such as private 5G-IoT and AI systems to monitor natural ecosystems [9,10].

5.2. Business Model Implementation Considerations

(i) Adaptive service-based approach

Some of the more exciting 5G technologies such as network slicing [16] and digital platforms [12] require a variety of key players and partners to deliver a range of intelligent services to customers. Therefore, a shift from a product-based to a flexible service-based business model is required. This is crucial because customer needs can change over time. Adaptive, service-based business models have the potential to improve user satisfaction and increase revenue for partners and operators alike.

(ii) Security-focused business model approach

Research on 5G business models has focused more on the economic value aspects of key network performance metrics such as data throughput, latency, reliability and device connectivity density, with relatively little attention paid to security objectives such as confidentiality and privacy data integrity. However, the involvement of many role actors and the complexity of the 5G ecosystem, each with different security levels, increases the vulnerability to cyberattacks [4]. Consequently, new business models should be security-focused by integrating AI and IoT-based forensics as well as various other means of combating cyber threats to ensure confidentiality, privacy and data integrity. AI and IoT forensics are also suitable tools to avert impending quantum security risks on 5G and future networks [22].

Table 1: Proposed Conceptual Business Model Framework for AI-based Private 5G-IoT Networks

Key Partners	Key Activities	Value Propositions	Customer Segment	Customer Relationships
- AI algorithm developers - IoT sensor manufacturers - Public MNOs - Platform owners & designers - Regulations & policy makers	- Managing partnerships - Network & platform maintenance - Mobile service delivery - Customer technical support - Research & development (R&D)	- Immersive mobile services - Automated manufacturing - High-speed broadband access - Smart city services - Automated factory production lines	- Mass market - Niche market - Multi-sided platforms - Individual consumers	- Personal assistance - Self-service - Automated service - Co-creation partner services
Key Resources	**Distribution Channels**	**Infrastructure Management**	**Cost Structure**	**Revenue Streams**
- Physical - Human - Intellectual - Financial	- Web-based sales - Operator's own store - Partner's store - Wholesale	- Spectrum acquisition - Backhaul infrastructure - Radio equipment - Tower space management	- Fixed costs - Variable costs - Capital expenditure - Operational expenditure	- Subscription fees - Usage fees - Leasing/renting assets - Brokerage fees - Advertising

Table 2: AI-based Private 5G-IoT Network Business Models, Vertical Industries, Key Drivers, and Use Cases

AI- based Private 5G-IoT Network Business Model	Vertical Industry	Key Drivers	Use Cases
Smart Factory	• Manufacturing	• Proliferation of mobile robotics in process automation.	• Connected workers • Production line flexibility • End-to-end logistics
Smart Mining	• Mining	• Demand for high safety standards in the mining industry. • Rapid transition from human-driven machine control to automated remote controlled applications	• Early warning disaster signaling • Safety signal dissemination • Automated drilling machine communication
e-Health (Healthcare 5.0)	• Health	• Advancement in medical research • Low density of health practitioners • Upsurge in remote surgery practice	• Wearable health monitoring devices. • Smart implants for medical diagnostics • Connected contact lenses
Smart Sea Port	• Maritime	• Surge in sea port activities mainly driven by cargo transportation which cannot be handled by the aviation industry.	• Remote-controlled & automated cranes • Automated guided vehicles (AGVs) • Unmanned aerial vehicles (UAVs) • Sea condition monitoring
Smart Airport (Airport 4.0)	• Aviation	• Rise in air freight activities. • Upsurge of passenger air traffic, post COVID-19 era.	• Automated AI-based boarding procedures for passengers. • Constant security monitoring • Automated fever detection • Optimized luggage handing
Smart Railway	• Transportation	• Increase in use of railway systems as a means of inland cargo transportation. • Increased number of train commuters due to road congestion.	• Smooth scheduling & operations of trains. • Secure and low latency communication between drivers and signaling controllers. • Automated AI-based boarding procedures for passengers.
Smart City	• Public	• Rapid urban/city population explosion • Increase in CO_2 emission levels in urban areas	• Remote monitoring of roads and city infrastructure. • Automated water sanitation and waste management systems • Air pollution level detection
Smart Grid	• Energy	• Multiple wireless sensors with uninterrupted 5G connectivity deployed in specific substations.	• Effective monitoring and forecast of energy demand and consumption • Automated adjustment of electric profile via load control.
Smart Farming	• Agriculture	• Multiple wireless sensors with uninterrupted 5G connectivity deployed in specific crop fields.	• Optimized soil moisture content • Efficient use of water and fertilizers via customized applications
e-Learning	• Education	• Immersive real-time interaction via virtual presence applications with minimal visual or audio delays	• Immersive real-time virtual interaction between learners and educators. • Tele-education use cases for distance-learning courses.

(iii) Support for green and sustainable energy-efficient communication

Supporting green and energy-efficient communication technologies through business models for AI-based private 5G-IoT networks is critical to the environmental sustainability of these networks. To reduce the reliance on conventional fossil fuels to power network devices, green energy sources must be utilized. One of the goals of 5G-based network design is to minimize carbon emissions and reduce energy consumption of network devices without compromising network quality. In [23], research was conducted on energy harvesting techniques that enable communication devices to harvest energy from a variety of renewable sources. However, so far neither industry nor academia have shown much interest in exploring business models aimed at enabling environmental friendliness in the 5G ecosystem. The lack of end-2-end (E2E) testbeds or digital twins for AI-driven private 5G networks is detrimental to the development of innovative and sustainable 5G-IoT services and business models.

6. Conclusion

This article presented a conceptual business model framework for AI-based private 5G-IoT networks. The conceptual framework, formulated from a strategic and technological perspective, consists of ten inter-connected components that can be adopted by private network operators. The technical aspects and associated applications of AI-based private 5G IoT networks were highlighted. In addition, a discussion of the industrial applications of the proposed conceptual framework was presented. In particular, typical business models, vertical industry target markets, key drivers and exemplary use cases were discussed. Finally, critical aspects of a sustainable business model that must be taken into account when implementing AI-based private 5G-IoT networks were highlighted.

Since the current work is based on a theoretically formulated conceptual framework, future research will be implemented on an E2E testbed with machine learning-based analysis applied to the collected primary data to support the development of sustainable business models and innovative services for current and future 6G AI/IoT-based smart and sustainable industries and the preservation of natural ecosystems.

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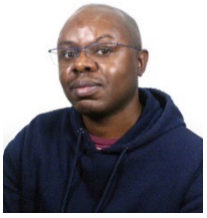

LAURENCE BANDA received the BEng degree in Electrical and Electronics Engineering from the University of Zambia, Lusaka, Zambia in 2006, the MSc in Electronics and Communications Engineering from EISEE, Paris, France in 2011, the MEng in Electrical Engineering from the Tshwane University of Technology, Pretoria, South Africa in 2012 and the PhD in Technology and Operations Management from the University of the Witwatersrand, Johannesburg, South Africa in 2024.

He worked for Huawei Technologies in South Africa for 10 years where he held various positions including Project Manager for Wireless Energy Management, Wireless Advisory Engineer and Technical Trainer. He has published widely in the areas of business models for wireless networks. His current research focus is on technology and innovation management for next-generation wireless networks incorporating AI and IoT.