Business model for rural connectivity using multi-tenancy 5G network slicing

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***Abstract*—Rural areas are often neglected while deploying newer mobile technologies. Hence, these place are digitally disconnected from the world. To overcome this challenge, 5G network slicing supporting multi-tenancy, also known as neutral host network, is studied to improve rural connectivity. The infrastructure provider (InP) deploys the rural 5G network and mobile network operators (MNOs) lease the slices from InP to serve their end-users. This aims to study the value network configuration (VNC) for the 5G network slicing architecture to understand the possible business model. As a result, three configurations are defined driven by micro-operator, MNO and community end-users respectively. The business models are constructed using SWOT analysis and business canvas models. The revenue streams for the proposed rural network are analyzed.**

***Index Terms*—neutral host network, infrastructure provider, 5G, mobile network operators, network slicing**

I. Introduction

Currently, the telecommunication infrastructure is deployed, operated and maintained by the mobile network operators (MNOs). This is a very capital intensive process, hence the MNO deploys mobile network where the return on investment (RoI) is high. Whereas in rural areas, there are less number of subscribers and limited demand for the mobile services. Mostly it is a non-profitable business. Hence, rural areas are given lower priority while deploying any telecommunication technology [1], [2]. This leads to rural villages having either inadequate mobile connectivity or are digitally disconnected from the world.

To improve the rural connectivity, different solutions are being tested around the world. In [1], the authors discuss different types of rural connectivity challenges and how 5G solutions can help in improving it. In [3], the authors look at the issues in providing 5G as universal access for all. The key challenge is earning revenue higher than the total cost of ownership (TCO) of the networks. The authors propose solutions like airborne base station (BS), 5G terrestrial network and satellite internet connectivity. Cloud radio access network (C-RAN) is suggested to jointly reduce capital expenditure (CAPEX) and operations expenditure (OPEX) of the network. [4] discusses about future mobile networks using network slicing, and open issues in the modified 5G architecture. Frugal network [5] is analyzed to provide rural connectivity using network slicing. The paper also considers multi-operator sharing to making the network economically feasible in rural areas. [6] demonstrates the effectiveness of using network slicing framework for 5G. [7] shows the trial at Hamburg seaport of using customized industrial 5G networks using network slicing. However, the economic feasibility and business model of these solutions is not studied in depth in these papers. [8] studies the techno-economic feasibility of 5G networks in university campus. Similarly, [9] discusses the usage of 5G network slicing for smart factory and its value network is analyzed in [10]. Network slicing with multi-operator co-existence is studied in [8], [9], [11]–[14]. The studies show the possible business use cases for a new telecommunication deployment framework which is neutral host network (NHN).

In this paper, we study the use-cases of 5G in rural scenario, which helps the infrastructure provider (InP) to decide the system requirements to deploy and also, the demand of the network by MNOs. Next, we study the role by different stakeholders of the network. We propose value network configuration (VNC) for rural 5G scenario, while analyzing the interaction between different stakeholders in the business. Later, we perform strength, weakness, opportunities and threats (SWOT) analysis for rural 5G NHN from InP and MNO point of view. Finally, the business canvas model for this network helps in evaluating the monetization streams to make the NHN business sustainable for long-term.

The major contributions of the paper can be summarized as follows:

- The infrastructure sharing model is presented with single InP and multiple MNOs. The revenue streams are analyzed for InP using business canvas model.
- The interactions of different stakeholders are analyzed in VNC and business canvas model.
- Subsequently, the trade-off of NHN in rural scenario is analyzed by performing SWOT analysis. It is shown that NHN business is sustainable when there is cooperation between MNOs and other stakeholders.

The paper is organised as follows. In section II, the system model is illustrated. In section III, the key stakeholders' role is described. Later in section IV, the VNC of the rural 5G network is analyzed. In section V, business model for improving 5G rural network investment is discussed. Finally,

in section VI, conclusions are drawn.

II. System model

Consider a village with low user density where InP deploys 5G network supporting NHN using network slicing. InP could be an MNO, or third party operator. InP can either use MNO's frequency or shared spectrum for network operations. In this scenario, each BS can be utilized by MNOs by renting network slices from the InP. The slice tenants use the InP network to serve their own users by sharing the same physical infrastructure. The end-users would not notice the difference in the service offered by the network. The slice tenants compete with each other in terms of quality-of-service (QoS) and their end-users on the network. One of the main reason for NHN is lower TCO for 5G providing services compared to traditional deployment while catering to the low demand for network capacity in rural areas [15]. Note that our study focuses on the MNOs as slice tenants, who are interested in long-term investment in the InP's 5G network.

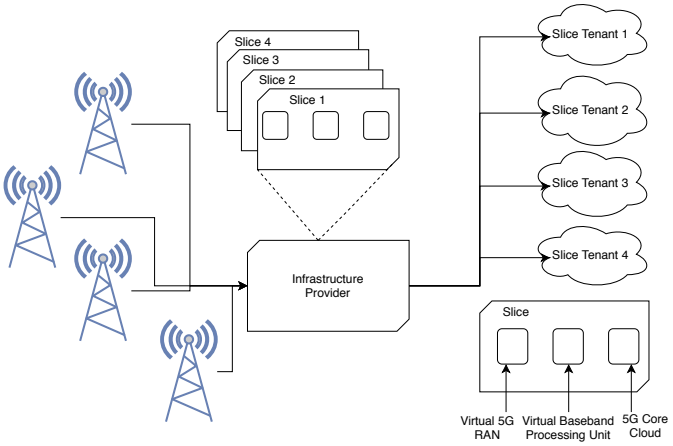

Fig. 1. 5G network slicing for multi-network operators

The architecture for 5G network slicing with multi-network operators is shown in Fig. 1. Assume that BSs are deployed to provide maximum coverage in the village of interest. Because of the low capacity demand in rural areas, generally a single InP's network can meet the demands of the village. We consider a single seller-multiple buyer market for infrastructure sharing. The InP's cloud is connected to the MNO's core network. One of the main motivation for the InP is the revenue generated from the decentralised telecommunication network. This will enable newer players, with low investment, to enter the market. InP would earn revenue from the rent paid by slice tenants. Similarly, the main motivation for the slice tenants would be to earn revenues from the end-users and also, entering an untapped market.

InP and MNO preferably could have a cooperative dialogue to keep the TCO as low as possible. MNO could state its requirements from the network and their expected investment cost. This helps the InP decide on the strategies for meeting the requirements. Furthermore, InP can analyze the techno-economic feasibility of deployment based on the requirements from the slice tenants. MNO and InP would negotiate and agree upon service level agreement (SLA) and the associated pricing paid by the MNO as per their usage. The resource allocation to the end-users and the pricing for services by the MNO is done as per their original goal of revenue maximization.

The regulatory body is considered as the decision making body, who would be authorizing the NHN business [16], [17]. The interactions between InP and MNOs can be modelled using game theory model as cooperative games. Game theory can help in understanding the strategical options available for each player in the game. Games like Nash equilibrium, Shapley value, Cournot Nash, Betrand model, stackelberg model and more help in modelling the pricing and resource allocation of 5G networks [18]–[21]. The regulatory body ensures the spectrum is used efficiently, and there is transparency in the operations between InPs and MNOs. The regulatory body can devise newer spectrum revenue opportunities.

Without doubt, such flexibility would generate relatively high complexity in the design of the network, connection to the MNO core, signalling, billing and more. But we assume that those aspects can be addressed. Assuming the network performs as per the expectation, business aspects of the network is analyzed.

III. Key Stakeholders

The stakeholders for a rural 5G NHN are:

- **Standardization bodies :** The standards for 5G network slicing enabling NHN are drafted by 3GPP [22]. The main expectation of standardization bodies is to create a broadly supported standards for manufacturing parts, network interfaces, working of different hardware and compatibility with previous generations to achieve a common goal. Similarly, signalling mechanism should be standardised to allow different devices and technologies to communicate with each other. The 5G NHN market will attract industry to apply intellectual property rights (IPR) as well.
- **National regulator :** In this proposed scenario, the national regulator plays a very important role in monitoring the spectrum usage [23]. As the MNO's spectrum bands could be reused by the InP operator(s), it will involve proper legal procedures with the national regulator and the licensee of the band for the usage. Meanwhile, the InP could also host 5G NHN on shared spectrum bands or unlicensed bands after obtaining legal permissions by the regulator to use those bands. The deployment approvals could be subject to optimization and automation by the regulator, to reduce the physical effort required. The regulator would develop a new charging mechanism to monetize this new business scenario and earn revenue while making sure that the long term investment by the MNO in the license auctions of spectrum-bands is not reduced.
- **Mobile network operator :** In the rural 5G NHN scenario, the MNO is able to expand their business to

new region with a lower capital investment compared to traditional deployment. MNO's existence in the rural market will help in entering into verticals industry. This model attracts new customers to join the MNO's network. They are guaranteed a QoS by InP. Security issues will be key concerns for the MNO when InP will connect to MNO's core network [20], [24]. Also, the interface to end-to-end control on the InP slice has to be addressed. This scenario is attractive for the MNO, if these issues are addressed.

- **Telecommunication equipment vendors :** Considering the 5G NHN model for rural scenario, it would involve telecommunication equipment vendors who will be manufacturing equipment to support the network functioning. They will adhere to the manufacturing standards developed by the standardization bodies and further develop verification actions and standards improvements to meet the actual requirements. Currently, NHN exist for in-building coverage using technologies like citizen's broadband radio services (CBRS) [25].
- **Infrastructure provider (InP) :** The InP will be deploying the end-to-end network and lease the slices to the MNO. The InP will discuss with the MNOs to understand the service level requirement of the MNOs. InP would negotiate with MNOs the capacity and pricing of the network before deploying it. By deploying a network based on cooperation, the InP and MNOs can mitigate losses [20]. As mentioned earlier, InP can either be a third party company, one of the MNOs or a community built network. The spectrum of operation can be decided jointly with the slice tenants. This open-discussion will allow InP to decide the required number of network slices to meet the demands.
- **Network slice manager** Network slice manager entity may be developed either by national regulator, equipment vendors or InP. Network slice manager will coordinate between various stakeholders and manage the service requests placed. This can be used to alter the system requirements as per the needs and also perform billing. It will act as a manager for the network.
- **End-user** In this proposal, the end-user will benefit with the internet connectivity and receive direct benefit from this deployment. The end-user can be mobile users, or other vertical sectors. When end-users will become more aware of benefits of rural connectivity, then their demand would increase. They will be able to connect to the world through internet connectivity and enjoy services which they could not without internet.

IV. VNC FOR 5G NHN

VNC consists of interlinked business actors and technical components [10], [26]–[28]. Fig. 2 shows the block diagram for VNC analysis. VNC includes the analysis on different possible scenario to better understand the most valuable network configuration to become profitable. Business leads to creation for value of outputs in terms of money, knowledge, reputation, and loyalty [9], [10]. Business strategies are interconnected to create value. This leads to uncertainty in the business roles to be played by the actors as it is interchangeable at times. Value network helps in understanding the roles played by actors in different businesses [26]. In this paper, we describe the VNC for InP driven business.

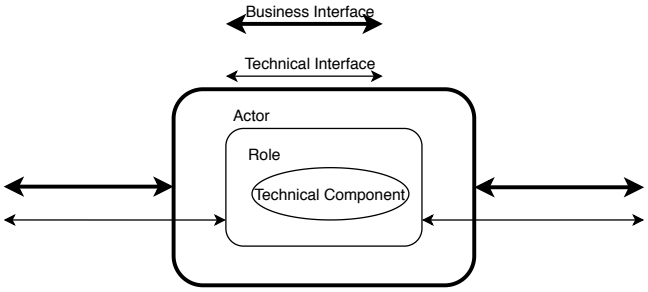

Fig. 2. VNC block and interfaces [26]

Technical components are the technologies that make the technological functionality possible, that is the the technical architecture [10] which leads to creation of value. The actors play the roles related to their technical components. Each actor has their own business role and interconnected by business interface. Table I shows the relations between key technical stakeholders and their roles. It can be seen that the different actors have business and technical interfaces which allows the study of roles outlined by the actors.

This VNC, shown in Fig. 3, is formed by the MNOs, InP and community end-users interacting over different overlapping domains like device domain, network domain and application domain. The InP could be a 5G infrastructure provisioning company, MNO, industry or other vertical who deploys the 5G NHN and rents slices to the MNOs. The MNOs use the slice to serve the end-users via InP infrastructure. The end-users pay the MNOs while the MNOs pays the InP. This is an InP driven business. The revenue is shared among InP and MNOs. Edge caching is done by InP to reduce latency. InP connects to the MNO's core to connect to the wide area network. The end-users can lease slices from the InP for private network and MNO services for wide area network. The InP will manage the accounts and operations for the 5G NHN. The InP can use frequency of either MNO or shared spectrum or unlicensed spectrum bands. The VNC in Fig. 3 also highlights the possible revenue streams. 5G allows vertical industry to exist in the same physical network as the retail consumers. Network slicing allows the independent operations of tenants.

V. BUSINESS MODELS

In the previous section, VNC was studied to understand the business strategies available for InP in rural 5G NHN. In order to describe the proposed business model, in this section SWOT analysis is performed for 5G NHN business, and business canvas model is created to understand the business model. These provide insights in to the business models and the

TABLE I
TECHNICAL COMPONENTS OF 5G NHN AND THEIR ROLE

Technical component	Role description
Device (Mobile/ Stationary)	The end-users who use 5G devices and its applications. It connects to the network directly. Devices should be compatible with different technologies and applications.
Network (Access and Core Network)	The component that connects device, gateway and network application server with each other. It also implements network slicing, and C-RAN.
Authentication, Authorization and Accounting (AAA)	The component that controls access to policies, regulations, billing, auditing, provisioning management and monitoring for services.
Network Slice Manager	The component that hosts slicing capabilities and enables use by multi-operator.
Cloud Service Provisioning	Includes security, data management, connection to slice tenants core.
Network Equipment Provisioning	Hardware and Software for enabling network slicing.
Spectrum regulator	Spectrum sharing, MNO's licensed spectrum or unlicensed spectrum band usage.

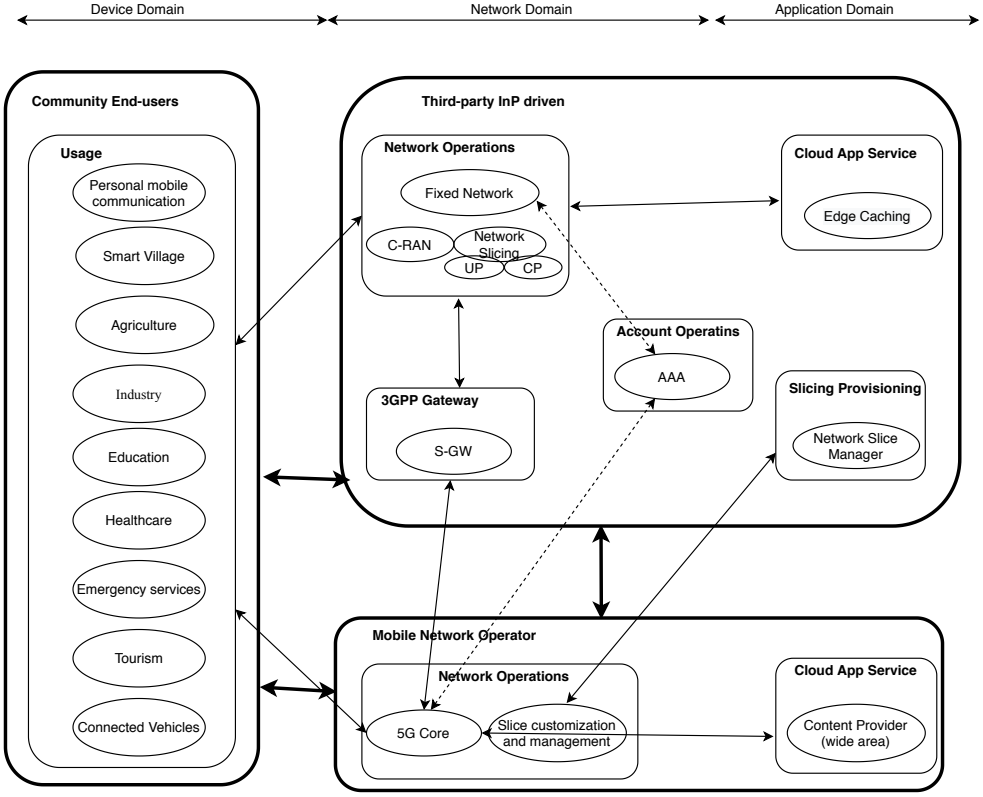

Fig. 3. Value Network Configuration 3rd-party driven 5G [10], [28]

key challenges to be addressed are analyzed. These help in understanding the feasibility of the business for rural scenario.

A. SWOT analysis

SWOT analysis helps in understanding the strengths, weaknesses, opportunities and threats in a business competition. This is used in strategic planning of the decision making process. It helps in identifying the pros and cons of taking a certain decision. It also helps in understanding the favorable and unfavorable factors in making the decision a success. Table II discusses the SWOT analysis of 5G NHN in rural scenario. It can be observed that 5G NHN can be considered a potential solution for improving rural connectivity.

The strength of the business lies in lowering the cost for rural areas with low population which would attract 5G network deployments. However, the main weakness of the model is openness for sharing the network deployed by the third party provider and trust over the service agreement. But once these issues are resolved, there exist many untapped opportunities with respect to connectivity, digital services, revenues and jobs. However, there exists risk of failure in this business due to regulatory or legal limitations. Once these factors are considered and corresponding challenges are addressed, then 5G NHN could become an attractive option for MNOs.

B. Business canvas model

Business canvas model is a strategic management template to understand the potential trade-off in the business. The nine block model was proposed by Alexander Osterwalder [30].

TABLE II
SWOT ANALYSIS FOR 5G NHN IN RURAL SCENARIO

Strength	**Weakness**
• Faster deployments [22]. • Lower TCO [28]. • C-RAN allows expansion as per demand for a shorter duration as well [29]. • Localised spectrum ownership leading to relatively lower cost for spectrum access [25]. • Guaranteed service level agreements during network congestion [4]. • Improved network utilization due to sharing [4]. • Remote monitoring and controlling of the network [8]. • End-users will not realize the difference. • Independent usage of slice [28]. • 5G applications for industry verticals [28].	• Increased complexity in the network design [28]. • Getting approvals from the regulator for deployments and spectrum access [22]. • Pricing should be attractive for rural use-cases and their income [12]. • Connection to the MNO's network is required for wide-area connection [3]. • Slice tenants can not customise the InP network. • Security considerations while connecting to the core of the MNO [24]. • Feasibility of network in remote rural areas [3].
Opportunities	**Threats**
• Internet access in not-spots or poor coverage regions [3]. • Profits generated from rural networks. • Opportunity to expand businesses into rural market [3]. • Additional income to the regulator [23]. • Better quality of life and increase in opportunity for the inhabitants [28]. • Creations of jobs. • Potential for spectrum sharing [23]. • Boost for local industry [3].	• Hard-handoffs while roaming. • NHN can be considered as a threat to existing telecommunication market [11]. • Non-cooperation between InP and MNOs would increase TCO for the 5G network. • Potential regulatory and legal limitations.

This helps the companies to think in terms of the business model rather than only product oriented. The possible revenue streams, cost associated with the network, key partners, key resources, value proposition of the network and its customer segments plus its channels are discussed in this subsection. Table III shows the business canvas model for 5G NHN. The business canvas model for the 5G NHN is as explained below. It explains the various relationship between the business partners and customers.

- Key Partners
  - *Partners*: InP, MNOs, national regulator, industry verticals, local government.
  - *Suppliers*: Equipment manufacturers, energy supplier.
  - *Motivations*: Additional revenue for the key stakeholders, business expansion, IPR.
- Key Activities
  - *Activities*: Technology development, creation of network slice manager, optimal pricing decision, usage predictions, network planning, coverage planning, demand prediction, network deployment.
- Value Propositions
  - *Value*: 5G mobile broadband, lower TCO, connectivity in not-spots, higher, business expansion, globalization for rural presence, access to digital applications like e-healthcare, online education, remote monitoring and managing of the network, e-governance, online banking and more.
  - *Needs*: Reliable, low latency, high speed Internet, broadcasting, seamless connectivity.
  - *Minimum value*: Same as urban pricing for services.
- Customer Relationship
  - *Customer growth*: Through negotiation and advertisement, the customer base would grow.
  - *Cooperation*: InP, MNOs and national regulator.
  - *Relationship*: User assistance, AI recommendation to improve network performance, self-organizing networks, network slice manager.
- Customer Segments
  - *Potential customers*: Consumers, retailers, slice managers, small-scale business, government, tourism and community.
  - *Most important customers*: MNOs and government.
  - *Archetypes*: People with awareness of mobile connectivity benefits.
- Key Resources
  - *Resources*: 5G network, spectrum, tools to monitor and optimize the network, employees.
  - *Distribution channel*: Direct channel.
  - *Customer relationship*: Personal assistance.
  - *Revenue streams*: Network usage monetization by slice tenants.
- Channels
  - *Advertising*: Word of mouth, social media, websites, telecommunication support channels, local governing bodies.
  - *Evaluation*: Surveys and network log analysis, desktop application.
  - *Purchases*: Online, and office.
  - *Delivery*: Online.

TABLE III
BUSINESS CANVAS MODEL FOR 5G NHN

<table>
<tr><td rowspan="2">Key Partners
InP, MNO, regulator, local council, telecommunication equipment vendors, cloud service provider</td><td>Key Activities
Demand estimation, 5G NHN deployment, pricing strategy</td><td rowspan="2">Key Proposition
Rural connectivity, lower cost for rural 5G services, business expansion, digital services</td><td>Customer Relationship
AI support, customer service, network slice manager</td><td rowspan="2">Customer Segments
Rural market, industry verticals</td></tr>
<tr><td>Key Resources
Human resources, network slicing software</td><td>Channels
Web pages, technology forums, referral from customers</td></tr>
<tr><td colspan="3">Cost Structure
Network cost, spectrum cost, human resources, operational cost</td><td colspan="2">Revenue Streams
Slice rent, subscription fees, enterprise customers, local area network</td></tr>
</table>

- *Post-sales*: Customer assistance

- Cost Structure

  - *Inherent cost*: 5G NHN deployment cost, employees, operational cost, advertisement, insurance, spectrum cost.
  - *Most expensive resource*: 5G NHN deployment cost and operational cost.
  - *Most expensive activities*: Network slice manager and technical component connections.

- Revenue Streams

  - *Revenue model*: A fixed monthly subscription, slice rent, enterprise usage, potential InP local area network, usage fees, roaming customers, data usage, industrial vertical applications, private networks, slices leased for short duration like concerts and more.

VI. CONCLUSION

In this paper, 5G network slicing with multi-tenancy for rural scenario was investigated as a potential solution to improve rural mobile connectivity. Business opportunity that will act as drivers and encourage deployment of such market model were studied. The VNC for the proposed solution is studied. SWOT analysis explains the potential trade-off of using rural 5G neutral hosting to improve rural connectivity. Then business canvas model summarizes the key resource, activities, value proposition, channels, cost structure, and revenue streams involved for InP in the 5G NHN business.

This paper not only lays down a solid framework for improving rural connectivity using 5G NHN architecture, but also describes how to implement the NHN by a third-party InP and the possible streams of revenue. One of the main advantages of such a network shared investment as well as shared risk. Slicing with NHN allows telecommunication service providers to enter rural telecommunication market by providing 5G services. We can conclude that 5G NHN could be considered as an option to serve rural community.

Based on the proposed architecture, future research work is needed to study the techno-economic feasibility conditions of the network and to compare the proposed solution with traditional deployed network.

REFERENCES

[1] E. Yaacoub and M. Alouini, "A key 6G challenge and opportunity—connecting the base of the pyramid: A survey on rural connectivity," *Proceedings of the IEEE*, vol. 108, no. 4, pp. 533–582, 2020.

[2] C. McGuire, M. R. Brew, F. Darbari, S. Weiss, and R. W. Stewart, "WindFi-A renewable powered base station for rural broadband," in *19th International Conference on Systems, Signals and Image Processing (IWSSIP)*. IEEE, 2012, pp. 265–268.

[3] A. Al-Dulaimi, X. Wang, and I. Chih-Lin, *5G networks: Fundamental requirements, enabling technologies, and operations management*. John Wiley & Sons, 2018.

[4] H. Zhang, N. Liu, X. Chu, K. Long, A. Aghvami, and V. C. M. Leung, "Network slicing based 5G and future mobile networks: Mobility, resource management, and challenges," *IEEE Communications Magazine*, vol. 55, no. 8, pp. 138–145, 2017.

[5] M. Khaturia, P. Jha, and A. Karandikar, "Connecting the unconnected: Toward frugal 5G network architecture and standardization," *IEEE Communications Standards Magazine*, vol. 4, no. 2, pp. 64–71, 2020.

[6] Q. Ye, J. Li, K. Qu, W. Zhuang, X. S. Shen, and X. Li, "End-to-end quality of service in 5G networks: Examining the effectiveness of a network slicing framework," *IEEE Vehicular Technology Magazine*, vol. 13, no. 2, pp. 65–74, 2018.

[7] P. Rost, M. Breitbach, H. Roreger, B. Erman, C. Mannweiler, R. Miller, and I. Viering, "Customized industrial networks: Network slicing trial at Hamburg seaport," *IEEE Wireless Communications*, vol. 25, no. 5, pp. 48–55, 2018.

[8] J. S. Walia, H. Hämmäinen, and M. Matinmikko, "5G micro-operators for the future campus: A techno-economic study," in *Internet of Things Business Models, Users, and Networks*. IEEE, 2017, pp. 1–8.

[9] J. S. Walia, H. Hämmäinen, K. Kilkki, and S. Yrjölä, "5G network slicing strategies for a smart factory," *Computers in Industry*, vol. 111, pp. 108–120, 2019.

[10] J. S. Walia, H. Hämmäinen, and H. Flinck, "Future scenarios and value network configurations for industrial 5G," in *8th International Conference on the Network of the Future (NOF)*. IEEE, 2017, pp. 79–84.

[11] P. Ahokangas, M. Matinmikko-Blue, S. Yrjola, V. Seppanen, H. Hammainen, R. Jurva, and M. Latva-aho, "Business models for local 5G micro operators," in *IEEE International Symposium on Dynamic Spectrum Access Networks (DySPAN)*, 2018, pp. 1–8.

[12] P. Ahokangas, M. Matinmikko-Blue, S. Yrjölä, V. Seppänen, H. Hämmäinen, R. Jurva, and M. Latva-aho, "Business models for local 5G micro operators," *IEEE Transactions on Cognitive Communications and Networking*, vol. 5, no. 3, pp. 730–740, 2019.

[13] E. Oproiu, M. Iordache, C. Costea, C. Brezeanu, and C. Patachia, "5G network architecture, functional model and business role for 5G smart city use case: Mobile operator perspective," in *International Conference on Communications (COMM)*, 2018, pp. 361–366.

[14] M. U. Alhuseini and M. M. Olama, "5G service value chain and network slicing framework using ecosystem modeling, agile delivery, and user-story automation," *IEEE Access*, vol. 7, pp. 110 856–110 873, 2019.

[15] A. Karlsson, O. Al-Saadeh, A. Gusarov, R. V. R. Challa, S. Tombaz, and K. W. Sung, "Energy-efficient 5G deployment in rural areas," in *IEEE 12th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*, 2016, pp. 1–7.

[16] K. B. S. Manosha, M. Matinmikko-Blue, and M. Latva-aho, "Framework for spectrum authorization elements and its application to 5G micro-operators," in *Internet of Things Business Models, Users, and Networks*, 2017, pp. 1–8.

[17] T. Sanguanpuak, S. Guruacharya, E. Hossain, N. Rajatheva, and M. Latva-aho, "On spectrum sharing among micro-operators in 5G," in *European Conference on Networks and Communications (EuCNC)*, 2017, pp. 1–6.

[18] Y. Jia, H. Tian, S. Fan, P. Zhao, and K. Zhao, "Bankruptcy game based resource allocation algorithm for 5G cloud-ran slicing," in *IEEE Wireless Communications and Networking Conference (WCNC)*. IEEE, 2018, pp. 1–6.

[19] P. Caballero, A. Banchs, G. De Veciana, and X. Costa-Pérez, "Network slicing games: Enabling customization in multi-tenant mobile networks," *IEEE/ACM Transactions on Networking*, vol. 27, no. 2, pp. 662–675, 2019.

[20] T. Sanguanpuak, N. Rajatheva, D. Niyato, and M. Latva-aho, "Network slicing with mobile edge computing for micro-operator networks in beyond 5G," in *21st International Symposium on Wireless Personal Multimedia Communications (WPMC)*. IEEE, 2018, pp. 352–357.

[21] M. Vincenzi, A. Antonopoulos, E. Kartsakli, J. Vardakas, L. Alonso, and C. Verikoukis, "Multi-tenant slicing for spectrum management on the road to 5G," *IEEE Wireless Communications*, vol. 24, no. 5, pp. 118–125, 2017.

[22] A. Ghosh, A. Maeder, M. Baker, and D. Chandramouli, "5G evolution: A view on 5G cellular technology beyond 3GPP release 15," *IEEE Access*, vol. 7, pp. 127 639–127 651, 2019.

[23] S. Yrjölä, P. Ahokangas, and M. Matinmikko, "Evaluation of recent spectrum sharing concepts from business model scalability point of view," in *IEEE International Symposium on Dynamic Spectrum Access Networks (DySPAN)*, 2015, pp. 241–250.

[24] R. F. Olimid and G. Nencioni, "5G network slicing: A security overview," *IEEE Access*, vol. 8, pp. 99 999–100 009, 2020.

[25] M. G. Kibria, G. P. Villardi, K. Nguyen, W.-S. Liao, K. Ishizu, and F. Kojima, "Shared spectrum access communications: A neutral host micro operator approach," *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 8, pp. 1741–1753, 2017.

[26] T. Casey, T. Smura, and A. Sorri, "Value network configurations in wireless local area access," in *2010 9th Conference of Telecommunication, Media and Internet*. IEEE, 2010, pp. 1–9.

[27] J. S. Walia, H. Hämmäinen, and H. Flinck, "Future scenarios and value network configurations for industrial 5G," in *8th International Conference on the Network of the Future (NOF)*. IEEE, 2017, pp. 79–84.

[28] J. Benseny and H. Hämmäinen, "Value network analysis in a low-cost and affordable internet," in *European Conference on Networks and Communications (EuCNC)*, 2016, pp. 148–152.

[29] S. Yrjölä, P. Ahokangas, and M. Matinmikko-Blue, "Novel context and platform driven business models via 5G networks," in *IEEE 29th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)*, 2018, pp. 1–7.

[30] A. Osterwalder, "A better way to think about your business model," *Harvard Business Review*, vol. 6, 2013.