Techno-Economic Analysis of IoT Networks in 5G

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***Abstract*—This article evaluates the Techno-economic analysis of IoT networks in 5G. The study analyzed the proposed model for the Internet of Things and the Femtocell in ascertaining the feasibility of the models for the 5G network. The study entirely majors on the analysis of the LoRa WAN network because of its adequate characteristics of low power consumption, easy scalability, and high coverage. It is license-free, which facilitates reduced costs and fast developments. Compared with the expected revenue to be collected during the growth period, the cost elements were Operating Expenditure (OPEX) and Capital Expenditure (CAPEX). The analysis of the results shows that the 5G network is more significant than the 4G LTE because of the lower cost associated with it and the increase in the data transferability that the 5G offers, and the increased number of users.**

***Index Terms*—IoT, CAPEX, OPEX, Femtocells, LoRa WAN networks**

I. Introduction

The 5G network has been conceived to support the needs of a hyper-connected society, demand for the high data rate access, broader coverage, and very low latency for the increasing number of almost permanently connected devices. Information and communication technology has become a collection of tools in everyday life in the economic sector by determining the emergence of new services, increasing production, stimulating cost production, and influencing the management system of an organization. The world economy is entering an age of the Internet of Things. In 2020, at an enterprise level, the Internet of Things (IoT) grew potentially in different continents, including North America at 14%, Europe at 9.7%, and Asia at 17%. The Internet of Things (IoT) is ushering in a new era that will transform civilization economically and socially, revolutionizing far more than the internet itself. The internet of things (IoT) is a model in which items link to humans, and data can be transferred without human involvement. By implementing the machine-to-machine learning process, 5G technology will and is expected to produce a linked society, and IoT is considered the future (M2M: Machine 2 Machine). With 5G, data transfer will increase significantly, making it easy for IoT functionality to have economic and social feasibility. The increased speed will allow IoT devices to transfer and communicate data faster. This implies that the 5G brings involuntary changes to IoT and will unlock the potential technologies such as Artificial Intelligence, IoT, and Extended Reality. Understanding the best technology solution from a techno-economic standpoint is critical to determining the IoT's commercial viability. It is expected that 5G technology will be implemented.

Several papers have been released on the linkage between IoT and 5G networks. For instance, an article by Boccardi et al. focused on technologies based on the belief that solutions such as device-centric architectures, smart devices, massive MIMO (Multiple-input/multiple-out), and support of M2M will form the basis of 5G networks.[1] Another paper by Akyildiz et al. titled the internet of Bio-Nano things describes the contribution of IoT to the evolution of the 5G network [2], and that of Bakhshi et al. describes the importance of the application IoBNT paradigm despite the difficulties in modeling bio-cyber interactions.[3] This paper will analyze the mathematical modeling approach and feasibility study. The techno-economic analysis of IoT in 5G was conducted using a new pricing model consistent with mobile broadband evolution. Operating Expenditure (OPEX) and Capital Expenditure were the cost aspects compared to the predicted income to be generated throughout the growth period (CAPEX)[4]. The analysis of the results shows that the 5G network is more significant than the 4G LTE because of the lower cost associated with it and the increase in the data transferability that the 5G offers, and the increased number of users.

In reusing the existing websites, there is an economic impact of reducing costs when developing a denser network of macros. The analysis of price elasticity gives a margin benefit because it will be feasible for the business to understand when the price is expected to be elastic and inelastic in the technology market. The macro websites are associated with the lack of limited coverage and capacity with negligible solutions such as WiFi and picocells developed with 5GmmWave and femtocells. This study uses a sensitivity analysis and a techno-economic analysis of IoT models to determine the feasibility of IoT networks in 5G. The paper's remaining structure is as follows. The proposed architectures and financial proposed models are summarized in Section II. Section III summarized the Techno-Economic Analysis of IoT and the femtocell network model. The last section summarizes the conclusion and future research.

II. PROPOSED MODEL

The section presents the proposed model and analyses it technically.

A. The IoT model

LoRa network architecture is a long-range WAN system architecture and communication protocol, while the LoRa defines the physical layer of the architecture. The figure 1 below shows the physical architecture of the LoRaWAN node.

<table>
<tr><td colspan="3">Application</td></tr>
<tr><td colspan="3">LoRa MAC</td></tr>
<tr><td colspan="3">MAC Options</td></tr>
<tr><td>Class A</td><td>Class B</td><td>Class C</td></tr>
<tr><td colspan="3">LoRa Modulation</td></tr>
<tr><td colspan="3">Regional ISM Band</td></tr>
</table>

Fig. 1. Physical Architecture of LoRaWAN Node

The modern IoT LAN technologies use the mesh network architecture, which helps the system increase the network's cell size and communication range. The nodes in a mesh network are responsible for forwarding messages to other nodes relevant to them. The start topology used by LoRaWAN helps increase the battery lifetime when the long-range connectivity is used.[5] Low-power wide-area networks (LPWAN) have arisen to meet the connectivity needs of the Internet of Things. An LPWAN is expected to be to the IoT what WiFi was to consumer networking: delivering radio coverage over a (very) vast area via base stations and modifying transmission power, transmission rates, duty cycles, modulation, and other characteristics, so that linked end-devices consume very little energy. LoRa's range is free, making it a cost-effective alternative to 3GPP technology.

LoRa network is a technology used in the IoT, but it has limits to the mass development in the economy. The paper presents a LoRaWAN feasibility assessment of the large-scale IoT application and influencing elements to its success. LoRaWAN has been chosen because of its adequate characteristics of low power consumption, easy scalability, and high coverage, and it's license-free which facilitates its reduced costs and fast developments.[6] As seen below in Figure 2, a typical LoRa network has a star of stars architecture and comprises several devices.

Over a long distance, the end devices broadcast little amounts of low data at low frequencies. LoRa gateways receive packets through radio links from end nodes and forward them to the server via 3G/4G broadband connections.[7]A network server maintains the entire network, whereas an application server is the end server to which all data from the end device is transferred to take the appropriate action. The 5G networks being deployed are built on 4G networks. They are expected to evolve into massive IoT within the 5G functionality required to support the narrow band use cases [8].

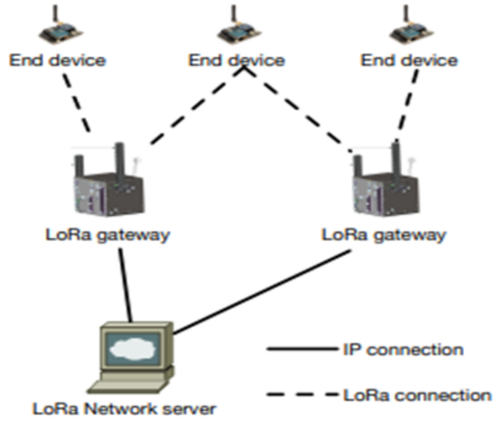


Fig. 2. The Architecture of the LoRa Network

With the understanding of LoRa network architecture, two different scenarios will be used based on device density to analyze LoRa WAN technology's employability. The cost-benefit analysis as a feasibility tool is employed in the analysis, which will help decision-makers make rational decisions on the development of LoRa WAN. From Figure. 3, LoRa has many gateways receiving data from a single node. Such elements can be represented in the Figure 3 shown below.

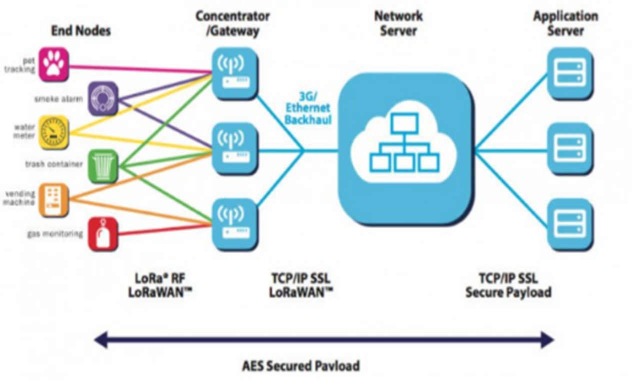


Fig. 3. LoRa WAN Network Topology

There is a potential for the immediate development of LoRa and LoRa WAN networks; the industry is considering the development of LPWA networks[6]. LoRa WAN networks should utilize ISM (industrial, scientific and medical radio bands) frequency ranges according to the LoRa WAN specification. These bands' maximum transmission power and duty cycle are governed by regulations, causing delays between the device's subsequent frames. If the limit is set to one percent, the device must wait for 100 times the length of the preceding frame before sending another frame in the same channel.[5]

B. *Femtocell Network Model*

Femtocell networks are cellular network access points that use household DSL, cable broadband connections, or optical fibers to link mobile devices to mobile operator networks. Demand for telephones has increased significantly, thus necessitating the need to meet the highest average and cellular performance requirements in contrast to decreasing revenue per user.

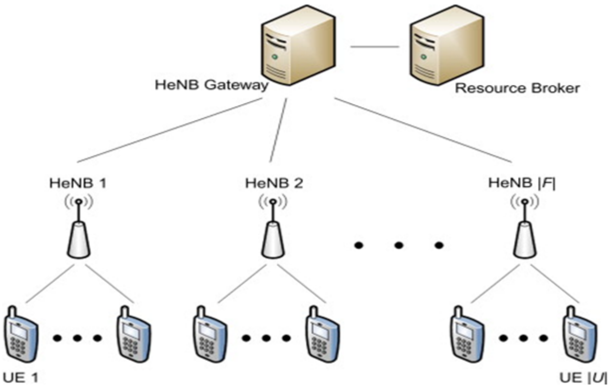


Fig. 4. LTE Femtocell Network Model

Each of the HeNB has specific resource demands to fulfill the requirement for UEs.[9]

III. TECHNO-ECONOMIC ANALYSIS

A. *IoT Model*

Capacity Assessment: As shown in Figure 5 below, the network's capacity can be calculated using Packet Time on Air (ToA) data.

Fig. 5. ToA Illustration

The ToA on capacity calculation determines the total capacity required. Options for the transmission of LoRa are 125KHz, 250KHz, and 500KHz in different countries. Because of regulatory limits, LoRa has a duty cycle limitation. The transmission mode determines the LoRa end device.

Coverage Assessment: The Free Space Path Loss is used to calculate coverage (FSPL). Path loss can calculate the number of gateways needed to cover the area.[10]

Number of Sites = (area size) / (site area)

Investment Analysis: The investment calculation has four components: operating costs (OPEX), capital expenditure costs (CAPEX), NPV, and IRR(Internal Rate of Return). The cost and benefit structures are as shown below in Figure 6 and Figure 7.

CAPEX consists of installation and material costs, while OPEX has maintenance and operation costs, customer service costs, and data transfer costs. The tables below in Figures 8 and 9 show the Capex and Opex elements in USD.

IoT market companies are the most frequent cloud consumers; thus, the information system is included in OPEX.

The value of operating and maintenance is ten percent of the total Capex. The NPV with CAPEX and OPEX known can be calculated as shown in Figure 10.

Where: **NPV** is the Net Present Value, $\mathbf{C}_t$ is the cost at the time t, $\mathbf{B}_t$ is the benefit at the time t, **r** is the discount rate

The sensitivity analysis is important in determining the materials subject to change. The material cost and the external benefits most influence the change of NPV.

Business Model Analysis: The Build Operational Transfer (BOT) business model for LoRa WAN is cost-effective compared to other models.

The available business model is built between vertical industries and the system integrator company.

The financial benefit provided by the development of femtocells for LTE mobile broadband services.

An LTE level system simulator and a wireless access network techno-economic model were used to size the entire access network from the macrocell base and macro base, the femtocells, to the transmission network, as shown below. We can compute the total cost of a network that requires a specific operating environment using the full sizing technique. In development, a clean macrocell network and a connected (common) macrofemto network are contrasted.[11]

B. *Techno-Economic Model for Femtocells*

The model helps analyze the advantages of introducing the Femtocells in developing the LTE macrocell network and evaluating its feasibility.[10] The analysis of the model is shown in the Figure 11 below.

Mostly analyzed costs are the Capital expenditure (CAPEX) and operational costs express operator costs (OPEX). Network-driven and business-driven costs make up OPEX. The study examines network-driven costs, which are taken into account because the company wants to deploy in both situations with and without femtocells. According to the comparisons, the cell radii achieved with the LTE macrocell simulator are relatively similar in both 890 MHz and 2.7 GHz deployment scenarios.[10] This implies that the system has reached its limit. As a result, the 890-MHz frequency band offers no advantage over the 2.7-GHz band because the 890 MHz spectrum is significantly more expensive than the 2.7 GHz spectrum, The 890 MHz frequency range is left out of the investigation, and instead, the 2.7 GHz frequency band is employed. The figures 13 Aand 14 below help differentiate the importance of Femtocell in terms of saving.

From the table, the savings are reduced by approximately 20% when femtocells are considered, but they are reduced when sites are reused.

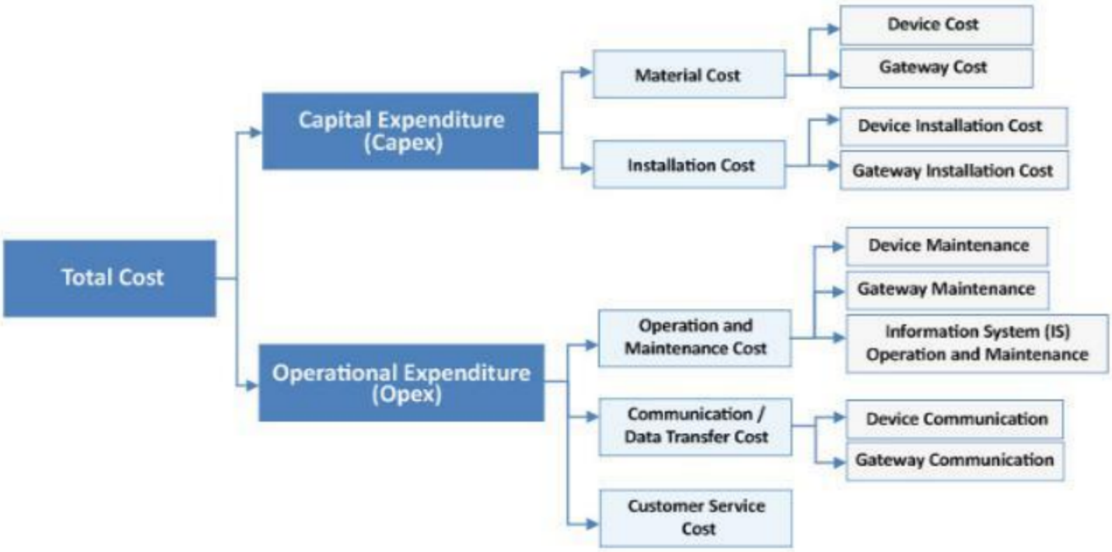


Fig. 6. Cost Structure

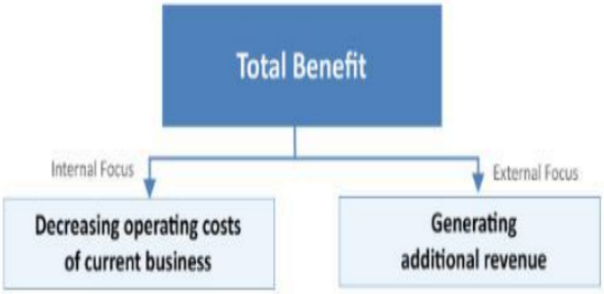
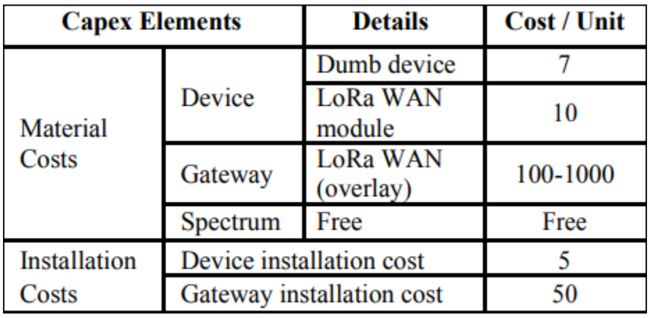
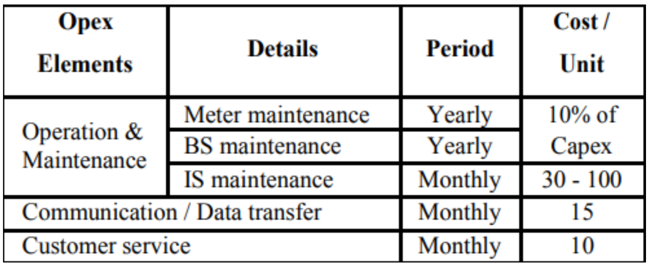


Fig. 7. Benefit Structure



Capex Elements		Details	Cost / Unit
Material Costs	Device	Dumb device	7
		LoRa WAN module	10
	Gateway	LoRa WAN (overlay)	100-1000
	Spectrum	Free	Free
Installation Costs	Device installation cost		5
	Gateway installation cost		50

Fig. 8. CAPEX Elements (in USD)



Opex Elements	Details	Period	Cost / Unit
Operation & Maintenance	Meter maintenance	Yearly	10% of Capex
	BS maintenance	Yearly	
	IS maintenance	Monthly	30 - 100
Communication / Data transfer		Monthly	15
Customer service		Monthly	10

Fig. 9. OPEX Elements (in USD)

$$NPV = \sum_{0}^{t} \frac{B_t - C_t}{(1+r)^t}$$

Fig. 10. NPV Calculation

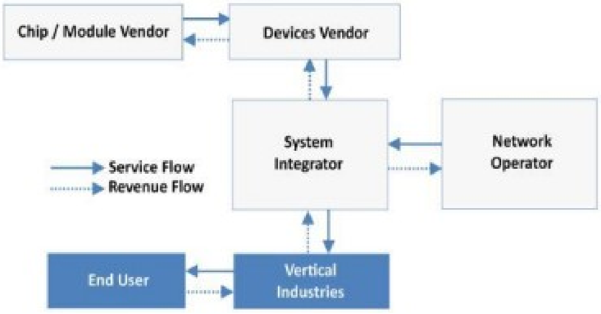


Fig. 11. LoRa WAN Deployment Business Model

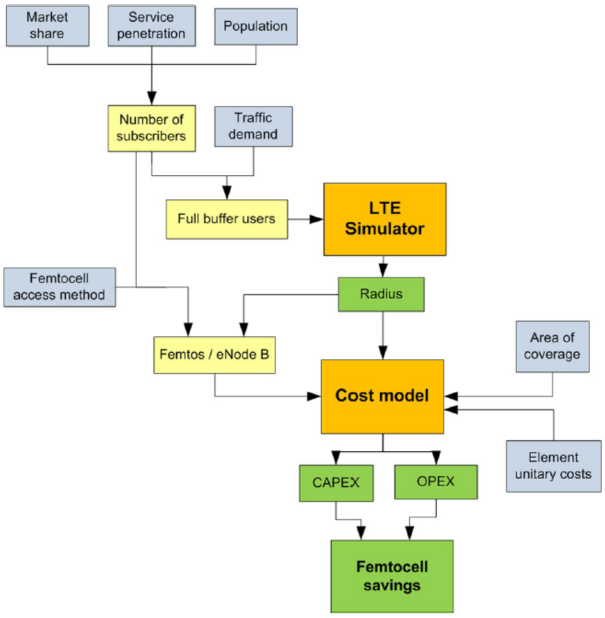
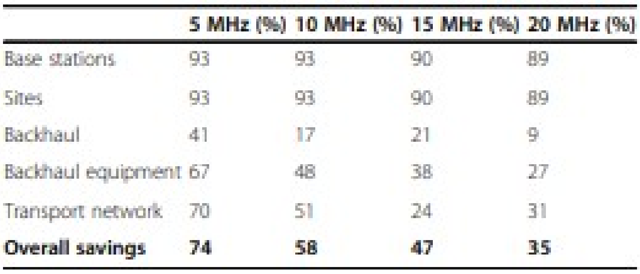
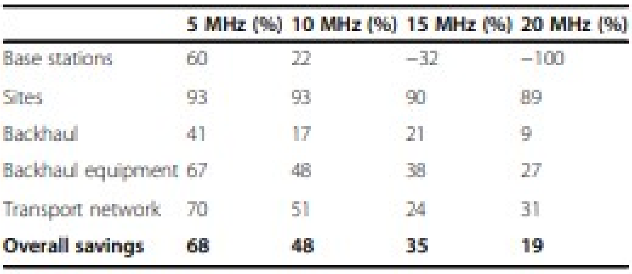


Fig. 12. Techno-Economic Model for Femtocells



	5 MHz (%)	10 MHz (%)	15 MHz (%)	20 MHz (%)
Base stations	93	93	90	89
Sites	93	93	90	89
Backhaul	41	17	21	9
Backhaul equipment	67	48	38	27
Transport network	70	51	24	31
Overall savings	**74**	**58**	**47**	**35**

Fig. 13. Savings in Network Related Cost Not Considering Femtocell Costs



	5 MHz (%)	10 MHz (%)	15 MHz (%)	20 MHz (%)
Base stations	60	22	−32	−100
Sites	93	93	90	89
Backhaul	41	17	21	9
Backhaul equipment	67	48	38	27
Transport network	70	51	24	31
Overall savings	**68**	**48**	**35**	**19**

Fig. 14. Savings in Network Related Cost Considering Femtocell Costs and Subscriber Loop Costs

IV. CONCLUSIONS AND FUTURE WORKS

The section concludes the paper and proposes further research on the topic. The work's objective is to provide a hypothetical assessment of telecommunications market forces as we move toward 5G, which will serve as further evidence for high-level planners to design future-proof market strategies. From the results, LoRa WAN is best for access to technology to support the application of two-way smart meters and integration of femtocells.[12] The best business model described is the Build Operational Transfer. Rapid technological advances make it difficult to predict the demand and long-term capacity, thus making it uncertain for the decision-makers. Quantifying the performance of the 5G supply strategies presented shows a great impact on future demand due to the dynamic increase in mobile traffic.

Rapid technological innovation in mobile telecommunications is affecting our ability to accurately predict long-term capacity and demand, necessitating rigorous scrutiny of this uncertainty to be quantified and visualized to support decision-making. The analysis presented here can help mobile network operators (MNOs), digital media businesses and government agencies understand the effects of growing demand (especially the economic impact) the change in traffic per user or by population fertility, mortality and migration. In addition, quantifying the performance of different 5G supply strategies was presented as a way for MNOs to cope with the dynamic increase in mobile traffic. We find that the increase in traffic per user has the greatest impact on future demand, while in comparison demographic change (fertility, mortality and migration) has less impact.

The move towards 5G will aid in serving the complimentary need for the increasing demand and serve as evidence for the high-level decision-makers.[13] In contrast to energy or transportation systems, technology forecasters should be encouraged to focus on enhancing demand for user data rather than producing population forecasts. According to outcome estimates, spectrum techniques could perform well in most situations by 2026 and play an essential role in addressing medium-term demand.

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