Broadband Penetration Beyond 5G: Challenges and Open Issues

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***Abstract*—This paper presents a review and analysis of the trend of broadband penetration in a developing country case study. The presentation is compared with the trend of broadband penetration in South Korea that has launched its' 5G in 2019. The year 2020 promises to be the implementation and commercialization of 5G globally. However, there are challenges facing developing nations with respect to the eventual launch. As the world moves to begin research work in beyond 5G and likely deployment in 2030, will developing countries be captured and what will be the drivers to give a critical attention? The findings of this paper is based on a 18 year data (2001-2018) of Nigeria as case study. It is recommended that Information and Communication Technology researches should be targeted at less developed and developing countries with the hope of expanding the reach of 5G and beyond 5G. To predict the expected broadband penetration in the nearest future, we used MATLAB R2019b linear regression trainer to train data and predict based on response plot. Result shows that there is a positive linear relationship between year under review and rise in number of broadband penetration. The regression model has an R-Squared value of 0.96 or 96% which is a good fit. Furthermore, we also implemented an Artificial Neural Network (ANN) model to predict broadband subscription. The model which was implemented using R-Programming gave an accuracy 93% with a projection of over 200million broadband subscription in 2021.**

***Index Terms*—ANN, Beyond 5G, broadband, NCC, 3GPP,**

I. Introduction

Broadband can be generally defined as the range of technologies making possible high-speed and high-capacity data communication through fixed or mobile connections. The deployment and trials with 5G began in 2018 and it is on record that as at 2019, the following countries top the race in 5G implementation: South Korea, China, United States, United Kingdom and Germany. Other countries include Switzerland and Nordic countries like Denmark, Finland, Iceland, Norway and Sweden who have began unique move to have an interconnected 5G network throughout the region. This paper compares the broadband penetration of South Korea being the first country to launch 5G services to work on 5G smartphones in April 2019 with a developing country like Nigeria who is yet to launch same.

One of the secrets in the success of South Korea is existing growth in broadband and willingness by existing customers to purchase 5G devices. The challenge in less developed and developing countries may be that of poor broadband penetration. This paper aimed at comparing broadband penetration growth and the possibility of 5G and beyond 5G growth in such countries. Table I shows the trend in 5G, beyond 5G (B5G) and 6G related researches as captured in IEEE Xplore Digital library. The Table I showed increasing interest in 5G as expected but there is now an attempt to peep into what is expected beyond the 2020 full and commercial implementation of 5G. Such researches are termed either as B5G or majority going ahead to call it 6G [1].

It is evident from the above that works on B5G and 6G are still at the infant stage. Motivated by this, we make the following contribution in this paper:

1) A comprehensive compilation of broadband penetration data of a developing country case study.
2) A review of broadband penetration performance of south Korea and lessons to be learnt by developing countries for B5G and 6G deployments.
3) Proposal of developmental framework for commercialization of 5G, B5G and possible 6G technologies in Less developed and developing countries.
4) Proposed Artificial Neural Network (ANN) for the prediction of Broadband Subscription using R-Programming.

The rest of the paper is arranged as follows: In section II, we briefly described broadband penetration trend in both countries. Section III presents a prediction into the diffusion of B5G or 6G. In section IV, a performance evaluation result was presented and research inferences made. Paper was concluded in Section V.

II. Broadband Penetration Trend in South Korea and Nigeria

Recent study into 5G deployment in South Korea showed a successful launch in April 2019 [2]. The paper also projected a likely successful deployment of 5G at the saturation time if technical features of 5G are considered by stakeholders. The major hints were on the provision of hot spots in urban areas and the need to retain the 4G at the early phase. The saturation stage of South Korea was put at estimated population of 52,941,342 in the year 2030 [2]. In Nigeria, however, estimated number of mobile cellular subscriptions in

TABLE I
TRENDS IN 5G, B5G AND 6G RESEARCHES IN IEEE XPLORE

Technology	Conferences	Journals	Magazines	Early Access Articles 2020	Books	Standards	Courses	Total
5G	13,465	4,283	1,321	341	315	17	6	19,748
B5G	60	18	8	4	0	0	0	90
6G	289	135	18	9	0	12	0	463

2018 was already about 172 million as shown in Fig 1. This further strengthen the position of this paper that capturing such market potential will fast track the growth of 5G and B5G deployments.

From March 2019, teledensity is calculated based on a population estimate of 190 million, up from 140 million in Nigeria. With this benchmark, there are 180,386,316 total number of subscriptions in Nigeria giving a teledesnity performance of 94.5% [3]. In South Korea however, the success rate is very encouraging as the country boast of close to 100% broadband penetration due to the following reasons: Government support and coordination evidence in National programs for Information Technology infrastructure, Regulation, Financial and legal support. On the supply side, price reduction, various technology options as well as dense housing pattern encouraged the supply by companies. Consumers are willing to demand for broadband due to attractive applications and an Information Technology friendly culture in South Korea. These trio has been judged to be responsible for the success of broadband penetration and Information technology in South Korea contrary to the situation in Nigeria [4]. It is projected that if developing and less developed countries follow these drivers, they may experience growth in Information technology. It is also the position of this paper that companies in the 5G and B5G business begin to adopt the supply drivers in south Korea while trying to penetrate other countries.

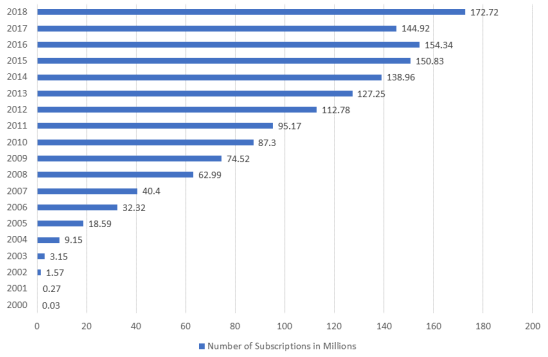

Fig. 1. Number of Subscriptions in Nigeria (in millions)

III. BEYOND 5G BROADBAND PENETRATION PROJECTION AND KOREA MODEL

Mobile broadband service penetration in Korea has been used by researchers as a model and a useful benchmark for countries to emulate [5]. Since the adoption of the five year master plan by Korea in 1995, the country has experienced consistent growth in her broadband and maintaining the lead as an advanced information society. To project into broadband penetration beyond 5G, a look at factors responsible for the growth in broadband penetration in Korea at this stage is considered helpful to other countries. summarising the position of [5], the factors responsible for the success in mobile broadband penetration in Korea can be described in Fig.2. While interested readers can read the article of authors in [5] for details, it is observable here that government support, market competition, supply side drivers such as price reduction and the dense housing patterns in Korea, demand side factors such as attractive applications and the IT friendly culture of Koreans were responsible for the growth in broadband.

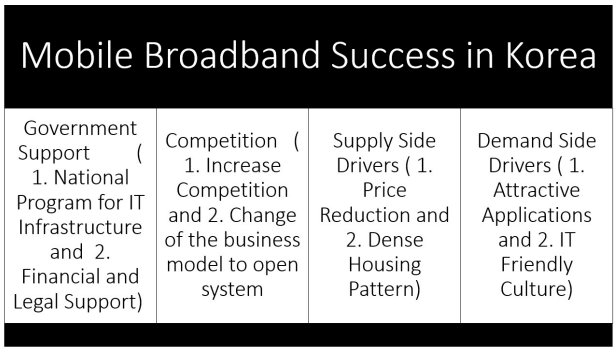

Fig. 2. Drivers of growth in Korea's Mobile Broadband Penetration [5]

For Korea and the world, beyond 5G will witness more services and ubiquitous usage of broadband services. It is therefore, imperative for the governments and stakeholders to consider the improvement in IT education, cyber ethics and security of mobile service transactions to gain confidence of customers on online services.

IV. CHALLENGES AND OPEN RESEARCH ISSUES

Recently, authors identified some challenges facing IT innovations and deployment to include those from system, business and policy challenges [6].

A. System Challenges as Open Research Issues

Several projections into the growth of broadband beyond 5G is expected to present researchers and engineers with contend-

ing issues of roll out, deployment and managing continuous increase in network subscribers. Several issues such as choice of used and unused broadband spectrum. For instance, it was observed by [6] that IoT networks selecting the appropriate Radio frequency technology with receiver sensitivity is critical as well as handling the challenge of missed packets due to crowded frequency bands of multiple networks. This calls for open research issues into effective and obstacle aware routing protocols capable of dealing with irregular traffic and handling uncertainties in terms of arrival time, contents, quality, size and destination mix [7].

B. Business Challenges as Open Research Issues

While the world rolls out to deploy 5G and indeed technologies beyond 5G such as the 6G already conceived, broadband penetration in less developed countries poses business challenges to telecommunication and broadband providers who are not expected to focus on the developed countries such as South Korea alone [8]. Since the variety of products expected from services available beyond 5G is expected to make the world a global village, stakeholders are of the opinion that limited or poor broadband penetration in one country may affect the business of providers who desire to deploy their products and make returns as quick as possible. It is therefore an open research issue for telecommunication and broadband mobile service providers to invest in researches that guarantee backward and forward compatibility such that products take into notice the disparity in broadband penetration among various countries.

C. Policy Challenges as Open Research Issues

Just as countries try have control over their territorial integrity, broadband and 5G technology was seen as global competition and it was evident towards 2020 how countries tried to outplay each other in the deployment. This is understandable since it is the business of policy makers in various countries to consider the interests of their countries first in all issues. However, mobile broadband service providers are caught in the web of pleasing all stakeholders where conflict exists in policies. For example, some countries considered the entrance of certain companies as security threats while others place emphasis on 'protecting' their local companies. Such a situation can hinder the growth of broadband and eventually slow down the expected gains of beyond 5G technologies and their range of useful products. A typical description of how policies affected broadband penetration in Nigeria is shown in Fig. 3 and calls for effective telecommunication policies [9].

This paper proposes the adoption of the common platforms as championed by the International Telecommunication Union (ITU) as a neutral policy making and monitoring body to accommodate the broadband needs of developed, developing and less developed countries.

D. Prediction of Broadband Subscription using Linear Regression

In this paper, MATLAB R2019b was used to train collected data and response plot was used to show the performance

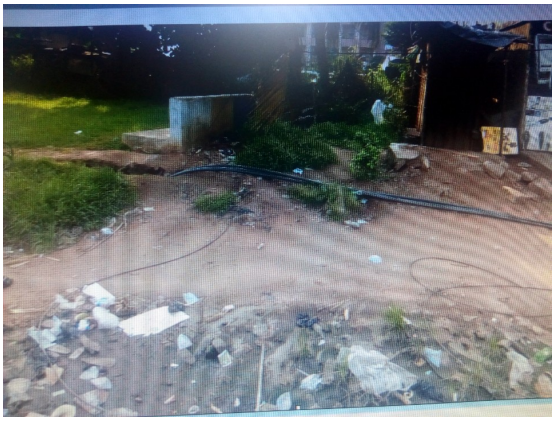

Fig. 3. Broadband Cables being destroyed due to Inconsistent Government Policies in a State in Nigeria. This is not common in Korea where the government already have Consistent Right of Way Policy through effective duct systems for Broadband cables

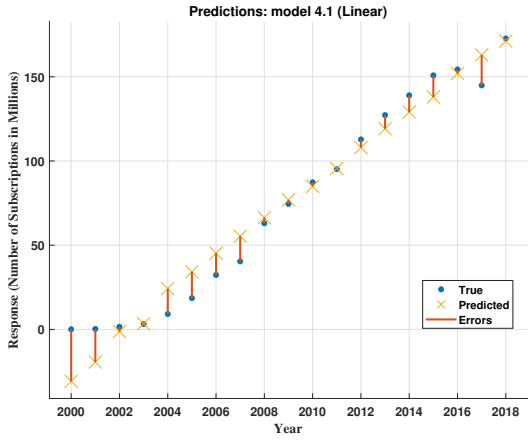

Fig. 4. Linear Regression Prediction of Number of Subscriptions in Nigeria (in millions) using MATLAB Trainer

of our prediction model. In predicting the relationship between the year under review and number of subscription, we compared linear regression model to other state of the art such as interactions linear, robust linear and step wise linear respectively. Fig. 4 shows the best performed prediction from the basic linear regression as it has the least errors as we move from 2000 to 2018. Prediction reliability or significance using R-Squared value was 0.96 or 96%. The result further consolidates our position that there will be a linear and continuous rise in broadband subscription going to the future and continuous need for more broadband and broadband management.

The next is to show our predicted versus actual plot which further show that our model represents the true relationship between broadband penetration and year progression. The Fig. 5 shows that the regression fit model has minimal errors considering how the lines of predcitions is fitted along the line.

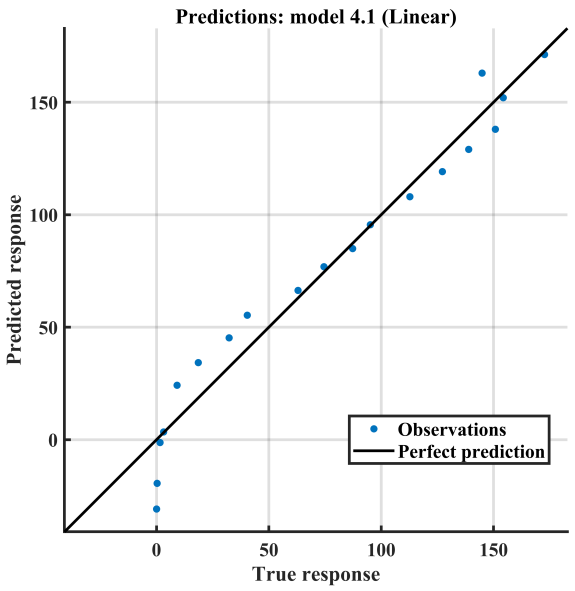

Fig. 5. Prediction Vs Actual Plot of Number of Subscriptions in Nigeria (in millions) using MATLAB Trainer

E. ANN Prediction of Broadband Subscription using R-Programming

We further used R-Programming to design two models of ANN. The first ANN model (ANN1) comprised five (5) Input layers, five (5) hidden layers, and five (5) Output layers, while the second (ANN2) contained two (2) Input layers, one (1) Input layers, and two (2) output layers. The decision to try various numbers of layers and batch sizes is premised on the research findings of [10] who opined that various of batch sizes and parameters affect the accuracy of neural networks. The accuracy of ANN1 gave 79% predicting about 212 million subscription in 2021. On the other hand, ANN2 which projected over 190 million gave 93% accuracy as shown in Fig. 6. This projection of over 200 million is considered fit and reliable as the records of Nigerian Communication Commission (NCC) in April 2020 is already put at about 190 million broadband subscription [3].

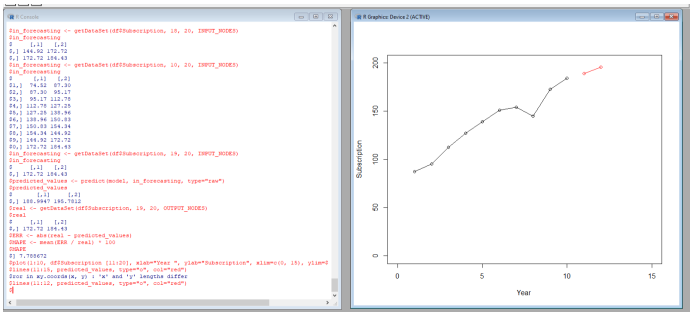

Fig. 6. ANN Model with 2 input layers, 1 hidden layer and 2 output layers designed using R-programming to predict broadband subscriptions in Nigeria (in millions)

V. Conclusion and Future Works

Broadband penetration has to do with the growth in the adoption and usage of broadband technology. The major causes of poor or low broadband penetration are: broadband distribution challenges (supply-side drivers) and low demand for broadband (demand side drivers). However, Nigeria has the potential to take charge of the market with time, adding that development in the market at the moment has already shown that this is possible. This is very critical to investment decision by Telecommunication companies as observed by stakeholders who said that factors considered by Mobile Phone manufacturing plant include: market size, return on investment and environment. It is a known fact that organizations are the major users or beneficiaries of broadband. It then implies that any significant investment decision that impacts on organizations must factor in the place of broadband. It is a future research direction to investigate the investment decision making of network and mobile broadband service providers with a view to decipher technical and non technical challenges as well as proffer solutions going forward.

Acknowledgment

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