

ROLES OF BIG DATA ANALYTICS IN NIGERIAN TELECOMMUNICATIONS INDUSTRY: A CONCEPTUAL EXPLORATION

¹Yusuf-Asaju, A. W*, ²Salau-Ibrahim, T.T, ¹Salihu, S.A

¹Department of Computer Science

Faculty of Communication and Information Sciences

PMB 1515 University of Ilorin, Kwara State, Nigeria.

²Department of Physical Sciences, Computer Science Unit

PMB I601 Al-Hikmah University Kwara State, Nigeria.

ayisatwuraola@gmail.com*, taofeekatsalau@gmail.com, salihu.sa@unilorin.edu.ng

*Corresponding author

ABSTRACT

Nigerian telecoms industry has witnessed a rapid growth in the last two decades. The growth has contributed to the social-economic growth and development of the country. In fact, Nigerian telecoms industry is presently referred to as the fastest growing industry in Africa. However, the growth does not come without the difficulties of inadequate quality of service and customer dissatisfaction with the mobile network services. These challenges has caused an increase in customer churn and attrition rate. Therefore, this study conducted a Critical review on previous studies to highlights the challenges facing the Nigerian telecoms industry. This study observed the main challenges facing the Nigerian telecoms industry are weak infrastructure, improper management of customer expectations, damages of network infrastructures and inadequate power supply. Based on the stated challenges, this study proposed the use of big data analytics that can be used by the MNOs to ensure adequate management of mobile network performance. The study envisaged that the use of big data analytics in Nigerian telecoms industry will enable the mobile network operators to understand the deterioration in the network traffic, kind of resources utilised, where the future traffic problems may occur and plan on how to efficiently reallocate infrastructural mobile network resources.

Keywords: Customer Satisfaction, Big data analytics, telecoms industry, Quality of Service, mobile network operators, mobile network.

1.0 INTRODUCTION

The telecommunications (telecoms) industry has experienced a tremendous growth and innovation over the past decades. The growth has impacted the globalisation, internalisation and effective coordination of economic activities in Nigeria [1]. For instance, [2] reported that the Nigerian telecoms industry contributed to the Nigerian economy with 8.7% Gross domestic product (GDP) in 2015. Similarly, the Nigeria telecoms industry has enhanced business productivity through an enabling information flows on prices, quantities and quality, which in turn improved the service efficiency of mobile workers, improved job search, promotion of entrepreneurialism as well as reduction in business costs and travel time [3]. In addition, the telecoms industry has improved the effective delivery of public services and support social development by offering an effective health care and education services to the remote and under-served areas through the provision of mobile-government incentive and mobile applications [3].

Although, the telecoms industry had immensely contributed to Nigerian's social- economy growth and development. However, these contribution does not come without the problems of Quality of Service (QoS) provisioning, customer dissatisfaction, resource

allocation management and a fierce competition among different Mobile Network Operators (MNOs) [4],[5],[6]. Under these circumstances, the telecoms industry seeks the use of advanced technologies to assist the MNOs to improve their delivered services and enhance customer satisfaction.

Therefore, this paper critically examined previous studies to determine Nigeria telecoms growth potentials, the challenges facing the Nigerian telecoms industry and discussed how big data analytics can be used in Nigerian telecoms industry to aid service provisioning. The use of big data analytics in Nigerian telecoms industry will aid the MNOs understand customers' requirements and expectations. One way to improve the mobile network services through big data analytics is making sense out of the data obtained in mobile network traffic. This will enable the process of seeking insights about the root causes of deterioration in the mobile network. In addition, the use of big data analytics can assist the MNOs to determine how the network elements are interconnected and how the variations of the QoS parameters measurements affect both the voice and data services.

The remainder of this article is organized as follows: Section 2 explores the Nigerian telecoms growth potentials. Followed by section 3 that discusses

the challenges facing Nigerian mobile telecoms industry. Section 4 presents an overview of big data analytics and techniques. Section 5 highlights the impacts of big data analytics in mobile telecoms industry. Lastly, section 6 presents the conclusion, limitations and implications of this study.

2.0 NIGERIA TELECOMS GROWTH POTENTIALS

The rapid changes in the development and renovation of the Nigerian telecoms industry can be traced back to the liberalisation of telecoms industry which gave birth to the usage of mobile Global System for Mobile Communications (GSM) in 2001. The liberalisation facilitates the establishment of telecoms regulatory body in lieu of Nigerian Communications Commission (NCC). NCC is responsible for creating an enabling competitive environment among the MNOs in the industry, to ensure the provision of qualitative and effective telecoms services throughout the country [7].

The advent of the mobile GSM overcomes the Nigerian Telecommunications (NITEL)'s monopolist observed in the telecom industry, thereby allowing the effective operations of the private MNOs in the telecoms industry. Among the early private MNOs licensed by NCC to operate in the telecoms industry in 2001 are Mobile Telephone Network (MTN), Mobile Telecoms (M-TEL) and Vmobile [4]. Subsequently, GLOBACOM limited (GLO) and Emirate Telecommunication Company (ETISALAT) were also granted license by the NCC to operate as one of the private MNOs in the telecoms industry in 2002 and 2008 respectively.

The increase in the number of MNOs granted license to operate in the telecoms industry contributed immensely to the number of mobile network subscribers in the country. For instance, there was a spontaneous increase in number of mobile network subscribers (customers) from 1.56 million to 147.21 million with a rapid increase in teledensity from 1.89% to 106.25% between 2002 and 2016 respectively [7]. Similarly, the growth has immensely contributed to the Nigerian Gross Domestic Product (GDP) ranging between 8.9% to 10% in 2010 and 2016 respectively [7], [8]. As a result of this growth, the Nigerian telecoms industry is regarded as the fastest growing telecoms industry in Africa, because the telecoms industry has experienced a major transformation in terms of growth, technological content and market structure [9].

In the same way, the telecoms industry is the largest generator of Foreign Direct Investment (FDI) to Nigeria after the oil and gas industry. Omoniyi [10] indicated that after the economic liberalisation in 2001, the FDI in telecoms industry came about 32 Billion US Dollars in 2015. This enables few international agencies and institutions such as International Finance Corporation (IFC), Export-Import Bank of the United States, the African Development Bank (AFDB) and the Development Bank of Southern Africa to invest in the Nigerian telecoms industry [11].

In addition, the growth had contributed to a better quality of life as several people had been directly or indirectly benefited from the employment generated by the MNOs such as nationwide mobile network dealers, vendors and the ubiquitous umbrella stand call centres. Subsequently, to enable the telecoms industry, maintain its status as the fastest growing telecoms industry in Africa till 2025, the telecoms industry had plan to improve its contribution to the nation's GDP from 10% to 25% by 2025 [8]. Likewise, NCC has also promised to provide an enabling environment, good policies and solve the challenges faced by the industry, in order to actualise the industry target by 2025. For this reasons the telecoms industry is perceived as an enabling industry that can transform all sectors and enhance the socio-economic development in the country.

3.0 CHALLENGES FACING NIGERIAN MOBILE TELECOMS INDUSTRY

Despite the aforementioned achievements made by the telecoms industry and the contributions made to the development of the economy, the telecoms industry is still faced with series of challenges inhibiting their speedy progress in Nigeria. Several studies had indicated that some of the challenges faced by the telecoms industry in Nigeria are as a result of weak infrastructure, improper management of customer expectations, damages of network infrastructures, inadequate power supply, illegal regulations by the telecoms regulators, taxation imposed by the Government and delay in securing approval of sites for new base transmission stations [4], [12], [13], [5], [6], [9], [11], [14], [15], [16]. All these challenges contributed to the problem of inadequate provision QoS and dissatisfaction of the mobile network subscribers [6], [16]. Thereby causing the increase in customer churn and attrition rate [9]. Hence, the customers are seriously faced with the problem of deciding the MNOs to choose based on cost comparison and better service benefits. In fact, it was observed that active mobile internet customers have reduced by 1.1 million in December, 2015, thereby causing a decrease in the teledensity from 108.66% to 107.87% [17].

Similarly, NCC also showed that there was a drastic decrease in the number of mobile network subscribers from 151.3 million to 148.7 million and a drop in teledensity from 107.87% to 106.25% between December, 2015 and March, 2016 respectively [7]. This pose a serious challenge on both the regulatory body and the MNOs because the MNOs has experienced a drastic decrease income within a short period of time, and the customers are also complaining of inadequate provision of QoS resulting in dissatisfaction with the provided network service. Hence, the challenges facing Nigerian mobile telecoms industry is summarised in table 3.1 below:

Table 3.1: Challenges facing Nigerian Mobile Telecoms Industry

No	Authors	Challenges
1	[4]	Weak Infrastructure base. Regulator incompetency in enabling law and regulation. Inadequate tariff regulations. Improper management of customer expectation. Inadequate power supply. Spectrum planning and allocation problems.
2	[8], [9]	Inadequate management of radio frequency among subscribers resulting in poor services by the MNOs and difficulties in Satisfying mobile network subscribers.
3	[5]	QoS problem as a result of vandalism of infrastructure, network failure due to network congestion, slow download and connection drops.
4	[11]	Rise of churn and attrition rate.
5	[12]	Delay in securing approval for sites for new base stations. Harassment by some government agencies especially at the state and local government levels.
6	[14]	Instability power supply. Security infrastructure. Inter-network connectivity problems (such as call drops, call set up failure and call retention). Network congestion. General poor QoS in mobile networks.
7	[6]	Dissatisfaction with the provided QoS such as call drop during telephony, low voice quality, poor interconnectivity and poor reception on network. High billing system on mobile network service. Problems of teledensity (network congestion) in the areas covered by the MNOs.
8	[13]	Long delay in obtaining permit. Multiple and illegal regulations. Taxation at federal, state and local government levels. Damage of fibre infrastructure during road works. Lack of green energy initiatives and support.
9	[15]	Poor network coverage. Unsatisfactory customer care support. Increase in number of dissatisfied customers as a result of poor QoS.

4.0 BIG DATA ANALYTICS

Organisations such as telecoms industry collects, store and analyse massive amounts of data. These data are usually referred to as big data because of its richness in volume, velocity, veracity, value and variety. Volume is the most important and distinctive criteria of big data, because it describes the size, scale and amount of the data in terms of terabytes, exabytes or petabytes [18].

Velocity refers to the rate of speed at which the data are generated and the resulting accelerated growth of the data [19]. Variety described the disparate sources of data generated with the organisation [20]. Value is also an important feature of big data, because it comprises of the potential of the data to be used for a particular analytics process. Veracity describes the quality of the data to be used for analytics processes in terms of consistency, accuracy and trust worthiness of the data [18].

All these characteristics of big data comprises the typical feature of the kinds of data generated in the telecoms industry. Big data has the potentials to generate new insight information about the services provided by the MNOs and facilitates the creation of a new generation support data management [21] that aid the organisation's decision making in improving their services through the analytical processes.

However, there is a growing debate about how the telecoms industry maximise the benefits of big data in improving their services [22]. Therefore, telecoms industry is actively seeking ways of intensifying the use of big data analytics to improve the existing services and creates new ones, in order to enable customer satisfaction and meet customers' expectations.

Big data analytics comprises of descriptive analytics, predictive analytics and prescriptive analytics [23]. The descriptive analytics enables the process of exploring historical trends of data to extract useful information from the data [24]. This facilitates the process of providing answers to what happened in the services provided by the MNOs in the past.

Predictive analytics employs the use of historical data to predict the future outcome of provided services. These analytics predict the future assumption based on the past failures observed in the dataset [25]. This answers the questions about what is likely to happen in future by uncovering the patterns and relationships in the datasets. Prescriptive analytics aid the process of decision making by gaining insights into the services provided by the MNOs [24].

This usually answers the questions about what should be done by the MNOs by providing an optimal solution to improve the services provided in the telecoms industry. Although, all these analytics aid the process of analysing historical trends of data and predict the future, in order to provide or suggest an optimal solution that can be used to improve the

services provided by the MNOs in the telecoms industry. Therefore, it is essential to be well informed about the different techniques that are usually used for extracting information from the historical dataset.

4.1 Big Data Analytics Techniques

Organisations usually employ the use of analytical techniques to efficiently process the massive amount of data (big data) within a limited run time. Number of studies have highlighted the techniques that can be used for the different types of analytical processes (such as descriptive, predictive and prescriptive [19],[26],[27]. The techniques commonly used for analysing big data comprises of several disciplines such as data mining, machine learning and statistical techniques, which are used to capture, analyse and visualise the datasets [26].

The statistical techniques are used in big data to organise and interpret data. This aid the process of exploring the correlation, casual relationship and numerical description of the dataset [26]. This technique is commonly used for descriptive analytics through descriptive statistics such as the mean, median, standard deviation, range and histogram. The result of the statistical technique is often displayed through charts, lines and graphics. The information extracted through the descriptive analytics are often used for other analytics processes like predictive and prescriptive analytics.

Data mining and machine learning techniques are used to extract valuable insights in the datasets. They enable the process of knowledge discovery by providing an automatic intelligent decision. These techniques adopt the use of several methods such as clustering analysis, classification analysis, regression analysis and association rule learning[26]. Although, big data mining is more challenging than the traditional data mining, because the big data mining comprises of an extended version of the traditional data mining techniques [26].

The machine learning and data mining techniques is used for both the descriptive and predictive analytics for analysing and predicting the future outcome of the dataset. Other techniques include mathematical programming, heuristics search and simulation modelling commonly used to identify optimal action [19]. All the aforementioned techniques can support the big data technologies that comprises of Apache Mahout, Dryad, Apache Hadoop and MapReduce [26].

The big data technologies have the potentials to accommodate the big data techniques in the form of algorithms for analysing the large dataset and address the complex real-life problems. Similarly, the algorithms used in big data analytics process has a huge potential to gain a very good analytics- driven insight such as network planning and resource allocation management about the mobile telecoms services. Therefore, the MNOs can employ the use of big data analytics to analyse the historical data generated in the mobile network traffic.

4.2 Impact of Big Data Analytics in Mobile Telecoms Industry

Big data analytics, most especially the predictive analytics has the potentials to inform the MNOs where and when a proactive measure are required to be provided, in order to satisfy the future demand of their customers. Similarly, the information constituted in network data can form a basis of predictive analytics, because such data consists of QoS parameters measurement variations that occurred in real time of the mobile network. Thereby, enabling the MNOs to understand the deterioration in the network traffic, kind of resources utilised, where the future traffic problems may occur and aid the MNOs to plan on how to efficiently reallocate infrastructural mobile network resources.

In addition, number of studies have described different ways by which big data analytics can impact the telecoms industry in order to aid service efficiencies of the MNOs in telecoms industry [22], [28], [29], [30], [31]. These are explained below.

- (i) **Network Planning and management:** The process of analysing the network traffic data in real time would assist the MNOs to optimise their network and ensure good provision of QoS [22]. This is envisaged to enhance the operational efficiencies in the mobile network performance. This tends to assist the MNOs to adjust their network traffic requirement and improve the resource allocation efficiency through the use of intelligent insight discovered in the big data analytics processes [30]. In other words, the insight discovered in the big data analytics process would enable the MNOs to appropriately allocate network infrastructure resources. Subsequently, a good network planning and management through the big data analytics would solve the challenges of weak infrastructure base, inadequate management of radio frequency among the subscribers as well as, spectrum planning and allocation.
- (ii) **Customer Profiling:** The historical data obtained from the network traffic has the potentials to capture a range of behavioural data of the customers that consists of the customer mobility, social network patterns and consumption preferences [22]. Collectively, these data can be used in big data analytics processes to determine the customer interest, socio-economic class, customer segmentation, likelihood of churn, level of interest of customers, mobility profile and tracked the dissatisfied customers [22], [28]. Big data analytics can enable the process of determining the customer interest based on the customer spending, type of devices used or website visited [22]. Similarly, big data analytics can determine the likelihood to churn, this means the number of customers likely to leave the services

provided by a particular MNO [22]. This is achievable by analysing and targeting the customers' existing service usage behaviour. Such analysis would provide new retention offers by targeting the root cause of customer dissatisfaction [28]. Likewise, determining the level of influence of customers would aid the MNOs to target each customer with promotions and incentives, thereby leveraging the mobility profile for location-based services.

(iii) Pre-emptive Service quality management: Big data analytics has the ability to employ the use of data generated from the network traffic to measure the delivered services through real-time analysis of QoS parameters measurement [31]. This facilitates the process of extracting and combining service components to create a unique service bundles that are correlated to the quality parameters. Similarly, big data analytics provide better insights and visibility over time by evaluating the network performance and QoS provisioning from a customer – centric perspective, such that the MNOs can take a proactive measure before a certain problem would arise.

(iv) Customer Experience and marketing: In general, the mobile network services operate in real-time. Thus, it is imperative to anticipate poor customer experience in real-time or near real-time so that the MNOs can deal with such issues proactively before it completely deteriorate the mobile network services provided by the MNOs[31]. Hence, enabling the MNOs to respond to customer experience issues in a very short time. In other words, using big data analytics to analyse the network data tends to enhance accurate billing, timely response to customer issues, personalised offers based on contextual insight, QoS prioritisation based on customer life-time value and ability to conduct advanced customer segmentation [31].

Subsequently, by leveraging the big data analytics to manage the mobile network services in real-time or near real-time creates an enabling environment for the MNOs to understand their customer behaviour, in order to improve the sales and marketing opportunities. At the same time, facilitating the MNOs to provide measures of meeting the customer's expectations prompt response to network issues and enhance their services so as to provide QoS satisfactory services to the customers.

5.0 CONCLUSIONS

This study provides a conceptual exploration of the Nigeria telecoms growth potential and the challenges facing the Nigeria telecoms industry. Equally, this study highlighted how big data analytics can enhance the provision of a good QoS and improve the satisfaction of customers with mobile network services.

Although, big data analytics may not solve the challenges of inadequate power supply in Nigeria. However, it can be used to efficiently manage the way the MNOs provide their services, by detecting the areas that is affected by inadequate power supply and provide an alternative provision of power supply in such areas. Similarly, NCC should provide measure that ensures competent law and regulations in areas where it is lacking, most especially when the MNOs are faced with getting a location to be used for base transmission station.

This study is based on critical review of previous studies. However, the significance of this study is to keep the MNOs informed on the usage of big data analytics to ease the problems associated with QoS and customer satisfaction. Future work will explores the MNOs performance using the data gathered from the mobile network traffic.

REFERENCES

- [1] B. Adi, "An evaluation of the Nigerian Telecommunication Industry competitiveness: Application of Porter's Five Forces Model," *World Journal of Social Sciences*, vol. 5, no. 3, pp. 15-36, 2015.
- [2] P. Ekwujuru and P. Ofili, "Telecoms, others contribute 8.7% to Nigeria's GDP," Vanguard Media Limited, Nigeria., 12 April 2016. [Online]. Available: <http://www.vanguardngr.com/2016/04/telecoms-others-contribute-8-7-nigerias-gdp/>. [Accessed 15 July 2016].
- [3] GSMA, "Digital Inclusion and the role of mobile in Nigeria," October 2015. [Online]. Available: http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2015/10/GSMA_Nigeria-Report_WEB.pdf. [Accessed 15 July 2016].
- [4] M. A. Mawoli, "Liberalisation of the Nigerian telecommunication sector: A critical review," *Journal of research in national development*, vol. 7, no. 2, 2009.
- [5] A. O. Hassan, "Telecommunications Reform and Effects of Competition on Availability, Quality and Cost of Services in Nigeria," *Public Policy and Administration Research* 1(3), pp. 8-20, 2011.
- [6] F. Longe, "Subscribers' Perception of the Quality of Service (QoS) of the Global System for Mobile Services in Ibadan, Nigeria," *Computing, Information Systems and Development Informatics Journal* 2 (2), pp. 1-14, 2011.
- [7] NCC, "Nigerian Communications Commission," Nigerian Communications Commission, [Online]. Available: http://www.ncc.gov.ng/index.php?option=com_

- content&view=frontpage&Itemid=107.
[Accessed 11 July 2016].
- [8] E. Elebeke, R. Udofia and K. Iruoma, "Telecoms industry to contribute 25% to GDP by 2025," Vanguard Media Limited, Nigeria, 10 July 2016. [Online]. Available: <http://www.vanguardngr.com/2015/11/telecoms-industry-to-contribute-25-to-gdp-by-2025/>. [Accessed 11 July 2016].
 - [9] B. E. A. Oghojafor, G. C. Mesike, C. I. Omoera and R. D. Bakare, "Modelling telecom customer attrition using logistic regression," *African Journal of Marketing Management* 4(3), pp. 110-117, 2012.
 - [10] T. Omoniyi, "Nigeria: Driving National Development Through Telecommunications," allAfrica, 12 November 2015. [Online]. Available: <http://allafrica.com/stories/201511121039.html>. [Accessed 23 September 2016].
 - [11] O. Iwuagwu, "The Revolutionary Years: Nigeria's Telecommunication Industry 2001 – 2011," *International Journal of Research in Arts and Social Sciences*, vol. 7, no. 1, pp. 23-36, 2014.
 - [12] B. M. Kuboye, B. K. Alese, O. Fajuyigbe and O. S. Adewale, "Development of models for managing network congestion on global system for mobile communication (GSM) in Nigeria," *Journal of Wireless Networking and Communications* 1(1) doi: 10.5923/j.jwnc.20110101.02, pp. 8-15, 2011.
 - [13] B. M. Kuboye, "Optimization models for minimizing congestion in Global System for Mobile Communications (GSM) in Nigeria," *Journal Media and Communication Studies*, vol. 2, no. 5, pp. 122-126, 2010.
 - [14] M. Kuliya, K. Abou, Z. Aliyu and M. Lele, "A review of mobile- broadband penetration in Nigeria," *Proceedings of the Academic Conference of African Scholar Publications & Research International on New Strategies and Approaches* 5(1), 2015.
 - [15] I. Nnochiri, "Evaluation Of The Quality Of Service of Global System for Mobile Telecommunication (GSM) operators In Nigeria," *Journal of Multidisciplinary Engineering Science and Technology (JMEST)* 2(7), pp. 1686-1694, 2015.
 - [16] J. Isabona and M. Ekpenyong, "End-User satisfaction assessment approach for efficient networks performance monitoring in wireless communication systems," *African Journal of Computing & ICT* 8(1), pp. 1-16, 2015.
 - [17] PremiumTimesNigeria, "Nigeria's active telecoms subscribers down by one million – NCC," Premium times Nigeria, 10 February 2016. [Online]. Available: <http://www.premium-timesng.com/business/business-data/198279-nigerias-active-telecoms-subscribers-one-million-ncc.html>. [Accessed 12 July 2016].
 - [18] Y. Demchenko, P. Grosso, C. de Laat and P. Membrey, "Addressing Big Data Issues in Scientific Data Infrastructure," IEEE, 2013.
 - [19] L. Duan and Y. Xiong, "Big data analytics and business analytics," *Journal of Management Analytics* 2(1) doi: 10.1080/23270012.2015.1020891, pp. 1-21, 2015.
 - [20] M. L. Berger and zV. Doban, "Big data, advanced analytics and the future of comparative effectiveness research," *Journal of comparative effectiveness research*, vol. 3, no. 2, pp. 167-176, 2014.
 - [21] H. J. Watson, "Big data analytics: Concepts, technologies and applications," *Communications of the Association for Information Systems* 34(65), pp. 1248-1268, 2014.
 - [22] ITU, "Measuring the information society report," International telecommunication union, Geneva, 2014.
 - [23] H. Mousanif, H. Sabah, Y. Douiji and Y. O. Sayad, "From big data to big projects: a step-by-step roadmap," in *International Conference on Future Internet of Things and Cloud*, 2014.
 - [24] D. Arora and P. Malik, "Analytics: Key to go from generating big data to deriving business value," in *IEEE First International Conference on Big Data Computing Service and Applications*, 2015.
 - [25] A. Gandomi and M. Haider, "Beyond the hype: Big data concepts, methods and analytics," *International journal of information management* 35, pp. 137-144, 2015.
 - [26] C. P. Chen and C.-Y. Zhang, "Data- intensive applications, challenges, techniques and technologies: A survey on big data," *Information science*, <http://dx.doi.org/10.1016/j.ins.2014.01.015>, pp. 1-34, 2014.
 - [27] H. Hu, Y. Wen, T.-S. Chua and X. Li, "Toward scalable systems for big data analytics: A technology tutorial," *IEEE* doi: 10.1109/ACCESS.2014.2332453, pp. 652-687, 2014.
 - [28] J. Spiess, Y. T'Joens, R. Dragnea, P. Spencer and L. Philippart, "Using big data to improve customer experience and business performance,"

- Bell labs technical journal* 18(4) doi: 10.1002/bltj.21642, pp. 3-17, 2014.
- [29] H. Yin, Y. Jiang, C. Lin, Y. Luo and Y. Liu, "Big data: Transforming the design philosophy of future internet," *IEEE Network*, pp. 14-19, 2014.
- [30] K. Zheng, Z. Yang, K. Zhang, P. Chatzimisios, K. Yang and W. Xiang, "Big data-driven optimization for mobile networks towards 5G," *IEEE network*, pp. 44-51, 2016.
- [31] A. Banerjee, "Advanced predictive network analytics: Optimize your network investment and transform customer experience," February 2014. [Online]. Available: http://www.sas.com/en_us/whitepapers/advanced-predictive-network-analytics-106994.html. [Accessed 14 July 2016].