Covenant University

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Efficient Data Exchange in Computer Networks:

Big Data and Security in the Emerging Smart World

Samuel Ndueso John

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DEDICATION

This Seventeenth (17th) Inaugural Lecture is dedicated to God Almighty and to the memories of my late father and mother, Chief John Akpan Etok (1914 – 1996) and Mrs. Lucy John Akpan (1926-1982), who made provisions for my education at their best.

Also, to my adopted mother Mrs. Mojisola Sadiku who supported and encouraged me to fulfill the dream of my late mother. Mom, as I always call her, I am very grateful and happy to be your son.

PREAMBLE

Protocol

The Chancellor, The Vice-Chancellor, The Deputy Vice-Chancellor, The Registrar and other Principal Officers of Covenant University; The Dean, College of Engineering; Deans of other Colleges and School of Postgraduate Studies; Directors, Professors and other members of Senate; The Head, Department of Electrical and Information Engineering; Heads of other Departments; Academic, Administrative and Technical staff of the University, Members of my nuclear and extended family, Distinguished invited guests and friends, Gentlemen of the print and electronic media, the Kings and Queens in Hebron, Ladies and Gentlemen.

The Chancellor, Sir, and our able Vice-Chancellor, it gives me great pleasure, privilege and honour to stand before you and your Management Team to deliver this lecture, marking my inauguration as a Professor of Computer Systems and Network Engineering in the College of Engineering of this great and unique University – Covenant University. My academic journey traversed Nigeria through Donetsk National Technical University, Donetsk – Ukraine; University of Lagos, Akoka to Covenant University, Ota – Nigeria where my professorial rank was attained.

Let me borrow a leaf from the great inspirational author – ***Orison Swett Marden's quotation: "Our thoughts and imagination are the only real limits to our possibilities"***

When I was growing up, computer technology was just coming up. Then, the old way of doing arithmetic was with the Abacus method of calculation. Films and documentaries were shown indicating that computers would rule the world. That was how my interest in computers and in this area of specialization came up. I started reading about computer, its essence, and application in, and to life. To God be the glory, I got a Federal Government scholarship to Soviet Union, then USSR, in 1988 to read Computer Science. But on getting there, during the counseling period of the language preparatory school in Rostov-On-Don - Russia, the counsellor intimated us of the advantage of learning both hardware and software Computer courses in Engineering. On completion of the language preparatory class, my journey in the study of Computer Engineering started when I was posted to Donetsk Polytechnic Institute later renamed Donestk National Technical University – Ukraine, where I successfully defended my thesis on: ***"Increasing the Efficiency of Data Exchange in Computer Networks based on TCP/IP Protocol Stack".*** This was widely aired on the local State Television and helped to showcase my university on a new pedestal of the emerging smart world of efficient data management through the research findings and results obtained from my research work. This 17th inaugural lecture which happens to be the 1st in the Department of Electrical and Information Engineering is another rare privilege given to me by the Covenant University Management to justify and bring useful information to our community on what has been achieved so far in the area of Efficient Data Management in Computer Networking and what impact this has contributed to our society and the world at large. I hereby, introduce the topic of today: ***"Efficient Data Exchange in Computer Networks: Big Data and Security in the Emerging Smart World".***

INTRODUCTION

Computer networks play an important and ever increasing role in the modern smart-world. The development of Internet, corporate intranet, smart devices and mobile telephones have extended the reach of network connectivity to places that hitherto, many years ago, would have been unthinkable. This intensive development of modern computer networks and the realization of their programme-hardware systems result in sharp increase of workload and complication of computer networks based on their protocols. In turn, this stimulates substantial increase of workload during utilization of such networks (John et al., 2011; 2012). This network congestion process influences the hardware of the network, as well as the software applications. Thus, based on the background of intensive expansion of the global Internet infrastructure both complication scales and workload of networks grow substantially. Accordingly, providing efficient functioning of networks; task-creation on them based on high-performance of their client-server; and the distributed computer systems become more difficult. An important solution for increasing the efficiency and productivity of networks lies in improving effectiveness and efficiency of data exchange within them (Barry et al., 1997).

Computer network protocols are modelled as finite state machines. It is very necessary to work and research on the factors that really affect the effectiveness of network connectivity towards the improvement of data exchange within them. One of the main factors militating against this is the adequate mechanism of the protocols that play great part in data transmission. In this case, this is termed Transport Control Protocol over Internet Protocol (TCP/IP). TCP/IP is a **flow and congestion control mechanism** that is used within the TCP as they directly influence network throughput. Research carried out based on this protocol shows that it is possible to increase the efficiency of data exchange with increased network throughput without additional overheads on infrastructure of the network (Minaev et al., 2002; John, 2005).

The optimum functioning of protocols is affected by the background complication of networks, increased number of users working in a network and workload occurrence (be it constant or periodic) which increase the network traffic to a critical level (John et al., 2008; Nuri et al., 2002). Well-founded select mode of data exchange allows, in many cases, the reduction of workload on a network; by the same token, increase the real bandwidth and efficiency function of a network as a whole, as well as the hardware/software of separate networks and programmable systems.

The problems relating to improving effectiveness of computer networks and managing the data transmission have been looked at by many researchers and published. In particular, account must be taken of the works conducted at the Donetsk National Technical University, the «Kiev Polytechnic Institute», the Institute of Cybernetics, the Kharkov National University of Radio Electronics, the Ukraine National Academy of Sciences, and other Technical National Universities in Ukraine. Internationally, noted works include those of Kleinrock L., Kamera D., Menaske D., Almeydy V., Steven V. and many others which have extensively covered this topic (John et al., 2005; Anoprienko et al., 2002). Currently, extensive research work is on-going, especially in Covenant University and in other selected Nigerian Universities. As the world population and awareness increase, development in technology and its attendant challenges keep increasing.

In modern computing network applications and environment, there is no alternative than to keep researching on ways and means of managing big data securely in our evolving smart world. Consequently, more research should be directed at improving data exchange efficiency and network throughput towards maximizing bandwidth usage (John et al., 2005; Anoprijenko et al., 2007).

For our collective information, ***big data*** *is a term used to refer to the study and applications of data sets that are too complex for traditional data-processing of application software to adequately deal with.*

Hence, **big data** challenges are numerous: big data projects have become a normal part of doing business. The problems of big data management for effective functioning of computer networks are now actual problems in the modern digital age (Benjelloun et al., 2015). In the history of mankind's development, information had traditionally been disseminated mostly through word of mouth. As time went by, the development of other media and technology such as: radio, telephone, telegram, television, internet etc. became the norm for sending and receiving information. The Internet has revolutionized the computer and communications world. The invention of the telegraph, telephone, radio, television and computers set the stage for this unprecedented integration of capabilities (Leiner et al., 2009). In recent time, the technical innovations have enabled us to collect exponentially growing amounts of data through the use of sensors, smart devices and other sources. All these have become complex, dynamic and reliable in the business world today. Also, a lot of new devices and services are introduced into networks as a whole and efficient management of these data become imperative. These services keep growing and their demands from time to time vary with the services associated with them. Data are transferred from one source to another through network infrastructure with different demands. For example, NASA will need a swift time in sending and receiving data from an unmanned vehicle. In the military, drones which are the novel weapons used in fighting terrorism have their controls on data carrying communication media; just as iRobotic systems in the industries are the way to go now. At airports, services such as baggage and self-check-ins are self-automated. The effectiveness of these data management in computer networks becomes crucial for accuracy, timing, speed and security purposes. More so, these factors that affect data management efficiency in computer networking can no longer be discountenanced.

Typical challenges of Network as per big data management include:

Packet Loss

– This is caused when packet sent from one end of the connection is not received at the other end, whereas, missing packet may need to be retransmitted.

Bandwidth Availability

– This is caused by serialization delay

Latency

– This is delay caused by distance between the sender and receiver or increase in the number of contentions.

The enabling propellants in the 21st century as it concerns data exchange/transmission are:

Entrepreneurship

Entrepreneurship is key to every economy and the Internet has 'democratized' business creation, enabling new, socially inclusive forms of entrepreneurship that falls back to more data usage in communication (Acs et al., 2007; World Economic Forum, 2012). The Internet allows anyone to run a business from his or her home at lower cost than before owing to global connectivity. This has given rise to new forms of economic activity.

Transformation

The Internet has become the mainstream of data transmission and exchange. What started with basic services such as email, now form the backbone of services from banking through to entertainment, medical and industrial supply chains. The supply of new online services and innovations shows no signs of slowing down (World Economic Forum, 2013). A company like Facebook with global brand recognition and more than one billion users is only 10 years old.

See Figure 1: Internet Growth – Usage Phases.

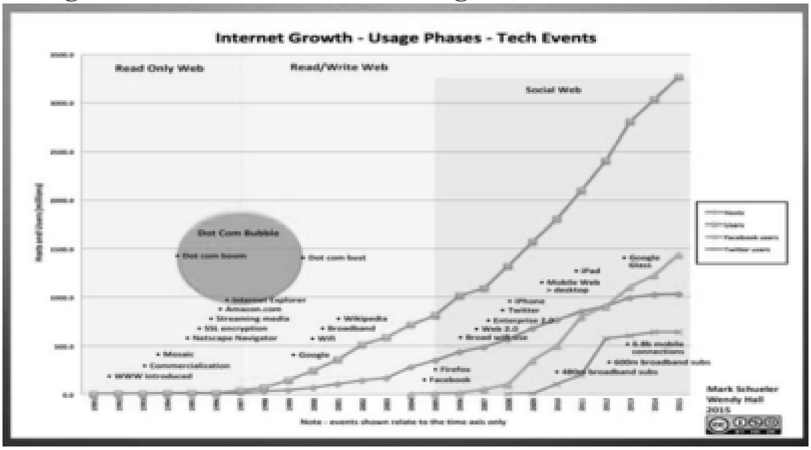

Figure 1: Internet Growth – Usage Phases

The 'Industrial Internet'

On a much larger scale, data-driven innovation is a key ingredient to a phenomenon that is described as the 'Industrial Internet'. Similar to the 'Internet of Things' (IoT), the Industrial Internet refers to a transformative force in which "the physical world of machines, facilities, fleets and networks can be more deeply merged with the connectivity, big data and analytics of the digital world (Evans et al., 2012). It is about making traditional industries 'smarter' by turning each machine into an information system that enables intelligent decision-making based on data. It is estimated that the innovations of the Industrial Internet could find direct application in sectors accounting for more than $32.3 trillion in economic activity. These sectors include aviation, power, healthcare, rail, and oil and gas. General Electric estimated that only a one percent saving and efficient gain across those industries would amount to a value in the multiple billions across a time span of 15 years (Evans et al., 2012). With all these developments going on and more complex services integrated into networking like *Smart Cars, iMobile, iRobotic, IoT (internet of* *things), IIoT (industry internet of things), car-aero-planes and so on*, data becomes bigger, more robust and difficult to manage.

Consequently, researchers have found it imperative to make efficient data exchange a priority. In connection with this, in 2000 at Donetsk National Technical University, I keyed into the research world to see how efficiency of data exchange and optimisation in computer networks can make services on the internet reliable with little or no network infrastructure upgrade against the backdrop that hardware and the topology of networks have been deeply researched (Anoprienko et al., 2001; 2001). We are all today, witnessing the research outcome in this topical area which has become key to our socio-economic life.

In the efficient transmission of data, certain factors affect the productivity/throughput of the computer network. These factors are hardware, topology and mode of data exchange (John, 2005). The high performance CPU (which is the processing power of the computer system) aids productivity. Likewise goes the topology of network which inappropriate design/connection will affect network performance. The hardware and topology were extensively researched on with some great results and still ongoing. However, another factor not well researched is the mode of data exchange that affects the network performance and this forms part of my research work (John et al., 2005; 2010).

In the case of big data exchange/transmission in computer networks, the availability of bandwidth is a challenge encountered in managing data transmission (John, 2002), even where there is available bandwidth management of it is very crucial. Independent of how much bandwidth is available, data traffic can easily consume it, hence the need to find more bandwidth becomes necessary.

According to IBM, there are some 2.5 quintillion bytes of data created every day, and an estimated 90% of all the data in the world today was created in the last two years alone (Wu et al., 2014; Kim et al., 2014). And while much of this "Big Data" may seem irrelevant to us, organisations around the world are taking it very seriously so much so that many are now employing the use of robotic process automation to help harness, analyse and leverage these by using some machine learning, AI mechanism to automate their systems.

Furthermore, taking the African countries as an example (Table 1), it can be observed that the internet user penetration is rising with the growth in population and the efficient management of big data will sooner or later be the biggest challenge as can be seen in Figure 1. Moreover, the emergence of Gigabit Passive Optical Network (GPON) broadband technology in our homes due to High Definition Television (HDTV) in demand is adding to the challenge of efficient management of big data.

Table 1: The World Internet Usage and Population Statistics as of December 2017

(courtesy InterWorld Stats: www.interworldstats.com/stats.htm)

WORLD INTERNET USAGE AND POPULATION STATISTICS
DEC 31, 2017 - Update

World Regions	Population (2018 Est.)	Population % of World	Internet Users 31 Dec 2017	Penetration Rate (% Pop.)	Growth 2000-2018	Internet Users %
Africa	1,287,914,329	16.9 %	453,329,534	35.2 %	9,941 %	10.9 %
Asia	4,207,588,157	55.1 %	2,023,630,194	48.1 %	1,670 %	48.7 %
Europe	827,650,849	10.8 %	704,833,752	85.2 %	570 %	17.0 %
Latin America / Caribbean	652,047,996	8.5 %	437,001,277	67.0 %	2,318 %	10.5 %
Middle East	254,438,981	3.3 %	164,037,259	64.5 %	4,893 %	3.9 %
North America	363,844,662	4.8 %	345,660,847	95.0 %	219 %	8.3 %
Oceania / Australia	41,273,454	0.6 %	28,439,277	68.9 %	273 %	0.7 %
WORLD TOTAL	7,634,758,428	100.0 %	4,156,932,140	54.4 %	1,052 %	100.0 %

REVIEWED ANALYSIS AND DEVELOPMENT IN IMPROVING THE EFFICIENCY OF DATA EXCHANGE IN A COMPUTER NETWORK

The emergence of large-scale corporate and specialised networks with the number of computers in the order of hundreds, thousands and millions marked a new stage in the development of network infrastructure (Castells, 2011), which urgently requires significant qualitative changes in the approaches to designing the structure of such networks. Due to the wide variety of modern network equipment used in building large-scale networks and the rapidly increasing complexity of such networks and network applications, a developer or system administrator can no longer rely primarily on intuitive solutions.

As the bottleneck grows, it is not enough to create in details the optimal network configuration for solving specific network tasks and efficient operation of various network applications. In the modern conditions, without conducting appropriate studies and using special tools, it becomes extremely difficult or almost impossible to improve network performance (Figures 2 and 3). In this regard, the main trend in the study of the architecture of computer networks is the shift in emphasis from autonomous systems towards large-scale network structures.

NB: Bottleneck refers to a discrete condition in which data flow is limited by computer or network resource against the backdrop that the flow of data is controlled according to the bandwidth of various system resources as shown in Figure 2 and Figure 4.

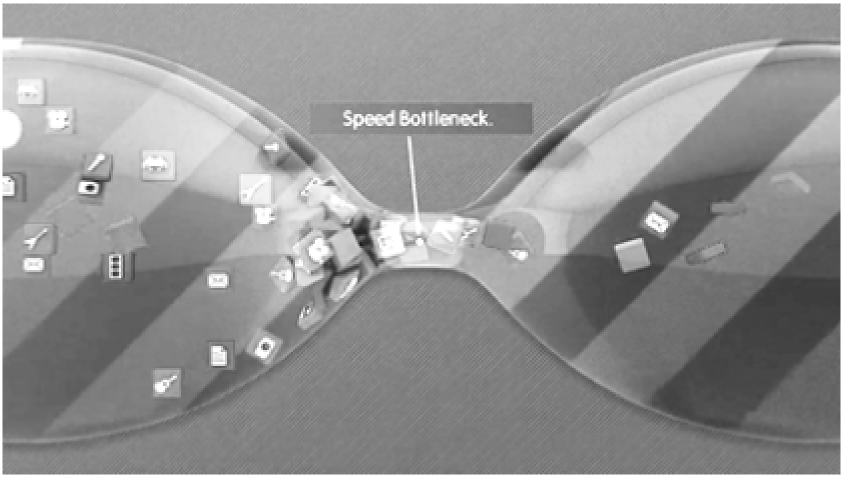

Figure 2: Speed Bottleneck in Computer Network

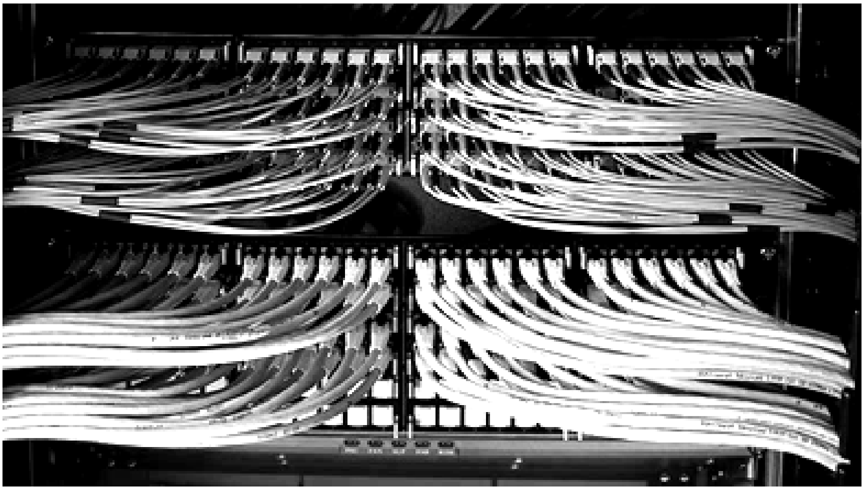

Figure 3: Bottlenecks in Local Data Networks Office

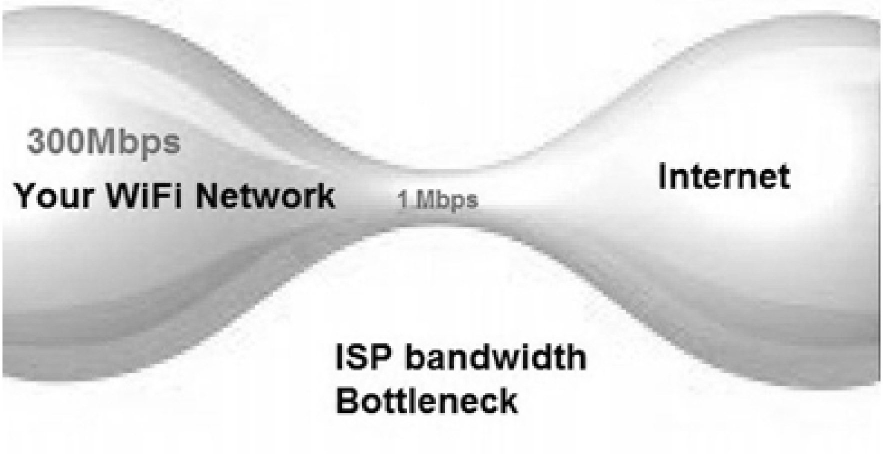

Figure 4: ISP Bandwidths Bottleneck in Computer Network

In the 70s, when high-speed computer networks first became economic and widespread, the period was declared "a decade of computer networks" (Kleinrock, 1979). Even then, in the late 70s, researchers noted that "the complexity of the issues encountered in building networks is dizzying" (Kleinrock, 1979). However, studies at that time were limited mainly to local networks or rather simple and low-productivity large-scale networks (Kleinrock, 1979; Leiner et al., 1997).

The 80s were characterised by relatively quiet evolutionary development of network technologies. During this period, the development of various methods for assessing the quality and optimizing computing systems and networks was further carried out (Aven et al., 1982). The situation began to change in principle in the 90s when, thanks to the explosive growth of the Internet infrastructure based on the TCP/IP protocol stack, large-scale network structures began to massively form on the mass scale, which are now virtually merged into one complex super net that connects hundreds of millions of computers as shown in Figure 1.

The intensity use and the scale of corporate and, primarily, university networks are increasing approximately every year in proportion to the overall growth and complexity of the network infrastructure. It is known that the first Advanced Research Projects Agency Network (ARPANET) (Stevens, 1998), the predecessor of the global INTERNET network, originated in the US universities. In 1998, the University Corporation for Advanced Internet Development (UCAID) initiative was created in the United States and began to operate a high-speed computer network Internet2, which united 37 universities at the first stage (Stevens, 1998). These were carried out to achieve various activities within the computer network which later became challenges to network management as services kept growing.

The numbers for these services are so enormous that they can only be shown using the 60 second time scale as shown in Figure 5 to present the current situation. These are bigger, and our brains cannot even process these massive quantities in any useful capacity. Hence, it becomes necessary to efficiently manage the big data in computer networks. Here are just a few key numbers scaled to a monthly basis, for insightful analysis of the growth in 60 seconds (Courtesy: http://www.visualcapitalist.com/internet-minute-2018).

42,033,600,000 Facebook logins

159,840,000,000 Google searches

1,641,600,000,000 WhatsApp messages sent

8,078,400,000,000 emails sent

On an annual basis, the data becomes even more ridiculous, with something close to 100 trillion or terabytes emails sent (No wonder it is so hard to get to inbox zero!). We need terabit per sec (Tbps) for data efficiency but the infrastructure will be very expensive and is not available yet eventhough research on it is ongoing.

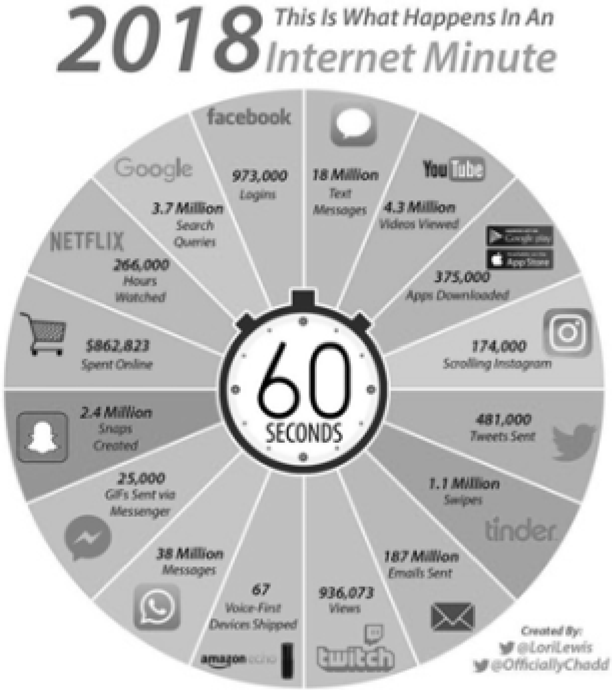

Figure 5: Number of Activities on the Internet in just 60 Seconds (Source: http://www.visualcapitalist.com/internet-minute-2018/)

This experimental academic structure, worth $500 million at the initial stage, was built on the basis of a Fiber-Optic Backbone with a length of more than ten thousand kilometers. The network, which initially had a capacity of 622 Mbps, has now reached a level of more than 10 Gbps. A similar development has been observed in Europe and other continents of the world in recent years. World practice shows that university networks in the foreseeable future, will be the main testing ground for the development and improvement of the “world wide web” as we are seeing today (Stevens, 1998; Gorman et al., 2000). Nigerian Universities, through NUC, have the Nigerian Research and Education Network (NgREN) anchored by Main One Company in Lekki, Lagos, Nigeria.

With such network scales, efficient management of resources seems almost impossible without proper research, including those based on simulation modelling. The problem of network infrastructure modeling and researching has become especially urgent with the expanding use of such complex network applications such as modelling environments for studying complex dynamic systems and data management analysis.

Before analysing and modeling the existing or projected computer network or a specialised network structure oriented to the operation of a certain network application, it is necessary to make a preliminary analysis of the network, which consists of determining the analysis objectives, the scope of analysis and the level of workload of the network under investigation. Figures 6 and 7 show respectively, the structure of preliminary analysis of computer network and typical algorithm for analysing the performance of a computer network (John, 2005).

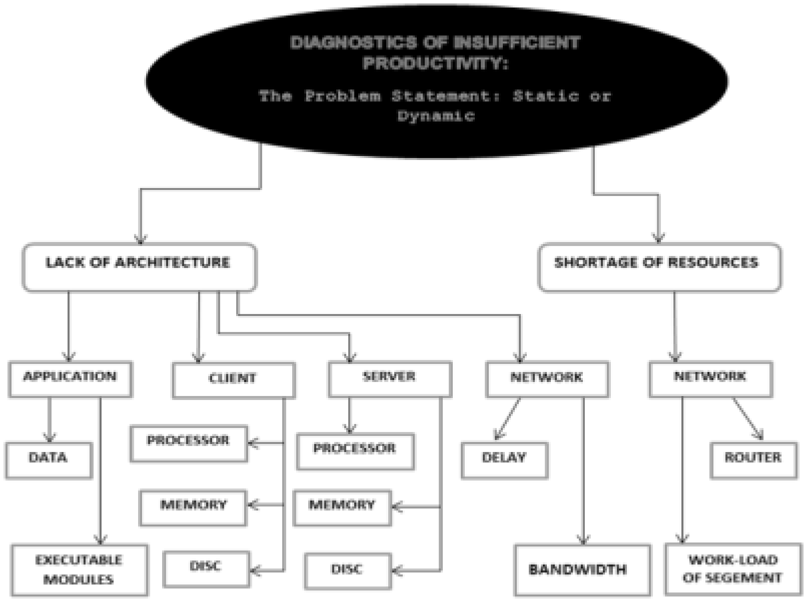

Figure 6: Structure of Preliminary Analysis of Computer Network

The Chancellor, Sir, the purpose of this inaugural lecture is to let people know my research results on how to achieve efficient big data exchange in computer networks based on the protocol stack by increasing the efficiency of transmission within them and also, the impact of big data on our socio-economic activities in the emerging smart world. As technology grows, the demand on service performance cannot be overemphasized; the need for high performance in data exchange is inevitable.

The recommendations for improving network performance can be carried out at three different levels: *bringing the network into operational state; "rough" network setup and fine-tuning the network.* To analyse the performance of a computer network, it is necessary to determine all the relevant parameters and factors that affect the speed of network performance (Ferrari et al., 1981; Boguslavsky et al., 1995). The most impactful network performance factors are:

- The type of communication protocols used and their parameters;
- Physical topology of the connections;
- Performance of communication equipment;
- Configuration of the software and hardware for the last miles (end nodes);
- Logical topology of links (the functional purpose of the active equipment used); etc. and
- Communication mode.

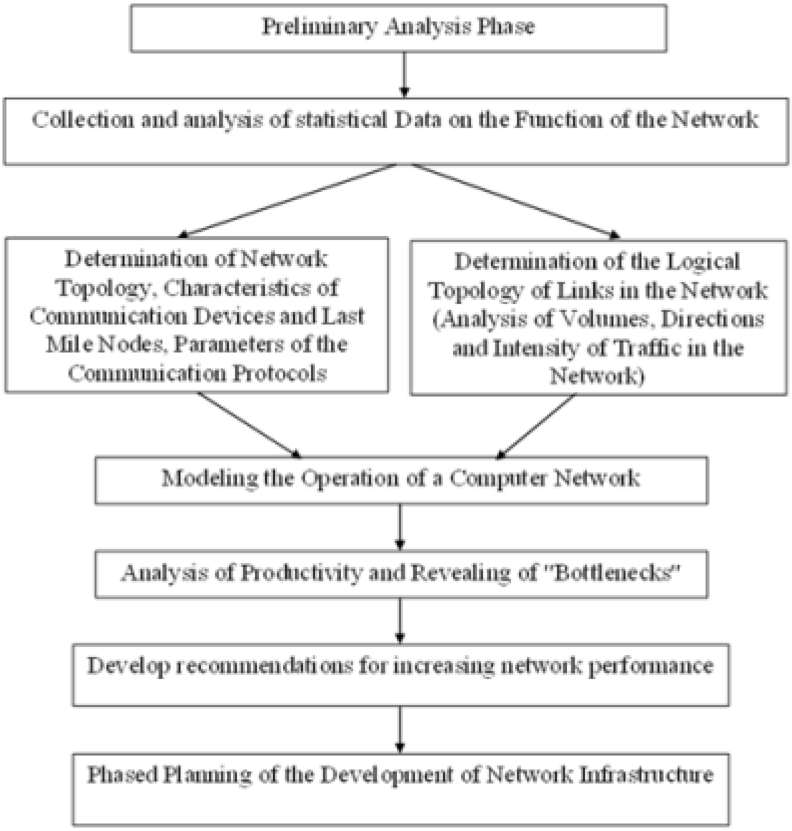

Figure 7: Algorithm for Analysing the Performance of a Computer Network

One of the first stages of modelling an existing network, in addition to documenting the communication topology used and the parameters of communication protocols, is the analysis and documentation of volumes, directions and types of data transmitted over the network.

As presented by Shehzad Karkhanawala, Director of Marketing at Aryaka SmartCONNECT networks, packet loss, latency, and distance degrade application performance. Research in this area shows great impact on our daily activities as regards efficient big data management (Shehzad, 2018). From Figure 8, we can observe that if the network has packet loss, the overall throughput between the server and the user significantly reduces with increasing distance.

Network + Packet Loss + High Latency => Application Performance for TCP Applications

This indicates that the further away the user is from the origin-server, the more unusable a network becomes. The main culprit of this phenomenon is Transmission Control Protocol (TCP) - the standard that defines how to establish and maintain a network conversation through which application programmes exchange data. The effect of packet loss on TCP has been widely analysed; there is a simple formula that gives an insight into the maximum TCP throughput on a single session of data exchange in a network when there is packet loss (Mathis, 1996; 2018).

The formula is as follow:
Throughput => $\left(\frac{MSS}{RTT}\right) \cdot \left(\frac{1}{\sqrt{P}}\right)$

where
MSS – maximum segment size
RTT – round trip time
P – packet loss rate.

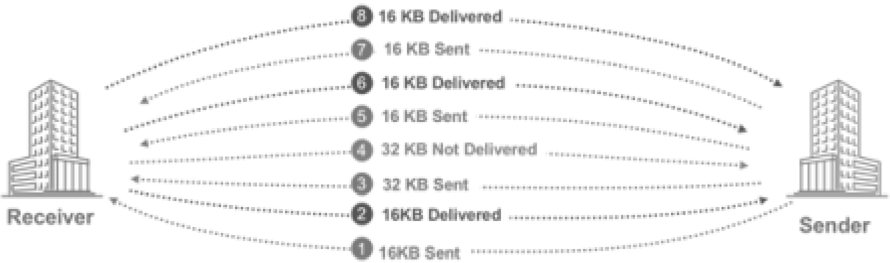

Figure 8: Impact of Latency, Packet Loss, and Distance on Application Performance (Courtesy: https://www.aryaka.com/blog/latency-packet-loss-distance-kill-application-performance/)

Figure 9 shows the impact of packet/data loss on the throughput of a single TCP network stream with a maximum segment size of 1420 bytes and varying values of Round Trip Time (RTT). This indicates that with a 1% packet loss and a RTT of 50 ms or greater, the maximum throughput is about 3 Megabits per second no matter how large the Wide Area Network (WAN) link may be. This can be seen in my research work on "Managing and Improving of Bandwidth Challenges in Computer Network" (John et al., 2011).

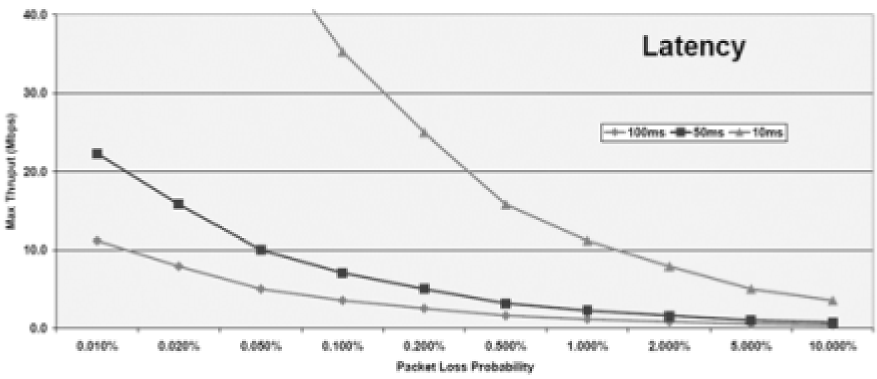

Figure 9: Impact of Data Loss on the Throughput (Courtesy: https://telnetnetworks.wordpress.com/tag/latency/)

REALIZATION OF THE PROTOCOL AND THEIR INFLUENCE

A set of protocols must be constructed carefully to ensure that the resulting communications system is both complete and efficient. Protocols are designed in complete cooperative sets called suites or families. Each protocol in a suite handles one aspect of communication as in Figure 10.

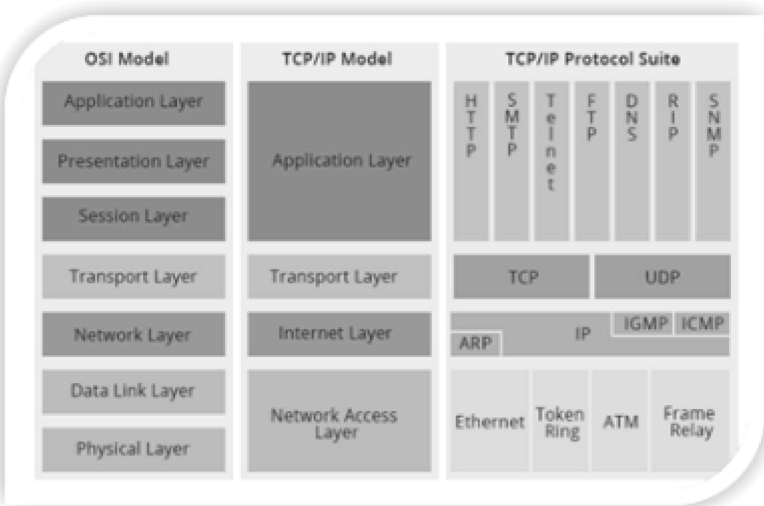

Figure 10: The OSI Model, TCP/IP Model and TCP/IP Protocol Suite (Source: http://myforgottencoast.com/osi-model-in-networking-with-diagram/osi-model-in-networking)

Together, all protocols in the suite handle all aspects of communication: the hardware failure and other exceptional conditions. A layer model describes how all aspects of communication work together. The visual appearance of figures used to illustrate layering is called stack as shown in Figure 11 and Figure 12 respectively.

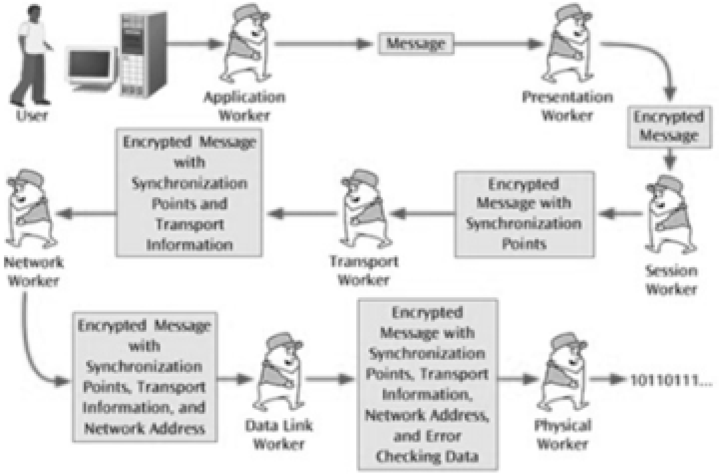

Figure 11: Model of Protocol Suites and Layering

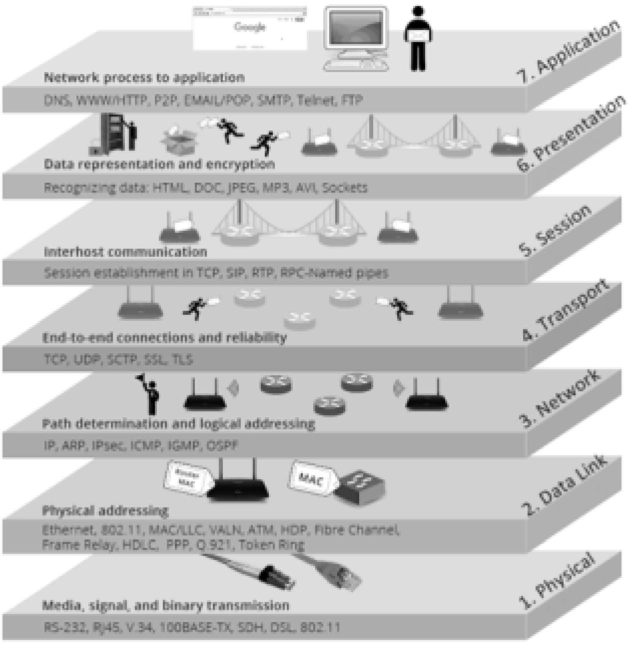

Figure 12: Seven Layers of the OSI Model (Courtesy:https://community.fs.com/blog/tcpip-vs-osi-whats-the-difference-between-the-two-models.html)

NETWORKS

One of the most important types of data communications in the business world is a network connection. A **network** connects one computer to other computers and peripheral devices, enabling sharing of data and resources with coworkers. There are a variety of network configurations, too many to discuss thoroughly here. However, any type of network has some basic characteristics and requirements (Figure 13).

In a **local area network** (LAN), computers and peripheral devices are located relatively close to one other, generally in the same building. If you are using such a network, it is useful to know three things: the location of the data, the type of network card in your computer, and the communications software that manages protocols and network functions.

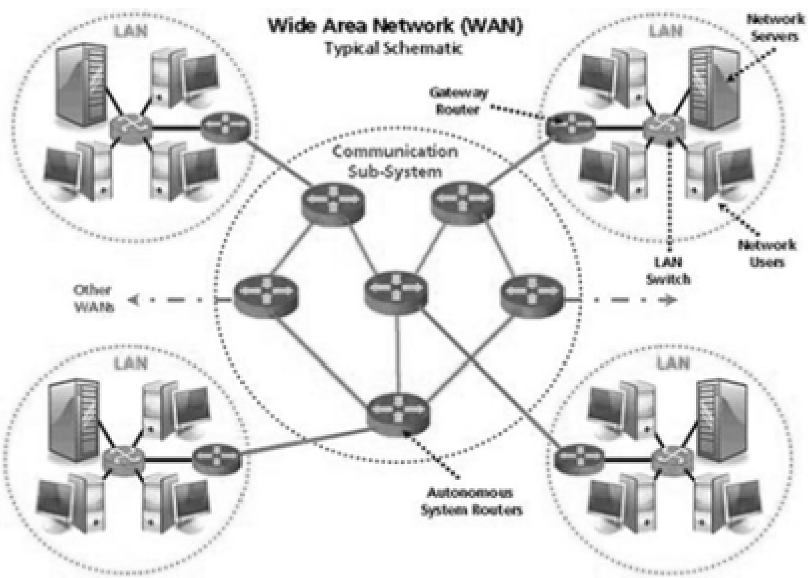

Figure 13: Sample of Network Topology WAN

The features in realizing the protocols and their influence on increasing efficiency of data exchange are considered since the indicated process affects both the hardware and software of a network. The special value in this case is to acquire efficiency in organising data exchange on a network which substantially affects the productivity of any network application.

The use of mathematical models (simulations) in designing networks is most preferable. A mathematical model is an aggregate of formulas, equations, inequalities and/or logical conditions determining the change in the process state of a system depending on their parameters, initial conditions and time. One of the classes of mathematical models is simulation models. These models are computer programmes with step-wise reproduction of real-time in-system events. Simulation models reproduce the processes of generation of reports by the applications, breaking up of messages into packages and frames of certain protocols, delays, which relates to messages, packages and frames from the operating system.

Modern requirements dictate the necessity of a wide introduction and use of multi-service networks, which are able to pass heterogeneous traffic effectively; including digital data, graphics, audio- and video-information (IPTV/HDTV). Presently, there exist few solutions that allow for effective combination of *free size* heterogeneous data communication within the framework of one network. This implies that heterogeneous traffic possesses a strong temporal correlation across various time scales and is thus *bursty* in nature (John et al., 2011; 2012).

The principle of the solution can be divided into three groups (Barry et al., 1997):

- Transmission of different types of traffic on separate physical

lines, created by independent network infrastructures;
- Transmission of different types of traffic on one line;
- Transformation of one type of traffic into another with subsequent transportation and communication.

Data link protocols are used in local area networks; this is a method of accessing network resources and is based on time sharing of the nodes. In this case as well as in all cases of division of resources, the situation of random streamline query seems likely and may lead to queuing. In describing this process the models of theory of mass service are usually employed (Barry et al., 1997).

During the development of the distributed computing and modelling based on the modern infrastructure of Internet, it is important to consider the increased effectiveness of network co-existing at all levels of the protocol stack, beginning with their *speed of signal distribution at physical layer level and onward to the application layer*. The most important characteristic of the effective functioning of a network is its productivity (Minaev et al., 2002; John, 2005).

MY PAST RESEARCH ACCOMPLISHMENTS

My past research was motivated by the rapid developments in communication and information technology and the ever-growing network user demands that make network traffic inefficient, a salient problem in today's Internet and Mobile Connectivity. The principle of processing information in computer network is performed by First in First out (FIFO) routine. As users engage this process, so does the sending and receiving of packets in networks which invariably improve network performance. To manage and improve data efficiency in networks due to propagation delay (i.e. queuing) well developed method of data exchange should be implemented. In order to achieve this, it is necessary to develop more advanced technology to manage and improve data efficiency in business. This has also brought about robust methodologies and models to deliver manageable, scalable, stable and reliable services. This is to fulfill the ever-growing demands for the quality of service (QoS) requirements and improvement in the networks. The basic task of research and simulation process of network infrastructure is hence, working out the recommendations for the most rational use of computer network resources. The necessity, thereby, arises at the development and deployment of application layers of new networks during management of existing network services.

The principal focus of my research was to increase the efficiency of data exchange in modern computer networks as applicable to businesses and thus, improve computing network environments, based on the protocol of TCP/IP suites. The major goal of this research was to develop and design simulation models for analysing computer networks, which allow the full/exact use of TCP/IP features; and their influences on improving data exchange efficiency within local (Intranet) and corporate (Extranet) networks as related to public domain of network management.

The method of increasing effectiveness function in computer networks was proposed and thus, offered stimulus by perfecting the modes of data exchange within and outside networks. This improves performance in the deployment of computer networks and network applications without additional overheads on the infrastructure of the network. Practically, some of the results obtained from this research work enabled significant increase in the efficiency benefits of data exchange and management, in a computer network environment at Donetsk National Technical University (DonNTU), Ukraine.

The outcome of my research was focused on the issue of data efficiency, that can be traceable to the Internet connectivity and which has a greater effect on our daily life and as investigated, this will continue for longer period of years to come.

However, in this digital era, society demands that good citizens make good decisions on network applications and adoptions for business. In this process, it is imperative to note that the Internet has opened a new arena for information gathering data mining and with the understanding that there is need to increase the efficiency of data exchange with improve network performance, throughput, without additional overheads on infrastructure of the network.

A related approach of the research ideas demands for a major requirement of any computer network scalability. This can be because of increase in the number of users' access to networks, upgrading of networks' services, as related to technological advancement, or additional services, or the need for performance improvement. The research investigated various probability scenarios of network processes and inevitably, found that the required change in infrastructure (hardware and software); deployment of new applications; and dealing with security will definitely improve network performance. The configuration of the hardware, software and firmware can affect the maintainability and growth of the network.

The research result showed that for the network to remain reliable and efficient, it is necessary that, implementation and administration of network process requirement is reconciled with the monitoring of both the model of the network structures and processes occurring within them. My research idea was inspired by the desire to improve efficiency of networks. On this basis, my unique research thus, presented solutions and frameworks for adoption in any network environment. My work further solved network application tasks as required and importantly added value, to improve efficient data exchange in modern computer networks based on the TCP/IP. The developed methodology of the research work was based on simulation modelling results obtained for enterprise agility in improving network performance.

In summary, based on my research outcomes, the main scientific results, conclusions and recommendations, were presented, referenced and found useful in business organisations as follows:

1. Revealing the main factors that affect effectiveness of data exchange in computer networks, based on the protocol of TCP/IP. For the first time, a formulated solution was presented as one of the main criteria in estimating the efficient data exchange in a computer network, using correlation of the real and desired bandwidth capacity; and the coefficient of data loss; which simply allows enough data exchange to carry out quantitative comparison of the efficient function of network;
2. A proposed multilevel way of simulating and analysing efficient function of computer networks was presented, and this was based on combined use of different model and analytical dependences of data exchange based on TCP/IP;
3. For the first time, detailed simulation models of the channel and transport layers of the TCP/IP were developed, taking into account all the main features of their operation necessary and sufficient for a model study of the efficient data exchange in different modes when interacting with nodes in local networks located within a dedicated local network;
4. For the first time, the research approach was presented and formulated based on the developed simulation models to conduct complex investigative research of efficiency function of computer networks (local and corporate networks);

5. For the first time, specified dependencies showed how different modes of data exchange with growth of required bandwidth capacity change the real bandwidth capacity of a computer network and has an exponential character;
6. A method was proposed for efficient data exchange of computer network based on the TCP/IP by improving mode of data exchange which makes possible an improved network application performance without additional overheads on network infrastructure; and
7. During the development and exploitation of computer networks using the recommended method an average of 10 - 15% increment in efficiency can be achieved.

I have successfully applied the results obtained from my research work in different spheres by designing network solutions for **companies:** (Union Bank Plc., F-Comp Ltd., Sintal Computer System Ltd., Abayomi & Co., SOS Medical Services); **schools** (DonNTU, Covenant University, Unilag, UniMaid) and **various individuals** to achieve significant improvements in data exchange efficiency in addition to network designs, installation and administration. The method of boosting data exchange efficiency using multi-layer simulation models was also found useful in ensuring rational and efficient use of computer network resources in diverse business activities (including: data mining, big data, IoT, IIoT and network security).

FACTORS AFFECTING THE EFFICIENCY OF DATA EXCHANGE IN COMPUTER NETWORKS

The mode of data exchange was examined as the main objective of this research, since its perfection often engenders a considerable improvement in network performance without substantial additional expenditure. The main task of analysis and modelling of the modes of data exchange in modern computer networks based on the protocols is increasing the performance efficiency of work on the networks and network applications, and above all, increasing their productivity. The mathematical representation of the research work can be expressed as a function of using simulation models for determining the effect of data exchange in network performance (John, 2008).

To find such parameters of a data stream block, at which the real bandwidth capacity of the networks (Q) is maximum, we have

$$Q = f\,(Q_N, L, \lambda, n_y) \qquad (2)$$

where, Q_N – nominal bandwidth capacity of the network;
L – size of the sent data blocks;
λ – parameter of data blocks stream (for every nodes)
n_y – number of active nodes in the networks.

Thus, the main object of investigation becomes mode of data exchange towards increasing the productivity in either wired or wireless computer networks. As shown in Figure 14, the effective use of bandwidth plays a great role in the efficient data exchange in the networks. The coefficient of data loss (K_L) depends on the workload of the system (John, 2005; 2008). The problem lies in finding the **file size and data processing frequency/data blocks stream** that the loss rate will **be minimal for a desired bandwidth** (Q_T), nominal bandwidth (Q_N), number of users (n_y) and the real bandwidth of the network (Q_R).

In the study of complex systems, in a theoretical way, to obtain their mathematical descriptions, simplifying assumptions are adopted that reduce the accuracy of the results obtained. More reliable results of the study of such systems can be obtained by modelling and experiment methods. *In Figure 14, a list of the main problematic/bottleneck components of the network is presented, ineffective implementation* *and/or use of which can negatively affect the performance and efficiency of the operation of both the entire network and its individual sections.*

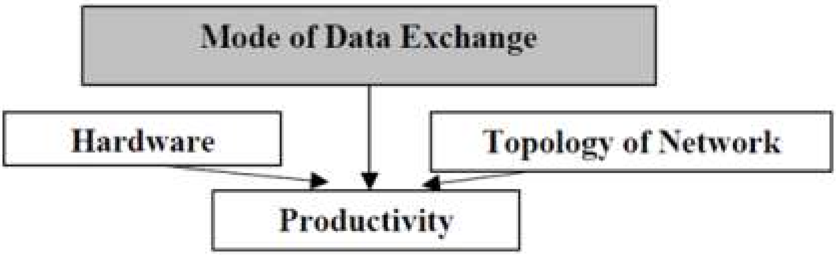

Figure 14: Factors that determine the Bandwidth of a Network

In the process of analysing the network, the following indicators should be put into consideration:
Nominal Bandwidth (Q_N) is the bit rate that is supported in the transmission interval of one packet.
Effective Throughput (Q_E) is the average transfer rate of user data, that is, the data contained in the data field of each packet. In general, the effective bandwidth of the protocol will be lower than the nominal because of the presence of service information (header) in the packet, and also because of the pauses between the transmissions of individual packets. The effective bandwidth differs significantly from the nominal bandwidth of the protocol, indicating that it is necessary to focus on the effective bandwidth when choosing the type of protocol for a particular segment of the network. For example, for Ethernet, the effective bandwidth is about 70% of the nominal bandwidth, and for the Fiber Distributed Data Interface (FDDI) protocol, about 90% ((Olifer et al., 1999).

Real bandwidth (Q_R) is the transfer rate of user data, taking into account all delays associated with both the transfer of service information/header and those occurring during the transfer (due to collisions, delays, etc.). The actual bandwidth in this connection, as a rule, is substantially lower than the effective bandwidth of the channel, which indicates that it is necessary to focus on the actual bandwidth in assessing the performance of a particular segment of the network.

Desired/Required bandwidth (Q_T) – this is the speed of generating transmitted data that reflects the actual needed bandwidth for the network. In general, the Q_T value may exceed Q_N, which, for example, may result from a certain redundancy in the generated data stream in order to maximize the use of network bandwidth:

$$Q_T \quad \frac{L}{T} \; n \qquad (3)$$

where, L - the average file size, KB;
n - number of connections through an external communication channel;
ΔT - time interval between file transfer (second).

Workload capacity or workload of the network (Q_W - workload) is the total network bandwidth, taking into account the total amount of data transmitted, along with all the service information/headers.

An important characteristic in the operation mode of the TCP/IP network is the transmission time "T_{total}" of the data block (Olifer et al., 1998) which consists of the transmission time of the data block, the overhead and the sum of the data block delay in the network elements ΔT_j:

$$T_{total} \quad \frac{L_F \quad L_S}{Q_N} \quad \overset{n_y}{\underset{i\ \ 1}{}} \quad T_i, \qquad (4)$$

where, L_F - the size of the data field in the frame;
L_S - the amount of overhead information in the frame, byte (18 bytes);
ΔT_j - the delay time at each of the n intermediate nodes;
i - the node number; and
n_y - the number of nodes.

When the first expression in equation 4 depends only on the nominal network capacity and the LF and LS values, the second expression in the equation depends on a large number of factors: network topology, protocol implementation features, hardware parameters, and so on. Therefore, it cannot be reliably determined analytically rather by simulating the network.

The bandwidth of the protocol can be measured in the number of frames transmitted per second, or in the number of bits transmitted per second.

A selected mode of data exchange allows in most cases a low workload on a network, thereafter increasing the real bandwidth capacity which subsequently results in an increased efficiency functioning of the network as a whole. A method of increased efficiency in a computer network was offered by means of perfecting the modes of data exchange in them, which allows for an increase in computer network usage efficiency without additional overheads on infrastructure of the network (John et al., 2003; 2005).

Recent studies have shown that TCP traffic displays strong multifractal scaling. However, a physical explanation of why such a behaviour occurs is still elusive. A cascade model was proposed based on the retransmission and congestion avoidance mechanisms of TCP (Anoprienko et al., 2001). At the same time, it relates to the physical tree-like organisation of networks. This model allows for relating the most salient multifractal features with basic traffic parameters such as the RTT and the loss probability of the network (Anoprienko et al., 2003).

RESEARCH CONTRIBUTIONS

Contemporary trends in research execution are towards interdisciplinary collaboration and internationalization. Hence, in my research career, I have collaborated with local and foreign colleagues as shown in most of my publications. In my research publications, most of my effort have been to place my broad expertise in **Computer Science, Computing Machines, Complex Systems, Cyber Security and Network Engineering.** My emphasis has been in the security of data delivery. Hence, I have developed models to determine the exact dependences in a computer network which are needed to attain the efficient parameters. This has generated fast methods for data exchange, enabling to predetermine necessary corrections in order to increase the efficiency of data exchange in computer network.

In achieving these, in the computer network, **Tasks, Methods and Tools for Simulation of Network Infrastructures were first looked into.** The problems of model support for network infrastructure, starting from LAN (intranet) through to large-scale extranet network structures for distributed simulation of complex dynamic systems were analysed. The main task of analysing and simulating network is to *work out a recommendation to rationalise the utilization of computer networking* resources. This is necessary, especially during the administration or development of the existing network; and also during the projection of new networks (John, 2001). Consider the rise in the complexity of network infrastructure (Figure 1 and Figure 15) in view of big data and the level of their usage, with the associated challenges. Solving these problems at the present time will help programme products in analysing productivity of network performance and these include the following:

- Determining the productivity of network during a given topology and workload;
- Analysing the dependence of passage ability during measurement of workload on network connections;
- Analysing the dependence of passage ability of network during measurement of their topologies;
- Selecting parameters protocols network for providing maximum passage ability of network during a given topology and workload; and
- Determining optimum topology and relative passage ability/cost of projecting networks.

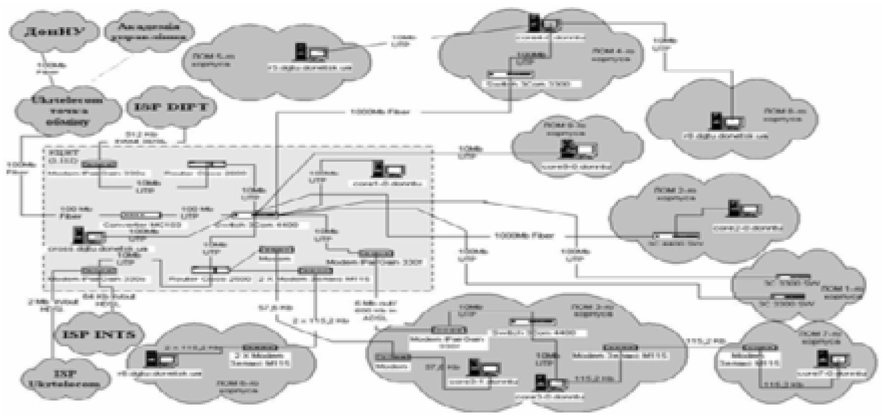

Figure 15: Generalised Infrastructure of Computer Network of DonNTU

A good administrator will not miss a chance of improving a network to increase its productivity. However, nobody wants to advance on the basis of a trial and error method. The tools for simulating the network allow us to project the results of various changes, before these can be implemented in practice.

During the development of a distributed simulation mean (John et al., 2011; 2012), based on modern infrastructure of the Internet, the special value requested is an increase of the network efficiency performance at all levels of the TCP/IP protocol stack layers - beginning from the distributed speed of their signals at physical layer and concluding at application layer (John, 2001). But what happens between the network layers (IP) and the transport layers (TCP) is important. Added to this, is the development of adequate and complete analytical models of the network, which are practically impossible, therefore, the basic method of network infrastructure research in this case is simulation, with the use of specialised means based on the universal simulation systems (John, 2002). This was achieved using multilevel simulation of networks based on the protocols in Matlab/Simulink environment.

Simulation, Analysis and Optimisation of TCP Protocol: The transmission control protocol (TCP) was used as the reliable protocol of dialogue between hosts - computers in communication computer networks with packet switching, and also in systems connecting the networks (John, 2002; Nuri et al., 2002). The main activities to recognise about connection teardown is that a connection in the TIME_WAIT state cannot move to the CLOSED state until it has waited for two times the maximum amount of time an IP datagram might live in the Internet. I used MATLAB (modules of SIMULINK and STATEFLOW) software in the research model of the TCP protocol and processes of interoperation between the communication devices. The client does an active open which causes its end of the connection to send a SYN segment to the server and to move to the SYN_SENT state. The arrival of the SYN+ACK segment causes the client to move to the ESTABLISHED state and to send an ACK back to the server. When this ACK arrives the server finally moves to the ESTABLISHED state. In other words, we have just traced the THREE-WAY HANDSHAKE as shown in Figure 16.

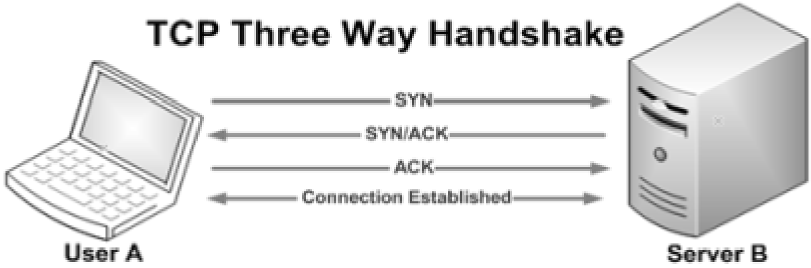

Figure 16: The TCP Three Way Handshake
(Courtesy: https://steemit.com/hack/@pierlave/understand-tcp-3-way-handshake)

You can compare this to two persons starting a conversation.

first person: Hi, do you want to talk (SYN)

second person: Sure let's talk (SYN, ACK)

first person: Ok let's talk (ACK)

Then, the conversation starts (data transfer)!

In the process of terminating a connection, the important thing to keep in mind is that the application process on both sides of the connection must independently close its half of the connection. The general scheme of the developed model for TCP transition state in Matlab/Simulink environment (Anoprienko, 2002) is shown in Figure 17.

The result shows an increase in the slide window congestion with the behaviour of TCP protocol as it approaches the optimal level. These optimal values can be defined by the differential algorithm control of the workload in the network from the threshold parameter.

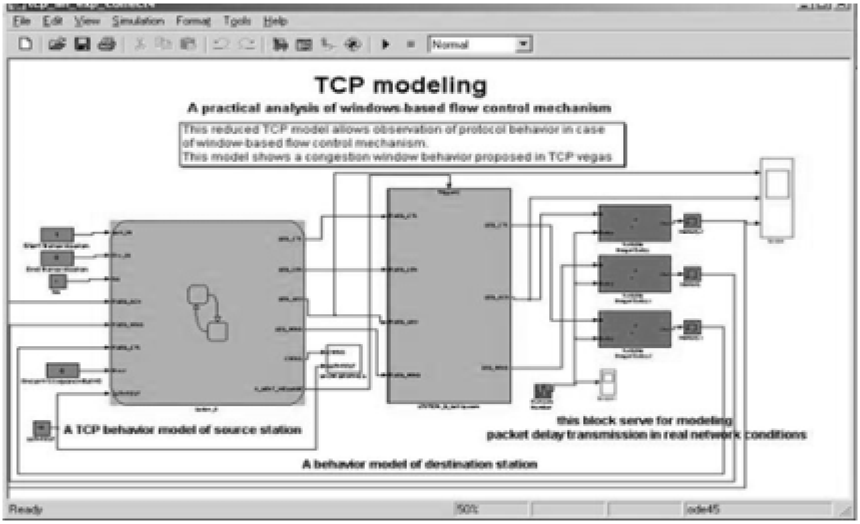

Figure 17: General Scheme of the Developed Model in MatLab/Simulink Environment

In order to boost data exchange efficiency using developed multi-layer simulation models (John, 2002; Minaev et al., 2002), well-developed methodology was proposed based on the research result obtained. The rapid developments in communication and information technologies and the ever growing network user's demands have made network traffic efficiency a prominent problem in today's internet. As users come and go, so do the packets they send: Internet performance is therefore largely governed by these inevitable natural fluctuations, it is, therefore, of great importance to develop more advanced as well as robust methodologies and models to deliver manageable, stable and reliable services in order to fulfill the ever-growing demands for the QoS requirements in the networks. The basic task of research and simulation of network infrastructure is to work out the recommendations for the most rational use of computer network resources. The necessity, herein, arises both at the development of new network application and deployments, and also, during administration or development of the existing networks. Boosting of data traffic has emerged as a critical property that protocol analysis can no longer ignore. In order to attain the required boosting or scaling phenomena in data exchange observed in aggregated TCP/IP traffic, multi-layer simulation model that captures the protocol was developed. The essence of the offered method consists of sharing the dependences obtained from analytical and simulated method, in the determination of the most efficient mode of data exchange (Anoprienko et al., 2000; 2002).

In connection with the wide variety of the network equipment used for construction of large-scale network and swiftly increasing complication of such networks, a system administrator cannot depend on intuitional decisions. It is more difficult, as a rule, to form optimum network configuration for the decision of concrete network tasks and effective work of different network applications.

Initially, the problem of no optimum work of network divides into the lack of architecture and shortage of resources (Anoprienko et al., 2002). As a result of lack of architecture, a bottleneck can appear to a network which by virtue of the small carrying capacity or large temporal delays is incapable of providing the normal passing of large data flow from the great number of directions. There can be problems with the separate applications intended for organisation of some works in a network, for which the lack of architecture can perniciously tell on the operative of the data processing and work of the executable modules. Possibilities in estimating the efficiency performance of the network include: documenting its current status, its optimisation productivity, analysing possible improvements and also making recommendations for the most rational way to use the network resources (John et al., 2011; Anoprienko et al., 2003).

Simulation and Monitoring of a University Network for Bandwidth Efficiency Utilisation: As organisations' networks grow, it is essential that network administrators have knowledge of the different types of traffic traversing their networks and the methods of monitoring such traffic. Traffic monitoring and analysis are essential in order to troubleshoot and resolve issues as they occur in order not to bring the network to a total collapse (John et al., 2013).

Network monitoring for a corporate network is a critical IT function that can save money in network performance, employee productivity and infrastructure cost overruns. A network monitoring system monitors an internal network for problems. It can find and help resolve snail-paced webpage downloads, lost-in-space e-mail, questionable user activity and file delivery caused by overloaded, crashed servers, dicey network connections or other devices (John et al., 2011; Fred, 1985).

Network monitoring can be achieved using various types of softwares or a combination of plug-and-play hardware and software appliance solutions. Virtually, any kind of network can be monitored. It does not matter whether it is wireless or wired, a corporate LAN, VPN or service provider WAN. Devices on different operating systems with a multitude of functions, ranging from BlackBerrys and cell phones, to servers, routers and switches can be monitored. These systems can help in identifying specific activities and performance metrics, producing results that enable a business to address various and sundry needs, including meeting compliance requirements, stomping out internal security threats and providing more operational visibility (John et al., 2010; 2008). The model follows a real topology of a section of Covenant University network and the performance characteristics of the model were to be ascertained. To determine this, server applications were modelled over the internet and local intranet and their performances evaluated.

Network simulation software was used in the simulation of the network and measurement of device performance and the management of applications in a virtual, scalable network environment (John, 2005). The network itself is based on a cascaded topology and all remote buildings are linked up to a central office as shown in Figure 18.

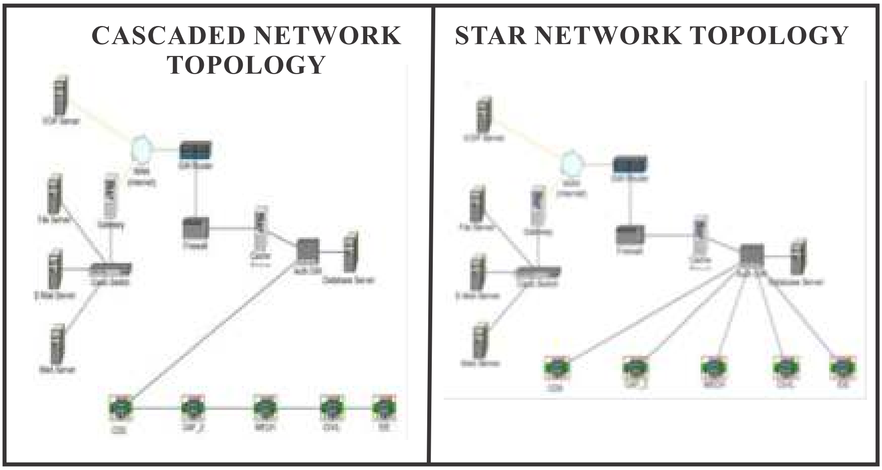

Figure 18: Covenant University Cascaded Topology and the Proposed Star Network Topology

The proposed network model is analogous to the current network topology setup except that the internal network distribution from the Authentication Gateway Router through the Cache Server, and the Database Server to the buildings is in star topology as shown in Figure 18. The buildings, therefore, are now connected directly to the Authentication gateway router which means that packets from the gateway are transmitted directly to the various buildings of the University.

For network operators and administrators, network monitoring and analysis provide the means of being proactive (i.e. ability to detect faults prior to a network experiencing downtime). It also allows them to manage service level contracts, to be assured of day-to-day operations and to validate system changes. The result of this work shows a highly improved network performance in the proposed star network topology than in the current cascaded network topology. This is an evidence of an optimized characteristic shown by the proposed star network topology.

Research of Throughput and Network Efficiency based on the Multiple Computer Simulation: In a network based on the protocol of TCP/IP, the main realization and functionality of a particular protocol depends on efficient mode of data exchange. It is necessary to define all meaningful parameters and factors affecting the throughput on a network simulation and analysis of computer network performances (Anoprienko et al., 2003).

The basic task of analysis and design of computer networks is to resolve the efficiency function of network and explore ways of increasing its productivity. A network performance is measured with the help of time-based indices, delays resulting from data exchange, bandwidth activities, and reflecting the information passed through a network per unit time. The exposure and removal of the existent or potentially possible "bottlenecks" in a network is by investigating and analysing the productivity of the network, and making some recommendations on how to increase the efficient data exchange on both network as a whole and its separate segments.

In general cases, the effective bandwidth capacity of protocol would be below nominal bandwidth capacity due to addition of headers in the packet, and also from pauses between the transmissions of separate packets. Accordingly, the ratio of the real bandwidth capacity segment of, channel or device to its effective bandwidth capacity is named the coefficient of the usage segment - Ku i.e. (U – utilisation) (Anoprienko et al., 2001; 2003), channel or device. An effective bandwidth capacity substantially differs from the nominal bandwidth capacity of protocol that speaks about the necessity of orientation exactly on an effective bandwidth capacity type of protocol for one or another segment of the network. As an example, for protocol of Ethernet, the effective bandwidth capacity makes an approximately 70% from nominal, and for the FDDI protocol – about 90% (Anoprienko et al., 2001). The bandwidth capacity of protocol is measured in the amount of frame transversed in a second.

Figure 19 shows the dependence of coefficient of loss (KL) from the workload of the TCP/IP local network with dormancy nodes of data exchange with different file sizes. Obviously, the substantial change in coefficient of loss (KL = 0 to 1) depends on the workload with the existing minimum loss of network performance.

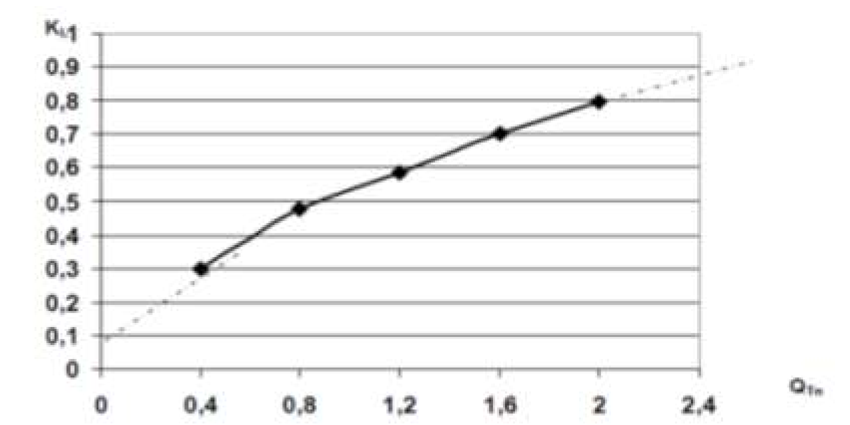

Figure 19: Dependence of Coefficient of Loss (KL) on the Workload of the TCP/IP Local Network

Analysis of the results obtained in the research in Figure 20, shows the dependence network (QR) performance from the work load on the TCP/IP network (QT) (John, 2002; Anoprienko et al., 2001). The zones B and C correspond to the intensive changes of the coefficient of loss as shown in Figure 19, which can be derived on this area by this dependence:

$$K_L = K_{LS} + K_{LTCP} + K_{Lf} \qquad (5)$$

where, KLS is coefficient of loss from the exchange of the headers, KLTCP is coefficient of loss from the features of work on TCP/IP protocol in the threshold routine.

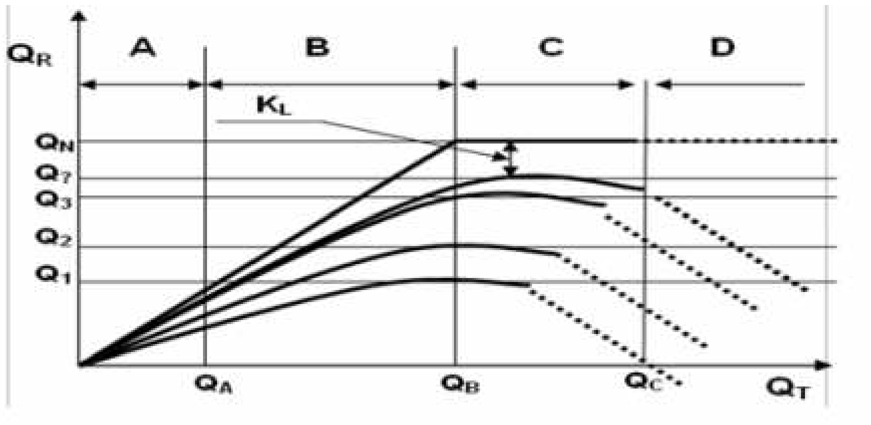

Figure 20: The Effective Usage of Computer Network in Data Management

The generalised result obtained from Figure 20 has four zones of Network performance, which are:

1. $Q_T << Q_N$, hence $Q_R = Q_T$,
2. $Q_T < Q_N$, hence $Q_R < Q_T$,
3. $Q_T \geq Q_N$, hence $Q_R < Q_T$,
4. $Q_T >> Q_N$, hence $Q_R = 0$,

When $Q_T \approx Q_N$ the threshold of the network has $Q_R = Q_{Threshold}$.

In this case, a desired bandwidth was propagated toward the data flow and real bandwidth was obtained from the data streamline of the experiment. It was obvious, that in zone A the dependence of bandwidth on workload Q_{TN} had a variable close to ideal network. Zone B is the zone of declination in network carriage capacity. Zone C is the saturation zone while zone D is the refusal area. It was observed that the mode of data exchange affects the mode in which computer networks operate, and also the effectiveness of the real bandwidth which was the throughput of the network.

In zone A the network was observed to operate far below its bandwidth capacity. The real rate of data exchange was below the rate that it was predetermined to generate and the efficiency of the distributed environment was limited by the bandwidth of the network. The results therefore showed a substantial underutilization of computing possibilities of the distributed environment (John et al., 2012). Zones B and C are of upmost interest due to the fact that an actual bandwidth capacity substantially differs from the theoretical bandwidth because of the losses, caused by the working zones that are close to threshold point. Many factors are associated with the increase in size of packet losses that make their exact determination by theoretical methods impossible. Hence, the use of simulated design method was considered to be appropriate. The D zone is characterized by complete degradation of the network.

As noticed already in the work "Features of Modelling and Estimation of Overall Performance of Network Infrastructure" (Anoprienko et al., 2003) complication of modern network infrastructure, the typical example of which is the computer network of large university campus, supports the complex use of different facilities in designing the functioning performance of the network, most effective modes of its usage and ways of developing it.

The main task in analysing and modelling of the modes of data exchange in modern computer networks based on the protocols of TCP/IP is increasing the performance efficiency of work on the network and network application, and also increasing their productivity. Studies have shown that mode of data exchange contributed to the performance of a network by revealing the characteristic dependences of bandwidth capacity of a network from the work load of a corporate network based on the stack of the TCP/IP protocols (John, 2002; Anoprienko et al., 2001). Increasing the efficiency of data exchange in the computer networks based on the TCP/IP protocol requires difficult decision associated with different problems in which we have: choice and optimisation of the network topology structure, optimisation of the bandwidth capacity of communication channels, choice of routers, choice of methods in control management of data streams and determination of the management parameters, analysis of the buffer memory in commutation and router with choice of strategy in spooling during workloads (Anoprienko et al., 2002; 2002). The study of computer network based on TCP/IP protocol requires determining the most effective topological structure within the framework that would result in the burst performance of the modes of data exchange. The decisions touching on the topology of a network determine the basic descriptions of the network (Anoprienko et al., 2001). It was important to describe vividly the structure of a distributed computer network.

In order to increase the efficiency of data exchange in computer networks based on TCP/IP protocol, a detailed study of the: topological structure of the network, carrying capacity of communication channels, choice of routers, choice of methods of management by data streams and preset control parameters, analysis of the communication nodes, routers, and the choice of strategy of spooling at the overloads was required.

For the exposure of critical regions of network or “bottlenecks”, it is necessary to simulate the functionality of the network at a given workload and changing the values of file sizes and the frequency of data exchange (data stream rate):

$$\frac{L}{} \quad \frac{Q_T}{n_c} \quad L_{\min}^{рац} \quad L \quad L_{\max}^{рац} \; ; \quad \overset{рац}{\min} \qquad \overset{рац}{\max} \qquad (6)$$

where, L – file size, Q_T – desired bandwidth, τ – data stream rate, and n_c – number of nodes.

The mode of operations in the distributed computer networks is affected by the critical level of workload which corresponds to the “bottleneck” of the network, resulting into degradation of the bandwidth capacity of the network (Anoprienko et al., 1996; 2001; 2002). The variants of chosen network structure on the second stage of the network execution sequence in the methodology are explored by using simulation technique. The most optimum networks are the network structures with less “bottlenecks” or completely absent in the conditions of obtaining high and stable network efficiency.

It is assumed also, that in a network, the observance of the following correlation condition nurtures the congestion avoidance of overloading the network using this index: $Q_T < 0,55Q_N$ as shown in Figure 21, obtained in the research work (Anoprienko et al., 2003).

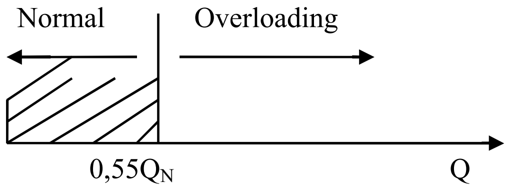

Figure 21: Establishing the Dependency Border of Optimum Performance of the Network

In the analyses of the results obtained, the three-dimensional dependence represented in Figure 22, the mode of data exchange based on the bandwidth capacity at different and constant time intervals, the observed dependences in every case show that the impact of efficient data exchange in computer network affects network performance (Anoprienko et al., 2005).

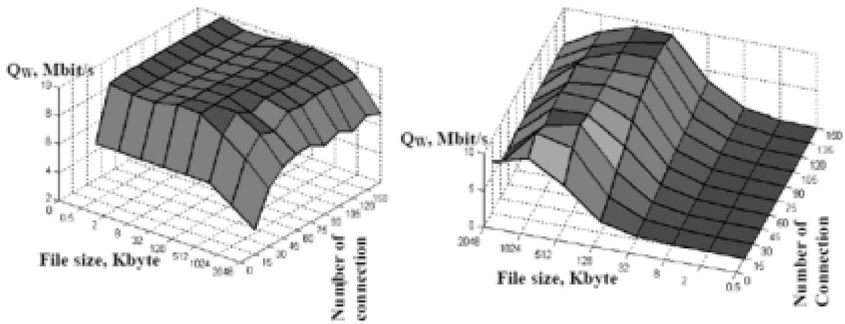

Figure 22: The Bandwidth Capacity of a Network versus Number of Connections at (i) a different and (ii) Constant Time Intervals between the Files Transmissions

Method of increasing the effectiveness of data exchange based on the research results are shown in Figure 23. All the basic data, simulated models, the dependences with the analytical estimation and some crucial recommendations are presented therein.

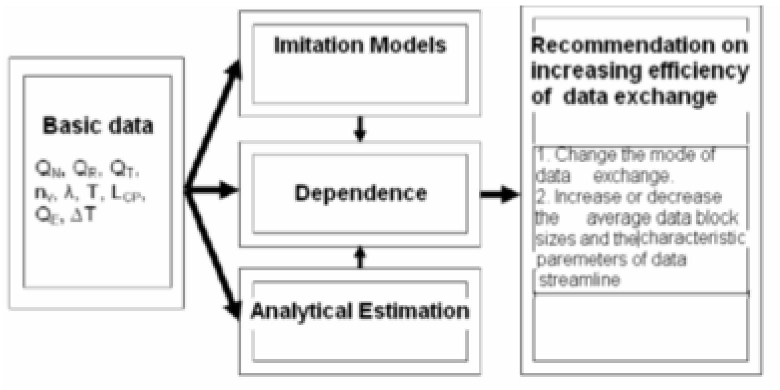

Figure 23: Method of improving data exchange in networks

To obtain the most efficient mode of data exchange, the proposed method consists of applying the analytic estimation and simulation models using the basic data dependence in achieving network performance. The method consists of the following:

1. Formulating the required bandwidth for the network;
2. Determining the minimum rational file size for the network;
3. Determining the maximal rational file size for the network;
4. Determining the minimum rational period of data stream rate for the network; and
5. Determining the maximal rational period of data stream rate for the network.

The developed model is a method to define the exact dependence required to determine the best parameters for efficient network performance (John et al., 2012).

BIG DATA AND SECURITY

Opportunities: the internet boom of the 1900s followed by social media explosion in 2000s have created the Monster called **big data.** In order for organisations to capitalize on the opportunities offered by big data, they have to do many things differently. And that sort of change can be tremendously difficult for large organisations even though entrepreneurs have capitalized on big data technology to create many new products and services. Those businesses that are able to identify the right infrastructure for their big data project and follow best practice for implementation will have a significant competitive advantage. Big data has a lot of capacity to profit organizations in any kind of industry, ubiquitously in the world. It is useful for decision-making and helpful to improve the financial position of any organisation, but in the competitive world, there is a lot of new technology to master, and this is changing fast (Benjelloun et al., 2015).

Definition: The management of big data consists of the following: organisation, administration and control of large volumes of both structured and unstructured data. The goal of big data management is to ensure a high level of data quality and accessibility for business intelligence and big data analytic applications as shown in Figure 24. Generally, there is no set unit of computing storage that separates "big data" from "average-sized data." Data stores are constantly growing, so what seems like a lot of data right now may seem like a perfectly normal amount in a year or two. In addition, every organisation is different, so the amount of data that seems challenging for a small retail store may not seem like a lot to a large financial services company (Jenn, 2014).

The era of big data is producing unprecedented amounts of data points giving us greater insights that drive exciting research, better business decisions, and in many ways, greater value for customers. To achieve these outcomes, organisations need to be able to handle it efficiently, quickly, and because often data will include sensitive information – securely, all at scale.

Unfortunately, many organisations hesitate looking at security – and more specifically, encryption – when it comes to big data solutions because they are concerned about deploying at scale or impeding the analytics tools that make these solutions so valuable in the first place. Big data security should not mean big headaches.

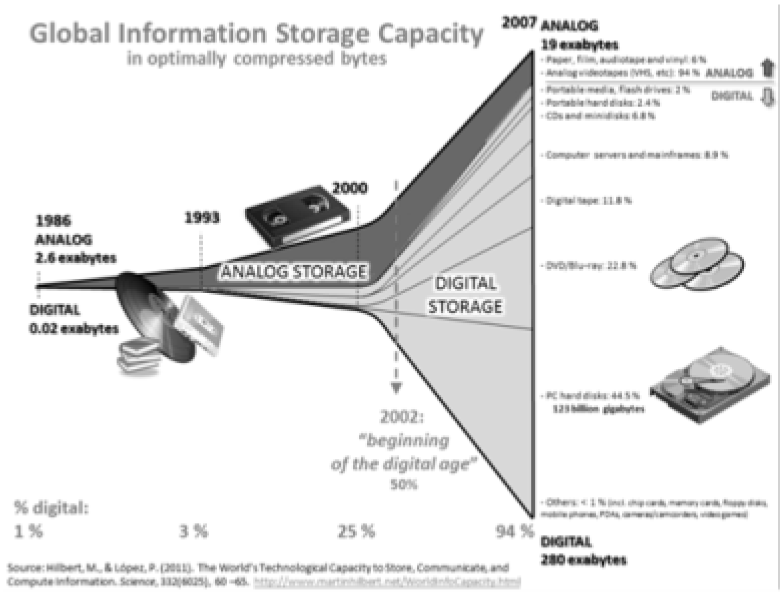

Figure 24: Growth and Digitization of Global Information - Storage Capacity

Globally, big data industry is presently in a period of rapid development. Technological evolution and innovation in applications are advancing with increasing speed. New forms of data storage, computing, and analysis technologies such as non-relational databases, distributed and parallel computing, machine learning, and deep mining have found a habitat for rapid evolution. At the same time big data mining analysis in fields such as telecommunications, Internet, finance, transportation, gaming and medicine is producing value in commerce and applications; it is also beginning to permeate traditional primary and secondary industries (Jenn, 2014). Big data is progressively becoming a national basic strategic resource and an essential factor of production in society. As useful and relevant as the efficient management of big data is, the issue of security of these data is of greater concern. Data security means protecting digital data, such as those in a database and in transit, from destructive forces and from the unwanted actions of unauthorized users, such as a cyber-attack or a data breach and corruption.

Data is increasingly being appreciated as a most valuable asset but this view is not just held by organisations alone, but by hackers alike. Big data projects (e.g. Facebook, Google, Clouding etc.) on the other hand have become unavoidably parts of our socio-economic life. As the goals of information (database) security include Confidentiality, Integrity and ready Availability (Figure 25) issues such as storing and analysing large, rapidly growing, diverse data stores, and deciding best-handling methods, then pose deleterious challenges to big data.

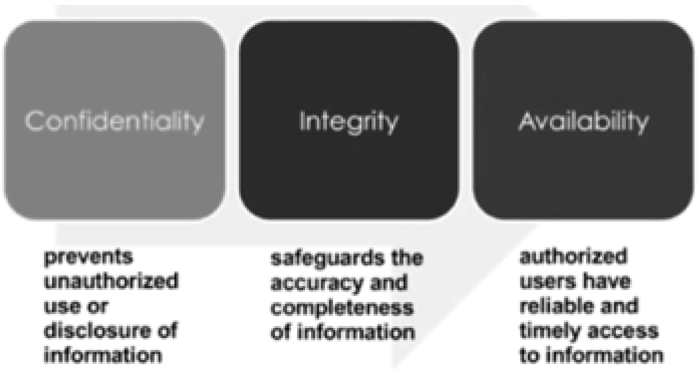

Figure 25: Goals of Information (Database) Security

Quoting from a **NewVantage Partners** Big Data Executive Survey of 2017, 95% of the Fortune 1000 business leaders surveyed said that their firms had undertaken a big data project in the last five years. However, less than half (48.4%) said that their big data initiatives had achieved measurable results. Another October 2016 report from **Gartner** found that organisations were getting stuck at the pilot stage of their big data initiatives as only 15% of businesses reported were able to deploy their big data project to production. Clearly, organisations are facing some major challenges when it comes to implementing their big data strategies. And in fact, the **IDG Enterprise** 2016 Data and Analytics Research found that 90% of those surveyed reported running into challenges related to their big data projects.

In its **Digital Universe** report, IDG estimates that the amount of information stored in the world's IT systems is doubling about every two years. It is no surprise, then, that the IDG report found, "Managing unstructured data is growing as a challenge – rising from 31 percent in 2015 to 45 percent in 2016." According to a recent study, the average cost of a data breach for companies has gone up to $4 million, representing a 29% increase since 2013.

According to the 2016 study, sponsored by **IBM**, cybersecurity incidents continue to grow in both volume and sophistication, with 64% more security incidents reported in 2015 than in 2014. The study found that companies lose $158 per compromised record. Breaches in highly regulated industries were even more expensive - with healthcare reaching $355 per record, $100 more than in 2013. The study found that companies that had predefined business continuity management processes in place found and contained breaches more quickly, discovering breaches 52 days earlier and containing them 36 days faster than companies without such processes.

While there is great concern about the risk posed by outside hackers, insider threats – intended and accidental - remain the most foremost problem, according to a recent IOUG-Unisphere Research report sponsored by Oracle. The Target data breach of 2013, for example the report notes, occurred because of an outside hacking, but it was a trusted contractor that unintentionally opened up the gates. The report makes the point that even those threats coming from outside can be the result of carelessness, unclear or non-existent policies, or inside vulnerabilities, either in data centres or among third-party partners.

Most experts define big data in terms of the Five Vs (Jenn, 2014). You have big data if your data stores have the following characteristics:

- **Volume:** Big data is any set of data that is so large that the organisation that owns it faces challenges related to storing or processing it. Big data requires a large amount of storage space, and organisations must constantly scale their hardware and software in order to accommodate increases. In reality, trends like ecommerce, mobility, social media and the Internet of Things (IoT) are generating so much information, that nearly every organisation probably meets this criterion.
- **Velocity:** If your organisation is generating new data at a rapid pace and needs to respond in real time, you have the velocity associated with big data. Most organisations that are involved in ecommerce, social media or IoT satisfy this criterion for big data. If a data analyst decides to scan through this amount of data, the speed has to be competitive. This requires the algorithms to be highly automated.
- **Value:** the worth of the data being extracted. Having endless amounts of data is one thing, but unless it can be turned into value it is useless. While there is a clear link between data and insights, this does not always mean there is value in Big Data. The most important part of embarking on a big data initiative is to understand the costs and benefits of collecting and analysing the data to ensure that ultimately the data that is reaped can be monetized.
- **Variety:** If your data resides in many different formats, it has the variety associated with big data. For example, big data stores typically include email messages, word processing documents, images, video and presentations, as well as data

that reside in structured relational database management systems (RDBMSes). However, in addition to variety, variability is required. It is perhaps even more important than variety. Variability is the change in parameter values of the big data sets between their minimum and maximum values.

- **Veracity:** Veracity is the quality or trustworthiness of the data. Just how accurate is all this data? For example, think about all the Twitter posts with hash tags, abbreviations, typos, etc., and the reliability and accuracy of all that content. Gleaning loads and loads of data is of no use if the quality or trustworthiness is not accurate.

Lately, it has become almost impossible to talk about business strategy without mentioning the transformative potential of big data. Many companies are already actively using advanced data analytics, while others are just getting started. Anyhow, gaining real business benefit from investments in big data and advanced analytics means overcoming key challenges that touch on technology, talent, culture etc.

Common Challenges and Proposed Solutions:

1. Data Growth

The most obvious challenge associated with big data is simply storing and analysing all the information. There is a school of thought that pre-supposes that by 2020, the total amount of information store will be enough to fill a stack of tablets that extends from the earth to the moon many times over. Enterprises have responsibility or liability for about 85% of the information generated, much of which are unstructured (i.e. they do not necessarily reside in a database). More so, documents, photos, audio, videos and other unstructured data can be difficult to search and analyse.

In order to deal with data growth, organisations are turning to a number of different technologies. As it concerns storage, converged and hyper converged infrastructure and software-defined storage can make it easier for companies to scale their hardware. Technologies like encryption, compression and tiering can reduce the amount of space used and the costs associated with big data storage. On the management and analysis side, enterprises are using tools like NoSQL databases, Hadoop, Spark, big data analytics software, business intelligence applications, artificial intelligence and machine learning to help them comb through their big data stores to find the insights their companies need.

2. Generating Timely Insights

Organisations do not just want to store their big data – they want to use the big data to achieve business goals. According to a **NewVantage Partners** survey in 2007, the most common goals associated with big data projects include the following:

1. Decreasing expenses through operational cost efficiencies;
2. Establishing a data-driven culture;
3. Creating new avenues for innovation and disruption;
4. Accelerating the speed with which new capabilities and services are deployed; and
5. Launching new product and service offerings.

All of those goals can help organisations to become more competitive — but only if they can extract insights from their big data and then act on those insights quickly. Another survey from **PwC's Global Data and Analytics** in 2016 found, "Everyone wants decision-making to be faster, especially in banking, insurance, transportation and healthcare industries". To achieve this speed, some organisations are looking up to a new generation of ETL (extract, transform, load) and analytics tools that dramatically reduce the time it takes to generate reports.

They are investing in software with real-time analytics capabilities that allow them to respond to developments in the marketplace immediately.

3. Recruiting and Retaining Big Data Talent

The enormous applications that generate insights in organisations need to be developed, managed and run by professionals with big data skills. In fact, in order to make real progress with big data, companies need an elite core of data scientists: highly trained professionals who know how to use the advanced statistical algorithms and machine-learning protocols that are necessary to handle large and varied amounts of data coming in at high velocity. This has driven up demand for big data experts — and big data salaries have increased dramatically because there are not many people today who are trained to handle and analyse data sets of this type and magnitude.

In order to deal with talent shortages, organisations have a couple of options. First, many are increasing their budgets and their recruitment and retention efforts. Second, they are offering more training opportunities to their current staff members in an attempt to develop the talent they need from within. Third, many organisations are looking up to technology by buying analytic solutions with self-service and/or machine learning capabilities designed to be used by professionals without a data science degree, these tools may help organisations achieve their big data goals even if they do not have a lot of big data experts staff.

4. Integrating Disparate Data Sources

The variety associated with big data leads to challenges in data integration. Big data comes from a lot of different places — enterprise applications, social media streams, email systems, employee-created documents, etc. Combining all that data and reconciling it so that it can

be used to create reports can be incredibly difficult.
Vendors offer a variety of ETL and data integration tools designed to make the process easier using data integration technology and analytics software.

5. Validating Data
Closely related to the idea of data integration is the idea of data validation. Often organisations are getting similar pieces of data from different systems, and the data in those different systems does not always agree. For example, the ecommerce system may show daily sales at a certain level while the Enterprise Resource Planning (ERP) system has a slightly different number. Or a hospital's Electronic Health Record (EHR) system may have one address for a patient, while a partner pharmacy has a different address on record. The process of getting those records to agree, as well as making sure the records are accurate, usable and secure, is called data governance which on its own is assuming a worrisome challenge.

Solving data governance challenges is very complex and it usually requires a combination of policy changes and technology. Organisations often set up a group of people to oversee data governance and write a set of policies and procedures. They may also invest in data management solutions designed to simplify data governance and help ensure the accuracy of big data stores — and the insights derived from them.

6. Securing Big Data
Security is also a big concern for organisations with big data stores. After all, some big data stores can be attractive targets for hackers or Advanced Persistent Threats (APTs) even as most organisations seem to believe that their existing data security methods are sufficient for their big data needs as well.

According to IDG survey, less than half of those surveyed (39%) said that they were using additional security measure for their big data repositories or analyses. Among those who do use additional measures, the most popular include identity and access control (59%), data encryption (52%) and data segregation (42%).

7. Organisational Resistance

It is not only the technological aspects of big data that can be challenging — people can be an issue too. In a **NewVantage Partners** survey, 85.5% of firms surveyed said they were committed to creating a data-driven culture, but only 37.1 % who attempted creating this data-driven culture said they had been successful with their efforts. Herein, they sighted impediments to this corporate culture shift. Furthermore, respondents pointed to three big obstacles within their organisations:

- Insufficient organisational alignment (4.6%)
- Lack of middle management adoption and understanding (41.0%)
- Business resistance or lack of understanding (41.0%)

Meanwhile, another report from PwC recommended that companies should continue to invest in strong leaders who understand data's possibilities and who will challenge the business in order to “improve decision-making capabilities at company level." A way to establish such sort of leadership is to appoint a Chief Data Officer, a step that NewVantage Partners said 55.9% of Fortune 1000 companies have taken. But with or without a chief data officer, enterprises need executives, directors and managers who are going to commit to overcoming their big data challenges if they want to remain competitive in the increasing data-driven economy. This data-driven culture might be most difficult challenge to overcome. When it comes to bringing big data into the corporate culture, there are two kinds of companies. Some firms - Google, Amazon, Netflix, and LinkedIn, for example — have big data baked into their business model. These companies have no culture issue around big data, because big data was part of the equation from Day One. Then there are the more traditional, mainstream companies - firms that have built and cultivated their management teams by heavily valuing intuition and experience as a way to make decisions. But no one is advocating using analytics as a replacement for judgment and intuition. Rather, analytics has the potential to become a much more powerful aid to judgment and intuition. The bigger picture, however, is that companies and their senior leaders have to realize that the era of big data is here and, even if they themselves do not fully embrace it, ignoring it is not an option. Because big data is so prevalent now, the technology and analytic solutions will also continue to improve, increasing the amount of insight that can be gleaned from each byte.

DATA SECURITY AND DATA EXCHANGE CHALLENGES IN 21ST CENTURY

Security breaches to personal computing devices, cloud storage accounts, portable media devices are rampant in today's world (Chinonso et al., 2018). The end to end of data and information exchange is now perpetually under threat. Even safely guarded locations and secrets of countries, corporations or individuals can be compromised in the **data exchange cycle.**

Firstly, data is created by the harvesting of an entity's behaviour, responses, choices and disclosures with or without the entity's consent. This continual harvesting of an entity's dialogue has ostensibly led to the growth of data also known as Big Data. The very nature of data means that the **data exchange cycle** is one where few details are **incentives** for harvesters to mine more details. However, harvesters are also less bothered about securing data in the process.

One way introduced to secure data in this cycle is the **end-to-end encryption** of Data, a way to limit the exposure of user information to nefarious actors while in transmission. These rules were implemented on Organisation to Organisation basis with only standards on encryption agreed upon and nothing else. User information for one system or application by practice was not restricted by law.

This has led to serious data breaches from legitimate third party agreements. The "**Facebook-Cambridge Analytica**" saga is illustrative of this fact; in this case, Facebook had entered into a seemingly legitimate transaction to explore how data mined from users could influence the political decisions and choices of those users. This very act was frowned at after investigation in 2017. This would have been embraced five years ago as a creditable use of technology. Indeed, the red lines of data use and misuse or breach are still evolving and as such cannot be held only at today's standards.

A host of **legislative actions** by political and global bodies has sought to provide all players involved the necessary protections; this include actions instituted by the European Union in 2018 on user data restrictions also known as General Data Protection Regulation or GDPR (European, 2018). This protection, I believe, will shape the future of data security and its innovations for years to come.

RECOMMENDATIONS

In order to increase the efficiency of data exchange in computer networks based on TCP/IP, detailed study of the: topological structure of the network, carrying capacity of communication channels, choice of routers, choice of data stream management and preset control parameters, strategy of spooling of the overloads, and analysis of the communication nodes is prerequisite.

In overcoming big data challenges and protecting their crown jewels - information from outside hackers and intentional misuse by insiders or contractors, organisations are embracing a range of methods in the cloud and on premises from across the data lifecycle, including **encryption, masking, monitoring.**

Ignoring Big Data would not make it go away, and while it may not immediately kill the business this should not be ignored for a very long time. The results of **big data** can generally be directly measured making it easy to determine a return on investment (ROI). Big Data is a tool definitely worth looking into and changing our world completely that shows no signs of disappearing anytime in the near future.

CONCLUSIONS

The major goal of my research work has been to develop and design simulation models for analysing computer networks. This allows for full and exact features extraction during the realization of the protocols and their influence on increasing the efficiency of data exchange in local and corporate networks. The method of increasing effectiveness function in computer networks was offered by perfecting the modes of data exchange within them. This allows for an increment in the network performance without additional overheads on infrastructure of the network. Practically, some of the results obtained from this research enable significantly an increase in the efficiency benefits of data exchange and management in a computer network environment. Test results from the algorithm showed an average of 10% to 15% increase and occasionally 60% and above increase in data exchange efficiency without additional overheads.

Against the background of earlier recommended measures at improving efficiency of data exchange in computer networks, in the emerging smart world, big data are very attractive targets for hackers because they contain valuable and sensitive information. This can range from financial or intellectual property to corporate data and personal user data. Cybercriminals profit by breaching the servers of companies and damaging the databases in the process. Thus, big data security testing is inevitable. This is because the numerous incidents where hackers have targeted companies dealing with personal customer details is prevailing. Data breaches in organisations like Equifax, Facebook, Yahoo, Apple, Gmail, Slack, and eBay just to mention a few, have been in the news in the recent past. Such rampant activities have raised the need for cyber security measures.

As it concerns the burning question of the army of **talent-heads** to confront the challenges of the big data enterprise, Graduate schools like our highly revered Covenant University should gear their efforts at producing more and more trained data scientists, because inevitably, companies that make a bet on big data will be drawn as matters stand, into a war for talents. Big data industry players on their part need to be prepared to fight that war. And having an elite core of data scientists is only part of the battle. Just as important is the cultivation of a group of people that I call **bilinguals** - i.e. people who can speak the languages of both business and analytics, and who can therefore translate between the advanced data scientists and the non-technical decision makers responsible for day-to-day business operations. After all, it is not enough to simply gather the data and analyse it - you also have to be able to apply the analysis to the business decisions you make every day. Big data users need someone who understands enough about the possibilities, potentials, and procedures of big data to help craft the solution that will ultimately be of value to the businesspersons.

Chancellor Sir, the Vice Chancellor, distinguished guests: data exchange, big data and network security are unavoidably

interwoven in the efficient and effective management of computer networks. These concern stands as the direction in research for a new approach to topical challenges in the data mining, network utilization, storage and security of this dynamic Information and Communication Technology industry.

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