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A Model for Congestion Mitigation in Long-Term Evolution Networks using Traffic Shaping

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Abstract- Long-Term Evolution (LTE) has evolved the field of data transmission, bringing about the era of 4th Generation Networks capable of providing broadband speeds to mobile users based on the development experienced in the field of data transmission. There has been a sporadic increase in the utilization of Long-Term Evolution (LTE) networks, due to the ever-growing utilization of network links and network services, certain issues begin to rise, one of such issues is the problem of congestion. The more utilized a network becomes, the more vulnerable it is to congestion. Data networks become congested when network cannot keep up with the growing demand for the networks resources. The focus of this work is on proposing a model to mitigate the effects of congestion on Long-Term Evolution (LTE) networks. The model was evaluated using the NS-2 network simulator and Network Utilization, Network Delay, Throughput metrics would be used to evaluate the efficiency of the model. The enhanced model performed better and more efficiently than previous solutions, offering a better way to mitigate the effects of congestion in Long-Term Evolution networks.

Keywords: long-term evolution, congestion, mitigate, delay, throughput.

GJCST-E Classification: C.2.1, C.2.3

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A Model for Congestion Mitigation in Long-Term Evolution Networks using Traffic Shaping

Kuyoro Shade O. [α] & Oyebode Aduragbemi [σ]

Abstract- Long-Term Evolution (LTE) has evolved the field of data transmission, bringing about the era of 4th Generation Networks capable of providing broadband speeds to mobile users based on the development experienced in the field of data transmission. There has been a sporadic increase in the utilization of Long-Term Evolution (LTE) networks, due to the ever-growing utilization of network links and network services, certain issues begin to rise, one of such issues is the problem of congestion. The more utilized a network becomes, the more vulnerable it is to congestion. Data networks become congested when network cannot keep up with the growing demand for the networks resources. The focus of this work is on proposing a model to mitigate the effects of congestion on Long-Term Evolution (LTE) networks. The model was evaluated using the NS-2 network simulator and Network Utilization, Network Delay, Throughput metrics would be used to evaluate the efficiency of the model. The enhanced model performed better and more efficiently than previous solutions, offering a better way to mitigate the effects of congestion in Long-Term Evolution networks. The results obtained from the simulations showed that the enhanced model if implemented in Long-Term Evolution network will reduce the effects of congestion, improving network throughput and overall performance.

Keywords: long-term evolution, congestion, mitigate, delay, throughput.

I. Introduction

The Internet, created as far back as January 1983, has revolutionized communication, business and also wealth creation (Sagar & Shankar, 2013). The Internet and basically all kinds of networks can be viewed logically as a queue of packets. Packets are unit of data fragments that are constantly being transmitted between nodes, and this is the foundation of all forms of networking. Networks perform the tasks of packet transmission between nodes thereby reducing the number of packets remaining in the queue waiting to be transmitted. The exponential increase of network usage and also network capacity brings up more comprehensive issues which are paramount to the network's overall performance (Alkharashi, 2016).

High-Speed Packet Access (HSPA) and Long-Term Evolution (LTE) technology (ERICSSON, 2007). It is estimated that global mobile users will surpass 5 billion by the end of year 2017 (GSMA, 2017), that is more than two-thirds of the world's population, one can only imagine the amount of traffic that will be generated with such great number of users (Internet World Stats, 2017). Long Term Evolution (LTE) has propelled the world into an age of affordable, reliable and also efficient data services, user experience is greatly improved; also improving the Quality of Service (QoS), giving room for more sophisticated applications requiring huge bandwidth including streaming services, mobile video blogging, TV over IP, advanced gaming services and so on.

The Long-Term Evolution technology brings about so many beneficial advantages over previous technologies to both users and the network administrators, these advantages can be categorized into three major points; which are performance and capacity; simplicity and a wide range of terminals (Khalil, 2015). The present advancement in communication technologies has led to an exponential and sporadic increase in the transmission of data, voice and also in multimedia application which makes use of packet switching technology, with this increase in traffic, problems involving proper routing of packets become paramount because when the subnet is flooded with too many packets, performance will be affected.

The problem of congestion has existed far back as the creation of computer networks, it has persisted to modern networks and solutions are far from being absolute. Long-Term Evolution technologies offers high speed broadband services at cheap and efficient rates to users (Sauter, 2011). This technology is built on packet switching which means that data is broken down into packets and these packets are transported via routes to their destinations, due to the dynamic nature of packet switching the packets can follow different routes and on getting to the destination all the packets are gathered and the data is rebuilt from the packets (Willassen, 2003). Congestion can easily disrupt network process, as a result of heavy traffic on the network packet can be delayed, timed out, contain error and sometimes even be lost. This is a serious problem leaving networks clogged with so much traffic and so little work is done.

II. Traffic Shaping

One of the major causes of congestion in most network is the fact that they take on huge amount of traffic and over time the network traffic limit is exceeded thus, congestion is created and if this is not addressed it leads to a congestive collapse (E-Learning Atria, 2013).

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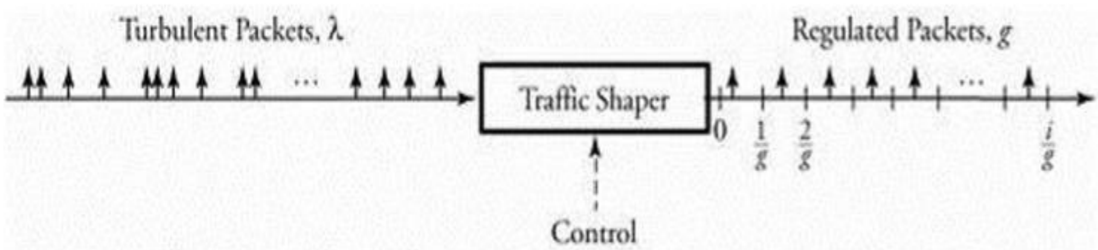
If the network host could be made to maintain a uniform rate of transmitting packets, congestion occurrence would reduce in the network. Also, another method to achieve congestion management would be to make packet transmit at a more predictable rate, this approach is also known as Traffic Shaping. In the practicality of networking, packets are transmitted with an irregular pattern and this could be problematic (Balchunas, 2010).

Traffic shaping in network communication controls the access to the bandwidth available for transmission of packets, it regulates both incoming and outgoing data in other to avoid congestive collapse and it controls the delay which occurs as packets are being transmitted (Agarwal, 2000). Packets with irregular pattern of transmission i.e. turbulent packets which are transmitted a rate of λ are regulated with the aid of a Traffic Shaper into regular patterns at an interval of 1/g.



Source: E-Learning Atria, 2013

Figure 1: How Turbulent Packets *λ* are shaped to Regulated Packets *g*

Traffic shaping deals with regulating the burstiness or average data transmission rate, it is different from other forms of congestion control. Other techniques such as the Transmission Control Protocol (TCP) congestion control set certain thresholds to the amount of data that can be transmitted once congestion begins to occur, it is not concerned with the rate at which it is sent. A Service Level Agreement (SLA) is a policy agreement which is reached between the consumer and the service provider, which makes the consumer to adhere to this data transmission rate (Hu & Guo, 2016).

There are major two methods for managing traffic that exceeds the specified rate, one method is traffic shaping which is being addressed in this study, the other is traffic policing although it is very similar to traffic shaping, it is different in terms of implementation and also operations. Traffic shaping is implement on the user or consumer side of the subnet and it would regulate traffic that exceed the specified rate stated by the network providers, as long as consumers and network providers adhere to this basic term congestion is reduced drastically (Balchunas, 2010). Monitoring of traffic flow is what is referred to as traffic policing. Traffic policing is implemented on the provider's side of the subnet, it forces the network provider's traffic to be drop or regulated to a constant rate as soon the specified transmission rate is exceeded. Data traffic that is dropped will in turn be forced to be retransmitted and this can result in a starvation of packets on the consumer side of the subnet. Traffic policing is implemented for outbound traffic (traffic leaving the network) and also inbound traffic (traffic entering the network).

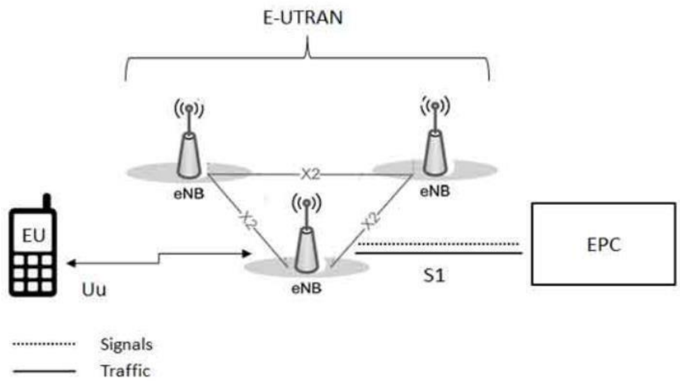
Traffic shaping is only implement on outbound traffic, therefore is prevents the loss of packets because sudden increase in system bandwidth usage is avoided. The architecture of the traffic shaper consists of a model that converts traffic of any form from being in deterministic to deterministic (Cisco Networks, 2017).

III. Long Term Evolution Architecture

The Third Generation Partnership Project (3GPP) Long Term Evolution architecture attempts to advance the pre-existing 3rd Generation Technology by actually realizing higher bandwidths availability, a wider coverage range, more efficient use of the data spectrum and also full integration coupled with an easy way to improve to upgrade existing 3G networks. Long Term Evolution architecture does all this through the use of an IP architecture, it can be described has a hybrid mobile network system architecture, due to how compatible the architecture is with other radio access technologies and several mobility mechanisms (Yahija, 2011).

At the highest level of abstraction, the network architecture is comprised of three major components:

1. The User Equipment (UE).
2. The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).
3. The Evolved Packet Core (EPC).



Source: Tutorials Point, 2017

Figure 2: The highest level of abstraction of the LTE Architecture

a) *The User Equipment (UE)*

The user equipment (UE) is any device which is used by the end user to gain access to a network. It could be of various forms, a hand held mobile phone, a computer i.e. desktop or laptop combined with a mobile broadband adapter and so on. The user equipment would connect the user to a base station but in the case of Long Term Evolution it connects to a eNodeB which a major component of the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN). The interface between the user equipment and the eNodeB is the Uu interface.

b) *Evolved UMTS Terrestrial Radio Access Network (E-UTRAN)*

The air interface of the Long-Term Evolution (LTE) network is the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) which provides an upgraded path for mobile network communication (Yahija, 2011). It's a new radio access network standard which is designed to be a replacement to the UMTS, GSM, HSDPA, HSUPA and even circuit switched technologies. The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) is a new system which provide air interface between Long-Term Evolution (LTE) network elements, providing higher data rates and lowering latency which is optimised for packet data networks (Nortel, 2008).

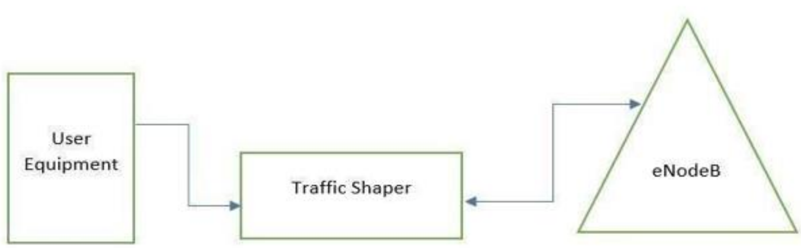
c) *The Evolved Packet Core (EPC)*

The Evolved Packet Core (EPC) is the framework which enhances the provision of data packets on the Long-Term Evolution network. The Evolved Packet Core is the major component of the System Architecture Evolution (SAE) architecture (Sauter, 2011). The Evolved Packet Core is at the core of the network and provides significant advancement to the existing 3rd Generation technology in the following categories:

1. It has a simplifies architecture.
2. It is an all-IP Network (AIPN).
3. It supports higher throughput and lowers the latency rate.
4. It supports mobility between multiple heterogeneous networks.

IV. Design of Experiment

The Long-Term Evolution architecture has various network element connected via interfaces. The User Equipment is connected via the air interface to the eNodeB, thus traffic flows in and out of the network via the air interface to the User Equipment. The traffic flow is not determined and the flow is not regulated. This work proposes that a module be added between the User Equipment and the eNodeB, a Traffic Shaper which shapes traffic and regulates the traffic flow. The traffic shaper would incorporate traffic shaping techniques, it would implement the token bucket and the leaky bucket algorithms. Outbound and inbound traffic were regulated using these techniques and the outcome of the traffic was adequately regulated and thus mitigate the effects of congestion in the network.



Source: Researcher Model, 2018

Figure 3: The Enhanced Model for Mitigating Congestion in Long-Term Evolution Architecture

a) Evaluation Procedure

This work would use a simulation approach to simulate the effect the enhanced model would have on a congested Long-Term Evolution network environment. The various performance metrics provided would be used to evaluate the performance of the model. The network throughout, average end-to-end delay, network utilization and packet delivery ratio were measured and thus provides the basics for evaluating the enhanced model.

V. Long-Term Evolution Network Environment Simulation Result

A Long-Term Evolution Network environment was created using the NS-2 installed on a Linux Operating System. The network comprised of 3 eNodeBs and each of these eNodeBs was be connected to 10 User Equipment, also a Relay Node was added in other to make the simulation appear as realistic as possible. A packet size of about 1500 Bytes was used with a simulation time of 100 seconds. The TCP protocols employed were TCP Reno and SCTP.

The link parameters employed for the Long-Term Evolution network environment includes allocating 100 megabits per second of bandwidth to the server with a delay of 100 micro-second and also have 2 routers with bandwidth of 1 gigabits per second with a delay of 3 micro-second each. The 3 eNodeBs would have a bandwidth of 1 gigabits per second and a delay of 3 microsecond and the same parameter was used for the relay node.

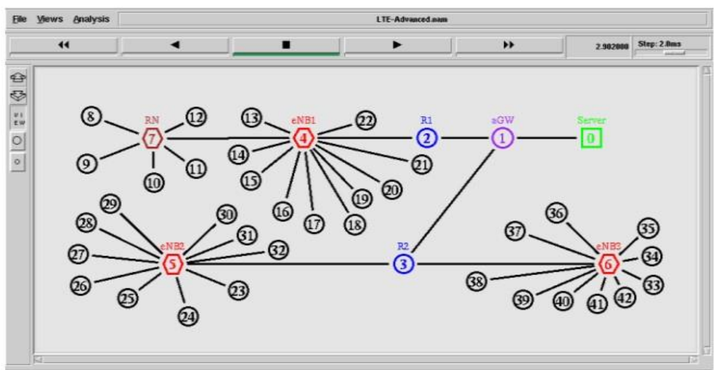


Figure 4: View of the Simulated Long-Term Evolution Network Environment

Figure 4 shows the real-time simulation of the Long-Term Evolution network environment. The green node in the Figure 4 represents the server, which symbolizes the Packet Data Network (PDN) aspect of the network and it is directly connected to the gateway. The two routers are connected to the gateway with a bandwidth of 1 gigabits per second and all the eNodeBs are connected to it in order to gain access to the server and this represents the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) segment of the network. Also, there are various User Equipment connected via the air interface to the eNodeBs.

VI. Performance Evaluation of the Enhanced model

This work focuses on using 4 metrics in evaluating the performance of the enhanced model, the performance metrics used include the following:

1. Network Throughput
2. Average End-to-End Delay
3. Network Utilization
4. Packet Delivery Ratio

The results of the various simulations conducted are outlined in Figure 5, Figure 6, Figure 7 and Figure 8.

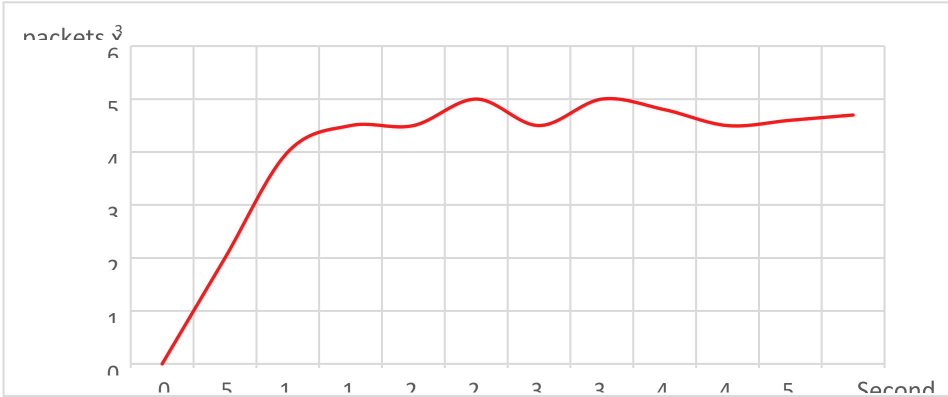


Figure 5: Network Throughput

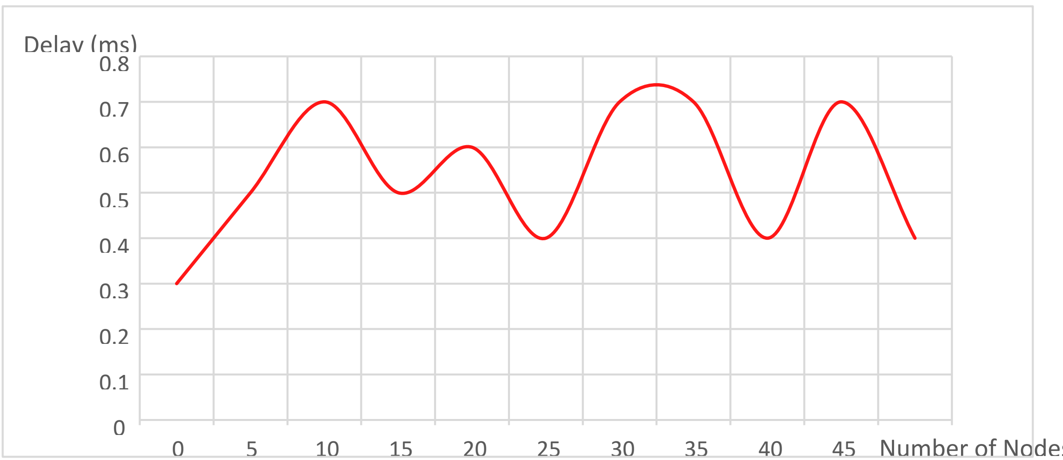


Figure 6: Average End-to-End Delay

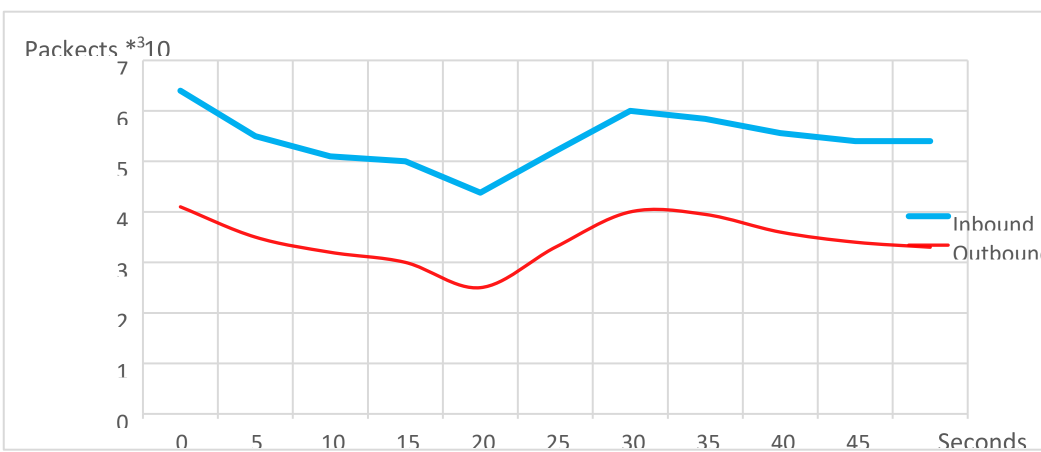


Figure 7: Network Utilization

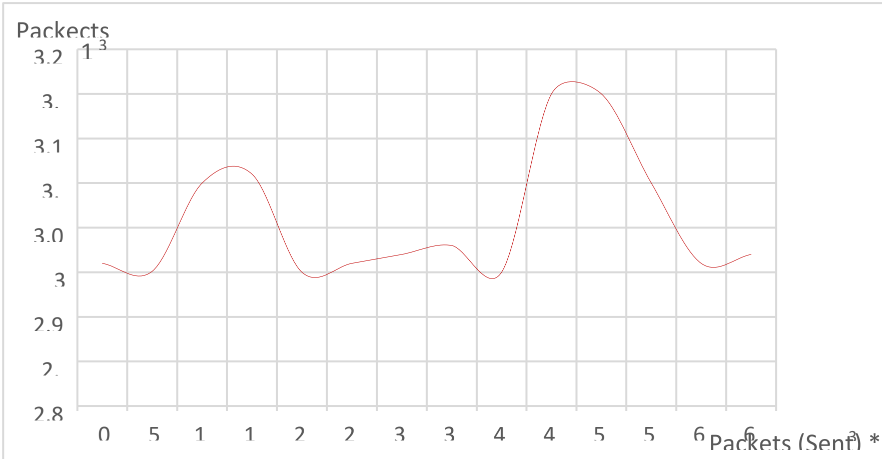


Figure 8: Packet Delivery Ratio

VII. Discussion

Figure 5 shows that the throughput in the network does not decrease even as traffic increases overtime and Figure 6 shows the average end-to-end delay is at a constant rate. Figure 7 and Figure 8 show that network utilization is kept optimal and also the Packet Delivery Ratio is greatly reduced.

The simulation results presented in Figure 4.105, Figure 4.116, Figure 4.127 and Figure 4.138 all show that the enhanced model provides a better way to mitigate the effects on congestion in Long-Term Evolution Networks. It can be seen from the results obtained that h#as traffic increases over time network performance does not diminish but kept at an optimal level.

As seen in Figure 5, network throughput does not diminish despite increasing network traffic and also network utilization is kept at a consistent level, showing that packets are not lost and are successfully delivered from source to destination. It can also be seen that the delivery time for data packets and also the delay experienced is kept at a consistence low rate as depicted in Figure 6 and Figure 8, ensuring that packets do not spent too much time on the queue and reduces the likelihood of packets being timed out.

VIII. Conclusion

Congestion is a difficult problem to solve across all networks of different types and sizes. Although different solutions are currently being used and also being proposed none has been able to adequately solve the problem. This research work focuses on Long-Term Evolution networks and proposed an enhanced model, which incorporates traffic shaping algorithms in other to be able to shape traffic as it enters into a network subsystem which gives networks better control over data traffic.

From the simulation results obtained, it can be seen that the enhanced model provides a better means to control congestion. The enhanced model offers improved throughput and better network utilization. This means that network can perform better even when traffic continues to increase over time and also packet loss is reduced. Also, the average end-to-end delay and also packet delivery ratio is kept at a minimum constant ensuring that packet do not stay too long on the network queue and are not timed out.

In conclusion, the proposed enhanced model has shown that it can provide a better way to address the problem of congestion in Long-Term Evolution Networks.

IX. Recommendations

In this work, the effect of congestion on Long-Term Evolution networks was analysed and a solution was proposed using an enhanced model which would help to mitigate the effect congestion has on Long-Term Evolution Networks. There for this study recommends that adequate research is done in other network types and architecture that is currently been affected by congestion. The scope of this work was limited to congestion mitigation in Long-Term Evolution networks, this scope can be broadened to other network types and architecture.

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