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Quality of Service (QoS) Optimization in Mobile Broadband Using Cloud-Based Content Delivery Network

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ABSTRACT

Mobile broadband utilizing Long-Term Evolution (LTE) has advanced the field of data transmission; with networks capable of providing broadband speeds to mobile broadband users. There has been a sporadic increase in the utilization of Long-Term Evolution (LTE) networks, but due to the rapid growth and utilization of network links and network services, certain issues begin to rise, such as the issue of poor Quality of Service (QoS) perceived by mobile users. Data network quality of service degrades over time when network cannot keep up with the growing demand for the network resources. The research reviewed various existing content delivery network models in order to understand the overall architecture and operations. An optimized model was developed and integrated into the existing Long-Term Evolution network models. The model was evaluated using the Network Simulator (NS-3) and Quality of Service (QoS) metrics, such as, Network Throughput, Round Trip Time, Bandwidth, Packet Loss, Jitter and Connection Ratio. The results obtained from the simulations showed that the optimized model performed better and more efficiently than previous solutions. And if implemented in Mobile Broadband, this will improve the Quality of Service, network throughput and overall performance of the network. This study concluded that cloud-based content delivery network provides a solution which would help improve the Quality of Service experience by Mobile Broadband subscribers. By actively redirecting network traffic to the nearest replica server on the network edge; thus, increasing efficiency and throughput.

Keywords : Content Delivery Network, Cloud Service, Long-Term Evolution, Mobile Broadband, Quality of Service (QoS).

I. INTRODUCTION

Throughout history, information and communications have always formed the foundation of human existence. And it has motivated ways to constantly seek the improvement of processing and communicating of information to one another, regardless of distance and on a timely fashion. It can be said that, the greatest legacy of 20th century scientists to mankind is the Information Revolution made conceivable by rapid development and advancement in telecommunications and computing technology. Today, without a fundamental telecommunications infrastructure, no modern economy can be sustained (Ernest, 2000). Till the 21st century, the Internet has evolved rapidly and greatly, intertwined with broadband capabilities, connecting billions of people, promising increased speed and opening up a boundless range of opportunities (Zizi & Anna, 2010). The International Telecommunications Union (ITU), in 1999, confirmed that the world's telecommunications and information technology industry was worth 1 trillion dollars in market capitalization. Taking a closer look at Africa, it is not an exciting story as the former South African President, highlighted the shortage of telecommunications infrastructure in Africa and pointed out that there were more phone lines in Manhattan - New York than in the entire Sub-Saharan Africa (Ernest, 2000). In recent times, Nigeria's telecoms industry, in terms of potential growth and collective size, is certainly the biggest in subscription market. Thus, remaining one of sub-Saharan Africa's most valuable markets. One key factor is that; Nigeria's mobile subscribers are proactively shifting from narrowband to broadband mobile services. But their reliance on narrowband Internet networks is as a result of limited to poor mobile broadband coverage that was existing. It is this shortfall that broadband is specifically intended to address: robust market, ubiquitous superfast access to internet combined with voice and messaging services (Kamar, 2016). Also, the acceptance of mobile devices has created exceptional demand for Internet access to mobile applications anywhere, at any time. Thus, increasing the amount of traffic flow recorded by the Telcos, and also transformed its composition; from the traditionally voice-only to now dominating video and data applications. This trend is on a continuous increase owing to the increasing variety of internet applications and services, and the growing subscriber base (Masoud & Sindhu, 2013). On a global scale, billions of dollars are been spent on equipment, spectrum, and deployments in advancement of mobile broadband networks. Through these advancements, Telcos aim to intensify capacities and improve network performance to entice more subscribers, in-turn maximizing the average revenue per unit (ARPU), and reducing subscriber churn through increased customer satisfaction – at the least possible cost (Karen, 2011). Consequently, with the rapid growth of the Internet, there has been a huge network traffic growth, motivated by the rapid reception of broadband access, and increasing complexity of the system and robustness of content (multimedia) (Markus & Leland, 2005). These brought about the emergence of new tasks in managing and delivering better Quality of Service (QoS) to subscribers. The increasing frustration of subscribers with the quality of service received has not been overlooked by the government who have made several exertions to encourage and, where needed, compel Telcos to improve mobile services. Quality of Service (QoS) comprises of a structure consisting of various standards that are widely used by Telcos to manage traffic in ways that differentiate subscribers and mobile services to improve overall network performance. This allows traffic isolation into flows built on attributes, such as traffic type (voice, video) or application needs (throughput, latency and/or jitter), and then to conveyance each flow accordingly. Also, reports mobile subscriber Service-Level Agreements (SLAs) by ranking traffic for critical users and applications, providing deterministic latency and jitter required by real-time applications, and minimization of network congestion. Thus, with the growing subscribers base, and the request for a much better user experience with differentiated levels of services. The new generation mobile carrier networks must integrate an increased degree of intellect to transport different applications and services over the internet in a way that delivers a suitable and inexpensive end-user experience, likewise maximizing revenue per user. Most Telcos offer different service packages built on different subscriber needs and applications, in order to attract and retain subscribers, and capitalize on average revenue per user (ARPU). This makes Quality of Service (QoS) a fundamental element in broadband network for reasonable delivery of applications and services with effective end-to-end management of network resources. To achieve this, the Telcos must integrate systems to manage diverse traffic features of the growing variety of multimedia applications and services. This can be accomplished through Quality of Service (QoS) systems that allow the network to recognize and manage a number of traffic-based attributes. As Telcos deploy more and more broadband networks, comprehensive Quality of Service (QoS) capabilities will be needed to sustenance the new generation applications and services (Masoud & Sindhu, 2013). With the rapid adoption of broadband services on a global scale and the erratic change in subscriber's usage patterns, several frameworks have been considered over the years to deliver better Quality of Service (QoS) to the growing mobile subscriber base and for the management and distribution of contents to satisfy diverse usage patterns. Along these lines, Telcos will need to optimize their mobile broadband network to convey better Quality of Service to subscribers.

Statement of the Problem

According to 2013 IHS iSuppli Research, the amount of mobile broadband subscribers alone is anticipated to reach over 1.1 billion in 2016. Also, according to the 2012 Ericsson Mobility Report, mobile broadband subscriptions pecked over 1.4 billion in 2012 and are likely to reach 6.5 billion by 2018 (Masoud & Sindhu, 2013). In Nigeria, efforts are currently being made to increase broadband diffusion from 8% to 30% by 2018. This is still behind the International Telecommunications Union (ITU) target of 40% by 2015 for evolving countries (Olabisi, 2015). Another area of concern is the poor service being experienced by the small subscriber population that currently have mobile broadband services access, and due to the growing expanse of mobile broadband users and limited bandwidth the situation could worsen (Okene & Emmanuel, 2017). According to Andy (2009); Forty hours of high-definition video is equivalent to a million email messages based on the amount of traffic generated on the network and higher data rates are required to sustenance such usage patterns. A decline in Quality of Service, together with increasing access delays triggered by long download times, leaves the subscribers in frustration. Hence, the need to improve the Quality of Service (QoS) experienced by subscribers. On this note, a growth of technologies with objective to improve content delivery and services has been seen over the past few years. When combined, a new network, which is often referred to as content network is formed (Mark, Brad, Gary, & Phil, 2003). Content networks was intended to address the performance problem by utilizing different instruments to improve the Quality of Service (QoS). Various content delivery method includes but not limited to upgrading the server hardware, caching proxy, hierarchical caching and server farms, but are still faced with some challenges. Such as, deployment of replica servers closer to the origin server, resulting in little improvement to the network performance due to congestion bottleneck. (Novella, Emiliano, & Salvatore, 2004) (Markus & Leland, 2005). To address these challenges, another content network type, known as Content Delivery Network – aimed at overwhelming the essential limitations of the Internet, was developed (Al-Mukaddim & Rajkumar, 2007). Along these lines, Telcos will need to optimize their mobile broadband network to convey better Quality of Service to subscribers, considering the increasing richness of content (multimedia), and the increasing broadband subscriber base. This research develops a system to optimize the Quality of Service (QoS) in Mobile Broadband network using Cloud-based Content Delivery Network. By storing the contents to be delivered in a cloud storage server (called origin server) and replicating these contents across cloud servers (called replica servers) on the network edge close to the end-users. Thus, achieving a highly scalability, bandwidth efficiency, cost effective and flexible service options

II. REVIEW OF LITERATURE

Mobile Broadband

Mobile broadband refers to the technologies that offer a high-bandwidth connection to the Internet for mobile subscribers–offering significantly higher bandwidth and lower latency response; and are quickly replacing dial-up technology. Mobile broadband has brought about a completely new online experience such as video stream, downloading music in seconds, video and voice chats, real-time gaming applications and so on. These are made available to mobile subscribers through the high bandwidth and low-latency properties of broadband (Ilya, Alexandra, Jer-Yee, Tushar, & Ilin, 2005). The increasing popularity of the Internet and the World Wide Web with both consumers and enterprises is creating a marketplace for information services that require telecommunication networks capable of interactive high-speed data transfer (Gerald & Christiaan, 2000). As the Internet marketplace continues to grow rapidly, the demand for greater bandwidth and faster connection speeds has brought about several technological methodologies to provide broadband access to all consumers. According to (Judith, 2001), Former Federal Communications Commission Commissioner William Kennard stated, "The most important issue on our agenda today is broadband… Broadband is going to change America… We want four things for consumers in the broadband world. We want fast deployment. We want ubiquitous deployment. We want competitive deployment. And we want open deployment." And same could be said for Nigeria. Broadband access is not only about providing the channels to convey the traffic but also about how the traffic will be supported on the Internet. According to the National Research Council (2002), in practice, what broadband users experience today is basically a superior version of the Internet access that they enjoyed in the past. This experience is enriched by better access to rich multimedia materials (video, music and Internet radio, and so on), with a few new broadband-only applications (network backup and storage) available today.

The concept behind Mobile broadband technology such as Long-Term Evolution (LTE), is a network communication standard which was designed for high-speed communication using wireless mobile device and other mobile terminals (Ahmed, 2009). It is designed to support just packet-switched data services, handling the transfer of data packets between nodes and network elements. This provides fast internet access, improving both uplink and downlink data rate connectivity between the user equipment (UE) and the packet-data network (PDN) (Alcatel-Lucent, 2009). Long Term Evolution (LTE) represents the advancement of Universal Mobile Telecommunications System (UMTS); which was the 3rd generation mobile communication standard developed based on the Global Systems for Mobile Communication standards present at the time. This provides an improvement on the Universal Mobile Telecommunications System (UMTS) radio access which is called the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) (Nortel, 2008). This development was made conceivable through the creation of a System Architecture Evolution (SAE) which serves as the core of the network providing an Evolved Packet Core (EPC) network. When Long Term Evolution (LTE) and System Architecture Evolution (SAE) are combined, we have an Evolved Packet System (EPS). Long Term Evolution (LTE) is the next major leap in mobile communications, it uses Orthogonal Frequency Division Multiplexing (OFDM) as its access technology combined with advanced antenna technologies (Tutorials Point, 2017). In the near future, new technologies with broadband compatible functionality will be anticipated, such as BPL (broadband over power lines).

Content Delivery Network

According to (Mukaddim, Rajkumar, & Athena, 2008) and (Citrix, 2014) Content Delivery Networks (CDNs) are large distributed infrastructures of replica servers placed in strategic geographical locations. By duplicating content of origin server on replica servers, the content is delivered transparently and effectively to end-users with reduced latency. A CDN is an overlay network that gives more control of asset delivery while monitoring network load. It strategically places servers closer to the user, reducing response time and network congestion. Thereby, overcoming the vital limits of the Internet such as user perceived quality of service when accessing Web content (Al-Mukaddim & Rajkumar, 2007). Content Delivery Networks have gained a prevalent role among application service providers (ASPs) and recently telecom operators. The rapid acceptance of broadband access among other factors, has caused massive growth in network traffic as users perceived the growth of the Internet, over the last decades. The rapid developing nature of the Internet brings new challenges in managing and delivering robust contents (Mukaddim, Rajkumar, & Athena, 2008). A Content Delivery Network (CDN) has a combination of a number of components that work together to achieve its aims. Components such as content delivery, request-routing, distribution and billing. The content delivery comprises of a set of replica servers on the network edge, also called surrogates, that deliver duplicates of content to end-users. The request-routing handles the responsible to directing user's request to appropriate replica servers. This in turns, networks with the distribution, to keep an updated view of the content stored in the replica servers and ensures consistency of content in the cache storages. The billing keeps logs of network accesses and records the usage; for traffic reporting and usage-based billing (Al-Mukaddim & Rajkumar, 2007). CDNs that utilizes conventional web technologies for its replica servers are also called traditional CDNs. The replica servers are either dedicated or storage space in a shared infrastructure e.g. Akamai, Limelight and Level 3. In recent times, new paradigms for CDN architectures has emerged such as cloud computing and Network Functions Virtualization (NFV) (Jagruti, Mohammad, Roch, Halima, & Wessam, 2016). The major drive for CDN customers is to distribute and deliver robust content to the end-users on the Internet in a reliable and timely manner. These customers include media and Internet advertisement companies, data centers, Internet Service Providers (ISPs), online music retailers, mobile operators, consumer electronics manufacturers, and other carrier companies. In practice, for dynamic Web content, CDNs are typically utilized in hosting static Web content (Al-Mukaddim & Rajkumar, 2007).

Components of a Content Delivery Network

(Novella, Emiliano, & Salvatore, 2004) highlighted some important components required in the establishment of a CDN, namely:

1. **Replica placement mechanisms** – This select the replica server locations and pre-fetches the appropriate content prior to the request arrival. Thus, the replica servers are pro-actively updated. This is required to actively handle the fluctuating traffic state.
2. **Content update mechanisms** – This actively and automatically check for changes, retrieves and updates content from the origin server to the replica servers on the network edges, guaranteeing content newness.
3. **Active measurement mechanisms** – This is supplementary to the cooperative access routers for real-time picture access of the Internet traffic, allowing faster routing of user request to the replica servers in any type of traffic circumstances.
4. **Replica selection mechanisms** – This is supplementary to the cooperative access routers to precisely detect the nearest and most accessible replica server from which the end user's requests can be retrieved and required content delivered.
5. **Re-routing mechanisms** – This allows swift re-routing of content requests in response to traffic bursts and congestion.

Content Delivery Network: How it Works

The following steps highlights how the CDN works (Jussi, 2002) (John, *et al.,* 2016):

1. Client sends HyperText Transfer Protocol (HTTP) content request to origin server
2. Once Domain Name Server (DNS) resolves the replica server's name
3. The client's request is directed to the replica server on the network edge
4. Which then requests content from the appropriate source
5. And satisfies the client's request by serving the content from the replica server closest to the end-user, and records its completion

Quality of Service (QoS) in Mobile Broadband

The rapid growth of various computing paradigms such as Internet of Things (IoT), Big data and cloud-based services sets new requirements for network performance. The provision of different IP services for broadband technologies, ranging from narrow-band to broadband, non-real-time to real-time, and unicast to multicast broadcast applications. Coupled with the drop-in hardware cost, resulting in mobile devices with advance capacities and the erratic increase in the amount of multimedia data. Additionally, the advancement of mobile networks in the direction of an all-IP broadband technology presents new challenges for traditional mobile services such as voice and data. The design of broadband mobile technology catered for different Quality of Services (QoS) structures to facilitate the delivery of the growing Internet applications. Providing satisfactory service delivery and managing network resources. With the increasing need for different levels of user mobility, access networks with Quality of Services (QoS) and other advance capabilities are required. To satisfy the technical quality of service (QoS) as well as a better user experience, broadband operators need to understand and manage both quality and performance of the services (Hongli & Mei-Ling, 2011) (Firas, Nidal, Mohd, & Charles, 2012) (Settapong, Dithdanai, & Wassana, 2016).

III. METHODOLOGY

Research Design

The Long-Term Evolution architecture has various network element connected via interfaces. Figure 1 show how the various elements are connected. 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 eNodeB and the Router, cloud-based content delivery network that redirect user's request contingent on their geographical location in the network giving by the previous placement of the replica servers. The cloud-based content delivery network would incorporate replica server placement algorithm; it would implement the Least Usage Greedy (LUG) Heuristic Algorithm. Outbound and inbound traffic would be optimized using this technique and the outcome would be a traffic which is adequately optimized and thus improving the Quality of Service (QoS) of the network.

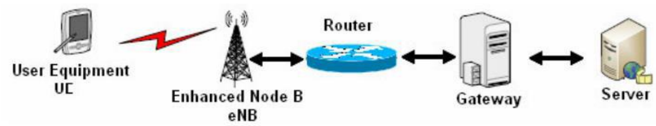

Figure 1. Showing the Long-Term Evolution **Architecture** (Abdul, Khalil, Sayed, & Abdul, 2015)

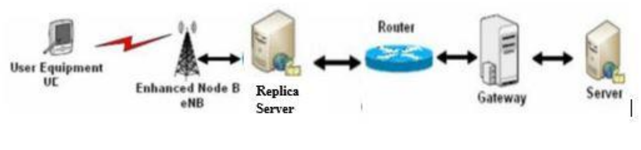

Figure 2. Design Framework (Researcher, 2018)

Figure 2 shows the replica server being added to the model to optimize the outgoing and incoming traffic. The cloud-based content delivery network would use Least Usage Greedy (LUG) Heuristic Algorithm for its replica server placement on the network edge. This process is carried out as follows:

Algorithm 1: Placement

This involves selecting replica servers in the rising order of operational cost and conveying end-users that are not yet assigned to a replica server.

Algorithm 2: Refinement (X)

This intends to improve the cost of the response produced by the placement algorithm. It aims at eliminating replica servers whose elimination results in cost improvement and re-assigning to other replica servers already designated. The replica servers are eliminated until no cost improvement is detected. For re-assignment, the next best replica server in terms of unit delivery cost (i.e. unit leasing bandwidth cost) is designated.

Algorithm 3: Least Usage Greedy ()

The response obtained by the refinement algorithm is considered as the solution of Least Usage Greedy.

Proposed Replica Server Placement

Greedy heuristic algorithm is employed to solving the replica server placement problem in cloud based CDN. A greedy algorithm is an algorithmic strategy that makes the best optimal choice with the goal of eventually leading to a globally optimum solution. This means that the algorithm picks the best solution without regards for consequences. The objective is to find optimal location and amount of replica servers and assignment of one of the replica servers such that the operational cost is curtailed and the Quality of Service (QoS) thresholds are satisfied. The cost includes the server deployment cost (i.e. storage cost) and update cost (updated from origin server only). The network cost of transferring content from source to destination includes the cost of downloading and uploading contents. This proposed replica server placement model is close to Uncapacitated Facility Location (UFL) model. In UFL model, each facility has an opening cost and is served by a facility by incurring a delivery cost. The storage cost is the equivalent of opening cost in UFL, besides the opening cost is a one-time cost. This proposed replica server placement model incorporates quality of service constraints to meet the viewing expectations. Relaxing the quality of service constraint makes this model an instance of the UFL. Since UFL is NP-hard, this proposed replica server placement model is also NP-hard.

Proposed Model for the Replica Server

The inputs to solve the above proposed model include a network topology of replica servers and end-users, request of end-users, QoS threshold of end-users, size of servers to be hosted as the replica servers and the leasing costs. Formally, let $G = (V, E)$ be a graph, where V is a set of nodes and E is the set of edges. We define two set of nodes: set of end-users' H and set of potential location of replica servers F, where $V = H \cup F$, $|F|=M$, $|H|=N$. Each end-user node $j \in H$ contains a request w_j that denotes the total load originated at that node. Each network edge $e \in E$ represents the logical communication relationship between two nodes. Each network edge between a replica server and end-user has a QoS metric. L_{ij} represents the QoS metric of the network edges (i, j) between a replica server $i \in F$ and an end-user $j \in H$. Each end-user j is connected with an satisfactory QoS threshold denoted as Q_j. We assume a replica of size W. Let α_i^S and α_i^B denote the leasing cost of unit storage and leasing cost of unit download bandwidth of replica server i F.

We formulate the replica server placement, having the following decision variables:

$$y_i = \begin{cases} 1 & \text{if cloud site } i \text{ on the network edge is selected for placing replica server} \\ 0 & \end{cases} \quad (3.1)$$

$$x_{ij} = \begin{cases} 1 & \text{if end-user } j \text{ is assigned to cloud site } i \text{ on the network edge} \\ 0 & \end{cases} \quad (3.2)$$

This is stated as follows:

Min

$$C = \sum_{i \epsilon F} W \alpha_i^S y_i + \sum_{j \epsilon F} \quad \sum_{j \epsilon H} wj \, \alpha_i^B x_{ij} \quad (3.3)$$

Subject to:

$$\sum_i x_{ij} = 1 \; \forall \; j \; \epsilon \; H \quad (3.4)$$

$$x_{ij} \; \leq \; y_i \; \forall \; i \; \epsilon \; F, j \; \epsilon \; H \quad (3.5)$$

$$\sum_i x_{ij} L_{ij} \leq \; Q_j \; j \; \epsilon \; H \quad (3.6)$$

In the objective function (3.3), the first term represents storage cost and the second term represents delivery cost. Constraint (3.4) guarantees assignment to exactly one of the replica servers. Constraint (3.5) specifies that an end-user *j* is assigned to a replica server *i* only if the replica server has been designated. Constraint (3.6) ensures that for each end-users *j*, the QoS metric of the network edge between end-user *j* and replica server *i* to which it is assigned must satisfy the QoS threshold of end-user *j*.

Algorithm for the Replica Server Placement in achieving the research goals

Algorithm 1 : Placement

1. Sort F in ascending order of storage cost
2. Sort F again in ascending order of unit delivery cost.
3. for each cloud site $i \epsilon F$
4. for each end-user $j \epsilon U_i$

//potential end-users of replica server i

5. if end-user j is not yet assigned
6. $A_i \leftarrow A_i U \{j\}$

//Assign end-user j to replica server i

7. end if
8. end for
9. if $| A_i | \neq \emptyset$ then
10. $S \leftarrow S \, U \{ i \}$ //Select replica server i
11. end if
12. end for
13. Construct solution X from sets S and A_i for each chosen replica server $i \epsilon S$
14. Return Solution X

Source : (Jagruti & Roch, 2016)

Algorithm 2 : Refinement (X)

1. $C^{cur} \leftarrow$ Cost of solution X
2. for each end-user $j \epsilon H$
3. Form set N_j of potential replica servers in S excluding the current replica server of j
4. $S_j^{min} \leftarrow$ current best site in N_j
5. end for
6. for each replica server $i \epsilon$ S
7. $Cnt \leftarrow NULL$
8. for each end-user $j \epsilon A_i$
9. if $S_j^{min} \neq NULL$ then
10. $Cnt \leftarrow Cnt + 1$
11. end if
12. end for
13. if $Cnt = | A_i |$ then
14. $C^{new} \leftarrow$ Cost after removing i and re-assigning j to S_j^{min}
15. if $C^{new} \leq C^{cur}$ then
16. for each end-user $j \epsilon A_i$
17. $A_{S_j^{min}} = A_{S_j^{min}} U \{j\}$ //Re-assign end-user j to replica server i
18. Update S_j^{min} //Next best replica server for end-user j
19. end for
20. $S = S - \{ i \}$ //Remove replica server i
21. $C^{cur} \leftarrow C^{new}$
22. end if
23. end if
24. end for
25. Construct solution X^* from sets S and A_i for each chosen replica server $i \epsilon S$
26. Return X*

Source: (Jagruti & Roch, 2016)

Algorithm 3: Least Usage Greedy ()

1. $X \leftarrow$ Placement ()
2. $X^* \leftarrow$ Refinement (X)
3. Return Solution X*

Source: (Jagruti & Roch, 2016)

Justification for Least Usage Greedy (LUG) Heuristic Algorithm

The heuristic proposed is based on greedy approach and it's called Least Usage Greedy (LUG) for the above proposed replica server placement. The proposed greedy heuristic has high computational effectiveness and high cost-efficiency. For each replica server, a potential end-user is the end-user for which the latency between the replica server and the end-user remain below the Quality of Service (QoS) thresholds of the end-user. Similarly, for each end-user, a potential replica server is the one which satisfy the Quality of Service (QoS) threshold of the end-user.

IV. DATA ANALYSIS, RESULTS AND DISCUSSION OF FINDINGS

The Cloud-based Content Delivery Network is integrated into the Long-Term Evolution architecture and the effects it has on Quality of Service (QoS) is measured.

Long-Term Evolution Network Environment Simulation Result

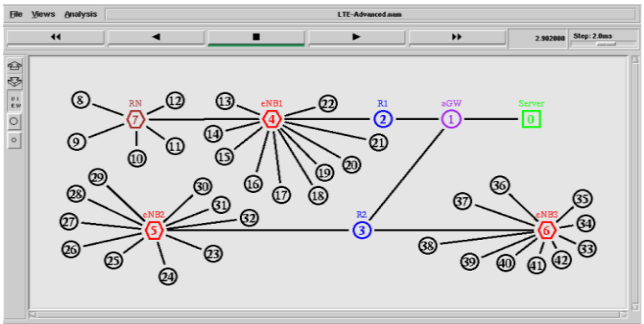

Figure 3 : View of the Simulated Long-Term

Evolution Network Environment

Figure 3 shows the real-time simulation of the Long-Term Evolution network environment. The green node in Figure 3 represents the server, which symbolizes the 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 gigabit 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. The results obtained from the Long-Term Evolution network environment simulation gives a general overview of network operations.

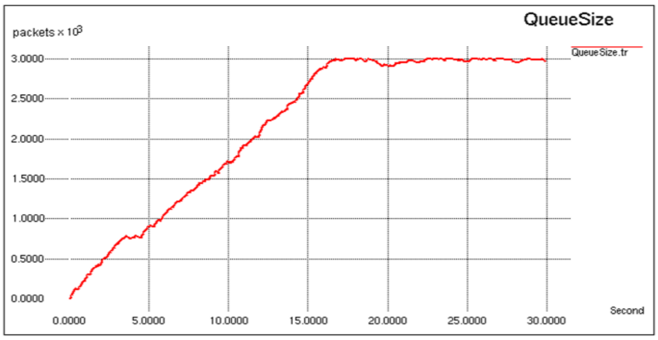

Figure 4 : Queue Size against time of TCP Reno over Long-Term Evolution network model

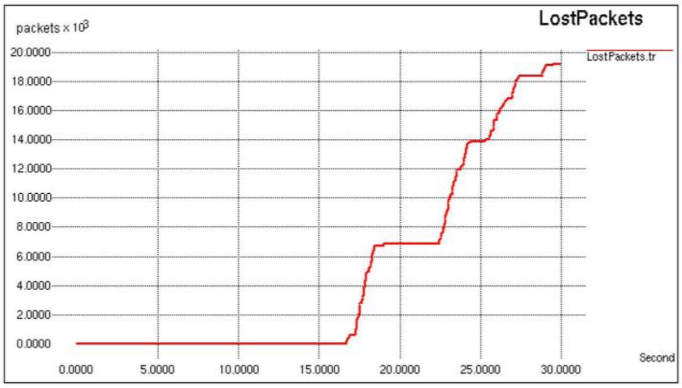

Figure 5 : Lost Packets versus time of TCP Reno over Long-Term Evolution network model

Figure 4 and Figure 5 shows how the queues size increases over time as more packets are added and if these packets are not attended to in a timely fashion, they tend to build up and lead to some of these packets being lost. Thus, poor Quality of Service (QoS) is experienced throughout the network.

Quality of Service Evaluation of Long-Term Evolution Simulated Network Environment

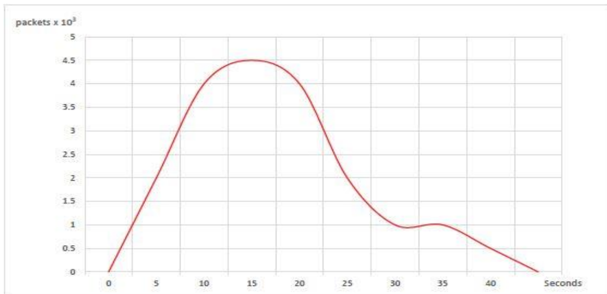

Figure 6. Network Throughput

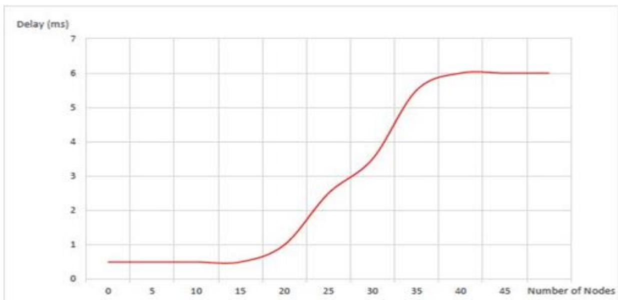

Figure 7. Round Trip Time

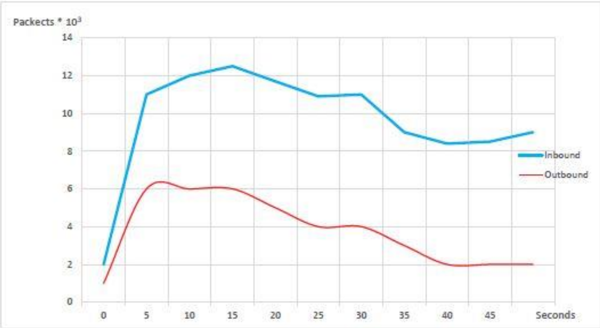

Figure 8. Bandwidth

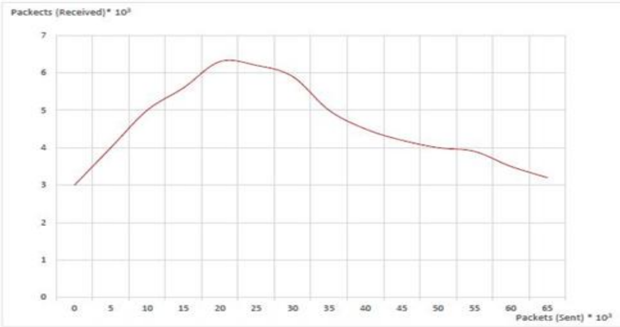

Figure 9. Packet Loss

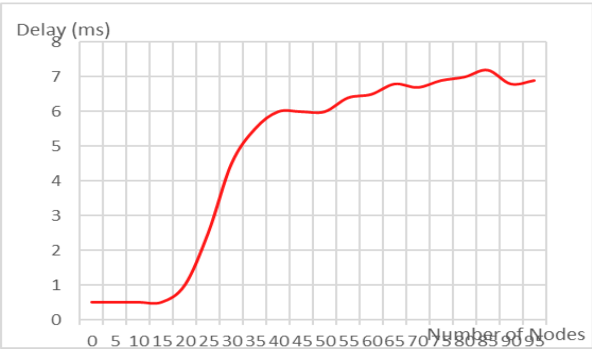

Figure 10 : Jitter

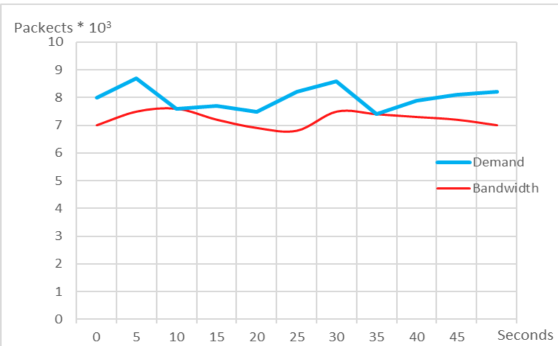

Figure 11 : Connection Ratio

Figure 6 shows how traffic increases over time. A pick level of throughput is reached after which throughput starts to decline. If this goes unchecked, it can lead to a situation where no reasonable work can be done on the network. Poor quality of service is reached when traffic and the requests of data packets gets so high that the network itself cannot handle the incoming traffic.

Figure 7 shows that with loads of packets in the queue waiting to be processed. And as the queue increases, the average time spent for a packet to move from source to destination and return increases. Figure 8 shows a massive difference between inbound and outbound traffic. The inbound traffic will keep piling up and will not be processed because the network is taking so much traffic and it cannot process it all. Figure 9 shows as traffic increases the packet loss increases, it shows that the network cannot keep up with the inflow and outflow of packets on the network and therefore the time taken for packets to be delivered to the destination node is significantly high. Figure 10 shows as traffic increases jitter increases, it shows that the network cannot keep up with the flow of packets on the network and therefore the end-to-end delay from one packet to the next packet is significantly high. Figure 11 shows a difference between the demand and actual bandwidth. With an increase in traffic, the actual bandwidth will not be able to serve all requests. Thus. resulting in poor quality of service.

The Optimized Model Simulation Results

The optimized model is expected to deal with this issue of Quality of Service (QoS), providing a better means to mitigate the effects of poor quality of service.

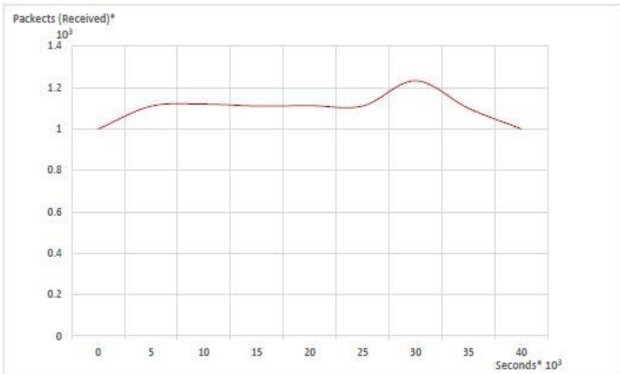

Figure 12. Queue Size of The Optimized Model Simulations

Figure 13. Packet Loss of The Optimized Model Simulations

Figure 12 show the optimized model queue size is kept at a constant rate due to the fact the model redirects traffic to the nearest replica server on the network edge. Figure 13 shows a minute level of packet loss. The optimized model uses a Least Usage Greedy (LUG) algorithm and with the implementation of this algorithm, packet loss is reduced drastically.

Quality of Service (QoS) Evaluation of the Optimized Model

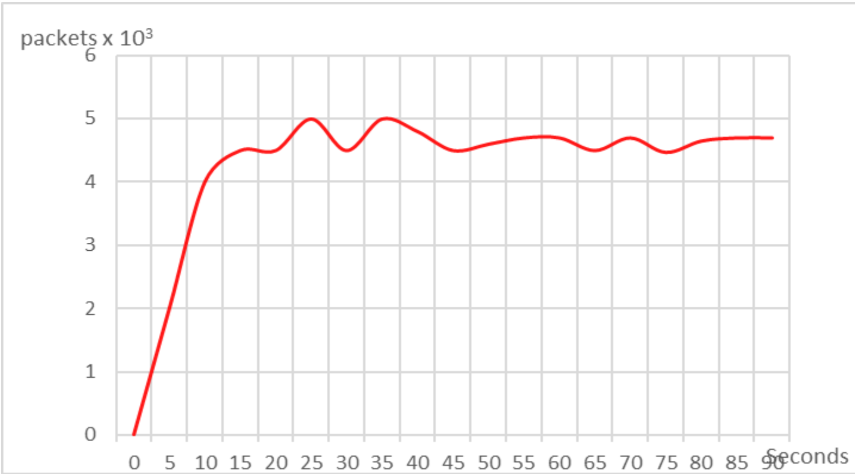

Figure 14. Network Throughput

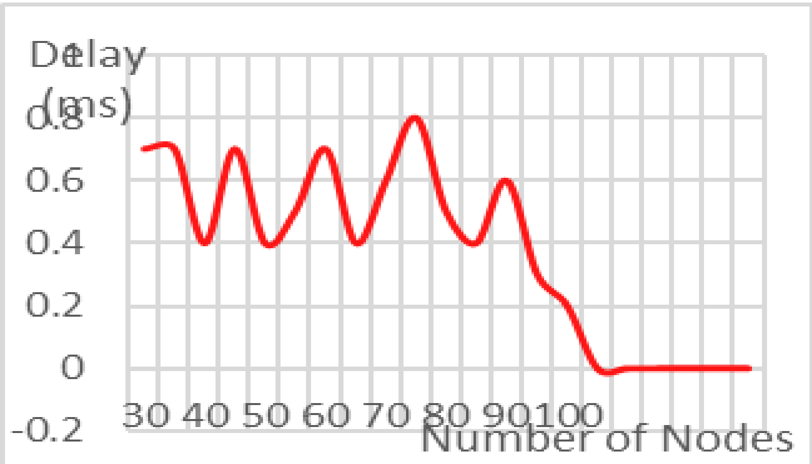

Figure 15. Round Trip Time

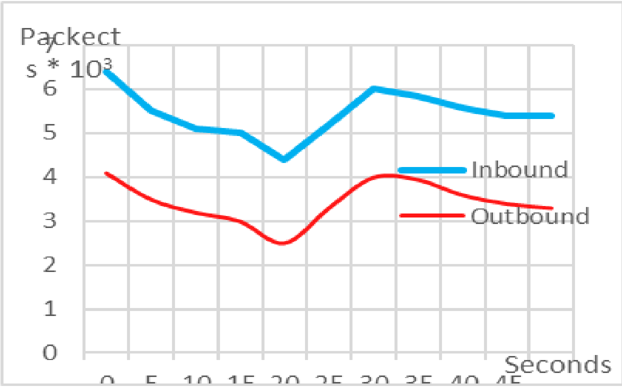

Figure 16. Bandwidth

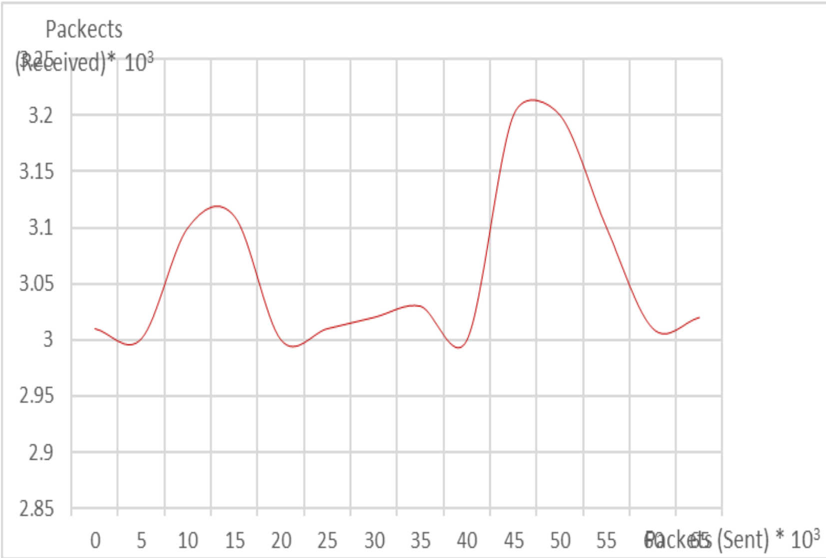

Figure 17. Packet Loss

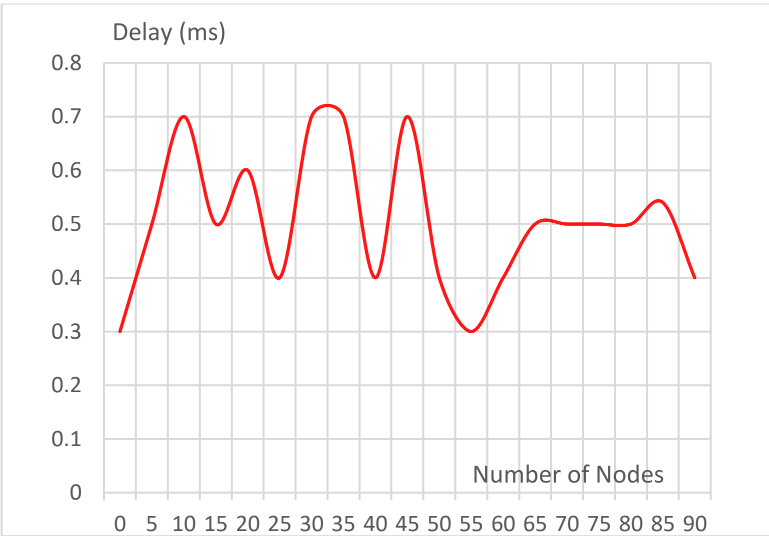

Figure 18 Jitter

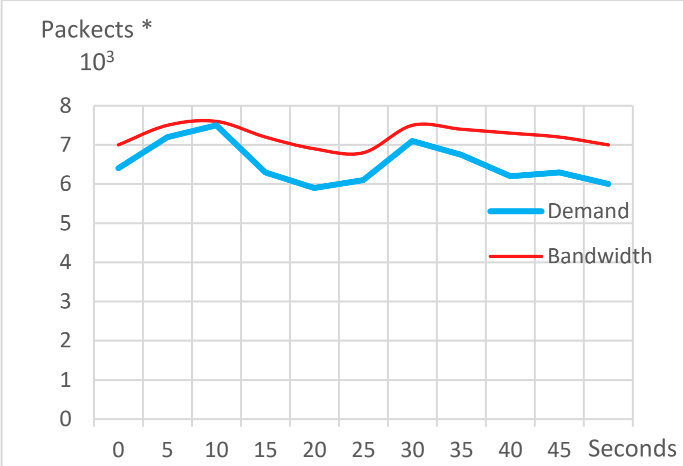

Figure 19 Connection Ratio

The simulation results presented in Figure 14, Figure 15, Figure 16, Figure 17, Figure 18 and Figure 19 all show that the optimized model provides a better means to mitigate the effects of poor quality of service in Long-Term Evolution Networks. It can be seen from the results obtained, that as traffic increases over time, network performance does not diminish but kept at an optimal level. As seen in Figure 14, network throughput does not diminish despite increasing network traffic and also in Figure 16, bandwidth 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 15 and Figure 17, ensuring that packets do not spent too much time on the queue and reduces the likelihood of packets being timed out. In Figure 18, jitter decreases as the end-to-end delay from one packet to the next packet is reduced even with increasing traffic. Also, the connection ratio improves as the demand is been adequately satisfied by the actual bandwidth in Figure 19.

V. SUMMARY, CONCLUSION AND RECOMMENDATIONS

Conclusion

Quality of Service (QoS) 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 optimized model, which incorporates Least Usage Greedy (LUG) Heuristic Algorithm in other to be able to adequately redirect network traffic as it enters and/or leaves the network subsystem which gives networks better control over data traffic. From the simulation results obtained, it can be seen that the optimized model provides a better means to improve Quality of Service (QoS). The optimized model offers improved throughput and better bandwidth utilization. This means that network can perform better even when traffic continues to increase over time and also packet loss is reduced. Also, the round-trip time 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 optimized model has shown that it can provide a better way to address the problem of Quality of Service (QoS) in Long-Term Evolution Networks. This research work can be extended further in the utilization of other emerging paradigms such as, Network Functions Virtualization (NFV), in providing better means of improving Quality of Service.

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