A Satellite LTE Delay Tolerant Capabilities Tunnelling: Design and Performance Evaluation

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Abstract. This paper presents basic considerations regarding IP-based tunneling support for transmissions for 4G-LTE communication networks that will pass satellite transmissions. In this paper, a delayed tolerance approach to traffic management in LTE via satellite links will be presented. Contribution to this paper will generate quality of service values on satellite communications by bringing 4G-LTE data traffic. We design, implement and evaluate the performance of transport protocol solutions based on the GRE RFC 1701 architecture in the LTE-satellite system. Our paper proposal, is (i) analyzing the current performance and design and implementing it for 4G via satellite using IP tunneling (ii) utilizing the GRE RFC 1701 standards, which creates an ethernet tunnel between two sending data communications on VLAN User Plane, MME and OAM in 4G. The resulting value parameters are throughput index, delay, and performance bandwidth and packet loss. The parameter values generated are Index \[ \sum \text{Throughput (bit/s)} \] number of data reaching the allocated bandwidth of 6836 Kbps, bandwidth utilization Index = \[ \sum \text{bandwidth utilization inbound and outbound reaches 100%} \] and packet loss value the resulting one is 0% on transmission connectivity.

1. Introduction

Long Term Evolution (LTE) or 4G is a cellular access network technology standardized by 3GPP. Together with System Architecture Evolution (SAE) as a core network architecture, both form the Evolved system Packet System (EPS) as used today [1]. The whole system has IP-based, forms an end-to-end IP connection. This packet-switching based technology allows LTE / SAE to have a much higher data rate compared to its predecessor, UMTS / 3G. The evolution of LTE improves air interface technology. In the physical layer, OFDM (Orthogonal Frequency Division Multiplexing) and MIMO (Multiple Input Multiple Output) is the main technology. Evolution of LTE can provide a downlink peak speed of at least 100Mbit / s and uplink 50Mbit / s in the 20MHz spectrum. LTE can also increase cell system capacity and reduce latency on a system. For cellular operators, one of the biggest challenges is finding the appropriate resources and technologies to backhaul voice and data traffic. As 3G and 4G technologies deploy, increasing data traffic challenges the capabilities of existing backhaul networks, and this trend is expected to increase [2]. What does this mean for subscribers or potential customers who don’t live in major metropolitan or rural areas? What does this mean for subscribers or potential customers who don’t live in major metropolitan or rural areas? Will the connectivity gap? The answer is no. The use of satellite technology, specifically Very Small Aperture Terminal (VSAT) systems, is
rapidly increasing, enabling cellular operators to backhaul voice and data traffic from remote and rural areas [3].

This research paper presents a transmission scheme using combined IP tunneling (GRE RFC 1701), circuit switching layer 2 (IEEE 802.1Q) and bridging (IEEE 802.1D), on transmissions that pass satellite communications to bring TCP connections User Plane (S1-U) data traffic, Mobility Management Entity (MME) and Operations and Management (OAM) from E NodeB to the Packet Data Network Gateway (P-GW) and Serving Gateway (S-GW). The application of a simple scheme, using Optimization on the use of bandwidth allocation that will be allocated 5120 Kbps on the VSAT transmission line of the IP tunnel system will function to encapsulate traffic data coming from eNodeB.

Testing throughput, bandwidth and packet loss values will be optimized and analyzed in the transmission process until the satellite backhaul is the tunnel router from the eNodeB client router. Furthermore, from the backhaul satellite will be continued with transmissions that use terrestrial media. Scheme on optimization and integration of Long Term Evolution (LTE) transport through satellite and tunneling for long distance mobile connectivity will be described in Figure 1.

![Figure 1. Scheme on Optimization and Integration of Long Term Evolution (LTE) Transport through Satellite and Tunneling For Long Distance Mobile Connectivity.](image)

2. Related Work

This paper takes a delayed tolerance approach to traffic management on the LTE network via satellite links. Design, implement, and evaluate the performance of transport protocol solutions based on IP-based Tunneling architecture in LTE satellite systems. Combined with Tagged Ethernet (802.1Q), 802.1W, and Bridging. In another paper entitled Challenges of Integration a VoIP Communication System on a VSAT Network [4] made a proposal to optimize the VDI network and local site network through Satellite transmission, especially through the implementation of QoS policies that support VoIP Traffic. In particular, tests between pilot sites have found Very Important latency (between 620 and 750 ms), high jitter (around 200 ms), but are offset by memory-buffer jitter compensation (jitter buffer), and the rate of media loss (between 0.5 and 1.5%), using the G.729 codec. In the paper [5] determine the feasibility of deploying 4G based LTE networks by considering the 800 MHz and 5 MHz (2 x 5MH) paired spectrum blocks in evaluating parameters. in the paper [6] compares 3G and 4G technology to online streaming methods to deliver voice communications applied by organizations for conference calls or voice operations. Results present bandwidth availability performance, jitter performance, latency, VoIP and current 4G- LTE analysis versus 4G WiMAX previous. It was identified that the average rating of 4 for 4G and 4G LTE networks. Based on the analysis that has been carried out shows that both jitter and latency are acceptable for 3G and 4G LTE networks. Good value of jitter and latency for both cellular networks meets QoS requirements for deploying VoIP systems. The MOS value is at an average rating of 4 for 3G and 4G LTE networks also a great achievement and performance for VoIP.
3. Literature Review

3.1. Ethernet Over Internet Protocol Tunnel

Tunneling is the transfer of data between two similar or different networks through an intermediary network. Tunneling wraps one type of data package into another protocol package. Before encapsulation takes place, the packet is encrypted so that the data cannot be read by anyone monitoring the network. These packaged packages are via the Internet, which serves as one example of an intermediary network until they reach their destination. After arriving, the package is decrypted and returned to its original format. The packet encapsulation protocol is understood by the network and by both points where packets enter and exit the network. Tunneling allows you to place packages that use no protocol used by the Internet in the IP package and send it safely through the Internet [4]. Design and implementation that will be carried out in this research, the Tunneling that will be used is Ethernet Over IP. This protocol will be used as a transmission over VSAT network to carry packages and traffic from the eNodeB LTE. Proposed scheme will be explained in the flowchart representation in Figure 2.

![Figure 2. Flowchart IP Tunneling Protocol.](image)

3.2. Tagged Ethernet (802.1Q)

The IEEE 802.1Q standard defines a 32-bit field embedded in Ethernet frame to generate Virtual LAN (VLAN). The purpose of the VLAN is to allows limiting physical LAN topology into logical network segments. 802.1Q is just as plug-and-play as normal Ethernet with respect to MAC learning and spanning trees [5]. They are both technologies that scale well in small-to-medium size enterprise or even large enterprise networks. However, they are not suitable for carrier grade backbone or access networks where flooding and customer MAC learning are unwanted features [6]. A large operator can easily serve millions of end stations, and learning all of their addresses would require an amount of memory most switches do not usually have. Additionally, 802.1Q has only 12 bits for VLAN identifiers, which allows for $2^{12} = 4094$ VLANs to exist inside a single domain (VLANs 0 and 4095 are reserved). Transport service providers can have thousands of corporate customers, each having multiple VLANs [7]. Proposed scheme will be explained in the flowchart representation in Figure 3.

![Figure 3. Tagged Ethernet (802.1Q).](image)

3.3. Bridge Interface

The network node that will be applied can appear (intentionally or not) in a complex topology. Without special treatment, the loop will prevent the network from functioning normally, because it will cause
package multiplication such as an avalanche. Each bridge runs an algorithm that calculates how loops can be prevented. RSTP at L2 Bridge will be applied in this study, which might be a bridge to communicate with each other, so they can negotiate free loop topology [7]. All other alternative connections that will form a loop must be standby, so the main connection fails, another connection can replace it. This configuration message exchange algorithm (BPDU - Bridge Protocol Data Unit) periodically, so that all bridges are updated with the latest information about network topology changes. RSTP selects the root bridge responsible for reconfiguring the network, such as blocking and opening ports on another bridge. Root bridges are bridges with the lowest bridge ID [8].

4. Research Method

The methodology that will be applied is in terms of integrating and analyzing the performance of the LTE network that will pass the Satellite transmission. The following is described the methodology that will be applied is as follows:

4.1. Topology Network Configuration Schema and Method

4.1.1. Ethernet Over Internet Protocol Schema

Ethernet over IP Tunneling is a protocol that creates an Ethernet tunnel between two terminal e-NodeB to a Hub node over an IP connection. Then at the next stage, the bridging of the router will be configured to be activated, so that all ethernet traffic (all ethernet protocols) will be bridged as if there is a physical Ethernet and cable interface between e-NodeB to the Hub satellite backhaul (with bridging enabled). This protocol allows multiple network schemes between terminal nodes to the Hub node satellite backhaul.

![Figure 4. Ethernet Over Internet Protocol.](image)

Figure 4. This protocol allows multiple network schemes between eNodeB to satellite backhaul satellite. This protocol will later carry a VLAN ID on the L2 Universal Terrestrial Radio Access Network (E-UTRAN) Interface, namely User Plane (S1-U), Mobility Management Entity (MME) and Operations and Management (OAM).

4.1.2. Interface VLAN Setup Schema

Each VLAN is treated as a separate subnet. This means that by default, hosts in certain VLANs cannot communicate with hosts that are members of other VLANs, even though they are connected in the same switch. The interface on the port will be set to trunk so that it can carry 3 VLAN IDs: namely User Plane (S1-U), Mobility Management Entity (MME) and Operations and Management (OAM).
As per the scheme in Figure 5, it will be explained in the pseudocode representation as follows:

1) Step.1 Passes 3 VLAN-IDs, namely VLAN-ID = UP-S1U, VLAN-ID = MME and VLAN-ID = OAM.
2) Step.2 The three VLAN-IDs will be passed to the interface that leads to the eNodeB interface Node.
3) Step.3 These three VLAN-IDs will be passed to the interface that leads to IP tunneling that leads to the satellite backhaul interface.
4) Step.4 Port: one of the ports on the router will be set as trunk. Ether2 is a trunk-port that passes all VLAN-IDs.
5) Step.5 Then the ether2 port becomes a member for all VLAN-IDs.
6) End

4.1.3. Bridge Interface Setup Schema

The network loop node to be applied may appear (intentionally or not) in a complex topology. Without special treatment, the loop will prevent the network from functioning normally, because it will lead to packet multiplication such as an avalanche. Each bridge runs an algorithm that calculates how loops can be prevented. RSTP on L2 Bridge will be applied to this research, which is possible bridges to communicate with each other, so they can negotiate free loop topologies. All other alternative connections that will form loops must be standby, so the main connection fails, other connections can replace it. This configuration message exchange algorithm (BPDU - Bridge Protocol Data Unit) periodically, so that all bridges are updated with the latest information about network topology changes. (R) STP selects the root bridge that is responsible for network reconfiguration, such as blocking and opening port on another bridge. Root bridges are bridges with the lowest bridge ID.

Figure 5. VLAN-ID Setup.

Figure 6. Schema Interface VLAN Setup.
Figure 7. Bridge Interface Setup.

The following scenario in figure 7, is having a set of interfaces (not necessarily physical interfaces) and then in each ID is in the same Layer 2 segment, the solution is to add it to a single bridge, but requires traffic from one port to mark all last cross to certain VLANs. This can be done by creating a VLAN interface above the bridge interface and by creating a separate bridge containing this newly created VLAN interface and interface, which will send marked traffic. Network diagrams can be found below:

Figure 8. Schema Bridge Interface Setup.

4.2. Proposed Integration and Optimization

System design integration and optimization as well as research design specifications are modeled as Figure 8. The network configuration design that is modeled to resemble a Metro-Ethernet transmission. Where LTE transmission connectivity from eNodeB to the modeled aggregator gateway, will carry traffic packets from eNodeB to the gateway. Discussion of this study does not focus on the hub configuration and satellite remote. The existing satellite configuration is running and is focused on how to bring layer 2 eNodeB LTE transport to the gateway aggregator. Well, so the first step we will make EOIP Tunnel first, then we will pass the VLAN distribution through the tunnel. The topology and scheme in Figure III-6 are the overall proposed integration and configuration optimization that will be applied [9]. Layout model in figure 9 has the following design specifications and instrumentation hardware and software requirements:
### Table 1. Hardware and Software Instrumentation Design and Specifications.

| Hardware                  | Device Function                        | Software Monitoring |
|---------------------------|----------------------------------------|---------------------|
| RB760iGS (HEX S)          | Tunnel Client                          | MRTG Cacti          |
| WS-C2960-24TT-L           | Management VLAN Tagging and Member      | PRTG                |
| MDM3100 IP Satellite Modem| Satellite Modem                        |                     |
| CCR1036-8G-2S+            | Tunnel Server                          |                     |

| Transport | Bandwidth Management | Protocol EOIP Tunnel | VLAN-ID LTE |
|-----------|----------------------|----------------------|-------------|
| Inroute   | Outroute             | Max Upstream         | User Plane (S1-U) |
| Symbol Rate | Frequency | Max Downstream       | Mobility Management Entity (MME) |
| FEC Rate  | Symbol Rate          | Local Address        | Operations and Management (OAM) |
| DVB Mode  |                      | Remote Address       |             |
| FEC Rate  |                      | Tunnel-ID            |             |

**Figure 9.** Designing a Long Term Evolution (LTE) Topology Model for Transport through Satellite and Tunneling For Long Distance Mobile Connectivity.

4.3. **Data Collection and Data Analysis Quality of Service (QoS)**

QoS monitoring can be classified into two categories: end to end QoS monitoring (QM EE) and QoS distribution monitoring per Node (distribution monitoring (DM)). In the QM EE, monitoring QoS is done by measuring the QoS parameters from the sender to the recipient. Where as in DM, the QoS...
monitoring process is carried out in segments of the delivery line or between certain desired nodes along the data packet transmission path. The measurement of QoS values in this study will be measured based on segments from eNodeB package to backhaul satellite. The process of measuring Quality of Service parameters consists of:

1) **Index Throughput (bit/s)**
   
The transmission speed of the data transfer rate is effective, which is measured in bps. Throughput is the total number of packets that reach the destination, which is observed at the destination for a certain time interval divided by the duration of the time interval. Throughput calculation equation with the following equation:

   \[
   \text{Throughput} = \frac{\sum \text{number of data sent (bit)}}{\text{data delivery time (s)}} \times 8\text{bit/s}
   \]

   \[
   \text{Category Throughput (%) =} \frac{\text{Bandwidth Allocation (Kbps)}}{\text{Average } \sum \text{Number of Data Sent (Kbps)}} \times 100\%
   \]

2) **Bandwidth Utilization**

   - **Inbound Traffic (C)** is the maximum number of bits per second a network element can transfer (Upload). The capacity of an end-to-end path is determined by the slowest network element along the path.
   - **Outbound Traffic (C)** is the maximum number of bits per second a network element can transfer (Download). The capacity of an end-to-end path is determined by the slowest network element along the path.
   - **Utilization (U)** is the percentage of the capacity on a link or path currently being consumed by aggregated traffic.

   \[
   \text{Bandwidth Utilization} = \frac{\sum \text{Total Bytes In Traffic (Inbound)}(\text{bps}) + \text{Total Bytes Out Traffic (Outbound)}(\text{bps})}{\sum \text{Bandwidth Capacity (Kbps)}}
   \]

   \[
   \times 100\% = \frac{\sum \text{Total Bytes In Traffic (Inbound)}(\text{Kbps}) + \text{Total Bytes Out Traffic (Outbound)}(\text{Kbps})}{\sum \text{Bandwidth Capacity (Kbps)}}
   \]

3) **Index of Packet Loss Level (%)**

   Packet loss is a parameter index value that describes a network environment condition that shows the total number of lost packets, which can occur due to collision and congestion in data communication. Table III-1 shows the ranking and criteria for packet loss.

   \[
   \text{Packet loss (\%)} = \frac{\text{packet data sent} - \text{data packet received}}{\text{packet data sent}} \times 100\%
   \]

**5. Results And Discussion**

5.1. **Index Throughput (bit/s) Performance**

The parameter values for each inbound and outbound traffic throughput can be seen in table 2. In the observation process, it can be seen that the throughput value reaches the width allocation of the applied pipe which is 5120 Kbps. Throughput is the data transfer rate on average from the success of packets sent per second, and the units used are bytes per second (Bps), Kilo byte per second (Kbps) Megabyte per second (Mbps). Taking throughput parameters in this study is done by MRTG monitoring, it can be...
seen throughput values generated in the transmission connectivity from the eNodeB source to the backhaul satellite router. Figure 10-13 can be seen from one month, and divided into a week at each average throughput value.

![Figure 10. Throughput Performance in the first week.](image)

![Figure 11. Throughput Performance in the second week.](image)

![Figure 12. Throughput Performance in the third week.](image)

![Figure 13. Throughput Performance in the fourth week.](image)

Figure 10-13 above can be seen the relationship between throughput with the amount of bandwidth capacity utilization provided. At the first week, the second week, the third and fourth week of the experiment, shown in figure 10-13, the results obtained can be seen from the distribution of throughput values on the 4G / LTE cellular network that has an average total capacity of the pipe width provided. Table 2 shows the average of the tests observed in the first week to the fourth week \( \sum \) throughput (bit/s) successful packages are observed at destination during certain time intervals are divided by interval duration.

### Table 2. Result Index \( \sum \) Throughput (bit/s).

| Date and Time          | Data Delivery Time (s) | \( \sum \) Throughput (kbps/s) |
|------------------------|------------------------|-------------------------------|
| 2018-08-01 23:00:00    | 7200                   | 6836.217880                   |
| 2018-08-07 23:00:00    | 7200                   | 5271.872900                   |
| 2018-08-08 01:00:00    | 7200                   | 5120                          |
| 2018-08-14 23:00:00    | 7200                   | 4047.601960                   |
| 2018-08-15 01:00:00    | 7200                   | 5120                          |
| 2018-08-21 23:00:00    | 7200                   | 5240.956033                   |
| 2018-08-22 01:00:00    | 7200                   | 5120                          |
| 2018-08-31 23:00:00    | 7200                   | 5120                          |

### 5.2. Index Bandwidth Performance

Measurement of available network bandwidth is very dependent on the time interval used for measurement. Figure 14-17 shows the available network bandwidth measured at intervals of 1 month and indicates that the measurement of available bandwidth varies greatly depending on what time interval is used. seen outbound or download package value parameters that have the highest utilization.
of traffic because download activity is very often used. Accuracy requirements for available bandwidth depend on usage measurement intervals. For short interval measurements, it needs to be accurate to reflect the utilization at that time or in real time. For long-term measurements, the available bandwidth must have two values, the average value and the range between the minimum value and the maximum value that must be applied to the best effort value. Results of the study show that the allocation provided by the results of bandwidth performance shows the value obtained from the maximum bandwidth reaching traffic average 5465 Kbps. Table 3 is $\sum$ Bandwidth Utilization Outbound (Kbps) + $\sum$ Number of Data Sent(bit) Inbound (Kbps) divided Bandwidth Capacity (Kbps). Utilization of percentage bandwidth obtained is maximum on the link or path provided and consumes 100% of the pipe width allocation.

Table 3. Index Bandwidth Utilization Traffic.

| Date and Time             | Data Delivery Time (s) | $\sum$ Bandwidth Utilization Inbound + Outbound (Kbps) | Bandwidth Utilization(%) | Bandwidth Capacity (Kbps) |
|---------------------------|------------------------|---------------------------------------------------------|---------------------------|---------------------------|
| 2018-08-01 23:00:00       | 7200                   | 5465.035534                                             | 100%                      | 5120                      |
| 2018-08-07 23:00:00       | 7200                   | 4119.323988                                             | 80%                       | 5120                      |
| 2018-08-08 01:00:00       | 7200                   | 3782.688398                                             | 74%                       | 5120                      |
| 2018-08-14 23:00:00       | 7200                   | 4081.109501                                             | 80%                       | 5120                      |

Figure 14. Bandwidth Performance in the first week.

Figure 15. Bandwidth Performance in the second week.

Figure 16. Bandwidth Performance in the third week.

Figure 17. Bandwidth Performance in the fourth week.
5.3. Index Packet Loss (%) Performance
Packet loss analysis in this study is used to find out how big the package is lost when sending with designing LTE network transmission configuration with IP tunnel. The larger the data packet lost in the shipping process, the worse the quality of the network. After experimenting with downloading and uploading data packages on the design of the LTE network transmission configuration, the distribution of packet loss (%) is obtained. The distribution of values has been implemented in graphical form which can be seen in figure 18. Figure 18 can be seen from 1 month sending and uploading done that the distribution of packet loss values on TCP protocol with 4G network produces an average value is 0%. The maximum packet loss recommended by TIPHON and ITU is 0-15%. Implementation of LTE transport through satellite and tunneling for long distance mobile connectivity, it included a very good category in the transmission media because the value was 0%.

![Graph showing packet loss distribution over a month.](image)

**Figure 18. Index Packet Loss (%) Performance.**

6. Conclusion
Paper presents a packed IP tunnel application, combined with Tagged Ethernet (802.1Q), 802.1W and Bridging. This application is done by sending via satellite transportation. Analysis of TCP performance measurement on 4G LTE, QoS focus parameters are throughput, bandwidth utilization and packet loss and all data compared to ITU-T and ITU. Based on the analysis that has been done, it can be concluded that, in the observation process, it can be seen that the throughput value reaches the width of the pipe allocation used, namely 5120 Kbps. The results obtained can be seen from the distribution of throughput values on 4G-LTE cellular networks that have an average value of reaching the total pipe width capacity provided. From 1 month, and divided into a week at each average bandwidth value and the results of experiments, conducted that the distribution of bandwidth performance values on 4G / LTE. Cellular networks has a higher average value and achieves traffic index \( \sum \) throughput (bit / s ) \( \sum \) sent number of data outbound + \( \sum \) inbound sent number of data reaches the allocated bandwidth of 6836 Kbps. Bandwidth Utilization Index = \( \sum \) Bandwidth Utilization inbound and outbound reaches 100%, and from 1 month downloading and uploading, distribution of packet loss values on TCP protocol with 4G network produces an average value of 0%. Both the value of throughput, bandwidth performance and losses on applications carried out on 4G LTE cellular networks meet QoS requirements.

The concept of implementing tunneling is a solution that allows cellular operators to expand their network coverage in underserved areas while maintaining the quality of experience for end users and managing the satellite bandwidth costs used to backhaul 4G LTE.

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