QoE for LTE

Ensuring Quality of Experience (QoE) for LTE Subscribers over Satellite

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End users have come to associate the tiny LTE symbol on their smartphones and wireless devices as a guarantee of high performance for Internet access. Whether in urban centers, shopping malls, automobiles or extreme rural locations, their expectations of high performance persist regardless of the technical challenges that Mobile Network Operators (MNOs) are faced with to deliver that performance. Comtech's LTE optimization solutions can provide highest level of performance while supporting LTE over satellite links. The solution opens up the LTE/S1 interface and optimizes the aspects of web traffic that affect the end user's Quality of Experience (QoE), including:

1. The compounded effect of high delay on the Internet Protocol (IP) Transport Control Protocol (TCP)
2. The increasing complexity of modern websites

Comtech has extensive experience in delivering PEP solutions to military and commercial customers alike. This paper summarizes how our solutions improve LTE's performance over satellite by addressing the two above issues.

TCP Performance Enhancements

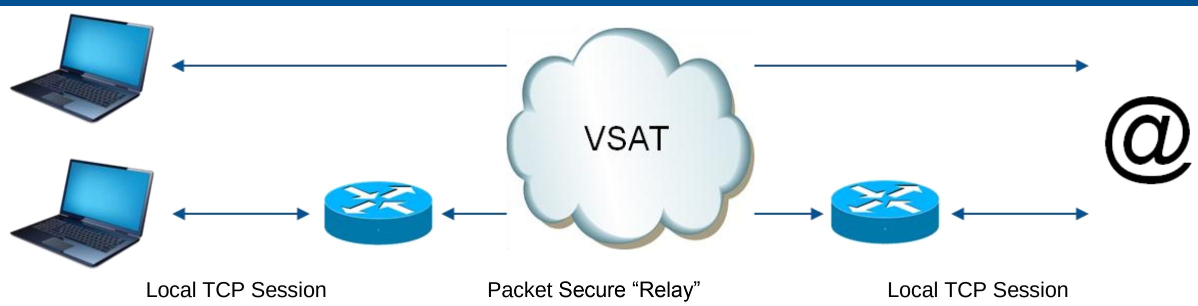
TCP is the basis of all reliable communications across the Internet supporting important Internet protocols such as HTTP/HTTPS and FTP. Performance Enhancement Proxies (PEPs), also referred to as TCP acceleration, have been touted as the solution to mitigate the effect of high delays on TCP. But, are all PEP solutions considered equal?

In the past, a TCP session's throughput would be limited to <1 Mbps based on the TCP window size of 64 kbytes and 600 msec round trip. This throughput limit is primarily a result of TCP factors, such as Round Trip Time (RTT), which throttle how fast a session speed can ramp up in a reliable manner. Lost packets would result in the TCP window size being reduced to a lower value and throughput falling off drastically.

Today's modern operating systems assume much higher quality links and, therefore, offer better TCP performance. It is possible for some operating systems to support traffic up to 3-4 Mbps per TCP session with TCP window size scaling from the default of 64 kbytes to factors of 8 or even 16 times higher. This may be considered adequate for some, but when running large file transfers, the real performance is defined as the speed of the download. The priority is to ramp up the TCP windows as high and as quickly as possible while preserving high reliability. For instance, our PEP solution can be configured to reliably accelerate traffic to any speed required up to 150 Mbps throughput for single FTP sessions to a user.

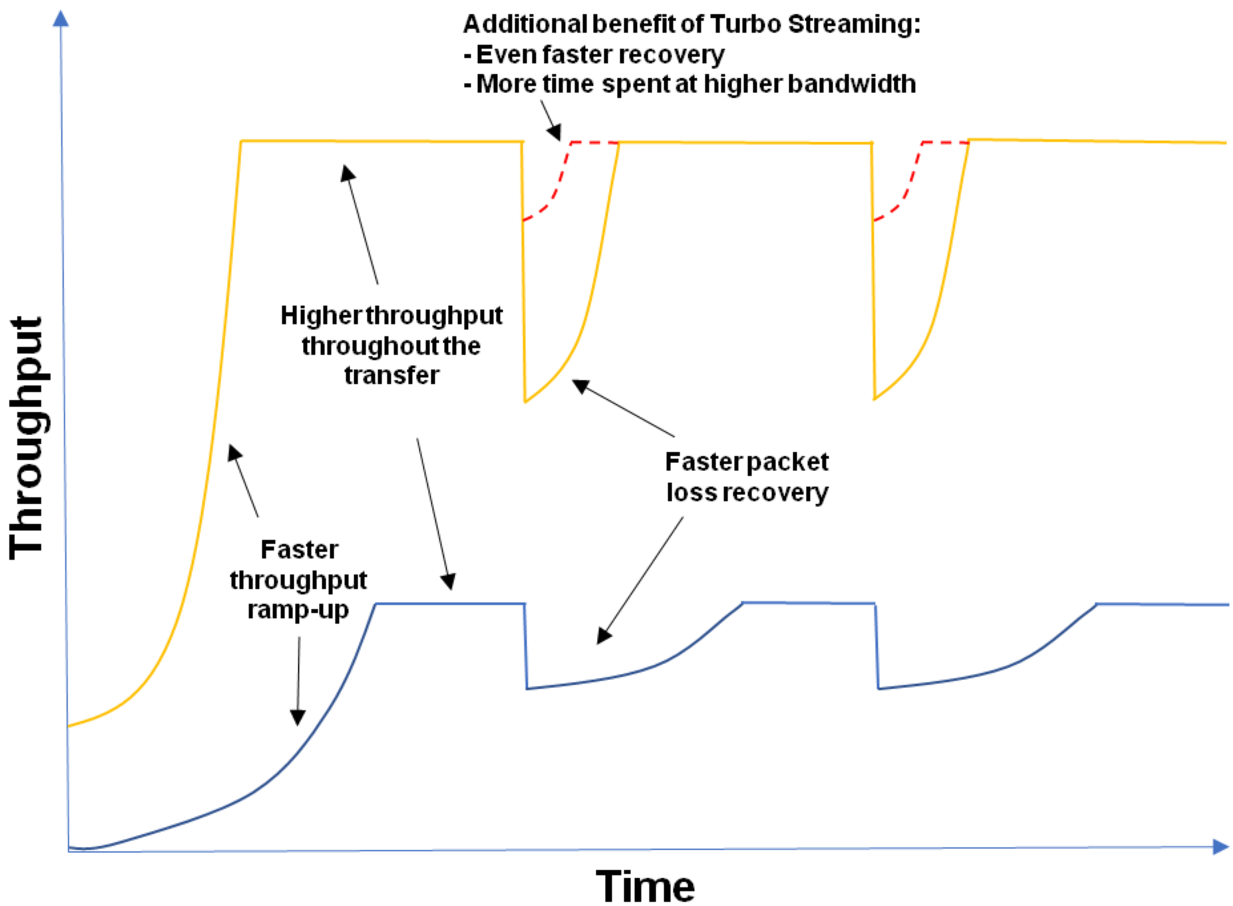
The traditional philosophy of PEP involves the breaking up of long end-to-end control loops into several smaller control loops and relaying the data more efficiently across the portion of the link which causes the degradation. The TCP sessions, now being "local" versus end-to-end, respond much quicker since the perceived RTT is virtually instantaneous. By adopting this procedure, they allow for the TCP flows to have a shorter reaction time to packet losses that may occur within the network and, thus, guarantees a higher throughput. Standard PEP-based TCP acceleration is especially beneficial for large FTP or HTTP file transfers as the TCP windows have time to open up and optimal speeds can eventually be observed. For small file transfers, such as a few hundred or thousand bytes, PEP will not provide meaningful benefits, since the time required to establish the three TCP sessions is actually longer than the time it takes to transfer the file.

No TCP Acceleration – End to End "Slow Start" for TCP



With TCP Acceleration – Mitigates the "Slow Start" for TCP

Some vendors may define a maximum PEP TCP window for “normal” operations sufficient to providing throughputs in the range of 25 to 50 Mbps per TCP session for better overall bandwidth control and memory management. In order to achieve or demonstrate high speeds such as 150 Mbps, PEP vendors may allow windows to be tuned to very high levels (i.e. 8 MByte window required for 150 Mbps TCP throughput). Considering most VSATs provide 1E-8 bit error rates, it would mean that one out of every 12.5 Mbyte is in error. Operating such large TCP windows implies that when these errors occur, the window will register a packet loss and the TCP sessions fall back to a safer speed. The result should be a sawtooth pattern of TCP ramp up, fall back due to packet loss, TCP ramp up, etc.



Comtech’s FX product line supports Comtech’s patented Turbo Streaming algorithms, which is the most effective method for reliably accelerating TCP sessions. In Turbo Streaming, VSAT TCP sessions are opened with 2 Mbyte windows, and if the file transfer persists, then multiple VSAT TCP sessions can be opened across the VSAT to achieve the highest speeds possible. If there is any byte error/packet drop on the VSAT, it affects only one of the multiple TCP sessions. The resulting impact of packet drop on total throughput is minimal.

Additionally, once a VSAT TCP session is opened, it will aggressively open up additional LAN TCP sessions and pipeline them across the existing VSAT TCP sessions providing them access to the existing high-speed sessions already in place. This avoids the “ramp up” process for each individual TCP session, which is typical in standard PEP. In this manner, even small file transfers benefit from acceleration since they no longer have to wait for individual VSAT TCP sessions to be established for each download.

Website Complexity

When it comes to web optimization, PEP/Turbo Streaming is only one of numerous techniques that need to be employed to improve QoE. When accessing Internet websites today, the QoE is really a measure of the time it takes the website to be loaded versus the maximum throughput of a single TCP session. In order to understand the factors that limit the performance of Internet QoE, you must first look at a typical website and observe how many TCP sessions and how many different hosts are actually opened to access a particular website. For instance, when accessing well known websites, such as CNN, the average user is not aware that the simple act of accessing the site unleashes a storm of DNS requests and TCP session establishments. Appendix 1 shows a summary of browser traffic when visiting this example site. On the day tested, no fewer than 246 objects required download across 70 unique hosts with most hosts requiring DNS lookups before TCP sessions can be established. The browser will establish multiple TCP sessions sequentially to download the site contents from all the hosts. In the statistics shown below, you can see that only a few hosts support a majority of the traffic while other hosts may only have one or two objects to download. Many sites have small objects (a few hundred or thousand bytes), which do not benefit significantly from standard PEP. In fact, statistically, the average object size is on the order of 80 kBytes, and standard PEP is only marginally effective at accelerating files of that size over VSAT. With our Turbo Streaming, up to 200 LAN TCP connections can be multiplexed into already existing WAN TCP connections, eliminating the time it takes to manage and establish each session individually as per standard PEP. As such, sessions are setup faster and small files are transferred quicker.

Across terrestrial infrastructure, DNS queries are quick and efficient enabling the TCP sessions to be established quickly. However, over VSAT, DNS queries require round trip transactions over VSAT. In case of CNN, DNS queries took 1/3 of the time it took to download the site contents. Once the host IP addresses are resolved, TCP sessions to download content can finally commence. As a result, we can make three observations regarding optimizing performance for web content delivery:

1. Many hosts need to be resolved resulting in excessive time being spent in DNS lookups before the TCP session can even be initiated.
2. Many TCP sessions need to be opened to support relatively small data transfers (average 80 kbytes).
3. It is important to factor in the number of TCP sessions supported when defining an optimization solution. Accessing www.cnn.com requires >60-70 TCP sessions supported at the LAN. This raises the question of: How many TCP sessions would be required to support an LTE site with dozens of connected and active users?

Comtech’s FX PEP differs from typical implementations in that the remote gateway maintains an intelligent DNS proxy (DNS lookup table) to provide “local” DNS host name resolution, which significantly reduces the delay before TCP sessions can be established. (Note: User IP DNS inquiry is still passed across to the host for DNS resolution. The response is captured by the gateways to maintain lookup accuracy and to ensure that the MNO can account for every byte transferred to the user device). Additionally, upon establishing the end-to-end session to support the file transfers between the user IP device and the host site, our Turbo Streaming effectively allows for all TCP transactions between the user IP/host to be multiplexed across a persistent high-speed TCP session over satellite. Turbo Streaming greatly increases the speed at which the multiple objects from a particular host can be transferred across the link on a per user IP/host basis.

Bandwidth Savings

MNO interest in QoE is important, but bandwidth savings (or rather pushing more bytes to users across existing VSAT capacity) is just as important. Caching (object or byte) is one such mechanism to provide more user bytes over existing capacity. Caching is essentially a process through which objects or blocks of bytes that represent duplicate information do not need to be sent across the VSAT link if that data has already been previously transmitted. Another bandwidth saving scheme is image resizing, where the optimization device can set threshold sizes for JPEG content and re-size the image to utilize less bandwidth. While the bandwidth benefit can be significant, the user perspective (QoE) is that the cached traffic is delivered at blazingly fast speeds since it is played out by the remote LTE optimizer instead of being transported across the WAN. With widespread use of https encryption (i.e. 60%+ of web traffic today is encrypted and that rate is climbing rapidly) the contribution of caching or other bandwidth savings schemes is expected to decline over time,. However, for now, a well implemented optimization solution can still provide significant savings. We have demonstrated 40% additional throughput over fixed capacity (i.e. 35 Mbps effective throughput over 25 Mbps VSAT link) through the use of caching.

Conclusion

In conclusion, when MNOs consider and evaluate LTE optimization, they should consider a solution that:

- Provides more than the standard PEP implementations
- Addresses the real issues which influence QoE

Firstly, while standard PEP is beneficial to large file transfers over VSAT, it is only marginally effective in improving web performance that is based on many smaller file transfers. Our Turbo Streaming implementation addresses both TCP acceleration for large file transfers and improves small file transfer speeds. Since most web browsing is based on many small objects, it is critically important to QoE that those smaller files get transferred as quickly as possible. It is especially important for MNOs to understand that testing large FTP file transfers across LTE over VSAT can demonstrate that PEP has an affect across the link. However, it is NOT a true measure of performance improvement when it comes to the typical web experience, which is traditionally dominated by small files.

Secondly, an LTE optimization solution over satellite should bring intelligence to the edge in the shape of intelligent DNS Proxy to eliminate additional long delays associated with simple DNS lookups over satellite, and allowing for quicker uptake on file transfers. Additionally, it should include bandwidth saving mechanisms to ensure that traffic that is going across the VSAT is always new traffic and not repeat traffic.

Finally, MNOs should start specifying TCP session performance requirements since an LTE optimization solution is only effective if the user TCP sessions get accelerated. Ideally, all TCP sessions that cross an LTE eNodeB should be optimized, and the MNO should set a TCP session expectation for typical LTE deployment. Based on our extensive experience in deploying PEP in ISP and enterprise environments, our customers have seen upwards of 30,000 TCP/HTTP connections to support links of 150 Mbps and typically require 5,000 or so TCP/HTTP connections to support sites with as little as 25 Mbps. Unfortunately, interest in the LTE optimization market has resulted in inexperienced new entrants into the PEP space, most making high bandwidth claims based on FTP file transfer download results, but not advertising or reporting number of TCP sessions supported. In the PEP space, it is the number of TCP sessions supported which is the real driver, not speed.

Comtech's FX product provides high TCP session count, high speed capacity, intelligence and superior PEP though out Turbo Streaming technology meeting all the requirements for the most aggressive LTE rollouts over VSAT.

For additional information, please contact us.

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Appendix 1:

```
Request Count:   246        <- number of objects requested across all hosts
Unique Hosts:    70         <- number of Hosts requiring DNS lookup
Bytes Sent:      227,897          (headers:195,367; body:32,530)      <- Header compression
will reduce backhaul bandwidth 7:1
Bytes Received:  3,150,369        (headers:94,059; body:3,056,310)    <- header compression
benefits 3%, payload compression benefits variable

ACTUAL PERFORMANCE
--------------
Requests started at:        14:59:35.012
Responses completed at:     15:00:04.119
Sequence (clock) duration:  00:00:29.107
Aggregate Session duration: 00:02:53.500
DNS Lookup time:            9,635ms     < - DNS look up times are almost ½ download time
TCP/IP Connect duration:    20,083ms    < - download time for all objects

RESPONSE CODES
--------------
HTTP/200:     221
HTTP/204:     8
HTTP/304:     8
HTTP/302:     7
HTTP/504:     1
HTTP/303:     1

RESPONSE BYTES (by Content-Type)
--------------
                   image/jpeg: 1,335,843  <- Image resizing can benefit 50% or more
application/vnd.ms-fontobject: 711,543
       application/javascript: 366,646    <- Compressible
              text/javascript: 209,766    <- Compressible
                     text/css: 153,031    <- Compressible
     application/x-javascript: 148,802    <- Compressible
                    ~headers~: 94,059     <- Compressible
             application/json: 38,055
                    text/html: 29,989     <- Compressible
                    image/png: 28,315
                  text/x-json: 13,108
    application/ocsp-response: 8,418
                    image/gif: 7,681
                     text/xml: 4,116      <- Compressible
                image/svg+xml: 808
       application/ecmascript: 189

REQUESTS PER HOST  (Note typical 6 TCP sessions can be opened per Host by the User browser.
Across 70 Hosts … possibly 100 TCP sessions or more)
--------------
                 i2.cdn.cnn.com: 33   <- the objects are ported across 6 TCP sessions)
              www.i.cdn.cnn.com: 24
                    s0.2mdn.net: 18
         ads.jetpackdigital.com: 13
            clients5.google.com: 11
                  i.cdn.cnn.com: 10
            logx.optimizely.com: 9
                    www.cnn.com: 9
                beacon.krxd.net: 8
                geo.moatads.com: 6
                 js.moatads.com: 6
optimized-by.rubiconproject.com: 5
            images.outbrain.com: 5
  pagead2.googlesyndication.com: 4
               log.outbrain.com: 4
                   cdn.krxd.net: 4
               hpr.outbrain.com: 3
               www.facebook.com: 3
                 z.cdn.cnn.com: 3
                 www.google.com: 3
               i.cdn.turner.com: 3
           cm.g.doubleclick.net: 3
           connect.facebook.net: 2
         aax.amazon-adsystem.com: 2
     googleads.g.doubleclick.net: 2
  d31550gg7drwar.cloudfront.net: 2
 securepubads.g.doubleclick.net: 2
         b.scorecardresearch.com: 2
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          mabping.chartbeat.net: 2
               cdn.livefyre.com: 2
   131788053.log.optimizely.com: 2
           static.chartbeat.com: 2
              ocsp.digicert.com: 2
      www.googletagservices.com: 1
         c.amazon-adsystem.com: 1
        ads.rubiconproject.com: 1
     tpc.googlesyndication.com: 1
               odb.outbrain.com: 1
            cdn3.optimizely.com: 1
               ocsp.godaddy.com: 1
                   t2.symcb.com: 1
          social-login.cnn.com: 1
  tracking.jetpackdigital.com: 1
             3409bcb2.mpstat.us: 1
                metrics.cnn.com: 1
             ad.doubleclick.net: 1
                   gp.symcd.com: 1
             cdn.optimizely.com: 1
              www.ugdturner.com: 1
             ping.chartbeat.net: 1
                   g2.symcb.com: 1
        tap.rubiconproject.com: 1
```