DELIVERING VOICE IN THE EMERGING ERA OF LTE

HOW TO DELIVER VoLTE WITH SCALABILITY AND HIGH PERFORMANCE IN THE EVOLVED PACKET CORE

APPLICATION NOTE

ABSTRACT

The new era of Long Term Evolution (LTE), and the new devices, behaviors and services it unlocks, will test the limits of both the data plane and the control plane in ways that Mobile Network Operators (MNOs) have not seen before. This paper details the unique capability of the Alcatel-Lucent 7750 Service Router (SR) as a mobile gateway to support the more stringent demands of Voice over LTE (VoLTE) concurrently with other LTE mobile broadband services.

The inherent IP service-aware architecture of the 7750 SR's mobile gateway offering provides complete separation of control and data planes, delivering the next generation of LTE services with exceptional performance, scalability and reliability. This paper describes how the approach of the 7750 SR represents an architectural imperative for MNOs; this is reinforced by an extensive multiservice performance test as it simultaneously processes a barrage of VoLTE, video, Internet and other control traffic.

TABLE OF CONTENTS

MARKET VIEW OF VoLTE

Current and future trends

LTE network deployments are steadily increasing. The Global Mobile Suppliers Association (GSA) states that 371 LTE network deployments are complete, planned or in progress in 116 countries, including 175 networks that are commercially launched in 70 countries[1]. By the end of 2013, Yankee Group forecasts 114 million active LTE connections globally, increasing to 258 million by the end of 2014[2].

Pivotal to the success of the LTE system architecture are the multiservice delivery capabilities of the Evolved Packet Core (EPC). Located at the heart of the new all-IP mobile network, the EPC must mesh together a complex web of applications and network domains needed to create, deliver and monetize a new breed of services. This will be a challenge for MNOs because delivering on the promise of LTE by moving from best-effort Internet to delivering a plethora of new services with high scalability and stringent and deterministic performance requirements is unchartered territory.

Heavy Reading echoes this sentiment: *"Although the first EPC deployments have been successful, the need to support advanced services in all-IP mobile networks still presents a major industry challenge."*[3]

With the advent of LTE, VoLTE is an example of a service that, despite presenting unique and challenging entry barriers, many MNOs will eventually deploy. However, there is uncertainty about when VoLTE will be offered as a mass market option. Ovum states:

"While there are some questions about how to provide voice services during an interim period when the LTE network sits alongside legacy 3G and 2G networks, there is a general consensus that the ultimate destination is a solution based on IP multimedia subsystem (IMS) that has been designated as VoLTE – voice over LTE."[4]

VoLTE benefits

The desire to deploy VoLTE can be explained by some of the benefits that service providers could gain:

- Lower cost: More cost effective to deliver per customer than legacy circuit-switched networks
- Elimination of a separate voice network: With ubiquitous LTE coverage, a separate circuit-switched voice network could be eliminated
- Refarming of existing spectrum for LTE: A step toward freeing up precious spectrum and reclaiming it for LTE
- Quality benefits: Improved setup times and a better audio experience
- Possibility of new services: New services such as voice and video, and those offered through Rich Communication Services (RCS)
- First to market: Be known as a market leader or first mover
- Over-the-Top (OTT) services: Combat voice revenue erosion by OTT players

[1] Global Mobile Suppliers Association, *Evolution to LTE report: 175 commercial LTE networks launched in 70 countries; 100 launched in past year*, http://www.gsacom.com/news/gsa_376.php
[2] Yankee Group, *What's Next for Mobile Broadband?*, Nov. 2012
[3] Heavy Reading, Vol 10, No 13, *Evolved Packet Core Market Forecast & Competitive Analysis*, October 2012
[4] Ovum, *Future Strategies for VoLTE Deployment*, Jeremy Green, Feb 19, 2013

VoLTE entry barriers and challenges

Despite the benefits of and interest in VoLTE, there are barriers to entry that are slowing ubiquitous deployment. From the demand side, it may not be easy to monetize the value of VoLTE (and HD voice) services in the short term because voice and Short Message Services (SMS) are already being offered by OTT providers with pricing levels that are effectively commoditizing these services.

A significant investment is also needed in the IMS infrastructure to enable VoLTE. In addition, roaming with VoLTE will be a short-term challenge, especially in Europe, until VoLTE becomes mainstream. Other challenges hampering the adoption of VoLTE are outlined by Ovum[5] and Light Reading[6].

For these reasons, the first round of LTE deployments has been overwhelmingly focused on high-speed Internet access and other high-bandwidth applications such as streaming video. Most MNOs opted to continue to use circuit-switched voice in their initial deployments. However, as these business and technical challenges are being worked out, MNOs are now preparing to transition their voice services to VoLTE, making it imperative for them to address the unique implementation challenges of delivering VoLTE.

THE NEW SCALING CHALLENGES WITH LTE AND VoLTE

Impact of smartphones

A few years ago, if you asked an MNO about to deploy LTE what the major challenges would be to operate this new network, the answer at the top of the list would have been “supporting the rapid growth of data driven by the increase in LTE bandwidth expectations”. However, the popularity of smartphones has had a surprising impact on the volume of the control plane signaling in the newly deployed EPC.

As an example, to save network and power resources, a smartphone can continually transition to idle state, then transition back to active state when it needs to send or receive data. To get an idea of how signaling demands can increase, think about how many times you access your smartphone for email, web browsing and social media during the day.

A smartphone may have as many as 30 to 40 transitions from “idle to active” and “active to idle” in a busy hour, putting a severe and sometimes unexpected strain on the control plane. Furthermore, frequent handovers from LTE to 3G because of spectrum shortage or coverage holes adds to the control plane overhead. As a result, it is clear that, unlike its 3G counterpart, the LTE packet core will need to scale significantly and simultaneously on both the control and data planes.

[5] *Future Strategies for VoLTE Deployment*, Ovum, Jeremy Green, Feb 19, 2013
[6] *When Will Operators Bolt to VoLTE?*, http://www.lightreading.com/long-term-evolution-lte-/when-will-operators-bolt-to-volte/240137220

VoLTE-specific challenges

When we consider the delivery of VoLTE, more specific challenges arise. Many MNOs are choosing to deploy VoLTE using a separate Packet Data Network (PDN) connection from those initially set up and used for other Internet services. This allows for a logical separation of VoLTE and Internet traffic within the network resources. However, doubling the number of PDN connections per User Equipment (UE) also means doubling the number of control plane messages required for many control plane procedures. For example, each idle-to-active transition for each PDN requires twice as many control plane messages.

At first glance, VoLTE's impact on the data plane should be negligible. After all, we're talking about very small voice packets (as small as 64 bytes) and relatively low packet transmission rates (for example, 24 kb/s for HD voice). However, the network must dedicate those 24 kb/s for the lifetime of each call and provide a specific Quality of Service (QoS) to every VoLTE packet delivered.

In addition, the smaller VoLTE packets require the data plane to handle a correspondingly larger packet transmission rate when compared to transmitting much larger packets. This is further exacerbated by the requirement of concurrently delivering other services with completely different QoS requirements, such as video and all of its different speeds and formats.

VoLTE's combined challenges of an increase in control plane messaging coupled with a high packet transmission rate result in a significant challenge for legacy packet cores. Most of today's packet core products were developed when data rates were low enough that both control plane and data plane could be handled by common CPU-based forwarding architectures. These architectures require the operator to trade off control plane scalability with data plane scalability. Increase one and the other falls.

This lesson was learned years ago in the design and build-out of fixed-access IPTV networks as operators transitioned from CPU-based routers to those making extensive use of Network Processors (NPs). The heretofore narrowband nature of cellular data rates has allowed CPU-based products to hang on…until now.

Common CPU-based architectures require the operator to trade off control plane scalability with data plane scalability. Increase one and the other falls.

DELIVERING VoLTE WITH THE LTE-OPTIMIZED ALCATEL-LUCENT 7750 SR

Control plane and data plane challenges

The 3rd Generation Partnership Project[7] (3GPP) noted the importance of scaling independence between control plane and data plane by separating control plane-intensive elements such as the Mobility Management Entity (MME) from data plane elements such as the Serving Gateway (SGW) and the PDN Gateway (PGW). For many of the same reasons, this same type of separation is also required inside the data plane elements. Today's LTE packet core elements demand a logical and physical separation of compute and memory resources for control and data plane functions.

[7] 3GPP, http://www.3gpp.org/

This concept is further extended within the data plane itself because packet flows from each service may need differing levels of packet processing. For example, many MNOs deploy advanced packet processing capabilities using L4-L7 Deep Packet Inspection (DPI) techniques to identify and uniquely act on specific packet flows for Internet services. As an example, this capability allows an MNO to uniquely identify a specific packet flow and achieve differentiated billing across various Internet services, such as streaming video, social media, gaming, file sharing, email, etc.

Different data processing requirements

For many MNO-owned services, such as VoLTE, there is no need for advanced packet processing (that is, L4-L7 DPI techniques) but the services still require demanding processing requirements: L1-L4 Shallow Packet Inspection (SPI), QoS, accounting, filtering, reporting, etc. Therefore, it is important that the mobile service edge (the PGW) provides independent packet processing for packet flows requiring normal, yet high-touch, processing, such as VoLTE, from packet flows requiring advanced packet processing.

Some MNOs deploy external DPI appliances for advanced packet processing to decouple this from the mobile gateway's control plane functions; however, this increases cost and operational complexity. Others prefer to use DPI capabilities integrated in the mobile gateway, which presents scaling problems if this is part of the platform's shared management CPU pool.

Introduction to the 7750 SR as a mobile gateway

One of the cornerstones of the Alcatel-Lucent approach to delivery of the next generation of LTE-driven mobile broadband services is the Alcatel-Lucent 7750 SR functioning as a mobile gateway. With its purpose-built FP technology and industry-leading Service Router Operating System (SR OS), the 7750 SR allows MNOs to deliver advanced and personalized high-touch mobile broadband services with in a cost-effective manner.

The 7750 SR as a mobile gateway provides independent and concurrent scaling in three dimensions: the control plane (for network instructions), the Network Processor-based data plane (for normal high-touch packet processing) and the advanced data plane (for L4-L7 DPI).

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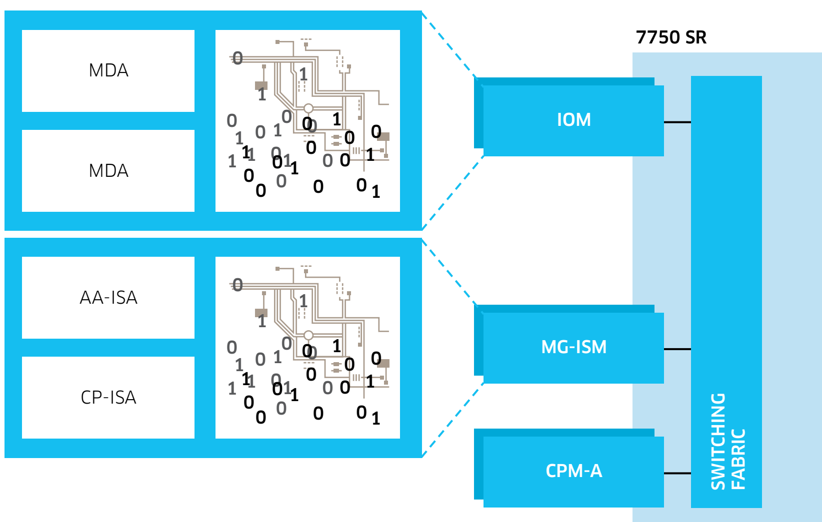
Logical architecture of the 7750 SR as a mobile gateway

Figure 1 shows the logical architecture the 7750 SR as a mobile gateway. The components of this architecture are:

- Switching Fabric: A purpose-built switching fabric designed for high-performance packet switching between Input Output Modules (IOMs) and Media Gateway-Integrated Services Modules (MG-ISMs)
- Control Processing Module (CPM): A hot-swappable module representing the brains of the 7750 SR, including common control functions
- Input Output Module (IOM): A purpose-built hot-swappable module that performs high-touch packet processing and houses two Media Dependent Adapters (MDAs)

- MDA: An adapter that holds various interfaces and is inserted into the IOM
- Mobile Gateway Integrated Services Module (MG-ISM): Provides control and data plane handling for the SGW, PGW and Gateway GPRS Support Node (GGSN) functions; each MG-ISM performs bearer management and packet delivery for a large number of subscribers
- Application Assurance Integrated Services Adapter (AA-ISA): A dedicated adapter located on the MG-ISM that performs sophisticated L4-L7 in-line traffic processing called Application Assurance[8]
- Control Plane Integrated Services Adapter (CP-ISA): A dedicated adapter on the MG-ISM providing a high-speed CPU that performs the control functions related to subscriber connections; for example, the CP-ISA handles all GPRS Tunneling Protocol (GTP) signaling and policy management messages along with charging record and key performance indicator/key capacity indicator (KPI/KCI) statistics record generation

Figure 1. 7750 SR: Internal architecture



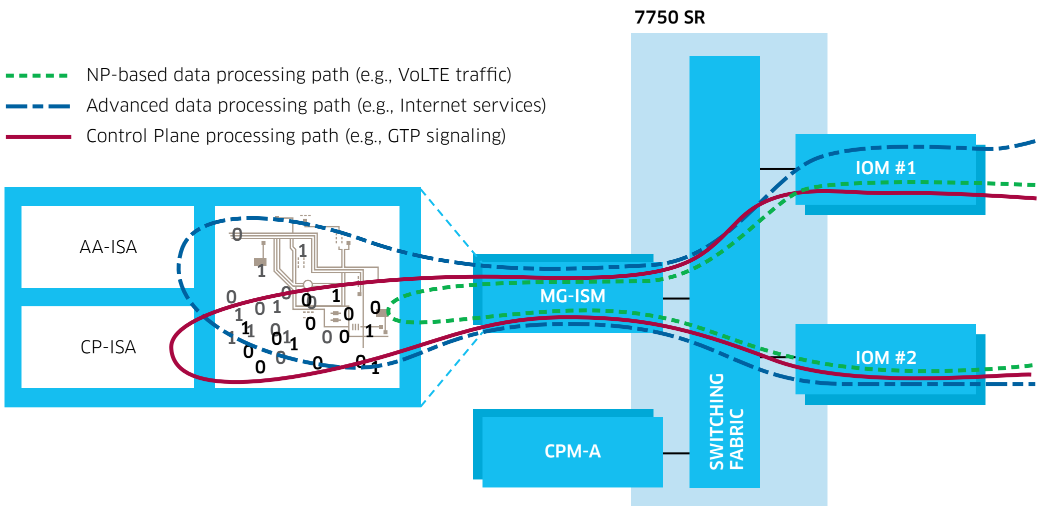
Internal packet processing

To show how this internal architecture works at a high level, it is instructive to show the path that different services take. Consider three different traffic flows: control traffic, VoLTE traffic and Internet traffic. The control traffic requires specific packet processing from the CP-ISA and follows the control plane processing path. The VoLTE traffic requires high-touch packet processing and follows the NP-based data processing path. The Internet traffic requires advanced L4-L7 packet processing from the AA-ISA and follows the advanced data processing path.

[8] For more detail about Application Assurance, see *Mobile Application Assurance on the Alcatel-Lucent 7750 Service Router*, Alcatel-Lucent, http://www.alcatel-lucent.com/solutions/wireless-packet-core

Figure 2 shows the internal packet flow for each of these scenarios.

Figure 2. 7750 SR: Internal packet processing



Features and benefits of the 7750 SR

Table 1 summarizes the features and benefits of the 7750 SR's approach to the delivery of VoLTE and other LTE-driven services.

Table 1. Features and benefits of delivering VoLTE with multiple services using the LTE-optimized 7750 SR

FEATURE	BENEFIT
Purpose-built architecture with dedicated NP data plane processing designed for the next generation of LTE-enabled services	Internal switching fabric and associated NP-based silicon designed specifically for the rigorous demands of packet processing (filtering, forwarding, QoS, accounting, charging, reporting, etc.) for each individual IP packet flow with scalability and high performance
Dedicated CPU for control plane processing (CP-ISA)	Logical and physical separation of control plane processing requirements (GTP-C, Authentication, Authorization and Accounting [AAA], Policy and Charging Control [PCC], Online Charging System [OCS], etc) from data plane packet processing, dramatically increasing scalability and performance for the emerging LTE service demands
Dedicated CPU for AA (AA-ISA)	Performs sophisticated L4-L7 in-line inspection, analysis and processing without additional equipment and without affecting data plane or control plane performance
True concurrent support for SGW, PGW and GGSN with scalability and high performance	Offers MNOs flexibility and growth options with true multi-function capability
Non-stop services and non-stop routing, supported by intershelf and instrashelf redundancy with no single point of failure	Provide the best-in-class high availability needed to preserve end-user Quality of Experience
Advanced Hierarchical QoS	Delivers advanced LTE services with uncompromising performance for each user and each application

TESTING THE 7750 SR WITH THE DEMANDS OF VoLTE AND OTHER TRAFFIC

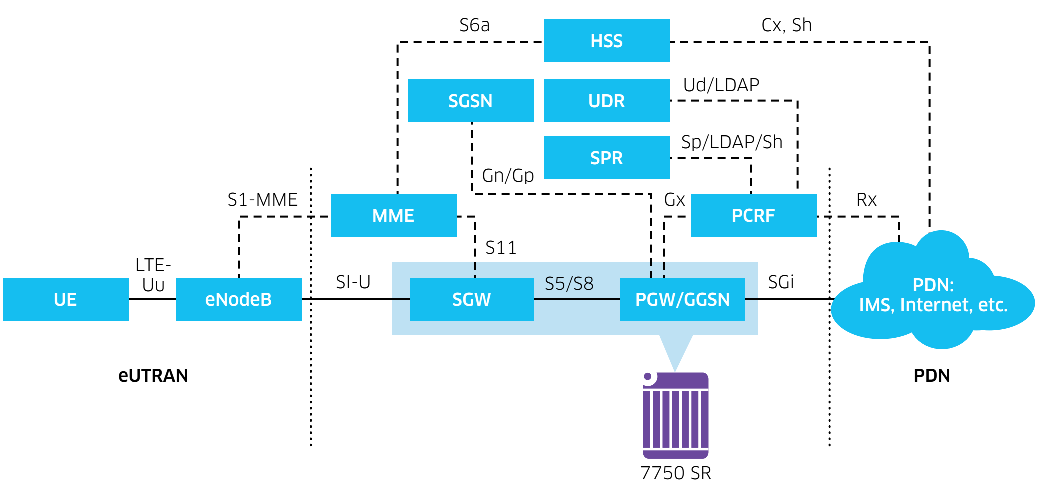
Introduction

Alcatel-Lucent conducted a multi-service test on the 7750 SR as a mobile gateway to demonstrate its three-dimensional architectural scaling of packet processing when concurrently delivering VoLTE and video traffic (both requiring NP-based data processing), Internet services (requiring advanced L4-L7 data processing) and control traffic (requiring control plane processing). These tests demonstrated the independent scalability of the AA-ISA and the CP-ISA from the NP-based data processing and forwarding capabilities.

The 7750 SR in a standard LTE network

To frame the testing discussion in this section, Figure 3 shows a standard LTE network and the role the 7750 SR as a mobile gateway plays within this architecture for the test. As shown, the 7750 SR assumes the role of an SGW, a PGW and a GGSN for this test. For more details on LTE in general, please refer to the white paper *The LTE Network Architecture: A comprehensive tutorial*[9].

Figure 3. The 7750 SR in the 4G LTE network architecture



The functional elements of the 4G LTE network that the 7750 SR simultaneously represents are:

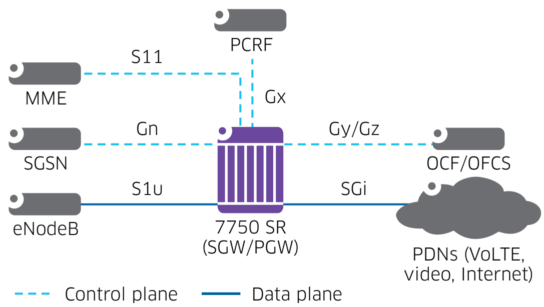
- SGW: All IP packets (signaling plus bearer) traverse the SGW, which is the local mobility anchor for bearers when the UE moves between different eNodeBs or hands over to legacy 2G or 3G network access.
- PGW: Provides IP address management, QoS enforcement and flow-based charging according to the policy rules it receives from the Policy Charging and Rules Function (PCRF). It provides the mobility anchor point for non-3GPP technologies such as CDMA, WiMAX, WiFi and fixed broadband networks. The PGW also connects IP bearers to the PDNs.
- GGSN: Is a main component of the GPRS network. The GGSN is responsible for the internetworking between the GPRS network and external packet-switched networks.

[9] Alcatel-Lucent, *The LTE Network Architecture: A comprehensive tutorial*, white paper. 2009, www.alcatel-lucent.com/4g-consumer-communications

Logical setup of the testbed

Figure 4 shows the logical setup of the testbed. The solid lines represent the data plane connections between the customer UEs on one side (behind he eNodeB) and the PDNs (VoLTE, video, Internet) on the other. The dotted lines represent control traffic from various control elements such as the MME, PCRF, Serving GPRS Support Node (SGSN), OCS and the Offline Charging System (OFCS).

Figure 4. The VoLTE and multiple services testbed – logical view



Test parameters

The traffic was run through two MG-ISMs. One MG-ISM was used as an SGW and the other MG-ISM card was used as a combination PGW/GGSN. The test results that follow reflect the scalability and performance of the MG-ISM card that was functioning as a PGW/GGSN.

The test was executed by using various test equipment and emulators to generate traffic load and control events from the various entities shown in Figure 4. This test used a realistic call model and traffic load for the control plane concurrently with Internet data traffic running through the AA-ISA and video traffic running through normal FP processing. VoLTE traffic was overlaid on top of the Internet traffic and video traffic. The control plane and data plane loads are consistent with a real-life model of 3G and LTE deployed in the network of a Tier 1 carrier.

Services tested

The services that were delivered in this test are summarized in Table 2. For the purpose of this test, services and control requirements were organized into separate Access Point Names (APNs). This does not reflect a design recommendation, and the performance and scale achieved in the test is not incumbent upon any particular methodology of organizing services.

The PCRF instantiated the creation of all bearers and policies for these services. There can be multiple bearers per subscriber and multiple SDFs per bearer to reflect the realistic scenario of having multiple bearers and SDFs per customer context.

The APN VoLTE reflects bi-directional HD voice and was tested with 250,000 subscibers, each with a default bearer and a Guaranteed Bit Rate (GBR) dedicated bearer. A total of 5,500,000 Service Data Flows (SDF)s were used across all of the subscribers. The APN Video was tested with 25,000 subscribers receiving video from large packets (1400 Bytes). Both the VoLTE and Video bearer were processed through the NP-based data processing path. The APN Internet was tested with 25,000 subscribers across 375,000 SDFs. Fourteen different PCRF-instantiated charging rules were used to identify and group each of these SDFs.

Table 2. Description of the services tested: VoLTE, video and Internet

DATA PLANE APN	DESCRIPTION	TOTAL RATE	PROCESSING MODE	SUB COUNT	BEARER COUNT	SDF COUNT
VoLTE	Bi-directional HD voice, 17 kb/s, 64-Byte payload	6 Gb/s	NP-based data processing	250,000	1 default and 1 GBR dedicated per subscriber = 500,000	11 SDFs per bearer = 5,500,000
Video	1400-Byte payload	10 Gb/s	NP-based data processing	25,000	1 default bearer per subscriber = 25,000	1 SDF per bearer = 25,000
Internet	Mix of various Internet traffic	10 Gb/s	Advanced data processing using the AA-ISA	25,000	1 default bearer per subscriber = 25,000	15 SDFs per bearer = 375,000

Control plane requirements

The description of the control plane requirements that were tested is summarized in Table 3. These requirements were processed simultaneously with the aforementioned service processing requirements. The APN Control was used for the control plane requirements and was tested with 100,000 subscribers. Several control scenarios were tested, including LTE-to-3G-to-LTE transitions, OCS and OFCS updates on simulated location changes, and PCRF updates on Radio Access Type (RAT) changes. The rate of control processing is measured in transactions per second (tps).

Table 3. Control plane APNs

CONTROL PLANE APN	DESCRIPTION	RATE (TPS)	PROCESSING MODE	SUB/BEARER/ SDF COUNTS
Control	• LTE-to-3G handovers • OCS/OFCS gets triggered on location changes • PCRF updates on RAT change	5,000 5,000 5,000	Control plane processing by the CP-ISA	100,000 100,000 100,000

Test results

There were no service degradations on any of the test cases performed. Up to 8 MG-ISMs can be equipped in a single 7750 SR chassis; therefore, the results summary in Table 4 reflects the demonstrated test results projected across an entire chassis.

Table 4. Testing summary across entire 7750 SR chassis

APN	SUBSCRIBERS	BEARERS	SDFS	TOTAL RATE
VoLTE	2,000,000	4,000,000	44,000,000	48 Gb/s
Video	200,000	200,000	200,000	80 Gb/s
Internet	200,000	200,000	3,000,000	80 Gb/s
Control	800,000	800,000	800,000	120,000 TPS
TOTAL	**3,200,000**	**5,200,000**	**48,000,000**	**208 Gb/s + 120,000 TPS**

It is important to note that the numbers in Table 4 do not reflect scaling limits of the 7750 SR but are shown to provide a view of the multiservice scalability that can be supported given the limits of the test equipment used. These numbers were used to reflect a comprehensive and diverse mix of data and control requirements whose purpose was to test the scalability of the 7750 SR in various dimensions.

CONCLUSION

In addition to data plane scalability, operators have found control plane scalability to be a surprising challenge for their LTE deployments. Today's MNO must prepare to deal with a simultaneous mix of high signaling rates, high packet rates for small packets, and a diverse mix of other traffic requirements for video and Internet services.

With its unique combination of control plane load and high packet rate challenges, VoLTE highlights problems with existing packet core platforms that use a common CPU for control plane handling, data plane forwarding and often DPI processing. An increase in one leads to a decrease in the others.

It is clear from the test results outlined in this paper that the 7750 SR as a mobile gateway with its three-dimensional scalability (data, control and advanced L4-L7 data processing) was able to process the unique demands of VoLTE traffic while satisfying a diverse and demanding set of traffic requirements from both the control plane and data plane.

The 7750 SR as a mobile gateway with its three-dimensional scalability was able to process the unique demands of VoLTE traffic while satisfying a diverse and demanding set of traffic requirements from both the control plane and data plane.

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ACRONYMS

3G	Third generation
3GPP	3rd Generation Partnership Project
7750 SR	7750 Service Router
AAA	Authentication, Authorization and Accounting
AA	Application Assurance
AA-ISA	Application Assurance - Integrated Services Adapter
APN	Access Point Name
CP-ISA	Control Plane - Integrated Services Adapter
CPM	Control Processing Module
DPI	Deep Packet Inspection
EPC	Evolved Packet Core
GBR	Guaranteed Bit Rate
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service
GSA	Global Mobile Suppliers Association
GTP-C	GPRS Tunneling Protocol - Control
IMS	IP Multimedia Subsystem
IOM	Input Output Module
LTE	Long Term Evolution
MDA	Media Dependent Adapter
MG-ISM	Mobile Gateway - Integrated Services Module
MME	Mobility Management Entity
MNO	Mobile Network Operator
NP	Network Processor
OCS	Online Charging System
OFCS	Offline Charging System
OTT	Over-the-Top
PCC	Policy and Charging Control
PCRF	Policy Charging and Rules Function
PDN	Packet Data Network
PGW	PDN Gateway
QoS	Quality of Service
SGSN	Serving GPRS Support Node
SGW	Serving Gateway
tps	transactions per second
UE	user equipment
VoLTE	Voice over LTE

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