Telefonica | BUSINESS SOLUTIONS

A Telefonica White Paper

LTE: Next generation technology, bringing your world closer_

2015

1. Executive Summary

The use of mobile data has risen significantly in recent years due to the penetration of intelligent devices in the market. Simultaneously, as the world becomes more inter connected, the need for businesses and individuals to travel increases. Recent research by global analyst Ovum highlights the growing impact of these trends, indicating that data roaming will generate approximately US$50bn in revenues by 2019, contributing as much as 56% to global roaming revenues.*

* Source: Press release 20th November 2014 – Ovum says mobile data will account for more than half of global roaming revenues by 2019.

Nowadays, customers are demanding from their mobile operators to be connected wherever they are, with accessibility to what matters most to them, and expect the experience to be seamless. As a result the ability to deliver a robust and cost-effective roaming service is paramount to an operator's bottom line.

Delivering a world-class, 'always-on', customer experience when roaming globally presents a complex set of challenges to ensure a consistent Long Term Evolution (LTE) experience is achieved anywhere, anytime.

LTE Diameter Exchange enables operators to enhance the subscriber LTE roaming experience through a service built over an IPX network, which ensures consistent delivery and high service levels, wherever and whenever needed. The network has built-in full redundancy, geographical diversity, reliability and scalability.

Additionally, the service enables an operator to rapidly launch LTE roaming globally without the worry of interoperability issues normally associated with different LTE Diameter carriers.

Our LTE Diameter Exchange Service offers an ideal solution for mobile operators requiring extensive LTE international coverage. It also reduces costs and removes the need to build multiple LTE interconnections, as through just one connection and one single contract an operator can access multiple international destinations. As a centralised solution, based on hub architecture, it combines international coverage expansion for LTE signalling traffic with invoicing, security and reporting functions.

Telefonica is an active contributor in the GSMA and i3forum and our service has been defined based on their standards and guidelines.

2. Introduction: Diameter Protocol and LTE Roaming

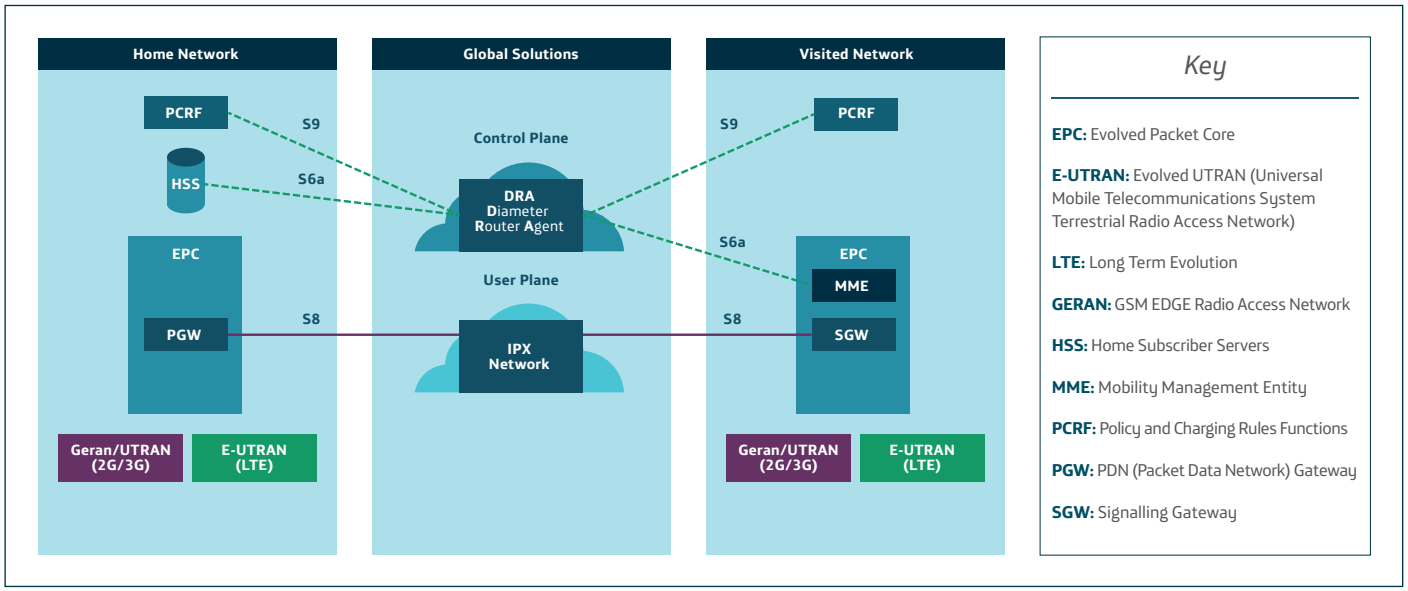
Mobility management in roaming defines a subscriber's ability to receive services, including home data services, when travelling outside their home geographical coverage area.

Diameter is an IETF-specified peer-to-peer protocol which is an extension to RADIUS protocol. It addresses Authentication, Authorisation and Accounting (AAA) services, and delivers greater reliability and the following enhanced capabilities:

- Flexible transportation option including TCP and SCTP
- Supports larger AVP fields (32 bits)
- Supports both stateless and stateful sessions
- Provides the option to define new or custom applications, commands and attributes

Diameter protocol has been chosen to implement many of these procedures and is increasingly used for inter-operator signalling networks and roaming infrastructure. The DRA (Diameter Routing Agent) is a functional element that guarantees all Diameter sessions.

LTE Roaming Architecture



Diameter protocol has a basic structure, on top of which a set of applications has been created to be used in different scenarios. This means Diameter is not limited to 3GPP-defined procedures. The basic structure provides peering setup, state control and disconnection; nevertheless one or more applications have to be set up for the transactions related to Roaming procedures, as well as others defined by 3GPP.

3GPP TS 23.401 describes the standard Roaming Architecture for LTE access to services, showing the subset of main 3GPP standardised interfaces which interconnect H-PLMN to V-PLMN.

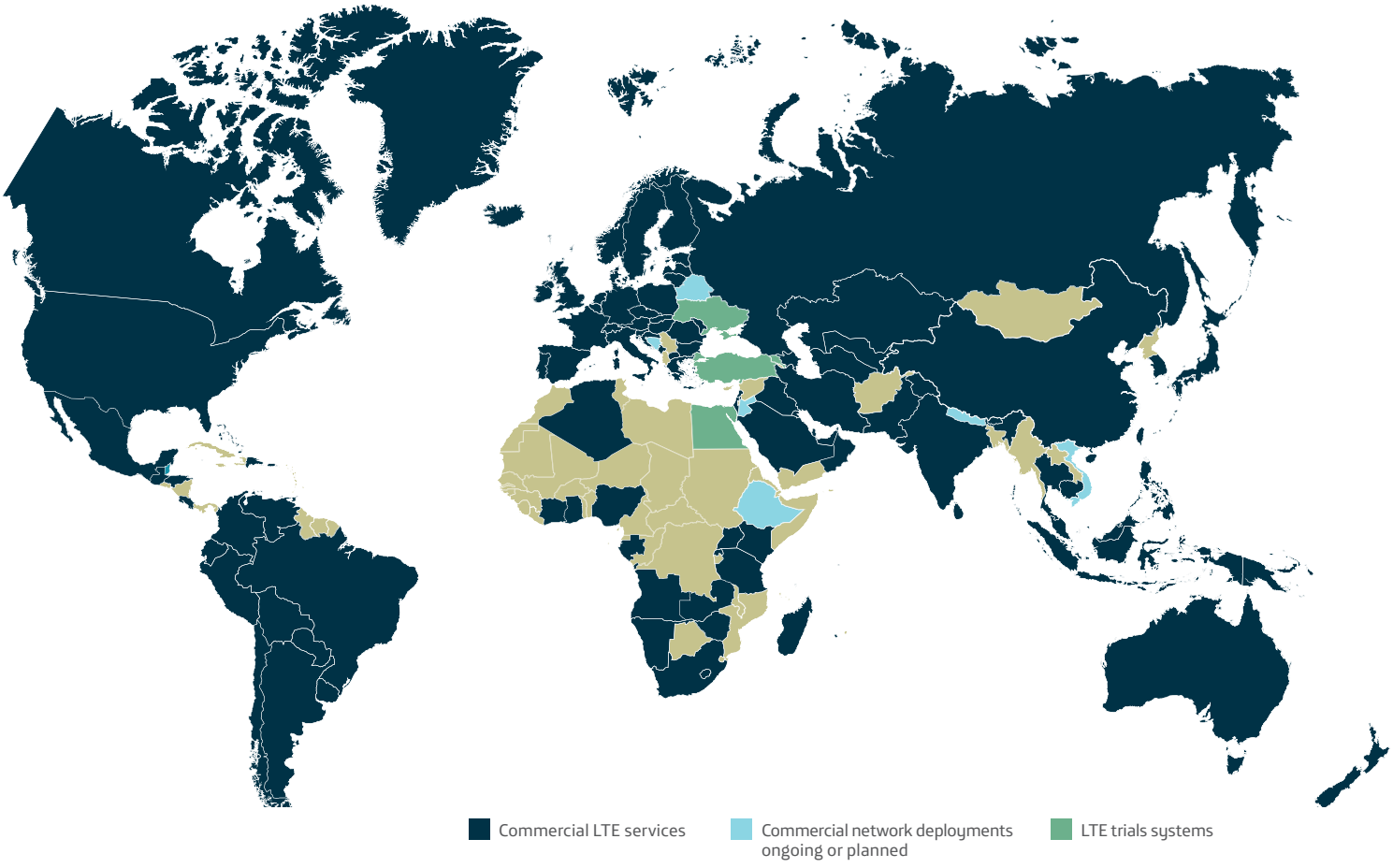
The above diagram shows the 3GPP network structure which defines the Architectures for LTE-EPS systems.

3. LTE Market Trends

The use of mobile data has increased significantly in recent years and this trend will continue in the near future due to the rapid market penetration of intelligent devices which generate a huge amount of data in the network. The use of smart phones has revolutionised the way in which people communicate; they have created the ability and driven the need to be connected anytime and anywhere. Worldwide mobile operators have leveraged this trend and are migrating their networks to support LTE technology. LTE is characterised by high-speed data provision that improves the mobile internet connection, including among others, multiple simultaneous sessions, HD video quality, real-time video calls, and high download rate – all improving and enriching the customer experience of end-users.

The expectation is that in the near future, business roamers will generate an increasingly large proportion of the overall roaming revenues. Capturing this revenue, whilst delivering a world-class service, represents an important opportunity for all operators.

LTE Global Trends



GSA forecasts that more than 450 LTE networks will be commercially launched by the end of 2015: 566 operator commitments in 166 countries and 45 pre-commitment trials in a further 8 countries.

Furthermore, GSA forecast 373 million LTE subscriptions globally: Q3 2014 GSA studies calculate almost 30% of operators are currently investing in LTE Advanced technology.*

*Source: GSA LTE Market Status: GSA's Evolution to LTE report, 7th January 2015

*Some 360 operators have commercially launched LTE networks and service in 124 countries, according to data released by the GSA (Global mobile Suppliers Association) in the latest update of the Evolution to LTE report.**

*Source: GSA Evolution to LTE Report, 7th January 2015

According to the Cisco Visual Networking Index, in 2014 a fourth-generation (4G) connection generated 10 times more traffic on average than a non-4G connection. Although 4G connections represent only 6 percent of mobile connections today, they already account for 40 percent of mobile data traffic.

Globally, the relative share of 3G- and 3.5G-capable devices and connections will surpass 2G-capable devices and connections by 2017 (45 percent and 38 percent relative share). The other significant cross over will occur in 2019, when 4G will also surpass 2G connection share. By 2019, 26 percent of all global devices and connections will be 4G-capable and global mobile 4G connections will grow from 459 million in 2014 to 3 billion by 2019 at a CAGR of 46 percent.*

*Source: Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2014–2019, 3rd February 2015

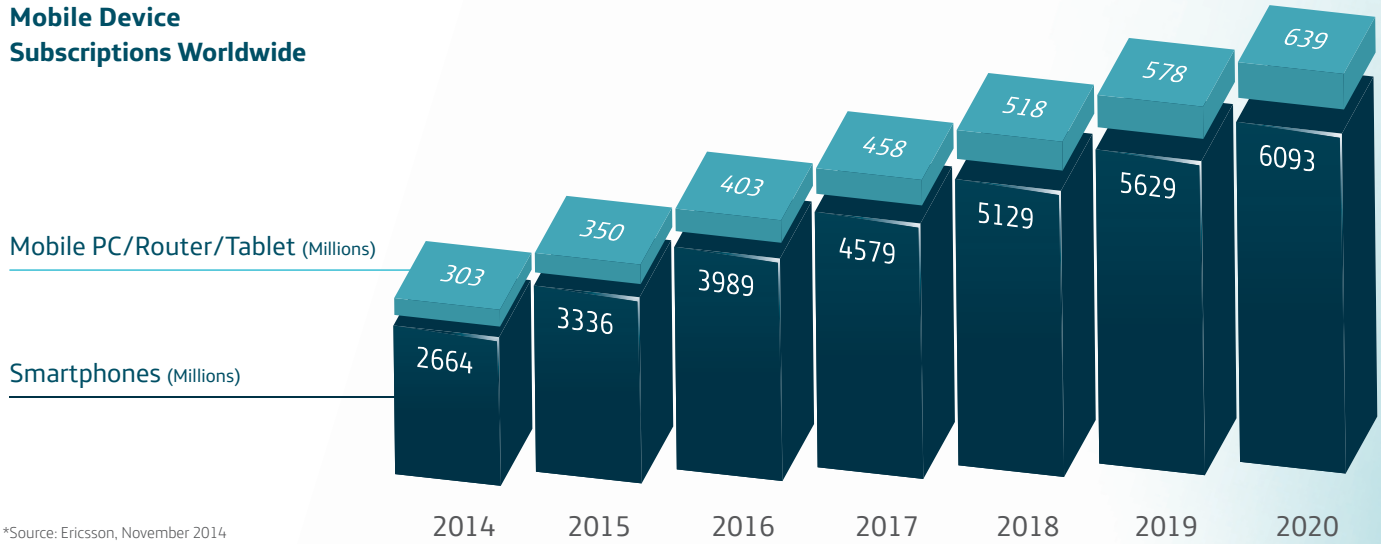
Mobile data traffic is skyrocketing, fuelled by the introduction of smartphones, laptops, flat-rate plans, social networking and applications like mobile video. Operators are looking to all-Internet Protocol (IP) networks such as Long Term Evolution (LTE) and IP Multimedia Subsystem (IMS) to provide the bandwidth required to support data-hungry devices and applications and to cost effectively address the growing gap between traffic and revenue growth.

In addition, the European Commission is reviewing and reforming the prices applied to roaming consumers in order to mitigate roaming 'bill shocks'. The so-called 'Eurotariff' is expected to substantially increase mobile usage abroad as it reduces 'bill shock' fear.

*Gartner estimates that worldwide mobile data traffic will grow from 6.4 million terabytes (TB) in 2011 to 91.3 million TB in 2016, with video expected to account for over 50% of mobile traffic during the next five years.**

*Source: Gartner Hype Cycle for Wireless Gartner Networking Infrastructure, 2014. Published: 24th July 2014. Analyst: Sylvain Fabre

Mobile Device Subscriptions Worldwide



*Source: Ericsson, November 2014

Some of the key factors that determine diameter traffic demand:

- LTE EPC, IMS and PCC network architecture and element configuration
- LTE coverage compared to 3G
- Growth in subscriber numbers
- Subscriber mobility including roaming
- LTE and IMS services offered by the operator
- Network policies implemented by the operator
- Service policies adopted by the subscriber
- Chargeable services for on-line and off-line subscribers
- Subscriber behaviour
- Network efficiency
- Growth margin

4. Addressing LTE Diameter Challenges

As LTE networks are increasingly used, the network structure is becoming more complex. The following challenges obstruct network expansion as carriers try to explore a new way to accelerate business growth:

- During communication between different networks, network topology cannot be hidden and therefore network security issues may arise.
- With the large-scale deployment of LTE networks, roaming imposes a challenge on the interworking between these networks.
- Many more devices are connected to each other making it more difficult for devices of different manufacturers to work with each other.
- As the number of subscribers increases, multiple Home Subscriber Servers (HSS) are deployed in the network. In this case, a Subscription Location Function (SLF) is required to implement the mapping between a subscriber and the HSS, which decreases the network's processing capability and increases the network delay.

For these reasons, Diameter Routing Platforms are needed to solve the following challenges:

- Subscriber roaming
- Policy roaming
- Signalling interworking
- Message routing
- Networking of big-scale network

Under such circumstances, the LTE Diameter Exchange Service is developed as a DRA (Diameter Routing Agent), whose functions are similar to the STP in SS7 networks. The DRA evolves from the STP and serves as a Diameter signalling transfer platform, roaming border gateway or signalling service processing platform in the LTE/PCC/IMS network. As such it can solve the following:

- When serving as a uniform signalling routing and transferring device, the Diameter platform simplifies the structure of the LTE/PCC/IMS network, addresses and routes subscribers to the corresponding HSS and Online Charging System (OCS), and implements the load-sharing function.
- When serving as a signalling border gateway, the Diameter platform implements the functions of subscriber roaming, signalling exchange, message routing and network security management.

5. Developing LTE Roaming

In the described framework, Global Solutions can play a key role in LTE roaming, leveraging our IPX ecosystem strengths, including global reach, Quality of Service (QoS), security and the overall reliability of Telefonica's operators.

With our LTE Diameter Exchange Service we provide efficient technical and commercial Hubbing or Service Transit models via Diameter routing and relay/proxy capabilities. This approach reduces the number of signalling interconnections required and guarantees overall scalability.

Furthermore it makes the setup and maintenance of routing rules easier for LTE operators, thus speeding up implementation of the increasing number of 4G bilateral network agreements between Roaming Partners. In addition, we can provide signalling interworking if and when a MNO implements specific Diameter capabilities and/or different dialects.

Our LTE Diameter Exchange Service supports S6a, S6d and S9 interface defined by 3GPP and GSMA standards.

The service enablement and provisioning is executed on a per-roaming route basis. We provision the necessary hardware and software required by the Diameter Signalling Service to support LTE roaming signalling traffic.

Our Diameter Routing Platform includes, but is not limited to, the following features:

Diameter Relay Agent

To forward a Diameter message to a peer device, the DRA receives a Diameter message and queries the routing table based on the routing information in the message, such as the Dest-Realm, to obtain the peer device address and forwards the message to the peer device.

This service simplifies interworking between different network elements, improves network scalability and facilitates network maintenance.

Diameter Proxy Agent

The Diameter Proxy Agent enables the routing of Diameter messages based on the following information included in the Diameter messages:

- Origin-Realm
- Origin-Host
- Command-code
- International Mobile Subscriber Identity (IMSI)
- Mobile Station International ISDN Number (MSISDN)
- IP Multimedia Private Identity (IMPI)
- IP Multimedia Public Identity (IMPU)

The LTE Diameter Service supports signalling forwarding where multiple Home Subscriber Servers (HSS) and Policy and Charging Rules Functions (PCRFs) are deployed in an Evolved Packet Core (EPC) or Policy and Charging Control (PCC) network. This simplifies interworking between different network elements, improves network scalability, and facilitates configuration and maintenance of routing data for IMSI, MSISDN, IMPI, and IMPU.

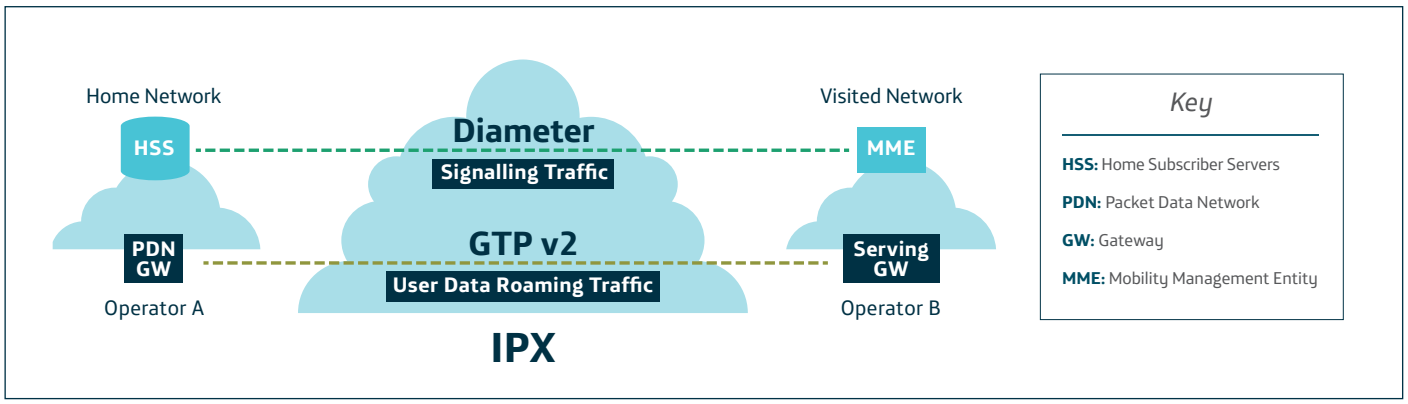
Diameter Basic Capability

This feature provides the following functions:

- Diameter connection establishment
- Capability negotiation
- Status management
- Diameter Attribute-Value Pair (AVP) coding/decoding

This allows interworking between different network elements in a Policy and Charging Control (PCC), Evolved Packet Core (EPC), or IP Multimedia Subsystem (IMS) network.

LTE Diameter Exchange



Diameter Routing

Diameter routing criteria includes, but is not limited to the following:

- Diameter Routing Based on Dest-Host
- Diameter Routing Based on Application ID and Dest-Realm
- Diameter Routing by Active/ Standby Mode
- Diameter Load-sharing by Polling Routing
- Diameter Routing Reselection
- Diameter Routing Based on Origin-Realm
- Diameter Routing Based on Origin-Host
- Diameter Load-sharing by Percentage
- Diameter Load-sharing by Priority

Transportation: Diameter over TCP

This service establishes a Diameter connection over Transmission Control Protocol (TCP) and offers TCP Multi-connection that enables the signalling service processing system to establish multiple Diameter connections over Transmission Control Protocol (TCP) with a peer device.

Transportation: Diameter over SCTP

Establishing a Diameter connection over Stream Control Transmission Protocol (SCTP) means it can be established over either SCTP or Transmission Control Protocol (TCP).

The SCTP Multi-Connection service enables the DRA to establish multiple Diameter connections with a peer device over Stream Control Transmission Protocol (SCTP).

SCTP Multi-Homing

SCTP Multi-Homing enables the use of multiple IP addresses to connect to a peer device; two Network Elements (NE) in a Stream Control Transmission Protocol (SCTP) association can be connected using multiple IP addresses. This ensures reliable end-to-end (E2E) multi-path transmission for the Diameter application layer.

Geographic Redundancy

We will deploy a pair of DRAs in different locations. The nodes can be connected to various Network Elements (NE) in order to construct a dual-plane network.

Overload Control

The Overload Control service enables automatic monitoring of the system load in real-time. It also facilitates overload control based on the status of system resources and the number of Diameter messages to be forwarded.

This service helps to prevent the solution and the network from being overloaded when the number of network messages increases abnormally.

Diameter Mediation

This functionality enables mediation between incompatible Diameter peers by modifying messages to a format that can be processed by peers. With the Diameter Mediation service, we can resolve the following incompatibility issues without changing Diameter peers:

- Equipment vendors have a unique understanding of the Diameter protocol and implement the protocol in different ways. When interfaces provided by different equipment vendors are used together, they may be incompatible with each other.
- The Diameter protocol may vary in different 3GPP releases. When Network Elements (NE) use different Diameter protocol releases, interfaces between the NEs may be incompatible.

Mediation operations vary among Diameter peers, their corresponding interfaces and message directions. The solution performs different mediation operations for the matched Diameter messages depending on the Diameter message's Application ID, Origin-Realm, Dest-Realm, Origin-Host, Dest-Host, Command Code and Message Type.

Diameter mediation operations include: Add AVP, Modify AVP, Remove AVP, Modify message header and Modify AVP header.

Security

Diameter Topology Hiding: enables the signalling service processing system to screen certain network configurations and topology structures, such as host names, realm names and number of network elements. It works when the Diameter nodes serve as the Diameter Edge Agent that is deployed as the EPC/PCC network gateway for interworking with other carriers' networks.

Diameter Signalling Screening: enables interception or specified Diameter messages to be displayed in order to ensure the security and reliability of the Diameter signalling network.

IPSec (Internet Protocol Security): with the IPSec service, the Diameter nodes can:

- Provide security for IP packets
- Protect against network attacks

Diameter platform supports the Authentication Header (AH) protocol and Encapsulation Security Protocol (ESP).

Hosted Diameter Edge Agent

We offer the option of a hosted DEA service to help operators expedite the process of launching LTE roaming services to their subscribers. It also reduces CAPEX and OPEX as a result of the provision of a dedicated customer virtual DEA.

6. LTE Roaming Case Studies

Telefonica is taking the lead in the LTE Roaming arena. Having successfully deployed two LTE Roaming technology pilot studies (detailed below), we also have customers already using the service.

1. Mobile World Congress 2014

Telefonica facilitated the first technological multi-operator 4G (LTE) Roaming experiment to offer roaming high-speed data services during 2014 Mobile World Congress. We opened up our 4G/LTE network to a large group of selected operators and technological partners from over 15 countries. Delegates from those operators – who came from the UAE, South Korea, Russia, the United States, Hong Kong, France, Portugal, Saudi Arabia and Italy, among others – as well as Telefonica operations that already have a commercial LTE service in place (United Kingdom, Germany, Brazil, Mexico and Colombia), for the first time, were able to enjoy roaming high-speed data services, simultaneously and without interruption. During the event, 3,600 Roaming-IN users were registered per day in the Telefonica-Spain network. One of the most important characteristics of this new technology was that it replicated the same 4G service quality level usually enjoyed in respective countries of origin.

This ground-breaking pilot demonstrates that Telefonica is at the forefront of LTE Roaming technology as we were the first operator to show we were ready to include roaming high-speed LTE services in our current extensive roaming coverage, which includes over 700 operators worldwide.

2. World Cup 2014

Following our successful multi-operator LTE Roaming demonstration at the 2014 Mobile World Congress, we played a leading role in the mobile customer experience of individuals attending the World Cup 2014 in Brazil. Our LTE Roaming service delivers the largest network of (Diameter) signalling routes, enabling mobile subscribers to seamlessly access their 4G applications over a fast and secure LTE network while they travel to international locations around the globe.

Mobile subscribers travelling to the World Cup were able to enjoy high-speed LTE data services as if on their home national network. During the event we reinforced the communication resources and tools that facilitate a better roaming customer experience, in collaboration with other companies within the Telefonica Group.

Using robots deployed in all venues and handset-based technologies, the solution produced a complete set of 3G and LTE measurements at key locations including stadiums, press centres, hotels, embassies and airports etc. As a result, international customers who travelled to Brazil benefited from a high quality service from our market leading Vivo network during the event.

7. Why Telefonica?

Our LTE Diameter Exchange Service is hosted on our own global IPX network, offering customers a unique set of basic features for optimum connectivity and routing of LTE signalling traffic:

- Inter-operability: Enables inter-operability amongst networks using different technologies.
- ROI: Increases ROI through quick market entry for international LTE reach, without initial heavy investment.
- Reduces CAPEX: Decreasing technical resources required to set-up/maintain bi-lateral connections.
- Reduces OPEX: Reducing commercial resources to set-up/maintain bi-lateral connections and through outsourcing operations and management functions.
- Global routes: We have points of presence all around the world which guarantees our customers the best connectivity conditions and means carriers can launch LTE services with global capillarity. We also have a robust presence in the Americas, representing a competitive advantage in this region.
- Service management and support 24x7: We understand that the effective, efficient and expeditious management of production issues and service requests is a major contributor to ongoing customer satisfaction. Staffed 24 hours, 7 days a week, our dedicated support team is comprised of highly qualified professionals who will serve as your primary first-level technical support group, the liaison between other support areas and the escalation contact for urgent matters.
- Availability of routes: The architecture of our network offers different routes to the final destination. It has minimum convergence with any contingency.
- Reports: Customers using our LTE Diameter Exchange Service have access via the web to statistical reports on the use of their links and network's indicators. The monitoring service portal provides real-time reports in terms of diameter transactions and service availability.
- Flexibility/Scalability: Service adapted to technological evolution.

For further information about LTE Diameter Exchange and our product portfolio, please visit our website **www.globalsolutions.telefonica.com/wholesale**

Glossary

2G	Second Generation
3G	Third Generation
3GPP	Third Generation Partnership Project
4G	Fourth Generation
AAA	Authentication Authorization and Accounting
AH	Authentication Header
AVP	Attribute-Value Pair
CAPEX	Capital Expenditure
DRA	Diameter Routing Agent
E2E	End-to-End
EPC	Evolved Packet Core
EPS	Evolved Packet System
ESP	Encapsulation Security Protocol
ETSI	European Telecommunications Standards Institute
E-UTRAN	Evolved UTRAN
GERAN	GSM EDGE Radio Access Network
GW	Gateway
H-PLMN	Home Public Land Mobile Network
HPMN	Home Public Mobile Network
HSS	Home Subscriber Servers
IETF	Internet Engineering Task Force
IMPI	IP Multimedia Private Identity
IMPU	IP Multimedia Public Identity
IMS	IP Multimedia Subsystem
IMSI	International Mobile Subscriber Identity
IP	Internet Protocol
IPSec	Internet Protocol Security
IPX	Internetwork Packet Exchange
LTE	Long Term Evolution
MME	Mobility Management Entity
MSISDN	Mobile Station International ISDN Number
NE	Network Element
NGN	Next Generation Network
OCS	Online Charging System
OPEX	Operating Expenditure
PCC	Policy and Charging Control
PCRF	Policy and Charging Rules Functions
PDN	Packet Data Network
PGW	PDN (Packet Data Network) Gateway
QoS	Quality of Service
ROI	Return On Investment
SAE	System Architecture Evolution (3GPP)
SCTP	Stream Control Transmission Protocol
SGW	Signalling Gateway
SLF	Subscription Locator Function
SS7	Signalling System No. 7
STP	Signal Transfer Point
TCP	Transmission Control Protocol
TPS	Transactions Per Second
UDP	User Datagram Protocol
UTRAN	Universal Mobile Telecommunications System Terrestrial Radio Access Network
V-PLMN	Visited Public Land Mobile Network
VPMN	Visited Public Mobile Network

About the GSMA

The GSMA represents the interests of mobile operators worldwide, uniting nearly 800 operators with more than 250 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and Internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces industry-leading events such as Mobile World Congress, Mobile World Congress Shanghai and the Mobile 360 Series conferences.

For more information, please visit www.gsma.com

About the i3forum

The i3forum brings together the communications expertise of more than 52 telecommunication providers. As a global industry association, i3forum is committed to helping the telecommunications industry transition its international bilateral voice to Internet Protocol (IP) by fostering a faster and more efficient migration.

For more information, please visit www.i3forum.org