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SCTP and Diameter Parameters for High Availability in LTE Roaming

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Master's Thesis

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Abstract

Today mobile network operators utilize IP Packet exchange (IPX) carriers to interconnect their networks with other operators. Mobile network operators are free to choose one IPX carrier for their data traffic and another for their control traffic. This thesis examines the case of control traffic, specifically Stream Control Transmission Protocol (SCTP) carrying Diameter protocol traffic arising from users roaming from their home Long Term Evolution (LTE) network to another operator's LTE network.

The thesis project aims to identify a set of SCTP parameter configurations that can provide improved application/service level availability between two Diameter nodes in different network connectivity environments, specifically for IPX carriers who are Diameter service providers. These service providers provide Diameter connectivity for their customers who are mobile network operators. These mobile network operators in turn provide LTE roaming services to their customers.

Unfortunately, applying the 'One size fits all' configuration recommendations given in the SCTP documentation is unsuitable for different network environments. In addition, the amount of Diameter signaling traffic is growing at a very rapid rate. Therefore, it is valuable to identify suitable parameter selection criteria for Diameter service providers to ensure 100% Diameter connectivity reliability for their customers. In this thesis project, author investigated how tuning SCTP parameter values affect Diameter message transmission in terms of Round Trip Delay and identified its determining parameters for packet loss recovery performance. Both IPX carriers and mobile network operators may use these values as reference when attempting to ensure high availability of Diameter transmissions under reliable, semi-reliable, and unreliable network transport conditions.

Keywords: *SCTP, Diameter, IPX, LTE Roaming, Seagull, RTD, RTO, Retransmission, DEA*

Sammanfattning

Mobilnätsoperatörer använder sig av IP Packet exchange (IPX) tjänstetillhandahållare för att koppla ihop sina nät med andra operatörers nät. Mobilnätsoperatörer kan fritt välja en IPX tjänstetillhandahållare för sin datatrafik och en annan för sin kontrolltrafik. Denna uppsats undersöker fallet för kontrolltrafik, specifikt Stream Control Transmission Protocol (SCTP) kommunikationsprotokoll för Diameter protocol-trafik vid användares roaming från sitt Long Term Evolution (LTE)-hemmanät till en annan operatörs LTE-nät.

Examensarbetet avser etablera en uppsättning av SCTP-parameterkonfigurationer som ger förbättrad applikations-/tjänstetillgänglighetsnivå mellan två Diameter-noder i olika nätmiljöer, särskilt för IPX tjänstetillhandahållare som är Diameter tjänstetillhandahållare. Dessa tjänstetillhandahållare erbjuder Diameter-konnektivitet till sina kunder, som är mobilnätsoperatörer. Dessa mobilnätsoperatörer tillhandahåller i sin tur LTE-roamingtjänster till sina kunder.

Tyvärr är det olämpligt att tillämpa de enhetliga konfigurationsrekommendationer, som ges i SCTP- och Diameter-protokollens dokumentation, i olika nätmiljöer. Samtidigt ökar Diameter-signaleringstrafiken mycket snabbt. Därför är det värdefullt att identifiera lämpliga parameterkriterier för Diameter-tjänstetillhandahållare att säkerställa 100% tillförlitlig Diameter-tillgänglighet för sina kunder. I detta examensarbete har författaren undersökt hur trimning av SCTP-parametervärden påverkar Diameter-meddelandeöverföring vad avser överföringstiden tur- och retur, och identifierat de avgörande parametrarna för återställande av paketförluster. Både IPX tjänstetillhandahållare och mobilnätsoperatörer kan använda dessa värden som referens för att åstadkomma hög tillgänglighet för Diameter-överföring vid tillförlitliga, halvtillförlitliga och otillförlitliga nättransportförutsättningar.

Nyckelord: *SCTP, Diameter, IPX, LTE roaming, Seagull, RTD, RTO, omsändning, DEA*

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List of acronyms and abbreviations

2G	2nd Generation
3GPP	3rd Generation Partnership Project
4G	4th Generation
AAA	Authentication, Authorization, and Accounting
AIR	Authentication Information Request
APN	Access Point Name
A_rwnd	Advertised Receiver Window Credit
AVP	Attribute Value Pair
CapEx	capital expenditure
CEA	Capabilities-Exchange-Answer
CER	Capabilities-Exchange-Request
DEA	Diameter Edge Agent
DNS	Domain Name Service
DoS	Denial-of- Service
DPA	Disconnection-Peer-Answer
DPR	Disconnection-Peer-Request
DRA	Diameter Routing Agent
DTLS	Datagram Transport Layer Security
DWA	Device-Watchdog-Answer
DWR	Device-Watchdog-Request
EIR	Equipment Identity Register
eNB	eNodeB
EPC	Evolved Packet Core
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
EU-APAC	European Union to/from Asia Pacific
FDD	Frequency Division Duplex
FQDN	Fully Qualified Domain Name
GRX	GPRS roaming exchange service
GSM	Global System for Mobile Communications
GTPv2-C	GPRS Tunnel Protocol - Control Plane
HD	High Definition
HLR	Home Location Register
HOL	head-of-the-line
HSS	Home Subscriber Server
ICT	Information and Communication Technology
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPI	IP Interconnecting
IPX	IP Packet exchange
LTE	Longer Term Evolution
MAC	Message Authentication Code
MAP	Mobile Application Part
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
MMS	Multimedia messaging service
MNO	Mobile Network Operator
MTU	Maximum Transmission Unit
NAI	Network Access Identifier
NAPTR	Name Authority Pointer

PDN	Packet Data Network
PCRF	Policy and Charging Rules Function
PLMN	Public Land Mobile Network
PMTU	The Current Know Path MTU
PPID	payload protocol identifier
QoE	Quality of Experience
QoS	Quality of Service
RCS	Rich Communication Service
RFC	Request for Comments
RTD	Round Trip Delay
RTO	Retransmission Timeout
RTT	Round-trip Time
RTTVAR	Round-trip Time Variation
SCTP	Stream Control Transmission Protocol
SLP	Service Location Protocol
SRTT	Smoothed Roud-trip Time
SRV	(DNS) service record
SS7	Signaling System No.7
STP	Signal Transfer Point
TCB	Transmission Control Block
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TLS	Transport Layer Security
TTL	time to live
TTI	Transmission Time Interval
UE	User Equipment
UDP	User Data Protocol
UMTS	Universal Mobile Telecommunication System
VLR	Visitor Location Register
WWW	World Wide Web

1 Introduction

This chapter describes the specific problem that this thesis addresses, the context of the problem, the goals of this thesis project, and outlines the structure of the thesis.

1.1 Background

With the penetration of the 3rd Generation Partnership Project (3GPP) Long-Term Evolution (LTE) as the 4th generation (4G) of mobile network systems worldwide, mobile users experience high data rates and low latency radio access. This experience has contributed to the rapid increase in mobile data consumption and the development of new IP-based applications. Mobile consumers not only expect instant seamless high-speed access and high quality data experiences everywhere in their home mobile network, but also when they roam to geographic locations covered by another mobile operator's network. Industry observers expect that both the amount of IP traffic and the number of LTE connections will continue to grow. The increase in numbers of mobile subscribers and compelling services will generate additional Diameter protocol signaling traffic over the network between network elements in a LTE network's Evolved Packet Core (EPC). Oracle Communications' white paper 'LTE Diameter Signaling Index[1]' predicts that the rate of LTE Diameter Signaling traffic growth will outpace the rate of mobile data traffic growth by more than a factor of two (see Figure 1-1).

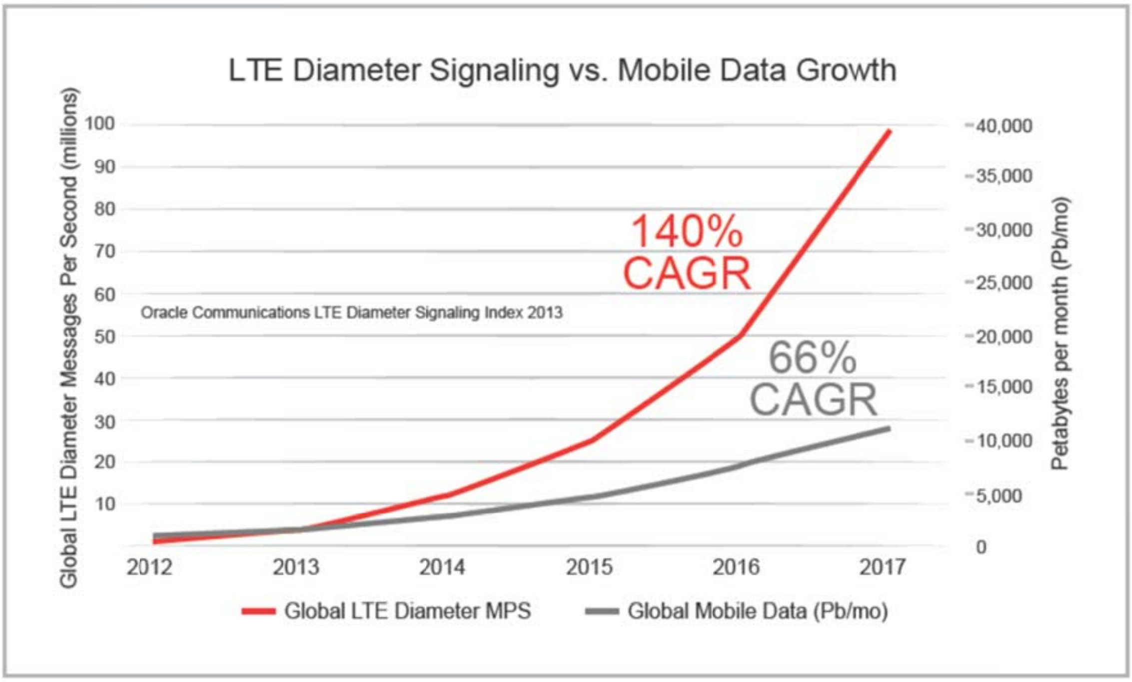

Figure 1-1: LTE Diameter Signaling vs. Mobile Data Growth [1]

Due to network, subscriber, and service growth and evolution, industry professionals expect Diameter traffic growth to continue steadily over the next several years as both implementation and roles of Diameter expand in LTE networks [1]. From the service providers' perspective, although a rigorous definition of a key performance indicator (KPI) for Diameter Signaling service has not been addressed by standardization bodies [2], maintaining robust Diameter connectivity availability is crucial to ensure Quality of Service

(QoS) and Quality of Experience (QoE) for their Diameter Signaling service. Therefore, understanding how to ensure service providers with the highest reliability of Diameter messages transmission is worth investigating.

To ensure reliable Diameter message transmission, the Stream Control Transmission Protocol (SCTP) [3] must to be studied, since it is the preferred transport protocol used by Diameter to transport messages. SCTP is a transport protocol developed by the Internet Engineering Task Force (IETF) SIGTRAN working group [4] for providing reliable and timely delivery of SS7 (Signaling System No.7 [5]) signaling information on top of IP. SCTP is much preferred to transfer Diameter messages compared to TCP, because SCTP is message oriented and has two new key features: multi-homing and multi-streaming. With its multi-homing feature, SCTP provides higher reliability due to its failover mechanism as communication automatically switches over to an alternate communication path if the primary path fails. Its multi-streaming capability allows the transfer of several independent message sequences within a single connection, which improves transmission efficiency.

The parameter configuration values of SCTP and Diameter are usually based on commonly used values that have been given in various public documents. IETF's Request For Comments (RFC) 4960 [3] section 15 recommends a generic value for SCTP Parameters (shown in Table 1-1). With regard to Diameter Transport Parameters, RFC 6733 [6] section 12 specifies a number of configurable parameters for the Diameter protocol (shown in Table 1-2). Whether these values achieve optimal Diameter messages transmission performance in various network circumstances is currently unknown, but this question will be the focus of this thesis project.

Table 1-1: SCTP Parameters set as recommended in IETF RFC 4960 [3]

Parameter	Value
RTO.Initial	3 seconds
RTO.Min	1 second
RTO.Max	60 seconds
Max.Burst	4
RTO.Alpha	1/8
RTO.Beta	1/4
Valid.Cookie.Life	60 seconds
Association.Max.Retrans	10 attempts
Path.Max.Retrans	5 attempts (per destination address)
Max.Init.Retransmits	8 attempts
HB.interval	30 seconds
HB.Max.Burst	1

Table 1-2: Diameter Transport Parameters defined in IETF RFC 6733 [6]

Diameter Peer	requires the configuration of either an IP address or the fully qualified domain name
Realm Routing Table	a table of REALM Names and the address of the peer to which the message must be forwarded
Tc timer	controls the frequency that transport connection attempts are made to a peer with whom no active transport connections exists. The recommended value is 30 seconds.

Many studies (as described in Section 2.4) have shown that the management of SCTP's retransmission timer is **not** suitable for transmitting thin traffic streams*, such as signaling traffic. Because SCTP has **not** been optimized for thin streams, when loss occurs - packets are *not* retransmitted rapidly enough. When data is sent in thin streams and needs to be retransmitted, the feedback from the receivers are infrequent which leads to high delays [8]. Fallon, et al. [9] revealed that the default SCTP mechanism for calculating Retransmission Timeout (RTO) values is unsuitable in a WLAN environment, because the increase of the Round Trip Times (RTT) in WLAN should be interpreted as network degradation and an imminent path failure, hence failover should occur in timely manner. However, this default mechanism leads to an *increase* in RTO; consequently delaying the time for the failover! With the default parameter values, the failover process took a long time (up to 187 seconds) in their WLAN test environment. It is worth noting that increasing the bandwidth of a link may be insufficient to improve network latency. However, eliminating time-outs and retransmissions can reduce excessive latency bottlenecks along the packets' path and eventually reduces network latency [10].

A conclusion is that the 'One size for all' configuration recommendations should **not** be blindly applied in different network environments when attempting to maintain 100% Diameter connection reliability. However, there remains a question: Is there an optimal set of SCTP & DIAMETER configuration parameters for service providers that ensure high reliability of Diameter transmissions under different network transport conditions?

1.2 Problem definition

There has been substantial research in general on SCTP's performance and reliability when transferring thin traffic (signaling messages) and thick traffic, various SCTP packet tools exist to generate SCTP traffic for tests. However, few works have evaluated the transmission performance of traffic generated by SCTP's upper layer protocols. At present, no published papers have evaluated an optimal SCTP parameter configuration for transferring Diameter traffic. The result is a research gap for this specific subject. With the increased usage of Diameter and the growth of Diameter signaling traffic in mobile networks worldwide, it is worth evaluating the transmission performance of Diameter signaling messages in SCTP. This is especially true as many previous research works have shown that the default SCTP protocol parameter values do not provide satisfactory performance when transferring thin traffic (more details can be found in Section 2.4). This research gap and the obvious need for providing better configurations of both protocols motivated the author to research optimal SCTP protocol configuration parameter settings, when transferring Diameter messages between Diameter nodes.

* Andreas Petlund, et al. define thin streams as "high interarrival-time between packets and with small payloads in each packet"[7].

The author of this thesis believes that there should be a set of optimal SCTP parameter configuration values for each type of network scenario when transferring Diameter messages between two nodes and that these values are different from the default values recommended in IETF RFC 4960 [3].

To verify this hypothesis, three generic network environments are considered (summarized later in Table 1-3):

1. Reliable network with low network latency (e.g., a national network environment),
2. Semi-reliable network with medium latency (e.g., an intra-continent network, for example, inside continental European Union/EU region), and
3. An unreliable network with high latency and long geographic distance (e.g., intercontinental networks, for example European Union to/from Asia Pacific (EU-APAC) connection).

The latency mentioned in the environments above refers to the bidirectional network latency, i.e., the delay introduced by the network from the time of the start of packet transmission at the sender to the time of receiving the acknowledgement of the original packet's receipt at the receiver.

1.3 Goals

The goals of this thesis project are:

1. Summarize previous research results to learn theoretical SCTP protocol parameter configuration values that provide improved transmission performance;
2. Test and evaluate Diameter message transmission performance with the theoretically optimal SCTP parameter values in the three different network scenarios, shown in Table 1-3.; and
3. To identify a set of determining SCTP parameters values that affect DIAMETER messages transmission reliability in each network scenario in Table 1-3.

Table 1-3: Three network scenarios to be evaluated in this thesis project

Scenario 1	**Reliable** network transport with *low latency*
Scenario 2	**Semi-reliable** network transport with *medium latency*
Scenario 3	**Unreliable** network transport with *high latency*

1.4 Purpose

The purpose of this thesis project is to evaluate how tuning SCTP parameter values affect Diameter protocol's message transmission reliability between two Diameter peers in the three different network scenarios listed in Table 1-3 and to identify a set of determining SCTP parameters that can be modified to provide improved packet loss recovery performance. These three scenarios are attempts to consider delays due to different geographic distances, packet loss probabilities, and delay. Laboratory tests will be conducted to evaluate our theoretically optimal parameter set in comparison with those reference values recommended in Table 1-1.

The investigation's results would have a direct benefit for Diameter service users and providers (for example, Mobile Network Operators (MNOs) and Internet Protocol (IP) Packet exchange (IPX) carriers) who want to ensure the reliability of their Diameter services, as the proposed parameter sets could serve as a configuration reference for optimal Diameter service connectivity (with respect to reliability).

1.5 Research Methodology

In order to achieve the goals of this thesis project, both qualitative and quantitative research methods were utilized. The literature study (which formed the basis for Chapter 2) provided essential background knowledge regarding the SCTP and Diameter protocols. Secondary research was used as a qualitative method to retrieve existent knowledge from previous work on tuning SCTP parameter values to achieve better transmission performance in order to derive a set of theoretical parameter values to be used for empirical tests.

A set of test cases were defined based on the literature study. These test cases were used to conduct quantitative research in a laboratory environment set up by author's employer (an IPX provider - TeliaSonera International Carrier [11]) to validate whether the modified SCTP parameter values provide better transmission performance when transferring Diameter messages. Based on an analysis of the results of these laboratory tests, a more optimal set of SCTP and Diameter protocol parameter values were proposed for each of the network scenarios described in Table 1-3.

1.6 Structure of the thesis

Chapter 2 presents relevant background information about SCTP & Diameter protocols as well as relevant background information concerning LTE, IPX and 4G roaming. Additionally, the Chapter 2 presents related research work. Chapter 3 presents the methodology and method used to solve the problem. Chapter 4 describes the tests conducted in the laboratory environment. Chapter 5 presents the analysis and results of the practical experiments. The final chapter concludes this thesis project and describes some suggested future work.

2 Background

In order for readers to comprehend and take advantage of this thesis, this chapter provides a concise and essential technical background for the technologies that are relevant to this project. The chapter starts with a description of SCTP and focuses on the transmission process, since SCTP provides the base transport protocol for Diameter messages. Next, the Diameter protocol is studied. The third section introduces LTE roaming, since LTE roaming is an important deployment of the Diameter protocol for both MNOs and IPX carriers. Additionally, this chapter describes related work with regard to SCTP transmission performance.

2.1 SCTP

This section introduces the basic knowledge that is required to understand SCTP, and the experiments conducted in this project as well as the discussions of the experiment results. This section introduces the most relevant configurable SCTP parameters and their functions; how SCTP establishes and disconnects associations between two endpoints; as well as the mechanism SCTP utilizes to calculate RTO.

2.1.1 Protocol Overview

As the creators of SCTP wrote in their book "*Stream Control Transmission Protocol (SCTP): A Reference Guide*"[12], 'SCTP was originally designed for Internet telephony, used as a transport protocol for IP network data communications.' It is more robust and secure than the Transmission Control Protocol (TCP). The invention of SCTP was motivated by the need to transport telecommunication signaling messages securely over an IP-based network, so that signaling messages are exchanged over a common packet-switched network instead of the legacy SS7 signaling network system. SCTP is used as the transport protocol for Diameter Protocol [6].

SCTP is a reliable transport layer protocol that combines the best features of TCP and User Data Protocol (UDP) transport layer protocol that runs on top of IP. SCTP is similar to TCP, as both are connection-oriented, use a checksum, (Transmission) Sequence Number (TSN), and flow and congestion control to ensure reliable transmission. SCTP's flow and congestion control is based on that of TCP, with the slow start and congestion avoidance mechanisms inherited almost directly from TCP. Furthermore, the timeout and fast retransmit mechanisms used for packet loss recovery were also inherited from TCP [13]. However, unlike TCP, which is byte-oriented, SCTP is message-oriented. This means that SCTP sends a sequence of messages within a stream, while TCP sends data as a single stream of bytes.

Two distinguishing features of SCTP are multi-homing and multi-streaming capability. Multi-homing allows a SCTP node to use multiple source and destination IP addresses within a single SCTP association. This allows a SCTP node to establish multiple paths to the same corresponding node. Among these established paths, one path is selected as a primary path, while the others act as backup paths. In the event of path failure or transmission quality degradation, this feature can provide SCTP with higher reliability by switching to a backup path that provides better connectivity. Another feature is multi-streaming. Unlike TCP, which sends data in a single stream and in the case of packet loss must delay delivery of data until the lost bytes are retransmitted. SCTP's multi-streaming capability allows several separate messages to be sent via different streams within an association; hence, a packet loss within one stream does not affect the delivery of messages via other streams. A stream in SCTP is an unidirectional channel within an association [3]. This feature improves transmission efficiency and avoids head of line blocking.

2.1.2 Key Terminology

The key terms and their definitions used in SCTP are listed in Table 2-1 in order to make it more convenient for readers to comprehend the subsequent sections regarding SCTP. The explanation of the terms are sourced from IETF RFC4960 [3]

Table 2-1: SCTP terminology used in this thesis

Association	A SCTP association refers to a protocol relationship between SCTP endpoints. Only one multi-homed association may be established between any two SCTP endpoints; however, one endpoint may have multiple single-homed associations.
SCTP endpoint	A SCTP endpoint is the logical sender/receiver of SCTP packets. An SCTP endpoint may have **more** than one IP address, but it always has one and only one port number for each association. In the case of multi-homing, an endpoint can use multiple IP addresses, but all of them use the same port number.
Stream	A stream is a unidirectional logical channel established from one SCTP endpoint to another associated SCTP endpoint.
Message	A user message is the data submitted to SCTP by an upper layer protocol.
Multi-streaming	Multi-streaming allows data to be partitioned into multiple streams. Within each stream, data is sent sequentially, but the streams are independent of each other. Message loss in one stream will not affect other streams. This makes it possible to continue sending messages via unaffected streams, while the receiver buffers messages in the affected stream until retransmission occurs.
Multi-homing	Multi-homing exploits the ability of an association to support multiple IP addresses or interfaces at a given endpoint. This provides better survivability of the session in the event of network failures.
Multi-homed	A SCTP endpoint is considered multi-homed if more than one transport addresses can be used as a destination address to reach that endpoint.
Stream Sequence Number	SCTP uses 16 bit stream sequence numbers to ensure sequenced delivery of user messages within a given stream.

Round Trip Time (RTT) / Round Trip Delay (RTD)	The RTT is the time between sending a packet and receiving an acknowledgment from the receiver.
Retransmission Timer	The retransmission timer is used to trigger retransmssion.
Retransmission Timeout (RTO)	RTO is the period of time before a lost packet is retransmitted.
Transmission Sequence Number (TSN)	TSN is the sequence number for transmitted DATA chunks.

2.1.3 Relevant SCTP Configurable Parameters

Since this thesis project evaluates how different SCTP Parameter values affect the transmission performance of Diameter Protocol messages, it is important to understand what the parameters are, as well as what functionalities they serve. IETF RFC4960 [3] defines several different SCTP parameters. Section 13 of [3] describes the necessary parameters for SCTP instance and association, as well as address parameters, INIT, and INIT-ACK parameters.

In this section of this thesis, we look only at the most important parameters mentioned in Table 1-1 and explain the functionally of each parameter. In later chapters, the author will modify some of these parameters values based on previous related research work, and then evaluate how the modified values affect Diameter message transmission.

Table 2-2 SCTP parameters relevant to this thesis (With the default values from RFC4960 [3] section 15)

RTO.Initial	Before the RTT of an association is calculated, SCTP sets RTO to the value of RTO.Initial. The default value is 3 seconds.
RTO.Min	RTO.Min defines the minimum value of RTO, thus SCTP will set RTO to this value if the calculated RTT is less than this value. By default, its value is 1 second.
RTO.Max	RTO.Max defines the maximum value of RTO, which means that SCTP will set RTO to this value if the calculated RTT is larger than this value. After this timeout, retransmission will be triggered. By default, RTO.Max is 60 second.
RTO.Alpha	α is a parameter used to determine how fast we forget the past, the default value is 1/8.
RTO.Belta	β is a parameter that determines how much the previous transmission can influence the current RTO calculation. The default value is ¼.
Association Max.Retrans	Association Max.Retrans defines how many retransmission attempts a SCTP node should attempt before giving up this association. The default value is 10 attempts.

Path.Max. Retrans	It defines how many retransmission attempts a SCTP node should attempt before giving up on the path The default value is 5 attempts.
Max.Init.Retransmits	It defines how many times a SCTP endpoint should retransmit INIT packet before it aborts the association initialization. The default value is 8 times.
HB.interval	It defines the interval time of sending HEARTBEAT message. The default value is 30 seconds.
HB.Max.Burst	As written in RFC4960 section 15, the HB.Max.Burst value is 'the number of HEARTBEAT sent at each RTO'. The default value is 1.
Max.Burst	The Max.Burst parameter is used to limit the number of packets sent. The default value is 4.

2.1.4 Establishing a SCTP Association

As RFC 4960 [3] describes, an SCTP endpoint may have multiple associations, but only one association can be established between two SCTP endpoints and the user messages are sent within each association. Once an SCTP association is established, the user messages will be sent within a stream or multiple streams between the two end points, depending on whether multi-streaming is enabled or not. It is necessary to understand the process of association establishment between two SCTP endpoints.

Unlike TCP, SCTP uses a four-way handshake to set up an association, while TCP uses a three-way handshake. RFC 4960 [3] section 11.2.4 explains that the four-way initialization handshake mechanism is designed to improve the protocol's security, by making it resistant to blind masquerade attacks that generate a large number of forged setup requests from a impersonated SCTP node.

Figure 2-1 illustrates the process of establishing an association between two SCTP endpoints A and B. A brief description of the initialization process is presented in the following paragraphs.

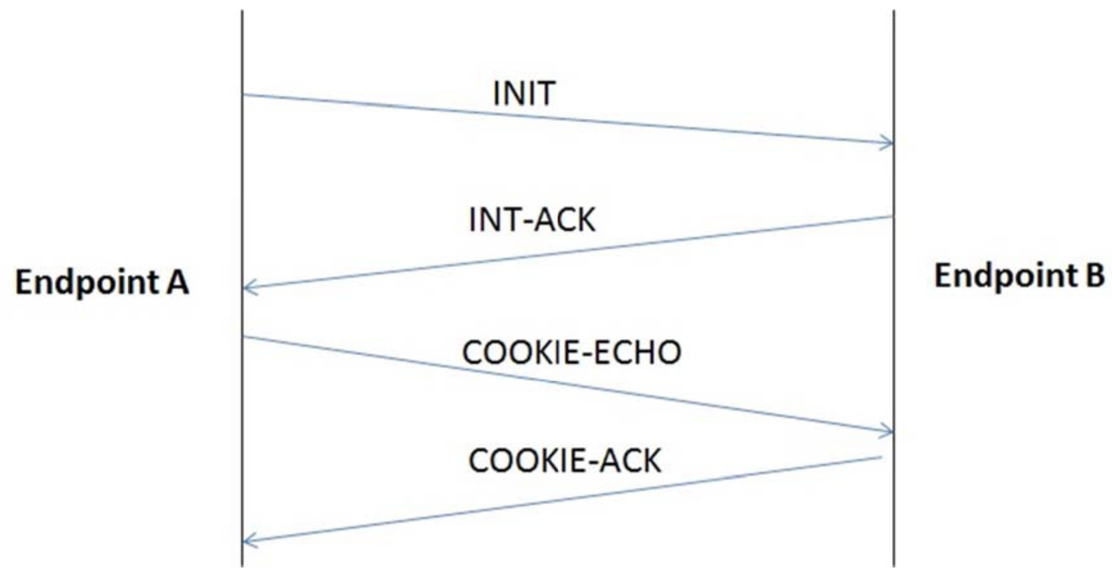

Figure 2-1: SCTP 4-way Initialization handshakes

- Step 1: Endpoint A sends an INIT chunk to "B", and starts its timer.
- Step 2: if INIT message was successful delivered to Endpoint B, it responds with an INIT ACK chunk.
- Step 3: Once A receives the INIT ACK from B, it stops the *timer for INIT* and sends COOKIE ECHO chunk to B, in the meantime, the timer for this COOKIE chunk is also started.
- Step 4: When B receives the COOKIE ECHO chunk, it replies with a COOKIE ACK.
- Step 5: Upon receiving the COOKIE ACK, A is notified that the association is now established and will stop the cookie timer and inform its upper layer protocol about the successful establishment of an association with Endpoint B. Data transmission can begin.

If an endpoint receives an INIT, INIT ACK, or COOKIE ECHO chunk, but decides *not* to establish a new association, it can respond with an ABORT chunk to terminate the association [3].

If Endpoint A does not receive ACK before its timer expires, it will retransmit the INIT packet. The value of the INIT timer is set to the value of **RTO.initial**. If the times of retransmission attempts exceed the value of **Max.Init.Retransmits,** then Endpoint A will terminate this initialization. This is the reason why some of our tests that will be introduced Section 4.2 could not establish SCTP association successfully when the sender did not receive an ACK before the INIT timer expires.

2.1.5 Data Transmission

Once the association is established, data transmission can start. As mentioned earlier, SCTP's multi-streaming feature can increase message transmission efficiency. In SCTP, another approach to improving transmission efficiency is to bundle small user messages into a large message before transmitting to the receiver. Since this thesis project focuses on transmission reliability and retransmission, we will *not* discuss the bundling feature and multi-steaming further. More details can be found in [3].

2.1.5.1 SACK

Once a SCTP endpoint receives a DATA chunk, it must respond with a Selective Acknowledgment (SACK) to acknowledge the receipt of the DATA chunk. SCTP uses SACK to ensure the delivery of packets and retransmission lost packets. This section introduces SACK, as it will be useful for readers when examining the captured packets from the experimental tests conducted in this thesis project and will enable these readers to comprehend how retransmission affects the calculation of RTD. The following paragraphs introduce SACK.

In SCTP, Selective Acknowledgement is used instead of the cumulative acknowledgment [14] which TCP uses. The advantage of SACK, as stated in [15, p. 1], is that since the SCTP receiver informs the sender of all successfully received packets, the sender only needs to resend lost packets, hence reducing the unnecessary retransmission of packets by the sender. When an SCTP endpoint transmits a packet to its peer, it needs to wait for a period of time for an acknowledgement. RFC 4960 [3] defines that the maximum time that a SCTP receiver should wait to acknowledge a received packet is 500 ms. If the ACK does not arrive at the sender within the expected period of time, then the packet is assumed to have been lost and the data needs to be retransmitted. When a receiver notices that a packet is missing, it sends a duplicate acknowledgment packet for the preceding packet, and attaches a SACK option indicating that the packets following the missing packet have been received, thus that sender only needs to retransmit the packet(s) that were *not* received by the receiver.

2.1.5.2 Retransmission

SCTP supports two ways of detecting packet loss and retransmission of the lost packets: fast retransmit and retransmission timeout. To use fast retransmit, an SCTP endpoint waits for four consecutive duplicate ACK from its peer before starting retransmission. In general, fast retransmit detects packet loss more quickly than retransmission timeout [16]. However, it does not work well for small amounts of data traffic, such as signaling traffic, since according to Petlund, et al. [17], signaling traffic often consists of small bursts of messages with long interval of time between the bursts, thus it can take much longer before the sender receives 4 SACKs to trigger fast retransmit.

Another approach to detect packet loss and thus to trigger retransmission is to use an RTO timer, as the expiration of the RTO timer will trigger a retransmission. The mechanism of calculating RTO in SCTP follows the same approach as in TCP [18]. Since this thesis project investigates transmission reliability of Diameter messages over SCTP, it is worth understanding in detail how RTO is calculated in SCTP.

The calculation of RTO is based on RTT measurements. Ideally, RTT should be constant; if so, then the RTO should be equal to RTT. However, network conditions vary, due to difference in geographic distance, network setup, and the fact that the different network elements are different in LAN, inter-continent, and intra-continent network environments. Therefore, it is very unlikely that RTT will be the same for the delivery of every packet between sender and receiver. As a result, RTO is **not** the same as RTT; hence some additional calculations need to be considered. SCTP introduces two state variables: Smoothed Round-trip Time (SRTT) and Round-trip Time Variation (RTTVAR) into the calculation mechanism. Each time a new RTT measurement is made, these two values are updated [3].

Based on RFC 4960 [3] section 6.3 and [19], the algorithm to calculate RTO is summarized and described as:

- If no RTT measurement has been made, then set RTO = **RTO.Intial** (by default 3 seconds[*])
- When the first RTT measurement R has been made:
  1. Set SRTT=R,
  2. Set RTTVAR=R/2, and
  3. Set RTO=SRTT + 4*RTTVAR.
- When a new RTT measurement R´ has been made:
  1. Set RTTVAR =(1- β[†])*RTTVAR+ β*|SRTT-R´|
  2. Set SRTT=(1- α[‡])*SRTT+ α*R´

[*] According to Table 1-1.
[†] β is a parameter that determines how much the previous transmission influences the current calculation. The default value is ¼.
[‡] *α* is a parameter used to determine how quickly we forget the past. The default value is 1/8.

3. Set RTO=SRTT+4*RTTVAR

- If RTO is less than **RTO.Min** (by default 1 second*), then set RTO=1 Second.
- If the RTO is greater than **RTO.Max** (by default 60 seconds†), then set RTO=60 seconds.
- Every time a transmission timeout occurs for an address, the RTO for this address will be doubled, thus RTO = 2 * RTO.

- Retransmit the missing packet.

RTO is an important parameter for transmission and stability of the protocol; hence, a lot of research has been done concerning SCTP's retransmission behavior. Section 2.4 presents and summarizes this related work.

2.1.5.3 Failover

One SCTP feature worth discussing in detail is multi-homing. If a number of retransmission attempts fail on the primary path, then SCTP attempts to use a secondary path via its multi-homing feature, i.e., it performs a **failover**. The number of retransmission attempts on each path is configured by the **Path.Max.Retrans** parameter. If the number of retransmission attempts exceeds the **Path.Max.Retrans** parameter (with a default value of 5 attempts), then the address will be marked as **inactive** by the sender and the failover process starts. By default, SCTP needs 6 consecutive retransmission timeouts, thus a failover takes about 30-60 seconds with the standard settings [20]. Note: if **Path.Max.Retrans** =0, then SCTP switches to a secondary path after a single timeout.

When the primary path between two SCTP endpoints fails, a backup path will be selected as the new primary path for transmitting subsequent packets. SCTP uses HEARTBEAT packets to probe the reachability of each destination address. If the sender does not receive HEARTBEAT ACK within it configured time, then this destination address is regarded as unreachable. If the sender receives a HEARTBEAT ACK within it configured time, then the path to this address will be considered available. If no data chunks have been sent to a destination address within the heartbeat interval, then the address is marked 'idle'. If the SCTP sender does not receive a response for a sent data chunk from the intended receiver within RTO, then the sender will consider this data chunk lost and retransmission occurs.

2.1.6 Closing an Association

According to RFC 4960[3], an association can be terminated by either an abort or a shutdown. The difference between these is that an abort is abortive, while a shutdown of an association is considered a graceful close of the association with its peer.

2.2 Diameter Protocol

This section gives a brief introduction of the Diameter Protocol, since this thesis mainly focuses on its underlying transport layer protocol's parameters and transmission

* According to the default parameter value in Table 1-1.
† According to the default parameter value in Table 1-1.

performance. The contents of this section are mainly based upon published documents from the IETF, 3rd Generation Partnership Project (3GPP), and GSM Association (GSMA). Additionally, some white papers from Diameter product & service vendors were used as references. For more detailed information about the Diameter Protocol, readers are referred to IETF RFC6377 [6] , especially as regards the message transport and configuration parts of Diameter.

2.2.1 Protocol Overview

As per IETF RFC 6377 [6], the Diameter protocol is designed to "provide an Authentication, Authorization, and Accounting (AAA) framework for applications, such as network access or IP mobility in both local and roaming situations". This protocol was initially developed in 1998 to provide a framework for AAA that could overcome limitations of the RADIUS [21]protocol, so as to deal more effectively with remote access, IP mobility, and policy control between clients and servers. Unlike RADIUS, TCP and SCTP were selected as the alternatives for the underlying transport layer protocol, rather than UDP. Diameter is a peer-to-peer protocol, since it exchanges messages between peers. In LTE roaming, the Diameter protocol is used for signaling messages.

2.2.2 Terminology

Understanding the Diameter terminology and the relations between these terms is fundamental and necessary to understand the remainder of this thesis. This is especially true with regard to understanding the details of the message transport and LTE roaming process described later in this thesis. Table 2-3 gives a summary of this terminology.

Table 2-3: Diameter terminology used in this thesis

Diameter Node	A host that implements the Diameter protocol.
Diameter Client	A node that supports Diameter client applications and the Diameter protocol. The client generates Diameter request messages.
Diameter Agent	A node/device that performs Diameter messages relaying, proxying, redirection, and/or routing functions, but does **not** provide AAA services for a user.
Diameter Server	A Diameter server performs AAA operations. In this thesis, Diameter Server is used to respond to a Diameter Request Message from a Diameter Client.
Attribute Value Pair (AVP)	An AVP is composed of a header and data.
Diameter Edge Agent (DEA)	The DEA is the only point of contact into and out of an operator's network at the Diameter application level.
Diameter Routing Agent (DRA)	A DRA provides real-time routing capabilities for Diameter nodes.

2.2.3 Diameter Message

According to IETF RFC 6377 [6], a Diameter message contains a Diameter header and AVPs. The AVPs of interest in this thesis carry specific authentication, accounting, authorization, and routing information; as well as configuration details for the request and reply. An AVP in turn includes a header and encapsulates protocol-specific data. Figure 2-2 below shows the structure of a Diameter message. For additional details of each of the fields in the message, the reader is referred to [6].

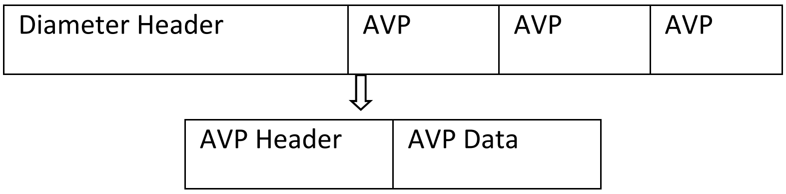

Figure 2-2: Diameter Message [6]

2.2.4 Transport

As mentioned earlier in this thesis, the Diameter protocol can uses TCP or SCTP as its transport layer protocol. RFC 4960 [3]recommends that Diameter use SCTP, rather than TCP, due to the advantages of SCTP as described in Section 2.1.1. In Diameter, transport is application-driven rather than network-driven, thus the transmission rate is limited by how fast a Diameter application can generate messages, rather than by the size of the congestion window [28].

One important Diameter parameter is *Tc Timer*. This timer determines the frequency of attempting to connect when no transport connections/associations exist to a peer. According to RFC 6733 [6], its recommended value is 30 seconds. In this project's experimental tests, we will use the default *Tc timer* value.

2.2.5 Related Configurable Parameters

RFC 6733 [6] section 12 specifies the configurable parameters in the Diameter protocol. These parameters are summarized in Table 2-4. In this thesis project, we configure only the IP addresses of Diameter peers in order to establish connectivity and will not make any changes in the routing table or default Tc timer value, since the lab network is intended to test the SCTP transmissions between two peers. For this reason, no other Diameter Relay or Routing agents are involved, and the focus is on modifying SCTP's parameter values. As a result we will keep the configuration as simple as possible.

Table 2-4: Diameter configurable parameters (quoted from [6] section 12)

Diameter Peer	A Diameter entity **may** communicate with peers that are statically configured. A statically configured Diameter peer requires that either an IP address or a fully qualified domain name (FQDN) be supplied (the latter would be resolved to an IP address via a DNS query).
Routing Table	A Diameter proxy server routes messages based on the realm portion of a NAI. The server **must** have a table of Realm Names, and the address of the peer to which the message must be forwarded. The routing table **may** also include a "default route", typically used for all messages that cannot be locally processed.
Tc timer	The Tc timer controls the frequency that transport connection attempts are made to a peer with whom no active transport connection exists. The recommended value is 30 seconds.

2.3 LTE Roaming

The advent of 3GPP's Longer Term Evolution (LTE) and the 4th generation (4G) cellular systems has brought much higher data transmission rates, hence mobile consumers expect instant seamless high-speed access and high quality data experiences everywhere, even when they roam to geographic locations covered by another mobile operator's network. Supporting 4G roaming is an essential element of mobile operators' business; hence, this roaming must be supported by the appropriate network capacity developments and business strategy. Diameter message transport plays an important role in the LTE roaming process. In this section, we will provide a brief summary of the fundamentals of LTE, Roaming, and IPX.

2.3.1 LTE

LTE is commonly referred as a 4G system. LTE evolved from the earlier 3GPP 3G system called Universal Mobile Telecommunication System (UMTS), which in turn evolved from the 2G system called Global System for Mobile Communications (GSM). Some facts about LTE, summarized from[22], are:

- LTE provides higher data rates than the earlier UMTS networks: 3 Gbps peak downlink and 1.5 Gbps peak uplink.
- LTE uses both Time Division Duplex (TDD) and Frequency Division Duplex (FDD) mode.
- LTE supports flexible carrier bandwidths, from 1.4 MHz up to 20 MHz as well as both FDD and TDD.
- All interfaces between network nodes from backhaul to radio base stations in LTE are IP based.
- LTE supports seamless connection to earlier cellular networks, such as GSM and UMTS.

The LTE network architecture is comprised of three major components: User Equipment (UE), Evolved UMTS Terrestrial Radio Access Network (E-UTRAN), and Evolved Packet Core (EPC). The functionalities of each component are:

- The UE is the equipment mobile users use to access LTE network services. A UE could be a mobile phone, laptop with LTE adaptor, or any other device with an LTE interface.
- E-UTRAN is the radio access network and only consists of one type of equipment - eNodeB (eNB), which is a base station and communicates with UEs via the Uu interface, with other peer eNBs via the X2 interface, with the EPC via the SGi interface.
- EPC is the core network, which connects to E-UTRAN and packet data networks (PDNs), such as the Internet or a private corporate network, or an IP multimedia subsystem as shown in Figure 2-3. The interface between UE and E-UTRAN is Uu, between E-UTRAN and EPC is S1, and the interface SGi connects the EPC to other PDNs.

Figure 2-3: The high-level network architecture of LTE(adapted from [23] Figure 1)

Figure 2-4 illustrates the key elements that comprise the core network as well as its interfaces.

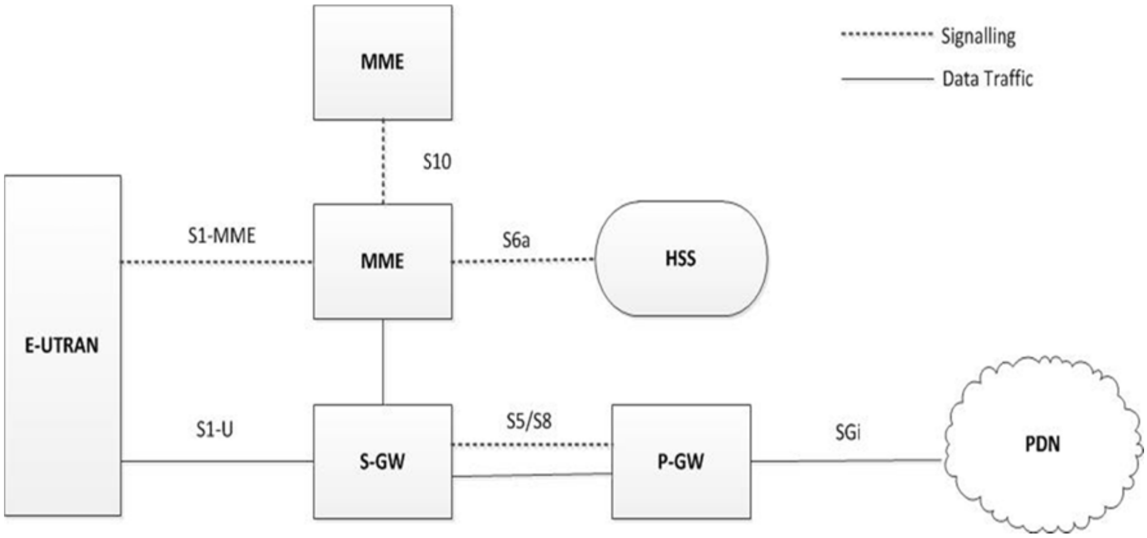

Figure 2-4: The Evolved Packet Core (adapted from figure 3 of [23])

Based on the description in [23] for each element in EPC , we summarize their functions in Table 2-5

Table 2-5 EPC elements and their functions (quoted from [23])

HSS	“The Home Subscriber Server is a database that stores mobile subscribers’ information. It is equivalent to the home location register (HLR) in GSM and UMTS systems.”
MME	“The Mobility Management Entity handles signaling messages with other network elements. It is equivalent to a visitor location register (VLR) in GSM and UMTS systems.”
S-GW	“The Serving Gateway acts as a router and forwards data between a base station and the P-GW.”
P-GW	“The PDN Gateway (P-GW) communicates with external PDNs.”
PCRF	“The Policy Control and Charging Rules Function (PCRF) is responsible for policy control decision-making, as well as for controlling charging functionalities in the Policy Control Enforcement Function (PCEF). The PCEF resides in the P-GW.”

2.3.2 Roaming

In mobile networks, roaming refers to providing mobile connectivity to an operator's mobile subscribers when a mobile subscriber travels outside the geographical coverage area of his/her home mobile network. Via roaming, the subscriber can use the same services in the visited network as in his/her own home network. Providing roaming service has become an important revenue-generating business for mobile operators.

In line with 3G roaming, LTE & 4G roaming also consists of two aspects: signaling relay and data transport. However, unlike 2G & 3G roaming, the signaling protocol utilized between the visited mobile network and home network is Diameter [24, 25], instead of Mobile Application Part (MAP) [26]. IETF RFC 6733 [25] defines Diameter as the protocol for message transactions in the signaling part of 4G roaming procedures. 3GPP has also specified several Diameter-capable logical nodes that are relevant to LTE's Roaming service, specifically the MME, HSS, PCRF, and Equipment Identity Register (EIR) [27].

With regard to 4G roaming data payloads (i.e., the MNO's subscribers' data traffic), MNOs can utilize the GPRS roaming exchange (GRX) provided by IPX carriers to transfer data traffic, in the same way as they do in conjunction with 3G roaming. It is worth noting that the LTE signaling service and roaming data transport are *separate* services provided by IPX carriers, thus MNOs may choose different IPX providers for these two services. Consequently, each MNO may choose a signaling provider different from their GRX provider.

2.3.3 IPX

At an international level, MNOs have chosen to leverage IPX networks for signaling messages in order to support LTE roaming between their roaming partners. They have selected this approach because interconnecting pair-wise* with each roaming partner worldwide would not be very scalable or resource efficient, as direct interconnection would require $\sim(N-1)^2$ point-to-point connections for N peers. Using IPX, roaming still requires this same number of *logical* interconnections between the peers, but requires only a *single* physical connection for each peer to the IPX. A spokesman at Swisscom, one of the first operators in Europe to launch their LTE roaming service (in early 2013), stated in an interview in 'Mobile Europe' magazine: "We are connected to an IPX carrier for Diameter interconnection. Direct interconnection with each roaming partner is too difficult and expensive." [28] In this section, we will further describe the concept of IPX.

IPX was first defined by GSMA in 2006 [29]. It is an alternative to the public internet, but is a global, private, trusted, and controlled IP backbone network. It is completely distinct (and separate) from the Internet and is capable of providing guaranteed end-to-end QoS for multiple services, such as Mobile network signaling, multimedia messaging service (MMS) interworking, mobile data roaming, international high definition (HD) voice service, and Rich Communication Service (RCS) through IMS interworking.

The IPX domain consists of a number of IPX carriers whom on a competitive basis provide interconnect services to support specific IP services at specific quality levels. Figure 2-5 shows examples of interconnection scenarios within an IPX domain.

* i.e., on a on a bilateral basis.

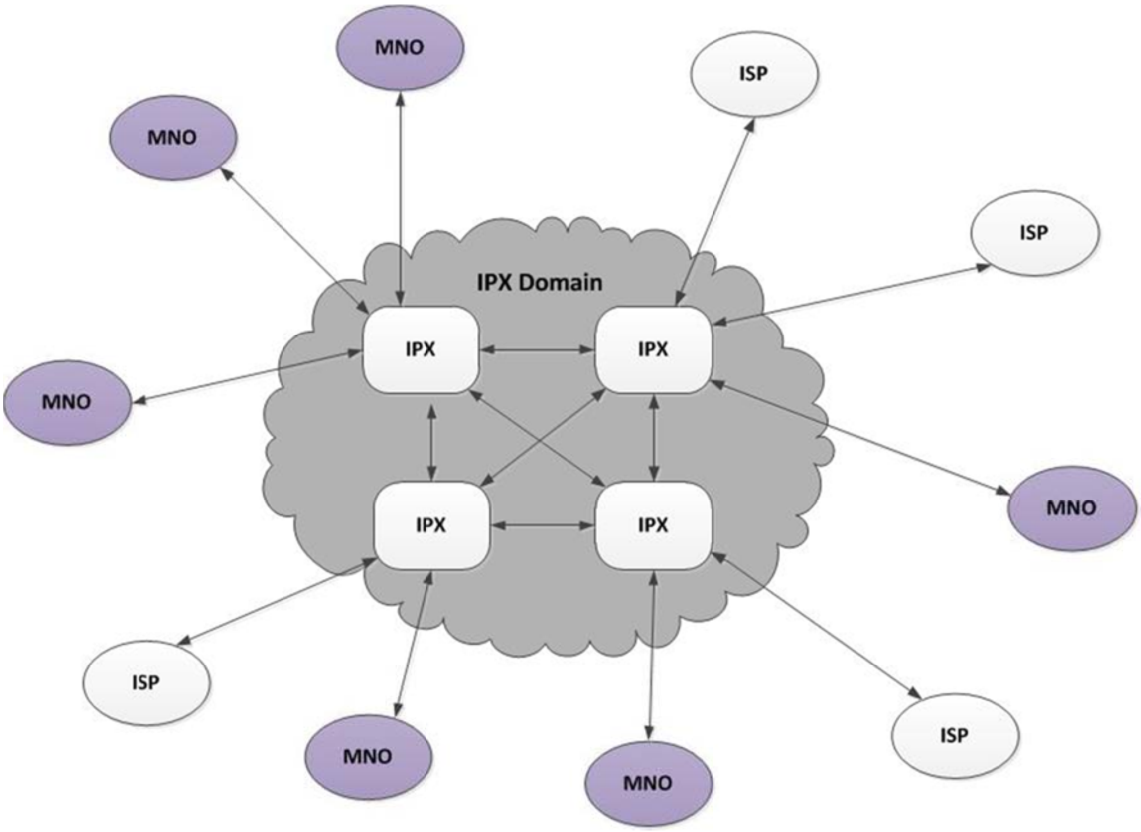

Figure 2-5: IPX Domain (Adapted from Figure 1 of [20])

In other words, IPX is an IP interconnection solution that promises error free delivery of IP data traffic. According to GSMA's implementation guidelines, the minimum availability requirement for an IPX carrier backbone is 99.995%. Some IPX providers guarantee even higher availability.

The IPX domain can be comprised of separate and competing IPX providers. These IPX providers are interconnected via a number of peering points. As shown in Figure 2-6, proxies play an important role in IPX. These proxies are utilized for multilateral connectivity management and enable an IPX provider to facilitate access to multiple service providers via a single agreement with each service provider. IPX proxies can also serve as proxy hubs for mobile data, signaling, and voice services; one of the services is to act as a Diameter signaling proxy. A simplified high-level architecture of IPX is illustrated in Figure 2-6.

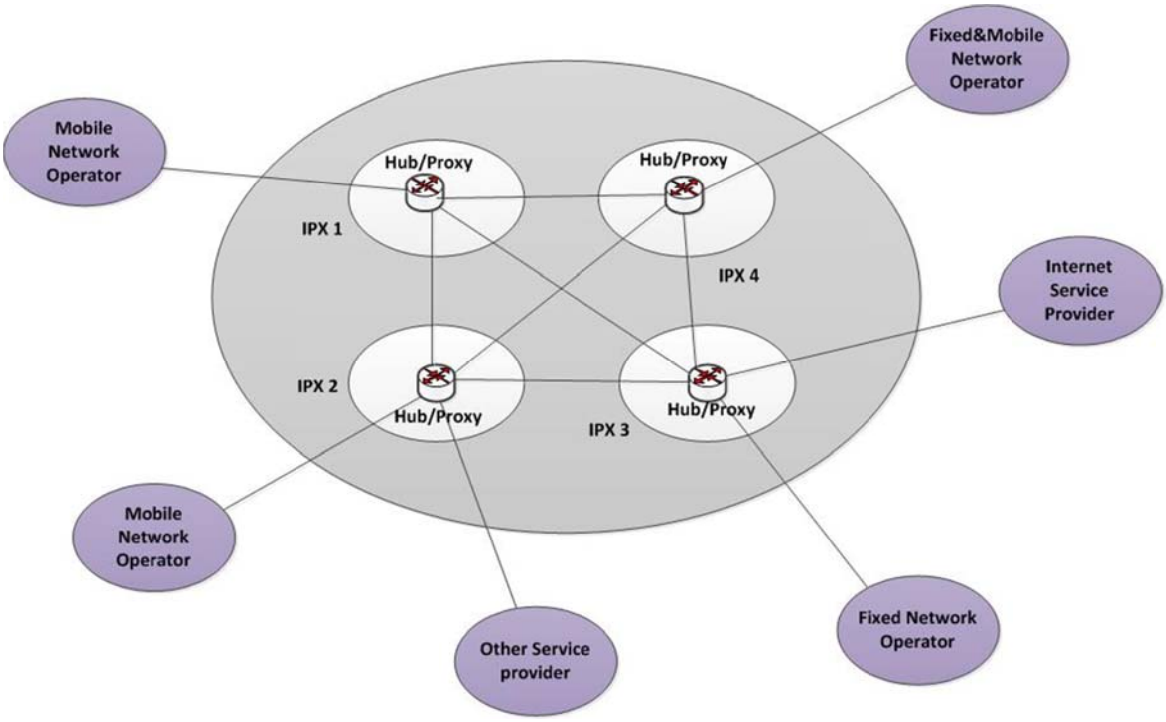

Figure 2-6: IPX Architecture (Adapted from Figure 5 of [18])

2.4 Related work

Since the time when IETF SIGTRAN first developed the SCTP protocol, substantial research has been conducted on reliable and secure transmission via SCTP. Although SCTP was initially developed to provide reliable and timely transfer of signaling messages in an IP network, many researchers have found that SCTP's retransmission mechanisms cause higher retransmission delays when transferring thin traffic stream (such as signaling traffic) compared to thick traffic. Petlund, et al [17] found that SCTP does *not* improve the timeliness of the reliable transport of thin traffic when compared to TCP. They recommend that the transmission of small and large streams in SCTP should be handled separately. Their study showed that they could reduce latency for thin traffic streams by modifying **timers** and introducing **fast retransmit** policies. Jon Pedersen's thesis [8] also revealed that SCTP's retransmission mechanisms work well with thick traffic, but cause thin traffic to suffer high transmission delays. Both documents point out that when the traffic is thin, most retransmissions occurs due to the expiration of the retransmission timer, hence fast retransmits are in practice rarely used. This behavior occurs because the number of SACKs for thin streams is small and there is rarely a chance to trigger a fast retransmit before the retransmission timer expires. To improve the retransmission delay of thin streams, several enhancements have been proposed and evaluated; for example, modifying the fast retransmit to be triggered after 1 SACK instead of 4; reducing the RTO minimum value from 1000 ms to 200 ms; correcting RTO values at timer restarts; etc.

Since retransmission and failover mechanisms are the keys to SCTP's reliability and availability mechanisms, some studies made by universities and telecommunication providers have sought to find out how the protocol configuration parameters influence the performance of SCTP's reliability. Fallon, et al. [30] evaluated latency in various real networks and an emulated network. They concluded that latency improvements depended upon **RTT**, packet loss, and the amount of competing cross traffic. Bokor, Huszak, and

Jeney [31] evaluated the effect of SCTP parameter configuration in terms of handover effectiveness, throughput, and delay between UMTS and WLAN, they concluded that the most important SCPT parameters are: **RTO.Min**, **RTO.Max**, **HB.Interval,** and **Path.Max.Retransmission**. They recommended keeping the **HB.Interval** value as low as possible (the default **HB.Interval** is 30 seconds). Similar research by Bao, Song, and Zhang [32] searched for the optimal protocol parameter configuration for SCTP transmission performance over WLAN (IEEE 802.11b), GPRS, and UMTS network environments in terms of throughput and also concluded that, an increase in **HB.interval** will lead to an increase in retransmission times. Their paper suggests modifying **MTU**, **HB.interval, Max.Init.Retransmits,** and **Association.Max.Retrans** values to achieve optimal throughput on SCTP links in all three network environments. However, they found that **Path.Max.Retrans** does not seem to have much impact on the throughput when compared to other parameters. The values they used for **Association.Max.Retrans** was 3-4 and for **Max.Init.Retransmits** 3-4.

Experimental results by Fallon, et al. [9] show that applying the default SCTP parameter values causes SCTP failover to take a **longer** time in a WLAN environment. They discovered that both **Path.Max.Retrans** value and **RTO.Max** value are the dominant parameters and recommended modifying both parameters' default values in order to reduce failover time and to reduce transmission latency. Their suggested **Path.Max.Retrans** value is in the range of 0-2 attempts, because the default of 5 attempts was found to lead to excessively large latency.

In a research project called "Secure and Reliable Communication in SCTP" [13] carried out at Karlstad University in Sweden in collaboration with Ericsson AB, researchers experimentally investigated the impact of a range of SCTP configuration parameters and network settings on SCTP failover performance and proposed a modified retransmission timeout strategy to improve the failover performance [13]. They reported the following findings with regard to failover performance:

1) **Path.Max.Retrans** and **RTO limits** are of great importance for failover performance.
2) Both the failover time and the maximum transfer time for a message depend upon the status of the network when the break of the primary path occurs.
3) SACK delay can significantly degrade failover performance when the traffic is thin, hence disabling SACK delay can improve failover performance. (Additionally, disabling of SACK delay can also improve retransmission delay, as was revealed in [8].)

As introduced in Section 2.1, SCTP can trigger retransmission by either fast retransmit or retransmission RTO. In the research project at Karlstad University [13], a modified retransmission timeout mechanism was proposed and evaluated, and their experimental study was presented in [33]. They showed that this modified mechanism could reduce the time needed for retransmission timeout with as much as 43%. The same authors in [34] describe a modified SCTP parameterization shown in Table 2-6. Their experiment results showed that these parameters provide faster loss detection for signaling traffic in their emulated network environment. However, this configuration might not meet the requirements of a real network environment, because the ACK might arrive later from a previous session due to network conditions when delays and congestions are high. Additionally, their proposed retransmission mechanism will cause many unnecessary retransmissions.

Table 2-6: Modified SCTP protocol parameters provided in [34]

Parameter	Recommended Values
RTO.Initial (ms)	200
RTO.min (ms)	100
RTO.max (ms)	400
$SACK_{delay}$ (ms)	20
Bottleneck bandwidth (Kbit/s)	500, 1000, 2000
One way end-to-end delay (ms)	5, 10, 15, 20, 25, 30

Previous work on improving SCTP's transmission efficiency and resilience have focused on modifying the retransmission and failover mechanisms by the mean of tuning SCTP's parameters. The primary differences between the modified parameter values and IETF's default recommendations are:

1) Reducing RTO related parameters values (setting RTO.Max value close to RTT; use smaller RTO.initial and RTO.min) and

2) Reducing Path.Max.Retrans and Association.Max.Retrans values.

However, this improvement comes at a cost. Rembarz, Baucke, and Mohnen [35] pointed out that setting RTO close to RTT or a too small value for Path.Max.Retrans can lead to spurious retransmission and even result in severe performance degradation when transient increases in delay occur due to network congestion.

Additionally, in previous works on finding the optimal SCTP protocol configuration parameters for transmitting thin traffic, most researchers have emulated the performance of thin traffic by generating traffic using various SCTP packet tools (for example, lksctp [36]). There have not been few works that tested the performance using traffic generated by SCTP's upper layer protocols. Until now, no published papers have evaluated Diameter message transmission performance over SCTP in different realistic network scenarios. This thesis project attempts to fill this research gap and motivated author to start this research work to find more optimal SCTP protocol configuration parameter settings to be used when transferring Diameter messages between Diameter nodes, specifically in the case of LTE roaming.

3 Methodology

The purpose of this chapter is to provide an overview of the research method used in this thesis. Section 3.1 describes the research process. Section 3.2 focuses on the data collection techniques used for this research. Section 3.3 describes the experimental design.

3.1 Research Process

The research process of this project begins with initial research on previous studies in SCTP's parameterization and transmission performance, in order to establish a basis of theoretical SCTP parameterization that can improve transmission reliability. Then test environment and instruments are designed and theoretical values are tested. The data are then collected and analyzed after the experiments to identify the parameters that have significant impact on transmission performance. Figure 3-1 also illustrates the Research process in diagram.

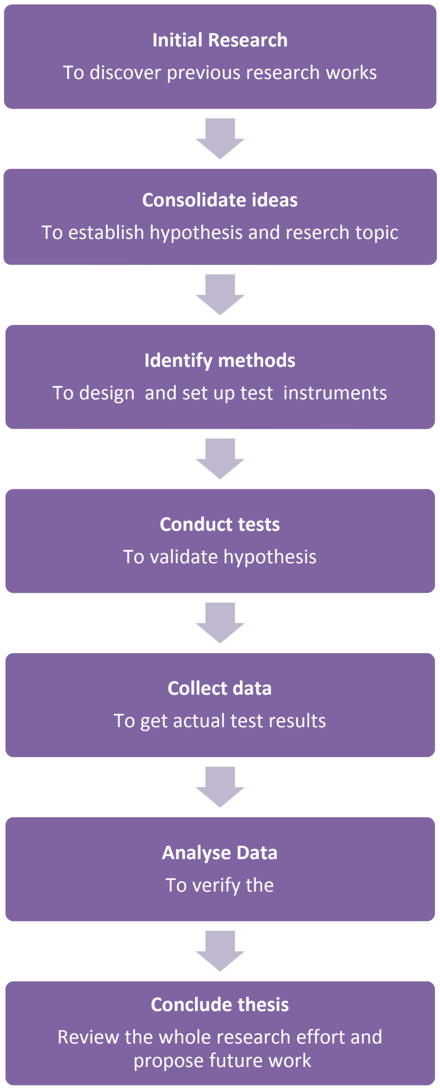

Figure 3-1: Research Process

3.2 Data Collection

The type of data this thesis aims to collect is ordinal data, since we will collect the time consumed from when a Diameter request message is sent from client node until the client receives the corresponding answer message from the server.

To collect Diameter traffic, a Diameter test tool is used to send and receive Diameter messages between two test nodes. The messages are sent at a given transmission rate between the nodes and these messages and their corresponding answers during a certain period of time are captured for subsequent data analysis. The time duration from when a Diameter request message is sent by the client node until the corresponding Diameter answer message is received at the Diameter client node is calculated from the collected data *after* the experiment is completed. At the Diameter server node, the time for the server to respond to a Diameter Request message is measured by calculating the time difference between when a Diameter request message is received and when a Diameter answer message is sent.

3.3 Experimental Design/Planned Measurements

This section describes the generic design of our laboratory environment and how the experimental tests are planned. First, the logical network architecture of the lab environment is illustrated; followed by an brief introduction of the hardware and software used in this project. Following this, the author explains how the network values for the three network scenarios in Table 1-3 are defined. Next the design of the experimental tests is explained. Lastly, a set of modified SCTP parameter values for each network scenario are proposed for laboratory tests.

3.3.1 Logical Network Architecture of the Lab Environment

Figure 3-2 shows the logical network architecture of the laboratory environment.

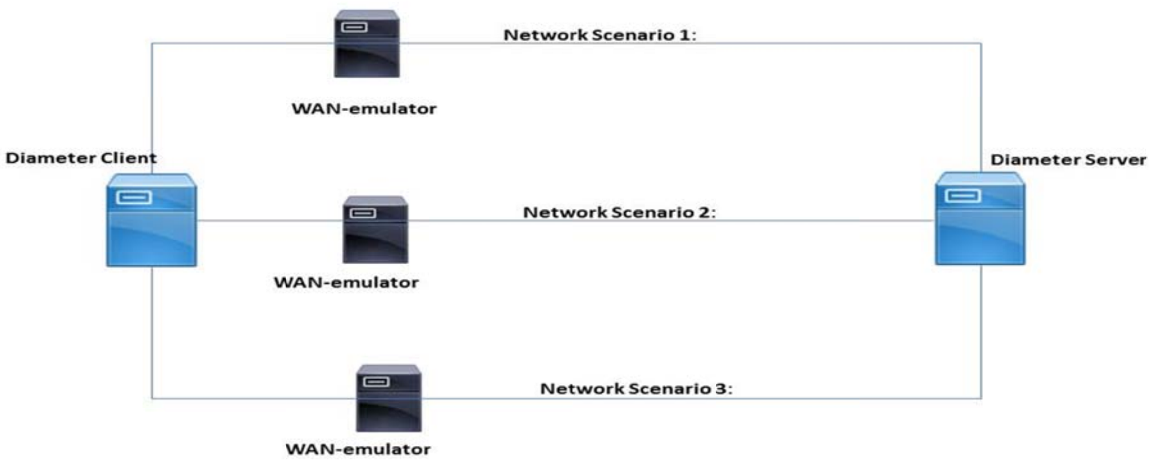

Figure 3-2: Logical network architecture of the laboratory environment

There are three physical network elements: two Diameter nodes, used to generate Diameter messages, and one WAN-emulator. The WAN-emulator is placed between the two Diameter nodes (Client and Server) to simulate the national, intra-continental, and intercontinental network environment by manipulating RTO/RTD, jitter, and packet loss values. Although Figure 3-2 shows three logical WAN-emulators, there is only one physical WAN-emulator in the network.

3.3.2 Hardware/Software to be used

This section describes the hardware and software used in the experimental tests. Two PCs were set up to act as Diameter nodes A and B. another PC running netem [37] is used as a network-emulator between the two Diameter nodes to simulate the semi-reliable and unreliable network environment with various latencies. To capture packets, tcpdump [38] is used. Wireshark[39] is utilized to analyze the captured packets.

3.3.2.1 Diameter nodes

Two PCs running the Linux operating system utilize a Diameter message generator tool to act as Diameter nodes (A and B). This Diameter message generator generates Diameter packets. Table 3-1 and Table 3-2 give the specifications of these two PCs (named Twopiar 1 and Twopiar 2).

Table 3-1: Characteristics of the Diameter Client node Twopiar 1

Specification	
Vendor, Model, Make	IBM xSeries 336
CPU	Intel® Xeon™ CPU 3.20 GHz
Memory	1 GB
Disk	30 GB
Network interface	Eth0, Eth1
Operating system	CentOS Linux release 6.3

Table 3-2 : Characteristics of the Diameter Server node Twopiar 2

Specification	
Vendor, Model, Make	IBM xSeries 336
CPU	Intel® Xeon™ CPU 3.20 GHz
Memory	1 GB
Disk	50 GB
Network interface	Eth0, Eth1
Operating system	CentOS Linux release 6.3

3.3.2.2 WAN-emulator

One PC running the Linux operating system provides a network emulation tool that is used as a network-emulator between the two Diameter nodes in order to simulate different network conditions. Table 3-3 gives the specifications of the PC used as the network-emulator.

Table 3-3: Characteristics of the PC used as WAN-emulator

Specification	
Vendor, Model, Make	Fujitsu Siemens RX300 S4
CPU	Intel® Xeon™ CPU E5420 2.50 GHz
Memory	500 MB
Disk	50 GB
Network interface	Eth0, Eth1
Operating system	CentOS Linux release 7.0.

3.3.2.3 Seagull

A Diameter traffic generator was used to simulate Diameter messages for the experiments. Unfortunately, there are few open-source Diameter test tools available. After extensive Internet searches for open source Diameter tests tools, Seagull [40] was chosen as the test tool to generate Diameter messages in our lab.

Seagull is a free, open source multi-protocol traffic generator tool that is widely used to generate Diameter traffic. It was released under the terms of the GNU GPL v2 license. Unfortunately, the developer of Seagull does not provide technical support and the only support available is through the email-based Seagull users' community forum. The latest release of Seagull was in 2009.

3.3.2.4 NetEm

NetEm [37] is a network emulation tool. It is an enhancement of the Linux traffic control facilities that allows a user to specify added delay, packet loss, packet duplication. NetEm is built into the Linux kernel and is controlled by the command line tool 'tc' [41].

3.3.2.5 Tcpdump

Tcpdump [38] is installed on both Diameter nodes and run from the command line to capture the sent and received messages between the nodes during each test case.

3.3.2.6 Wireshark

Wireshark [39] Version 1.12.3 is installed as packet analyzer to analyze the captured packets. Wireshark is regarded as one of world's most popular open source packet analyzers and is released under the GNU General Public License version 2.

3.3.3 Defining Network Performance Metrics Values

To emulate the different network conditions described in Table 1-3, three network performance metrics: delay, jitter, and packet loss were considered. Delay refers to the bidirectional network latency, which is from the time of the start of packet transmission at the sender to the time of receiving the acknowledgement of the original packet's receipt at the receiver. In following chapters, the term delay and RTT/RTD will be used interchangeably. Jitter represents the deviation in network delay, since it is unlikely that delay is constant in real network scenarios. Packet loss is the probability of packets not being successfully delivered to their destination.

In order to define credible values for these three metrics, these metrics should represent the actual network scenarios described in Table 1-3. To establish these metrics the author utilized the network traffic logs of TeliaSonera International Carrier's (TSIC) IPX network as a reference for the network delay, jitter, and packet loss in a production network environment. By utilizing TeliaSonera's looking glass tool [42], Ping [43] tests were made from three different routers located in Sweden, Spain, and Hong Kong to the TSIC's IPX router **s-b5**, which is located in Stockholm, Sweden. The purpose is to see how the packet delay, jitter and packet loss vary in national, intra-continental, and intercontinental networks. Figure 3-3 shows a screenshot of TSIC's looking glass page.

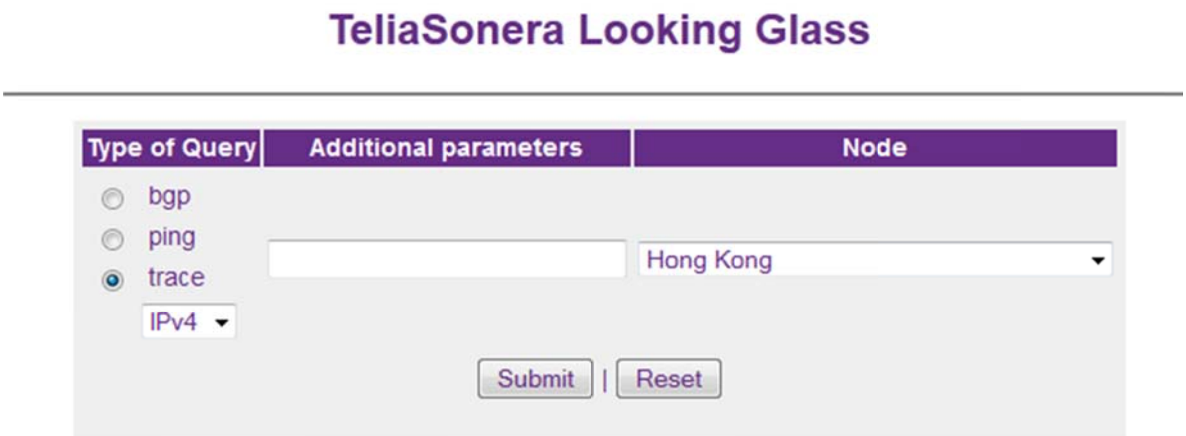

Figure 3-3: **TeliaSonera Looking Glass**

Figure 3-4 shows that the statistics of 5 Ping packages sent from another router that is located in Stockholm to **s-b5** and within TSIC's IPX network. This figure shows that the minimum RTD is 0.928 ms, average RTD is 0.984 ms, maximum RTD is 1.15 ms. and jitter is 0.085 ms. This gives us an idea of a reliable/domestic IP network's performance metric values: delay is around 1 ms, jitter is less than 0.1 ms. During the these with these 5 packets, no packet loss occurred.

TeliaSonera Looking Glass - ping count 5 s-b5

Router: Stockholm
Command: ping count 5 s-b5

```
qPING s-b5.telia.net (80.91.255.227): 56 data bytes
64 bytes from 80.91.255.227: icmp_seq=0 ttl=254 time=0.978 ms
>64 bytes from 80.91.255.227: icmp_seq=1 ttl=254 time=1.150 ms
>64 bytes from 80.91.255.227: icmp_seq=2 ttl=254 time=0.934 ms
>64 bytes from 80.91.255.227: icmp_seq=3 ttl=254 time=0.932 ms
�64 bytes from 80.91.255.227: icmp_seq=4 ttl=254 time=0.928 ms

--- s-b5.telia.net ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.928/0.984/1.150/0.085 ms
```

Figure 3-4: Ping results from router in Stockholm

Figure 3-5 shows that the statistics of 5 Ping packages sent from a router in Madrid, Spain to the router **s-b5** in Stockholm. This figure shows that the minimum RTD is 58.731 ms, average RTD is 58.817 ms, maximum RTD is 58.907 ms, and jitter is 0.064 ms. This gives us a sample of the performance metrics in an inter-continent IP network.

TeliaSonera Looking Glass - ping count 5 s-b5

Router: Madrid
Command: ping count 5 s-b5

```
PING s-b5.telia.net (80.91.255.227): 56 data bytes
64 bytes from 80.91.255.227: icmp_seq=0 ttl=252 time=58.860 ms
64 bytes from 80.91.255.227: icmp_seq=1 ttl=252 time=58.907 ms
64 bytes from 80.91.255.227: icmp_seq=2 ttl=252 time=58.731 ms
64 bytes from 80.91.255.227: icmp_seq=3 ttl=252 time=58.824 ms
64 bytes from 80.91.255.227: icmp_seq=4 ttl=252 time=58.761 ms

--- s-b5.telia.net ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max/stddev = 58.731/58.817/58.907/0.064 ms
```

Figure 3-5: Ping results from router in Madrid

Figure 3-6 shows that the statistics of 5 Ping packages sent from a router in Hong Kong to **s-b5**. From the figure, we can see that minimum RTD is 314.076 ms, average RTD is 315.08 ms, maximum RTD is 319.002 ms and jitter is 1.961 ms. These values represent the delay and jitter in an inter-continental IP network.

TeliaSonera Looking Glass - ping count 5 s-b5

Router: Hong Kong
Command: ping count 5 s-b5

```
PING s-b5.telia.net (80.91.255.227): 56 data bytes
64 bytes from 80.91.255.227: icmp_seq=0 ttl=251 time=314.088 ms
64 bytes from 80.91.255.227: icmp_seq=1 ttl=251 time=314.093 ms
64 bytes from 80.91.255.227: icmp_seq=2 ttl=251 time=314.140 ms
64 bytes from 80.91.255.227: icmp_seq=3 ttl=251 time=314.076 ms
64 bytes from 80.91.255.227: icmp_seq=4 ttl=251 time=319.002 ms

--- s-b5.telia.net ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max/stddev = 314.076/315.080/319.002/1.961 ms
```

Figure 3-6: Ping results from Router in Hong Kong

Based on these Ping statistics, we can have a general idea of the values of RTD and jitter in a national, intra-continental, and inter-continental network that have an well optimized network design. However, in order to extract generic value ranges for these three networks, the values that have actually been used are a bit larger than the observed values in Figure 3-4, Figure 3-5, and Figure 3-6. This is especially true for the inter-continental network, we I have taken the RTD range to be 500-1000 ms, in comparison to the actual RTD between the routers in Hong Kong and Stockholm of only around 300ms. This was because these Ping tests were made *within* TSIC's own IPX networks, hence these are direct route to these tested routers, i.e., no other operators' network or equipment were involved. However, in real life scenarios, especially those of inter-continental networks, it is common that the path will traverse more than one IP network.

As these Ping tests did not show any packet loss, the author consulted his industrial advisors at TSIC and looked into the traffic statistics within TSIC's network in order to understand the packet loss probability for different network scenarios. TSIC is one of the biggest international IPX providers and provides Diameter Routing Exchange for a number of mobile operators. To avoid disclosing any company confidential data, the author will not show the actual statistics in this thesis. However, based on these statistics, the author defined a packet loss ratio for of the three network scenarios for our laboratory tests. These packet loss ratios are: < 0.1% in a national network, < 0.5% in an intra-continental network, and < 1% in an inter-continental network.

Table 3-4 summarizes the delay, jitter, and packet loss value for the three different network scenarios used in our laboratory tests.

Table 3-4: WAN-Emulation parameters

Scenarios	Delay	Jitter	Packet loss
1: Reliable network (National network)	1-5 msec	<1 ms	< 0.1%
2: Semi-reliable network (Intra-continental network)	50-100 msec	1 ms	< 0.5%
3: Unreliable network with long geographic distance (Inter-continental network)	500-1000 msec	10 ms	< 1%

3.3.4 Proposing SCTP parameters for measurements

According to Kay [10], eliminating SCTP RTO can reduce network latency and improve throughput. However, if the values of RTO are too small, it will result in unnecessary retransmission and deteriorate transmission reliability; while, if the RTO values are too large, it can cause long waiting time to trigger retransmission – hence negatively affect transmission performance.

As defined in Table 2-2, the default value of RTO.Inital (3 seconds) means that SCTP will set the RTO to 3 seconds when SCTP initiates an association with its peer. If the sender's INIT packet fails to be acknowledged by the server, the sender will wait for 3 seconds before initiating a retransmission. In a reliable network environment, where the average network delay is between 1-5 ms and jitter is less than 1 ms, this waiting time for a packet to be retransmitted is considered very high. The default value of RTO.max (60 seconds) is considered way too high in such a network, because it is unlikely that a service provider would want a lost packet to wait for up to 1 minute to be retransmitted, especially for the time-crucial traffic, such as signaling messages. Therefore, the author believes it to be unnecessary to keep the RTO.max value that large. This was also pointed out in [9].

Based on the SCTP RTO mechanism and the related work summarized in Section 2.4, for the experimental tests in scenario 1, the author proposes that RTO.Init is 50 ms, the RTO.Min 25 ms, and RTO.Max 500 ms. The motivation for setting RTO.min = 50 ms is to enable the Diameter sender to stop negotiating an SCTP association once it detects that the network delay is greater than 50 ms, then it can choose a backup path to transmit data (if an alternative path is available). In our lab, we set RTD to 50ms as the threshold for reliable network conditions. Additionally, the author reduced Association.Max.Retrans from 10 attempts to 6 attempts and Path.Max.Retrans from 5 attempts to 3, so that the time to switch over to another association or path is shortened. Max.Init.Retransmits is also changed from 8 attempts to 3, to allow the sender to quickly give up a path that has a delay higher than its configured network threshold.

Changing the α and β values that affect the RTTVAR and SRTT will make RTO less affected by rapid changes in RTT. However, changing these two variables requires a complete evaluation of the RTO behavior, especially for the case of thin streams. Without a complete evaluation, changing the RTO calculation algorithm may lead to critical errors, unless it is proved to work properly [8]. Therefore, we will keep the α and β values as their default values. Max.Burst, HB.Max.Burst, and HB.interval will also remain unchanged.

Table 3-5 lists the modified SCTP values used for testing of Scenario 1.

Table 3-5 : Theoretical optimal SCTP parameter configuration values for Scenario 1

Parameter	Value
RTO.Initial (ms)	50
RTO.Min (ms)	25
RTO.Max (ms)	500
Max.Burst	4
RTO.Alpha	1/8
RTO.Beta	1/4
Valid.Cookie.Life	60 seconds
Association.Max.Retrans	6 attempts
Path.Max.Retrans	3 attempts (per destination address)
Max.Init.Retransmits	3 attempts
HB.interval	30 seconds
HB.Max.Burst	1

Similarly, the author proposes that RTO.Intial is set to 500 ms, RTO.Min to 250 ms, and RTO.Max to 2 seconds for network scenario 2. Table 3-6 lists the SCTP values used for Scenario 2.

Table 3-6: Theoretical optimal SCTP parameter configuration values for Scenario 2

Parameter	Value
RTO.Initial (ms)	500
RTO.Min (ms)	250
RTO.Max (ms)	2000
Max.Burst	4
RTO.Alpha	1/8
RTO.Beta	1/4
Valid.Cookie.Life	60 seconds
Association.Max.Retrans	6 attempts
Path.Max.Retrans	3 attempts (per destination address)
Max.Init.Retransmits	3 attempts
HB.interval	30 seconds
HB.Max.Burst	1

For scenario 3, the RTO.Intial is 3000 ms as the default value and RTO.Min 2500 ms. The RTO.Max is set to 12 seconds instead of default 1 minute, because the author expects retransmission should happen faster. Table 3-7 list the SCTP values used for Scenario 3.

Table 3-7: Theoretical optimal SCTP parameter configuration values for Scenario 3

Parameter	Value
RTO.Initial (ms)	3000
RTO.Min (ms)	2500
RTO.Max (ms)	12000
Max.Burst	4
RTO.Alpha	1/8
RTO.Beta	1/4
Valid.Cookie.Life	60 seconds
Association.Max.Retrans	6 attempts
Path.Max.Retrans	3 attempts (per destination address)
Max.Init.Retransmits	3 attempts
HB.interval	30 seconds
HB.Max.Burst	1

It is worth noting that these modifications in the parameter values are based on the summarized related works, SCTP RFC documents, and the author's assumptions, as no mathematical model has been used to obtain these values. The author does not know how these changes will affect Diameter message transmission when applying them in different network conditions. Therefore, it is necessary to conduct different tests to verify what the change in performance will be. This is in keeping with one of the goals of this thesis project.

3.3.5 Defining Test Cases

In order to define how many Diameter messages should be sent from the client node in our lab experiment, the author first referred to the statistics of the actual Diameter Messages transmitted via TSIC's Diameter routing Agent in 2014. Table 3-8 summarizes the general statistics of Diameter traffic at an international transmission level based on TSIC's current Diameter traffic profile.

Table 3-8: Diameter traffic parameters to be used for testing

Characteristic	Value
Average number of messages sent or received	12 messages/sec
Average bytes sent or received	8000 bytes/sec
Average message size	700 bytes
Highest rate of messages being sent or received	70 messages/sec

The values shown in Table 3-8 are based upon the average number of Diameter messages sent and received on a daily basis. We can see that the average number of sent and received is only 12 messages per second. During peak seasons (excluding public holidays) and rush hours, the highest rate of Diameter messages being transmitted through TSIC's Diameter agent reached 70 messages per second. It should be noted that the volume of Diameter message exchanged via TSIC's Diameter agent is expected to rapidly increase, as more MNOs commercialize their LTE roaming services.

The planned lab tests are composed of two parts. The first part is designed to send 200 Diameter messages between a Diameter Client and Server and to evaluate how the proposed SCTP parameter values influence the Diameter message transmission in terms of RTD, thus to find a correlation between these parameters and RTD. The second part of the tests is to validate the reliability of the proposed values by testing it with 60,000 Diameter messages for each test case.

For the first part of experiments, we send 200 Diameter messages at the rate of 1 message/second in different network scenarios. For Scenario 1, whose estimated RTD between two Diameter nodes is 1-5 ms, jitter <1 ms, and packet loss < 0.1%, six different test cases are planned as described in Table 3-9.

Table 3-9: Six tests for Scenario 1

	Delay	Jitter	Packet loss
Test 1	1 ms	0.5 ms	0.05%
Test 2	5 ms	0.8 ms	0.1%
Test 3	20 ms	1 ms	0.2%
Test 4	40 ms	1 ms	0.3%
Test 5	49 ms	1 ms	0.3%
Test 6	50 ms	1 ms	0.3%

For Scenario 2, the RTD between two Diameter nodes is around 50-100 ms, jitter around 1 ms, and < 0.5% packet loss, other test cases are planned. Some of the test cases in Scenario 1 are also included in Scenario 2, to see how the Diameter message's RTD vary when the network delay, jitter, and packet loss are the same, but with different SCTP parameter values. Table 3-10 shows the eight tests planned for Scenario 2.

Table 3-10: Eight tests for Scenario 2

	Delay	Jitter	Packet loss
Test 1	1 ms	0.5 ms	0.05%
Test 2	5 ms	0.8 ms	0.1%
Test 3	20 ms	1 ms	0.2%
Test 4	50 ms	1 ms	0.3%
Test 5	60 ms	1 ms	0.5%
Test 6	100 ms	1 ms	0.5%
Test 7	499 ms	5 ms	1%
Test 8	500 ms	10 ms	1%

For Scenario 3, the RTD between the two Diameter nodes is around 500-1000 ms, jitter around 10 ms, and ~1% packet loss. Ten test cases are planned as shown in Table 3-11.

Table 3-11: Ten tests for Scenario 3

	Delay	Jitter	Packet loss
Test 1	1 ms	0.5 ms	0.05%
Test 2	5 ms	0.8 ms	0.1%
Test 3	20 ms	1 ms	0.2%
Test 4	50 ms	1 ms	0.3%
Test 5	100 ms	1 ms	0.5%
Test 6	500 ms	5 ms	0.5%
Test 7:	800 ms	10 ms	1%
Test 8	1000 ms	10 ms	1%
Test 9	2990 ms	10 ms	1%
Test 10	3000 ms	10 ms	1%

After conducting all the above tests, the test results will be analyzed to find parameters that had significant impact on RTD. Based on these findings, a new set of modified values of SCTP parameters might be proposed (if needed). These new parameter values could be used to run another set of tests with a higher Diameter message transmission rate and longer duration. In this second set of tests, the transmission rate is set to 100 Diameter messages per second and test duration is set to 10 minutes. The author chose the highest estimated network delay, jitter, and packet loss from Table 3-4. For this more extensive testing, for Scenario 1, a delay of 5 ms, jitter of 0.8 ms, and 0.1% packet loss was chosen; for Scenario 2, a delay of 500 ms, jitter of 5 ms, and 0.5% of packet loss was chosen; and for Scenario 3 a delay of 1000 ms, jitter of 10 ms, and 1% of packet loss was chosen.

4 Practical Experiments

This chapter describes the technical details of the laboratory environment and planned tests. Section 4.1 introduces the test environment setup as well as the configurations of Diameter nodes and WAN-emulator. Section 4.2 explains how to manipulate SCTP parameter values and the network delays, jitter, and packet loss at the Diameter client and WAN-emulator. Finally the experiments are introduced.

4.1 Test Environment Setup

This section explains the details of the test environment set up to emulate Diameter transmission between two Diameter nodes in the three different network environments described in Table 1-3. Figure 4-1 illustrates the network topology of the laboratory environment.

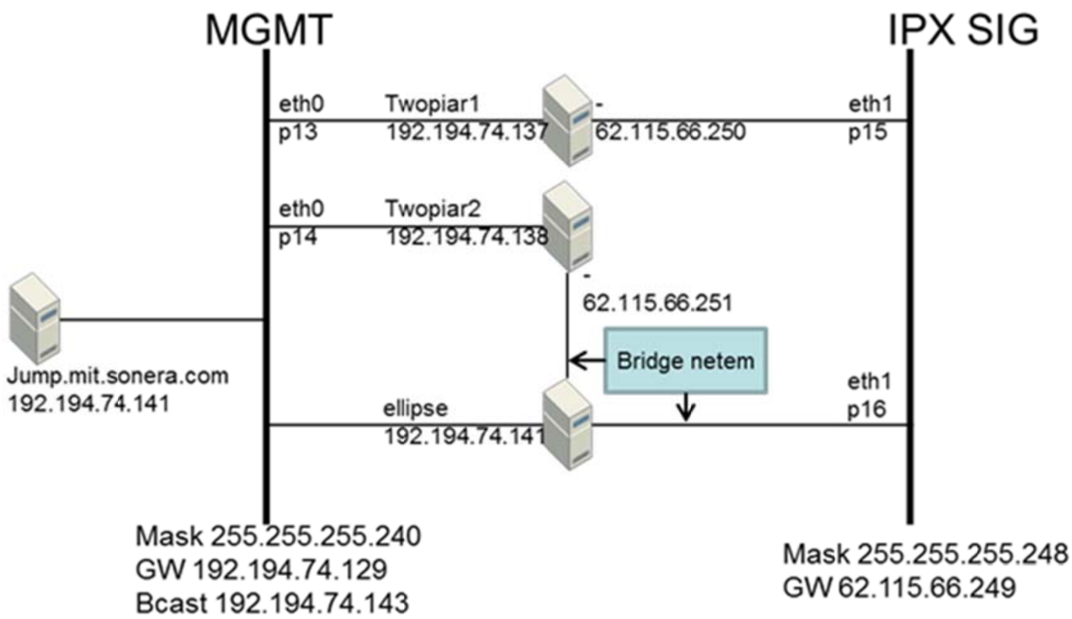

Figure 4-1: Laboratory environment network topology

The network is composed of three hosts named Twopiar1, Twopiar2, and Ellipse, and divided into two subnets: MGMT (192.194.74.128/28) and IPSIG (62.115.66.248/29). The path via the IPX SIG subnet between two hosts is configured as the primary link for Diameter message transport, while the path via the MGMT subnet is configured as a backup link. The Twopiar hosts running Seagull software [57] are used as the two Diameter nodes, with Twopiar1 acting as a Diameter Client and Twopiar2 acting as a Diameter Server. The other node (jump.mit.sonera.com) provides secure SSH connection to access the hosts in the test network for configuration & management. The host Twopiar1 generates Diameter messages and sends them to host Twopiar2 by utilizing SCTP as the transport protocol. The host named Ellipse acts as a network-emulator between these two Diameter nodes to simulate the semi-reliable and unreliable network environments with various latencies, jitters, and packet loss rates.

Host Twopiar1 has two Ethernet interfaces configured as:

- eth0:192.194.74.137/28
- eth1:62.115.66.250 /29

Host Twopiar2 has two Ethernet interfaces configured as:

- eth0:192.194.74.138/28
- eth1:62.115.66.251 /29

4.1.1 Diameter nodes

Once the laboratory network is setup and configured, the next step is to install Seagull on both Twopiar1 and Twopiar2. Following the installation instructions [44] on Seagull's official website [40], seagull version 1.8.2 was installed on both hosts. The following files are created in the /usr/local/bin directory:

```
/usr/local/bin/
     seagull
     computestat.ksh
     plotstat.ksh
     startoctave_plot.ksh
     startoctave_stat.ksh
     csvextract
     csvsplit
     [library-files].so
```

In order to enable SCTP transport in Seagull, an external SCTP library must be used as Seagull is built using **sctplib** and **socketapilib** and hence does not utilize the Linux Kernel SCTP. According to the Seagull configuration guide, the SCTP library and SCTP API can be fetched from www.sctp.de [45]. In our configuration, we chose version sctplib-1.0.15 and socketapi-2.2.8.

Once the external SCTP library is installed successfully, the file **libtrans_extsctp.so**, will be created under /usr/local/bin/. This library will be used as the transport library in a configuration file (described later).

In our Diameter nodes, this library file is found in /usr/local/bin, as shown below:

```
[shxi00@twopiar1 bin]$ cd /usr/local/bin/
[shxi00@twopiar1 bin]$ ls
computestat.ksh        libcpppsocketapi.so.2.0.2  libsctpsocket.a
runsctptest
csvextract             lib_generalmethods.so      libsctpsocket.la
seagull
csvsplit               libparser_xml.so           libsctpsocket.so
startoctave_plot.ksh
iperf3                 libsctplib.a               libsctpsocket.so.2
startoctave_stat.ksh
libcpppsocketapi.a     libsctplib.la              libsctpsocket.so.2.0.2
stt
libcpppsocketapi.la    libsctplib.so              libtrans_extsctp.so
libcpppsocketapi.so    libsctplib.so.1            libtrans_ip.so
libcpppsocketapi.so.2  libsctplib.so.1.0.8        plotstat.ksh

[shxi00@twopiar2 /]$ cd /usr/local/bin/
[shxi00@twopiar2 bin]$ ls
computestat.ksh        libcpppsocketapi.so.2.0.2  libsctpsocket.a
runsctptest
csvextract             lib_generalmethods.so      libsctpsocket.la
seagull
csvsplit               libparser_xml.so           libsctpsocket.so
startoctave_plot.ksh
iperf3                 libsctplib.a               libsctpsocket.so.2
startoctave_stat.ksh
libcpppsocketapi.a     libsctplib.la              libsctpsocket.so.2.0.2
stt
libcpppsocketapi.la    libsctplib.so              libtrans_extsctp.so
libcpppsocketapi.so    libsctplib.so.1            libtrans_ip.so
libcpppsocketapi.so.2  libsctplib.so.1.0.8        plotstat.ksh
```

Now it is time to modify the generic configuration file, which describes the network environment and traffic parameters. The default configuration file named **conf.<client|server>.xml** is created in the /Seagull/Diameter/config directory.

In our Diameter nodes, I renamed these files to be **conf.shawn.xml** on host Twopiar1, and **conf.shawn_server.xml** on host Twopiar2. Since the default configuration uses TCP as the transport protocol, we need to change it to SCTP. To do so, "libtrans_ip.so" needs to be replaced by "**libtrans_extsctp.so** " in the "transport" entity field. The destination IP address and SCTP is set as 62.115.66.251: 3868, where 3868 is used as the SCTP port number on client node Twopiar1. The same IP address is used on server node Twopiar2 as the source address. Figure 4-2 shows the modified configuration file on the Client node.

```
 (c)Copyright 2006 Hewlett-Packard Development Company, LP.

-->

<?xml version="1.0" encoding="ISO-8859-1"?>
<configuration name="MME_configuration">

  <define entity="transport"
    name="trans-sctp"
    file="libtrans_extsctp.so"
    create_function="create_cipsctpio_instance"
    delete_function="delete_cipsctpio_instance"
    init-args="type=tcp">
  </define>

<!--    init-args="type=tcp;decode-buf-len=16384;encode-buf-len=16384;read-buf-len=4096">
-->

  <define entity="channel"
    name="channel-sctp"
    protocol="diameter-v1"
    transport="trans-sctp"
    reconnect="yes"
    open-args="mode=client;dest=62.115.66.251:3868">
  </define>
```

Figure 4-2: **Settings in Seagull's configuration file**

As mentioned earlier, Seagull uses an external SCTP library, hence the Linux Kernel SCTP module must be unloaded before you run seagull. Otherwise, the error shown below will occur:

```
ERROR: Kernel SCTP seems to be available! You cannot use sctplib and
kernel SCTP simultaneously!
Aborted (core dumped)
```

To verify whether the Linux SCTP model is loaded into the kernel, the command: *lsmod* can be used. The results of using this command is shown in Figure 4-3.

```
[root@twopiar1 run]# lsmod
Module                  Size  Used by
sctp                  196141  2
libcrc32c               1246  1 sctp
autofs4                26705  3
sunrpc                261736  1
p4_clockmod            20200  0
freq_table              4881  1 p4_clockmod
speedstep_lib           5401  1 p4_clockmod
```

Figure 4-3: **Verify loaded Kernel SCTP in Linux**

To avoid loading the Kernel SCTP module, we add sctp to the **blacklist.config** file in the /etc/modprobe.d/ directory as shown as Figure 4-4.

```
# watchdog drivers
blacklist i8xx_tco

# framebuffer drivers
blacklist aty128fb
blacklist atyfb
blacklist radeonfb
blacklist i810fb
blacklist cirrusfb
blacklist intelfb
blacklist kyrofb
blacklist i2c-matroxfb
blacklist hgafb
blacklist nvidiafb
blacklist rivafb
blacklist savagefb
blacklist sstfb
blacklist neofb
blacklist tridentfb
blacklist tdfxfb
blacklist virgefb
blacklist vga16fb
blacklist viafb

# ISDN - see bugs 154799, 159068
blacklist hisax
blacklist hisax_fcpcipnp

# sound drivers
blacklist snd-pcsp

# I/O dynamic configuration support for s390x (bz #563228)
blacklist chsc_sch

blacklist ipv6
blacklist sctp
/etc/modprobe.d/blacklist.conf (END)
```

Figure 4-4: Blacklisting kernel SCTP module

This modification will take effect after rebooting the PC. This can be verified by using command ***lsmod*** again. Figure 4-5 shows that the kernel sctp module is no longer loaded.

```
[root@twopiar1 run]# lsmod
Module                  Size  Used by
autofs4                26705  3
sunrpc                261736  1
p4_clockmod            20200  0
freq_table              4881  1 p4_clockmod
speedstep_lib           5401  1 p4_clockmod
ipv6                  320841  42
```

Figure 4-5: Verify kernel sctp unloaded

Once the kernel SCTP module is disabled, Seagull is ready to run by using the command below:

/opt/seagull/Diameter/run

[shxi00@twopiar1 run]$ ./start_shawn.ksh

If Seagull is installed and configured successfully, then a screen similar to that shown in Figure 4-6 will appear.

```
[root@twopiar1 run]# ./start_shawn_ksh
|------------------------+------------------------+------------------------|
| Start/Current Time     |    2015-02-20 11:29:46 |    2015-02-20 11:29:46 |
|------------------------+------------------------+------------------------|
|    Counter Name        |     Periodic value     |    Cumulative value    |
|------------------------+------------------------+------------------------|
| Elapsed Time           | 00:00:00:003           | 00:00:00:003           |
| Call rate (/s)         |    0.000               |    0.000               |
|------------------------+------------------------+------------------------|
| Incoming calls         |        0               |        0               |
| Outgoing calls         |        0               |        0               |
| Msg Recv/s             |    0.000               |    0.000               |
| Msg Sent/s             |    0.000               |    0.000               |
| Unexpected msg         |        0               |        0               |
| Current calls          |        0               |    0.000               |
|------------------------+------------------------+------------------------|
| Successful calls       |        0               |        0               |
| Failed calls           |        0               |        0               |
| Refused calls          |        0               |        0               |
| Aborted calls          |        0               |        0               |
| Timeout calls          |        0               |        0               |
|------------------------+------------------------+------------------------|
| Last Info              | Outgoing traffic                                |
| Last Error             | No error                                        |
|--- Next screen : Press key 1 ----------------------- [h]: Display help ------|
|------------------------+------------------------+------------------------|
| Start/Current Time     |    2015-02-20 11:29:46 |    2015-02-20 11:29:47 |
```

Figure 4-6: **Launching Seagull**

4.1.2 WAN-evaluator

As described in previous sections, a third PC (named Ellipse) acts as a WAN-evaluator in order to allow us to manipulate the network delays between the two Diameter nodes. In order to set network delay, jitter, and packet loss as desired, the ***tc*** command [41] is used.

According to Netem's configuration guide[37], the command line below gives an example of setting delay, jitter to desired values:

tc qdisc change dev eth0 root netem delay 50ms 1ms

This will add fixed network delay of 50 ms with 1 ms deviation to all the packets that are sent out from Ethernet interface eth0. To add packet loss values, this command line below will cause 1 out of 1000 packets to be randomly dropped.

tc qdisc change dev enp15s0 root netem loss 0.1%

To verify the traffic delays settings, the command ***tc qdisc*** can be used .

4.2 Laboratory Tests

This section gives the details of how SCTP parameter values and network delays are modified in order to conduct the planned tests.

4.2.1 Manipulating SCTP parameters

In order to test and evaluate how the modified SCTP parameter configuration values as defined in Table 3-5, Table 3-6, and Table 3-7 affect the transmission performance of Diameter protocol messages, the default parameter values in SCTP need to be changed. However, due to the fact that Seagull is using an external sctp lib, our approach to modifying the SCTP parameter values is to modify the corresponding values in the source code of sctplib-1.0.15[45] before installing the code.

This modification is made in file **distribution.h** in the **sctp_lib/sctplib-1.0.15/sctplib/sctp** directory. Figure 4-7 shows a screenshot of the modified parameter values in the **distribution.h** for scenario 1.

```
  I A  distribution.h (c)  */
/* define some important constants */
#define ASSOCIATION_MAX_RETRANS 6
#define MAX_INIT_RETRANSMITS    3
#define MAX_PATH_RETRANSMITS    3
#define VALID_COOKIE_LIFE_TIME  60000
/*
#define RWND_CONST              64000
*/
#define SACK_DELAY              20
#define RTO_INITIAL             50
#define IPTOS_DEFAULT           0x10    /* IPTOS_LOWDELAY */
#define RTO_MIN                 25
#define DEFAULT_MAX_SENDQUEUE   0       /* unlimited send queue */
#define DEFAULT_MAX_RECVQUEUE   0       /* unlimited recv queue - unused really */
#define DEFAULT_MAX_BURST       1       /* maximum burst parameter */
#define RTO_MAX                 500
```

Figure 4-7. SCTP Parameter setting for Scenario 1

Figure 4-8 shows a screenshot of the modified parameter values for Scenario 2.

```
  I A  distribution.h (c)  */

/* define some important constants */
#define ASSOCIATION_MAX_RETRANS 6
#define MAX_INIT_RETRANSMITS    3
#define MAX_PATH_RETRANSMITS    3
#define VALID_COOKIE_LIFE_TIME  60000
/*
#define RWND_CONST              64000
*/
#define SACK_DELAY              20
#define RTO_INITIAL             500
#define IPTOS_DEFAULT           0x10    /* IPTOS_LOWDELAY */
#define RTO_MIN                 250
#define DEFAULT_MAX_SENDQUEUE   0       /* unlimited send queue */
#define DEFAULT_MAX_RECVQUEUE   0       /* unlimited recv queue - unused really */
#define DEFAULT_MAX_BURST       1       /* maximum burst parameter */
#define RTO_MAX                 2000
```

Figure 4-8: SCTP Parameter setting for Scenario 2

Figure 4-9 shows a screenshot of the modified parameter values for Scenario 3.

```
   I A  distribution.h (Modified) (c)   */
/* define some important constants */
#define ASSOCIATION_MAX_RETRANS 6
#define MAX_INIT_RETRANSMITS    3
#define MAX_PATH_RETRANSMITS    3
#define VALID_COOKIE_LIFE_TIME  60000
/*
#define RWND_CONST              64000
*/
#define SACK_DELAY              20
#define RTO_INITIAL             3000
#define IPTOS_DEFAULT           0x10    /* IPTOS_LOWDELAY */
#define RTO_MIN                 2500
#define DEFAULT_MAX_SENDQUEUE   0       /* unlimited send queue */
#define DEFAULT_MAX_RECVQUEUE   0       /* unlimited recv queue - unused really */
#define DEFAULT_MAX_BURST       1       /* maximum burst parameter */
#define RTO_MAX                 12000
```

Figure 4-9: **SCTP Parameter setting for Scenario 3**

4.2.2 Manipulating Network Delays

As introduced earlier, the PC named Ellipse acts as WAN-evaluator in order to manipulate the network delays, jitter, and loss rate between nodes Twopiar1 and Twopiar2. In our laboratory experiments various network delay, jitter and packet loss with various values are simulated using the command line tool 'tc' according to the test cases defined in Table 3-9, Table 3-10, and Table 3-11.

It is worth noting that Netem can only add delays to the outbound packets. In our lab environment, we chose to add network delays for all the packets that pass interface **enp15s0** on the node Ellipse towards Diameter server Twopiar 2. Thus, the commands used for test cases in Scenario 1 were as listed as below:

```
tc qdisc change dev enp15s0 root netem delay 1ms 0.5ms  loss 0.05%
tc qdisc change dev enp15s0 root netem delay 5ms 0.8ms  loss 0.1%
tc qdisc change dev enp15s0 root netem delay 20ms 1ms  loss 0.2%
tc qdisc change dev enp15s0 root netem delay 40ms 1ms  loss 0.3%
tc qdisc change dev enp15s0 root netem delay 49ms 1ms  loss 0.3%
tc qdisc change dev enp15s0 root netem delay 50ms 1ms  loss 0.3%
```

4.2.3 Conducting Tests

After modifying the SCTP configuration parameters to the desired values and defining the network conditions, it is time to start sending Diameter calls from Twopiar1 to Twopiar2. To do so, the Seagull server first needs to be started at Twopiar2, then Seagull client is started on Twopiar1. If there are no misconfigurations or network failures, then the client will start sending Diameter calls to the server at the rate of 1 call/second (by default).

Figure 4-10 shows that the Seagull client has sent 122 successful Diameter calls to its server in network Scenario 1, where the delay is 20 ms, jitter is 1 ms, and packet loss is 0.2%.

```
|-----------------------+-------------------------+-------------------------|
| Start/Current Time    |     2015-02-20 22:59:59 |     2015-02-20 23:02:00 |
|-----------------------+-------------------------+-------------------------|
|    Counter Name       |     Periodic value      |    Cumulative value     |
|-----------------------+-------------------------+-------------------------|
| Elapsed Time          | 00:00:00:749            | 00:02:00:780            |
| Call rate (/s)        |    1.335                |    1.010                |
|-----------------------+-------------------------+-------------------------|
| Incoming calls        |        0                |        0                |
| Outgoing calls        |        1                |      122                |
| Msg Recv/s            |    1.335                |    1.010                |
| Msg Sent/s            |    1.335                |    1.010                |
| Unexpected msg        |        0                |        0                |
| Current calls         |        0                |    0.000                |
|-----------------------+-------------------------+-------------------------|
| Successful calls      |        1                |      122                |
| Failed calls          |        0                |        0                |
| Refused calls         |        0                |        0                |
| Aborted calls         |        0                |        0                |
| Timeout calls         |        0                |        0                |
|-----------------------+-------------------------+-------------------------|
| Last Info             | Stopping traffic                                  |
| Last Error            | No error                                          |
|--- Next screen : Press key 1 ---------------------- [h]: Display help ------|
```

Figure 4-10: **Sending Diameter Messages at Client node**

Figure 4-11 shows that the Seagull server has successfully received 122 Diameter calls.

```
|--- Next screen : Press key 1 ---------------------- [h]: Display help ------|
|-----------------------+-------------------------+-------------------------|
| Start/Current Time    |     2015-02-20 22:59:54 |     2015-02-20 23:14:15 |
|-----------------------+-------------------------+-------------------------|
|    Counter Name       |     Periodic value      |    Cumulative value     |
|-----------------------+-------------------------+-------------------------|
| Elapsed Time          | 00:00:01:000            | 00:14:21:225            |
| Call rate (/s)        |    0.000                |    0.142                |
|-----------------------+-------------------------+-------------------------|
| Incoming calls        |        0                |      122                |
| Outgoing calls        |        0                |        0                |
| Msg Recv/s            |    0.000                |    0.142                |
| Msg Sent/s            |    0.000                |    0.142                |
| Unexpected msg        |        0                |        0                |
| Current calls         |        0                |    0.000                |
|-----------------------+-------------------------+-------------------------|
| Successful calls      |        0                |      122                |
| Failed calls          |        0                |        0                |
| Refused calls         |        0                |        0                |
| Aborted calls         |        0                |        0                |
| Timeout calls         |        0                |        0                |
|-----------------------+-------------------------+-------------------------|
| Last Info             | Incomming traffic                                 |
| Last Error            | No error                                          |
|--- Next screen : Press key 1 ---------------------- [h]: Display help ------|
```

Figure 4-11: **Receiving Diameter Messages at Server node**

4.2.4 Capturing Packets

As described earlier, we use '**tpcdump'** to capture all the packets sent and received at Diameter Client and Server. It is worth noting that **tcpdump** needs to be executing on both client and server nodes *before* sending Diameter calls, so that the packets sent and received at Twopiar1 and Twopiar2 can be captured.

In our lab tests, we name each captured packet file in the format of ***scenario x_xms.cap*** and ***scenariox_xms_server.cap.*** For Scenario 1, the following packet capture files are generated:

scenario 1_1ms.cap

scenario 1_5ms.cap

scenario 1_20ms.cap

scenario 1_40ms.cap

scenario 1_49ms.cap

scenario 1_1ms_server.cap

scenario 1_5ms_server.cap

scenario 1_20ms_server.cap

scenario 1_40ms_server.cap

scenario 1_49ms_server.cap

When the delay value was set to 50 ms, Seagull stops sending Diameter calls. This occurs because we modified the RTO.init value to 50 ms for Scenario 1. As described in Section 2.1.5, at the beginning of a SCTP data transmission, if no RTT measurement has been made, SCTP sets RTO= RTO.Intial, in this case, the RTO will be set to 50 ms. However, Twopiar 1 gives up after sending 3 INIT messages without receiving an INIT ACK within 50 ms. Therefore, the files ***scenario 1_50ms.cap*** and ***scenario 1_50ms_server.cap*** *are* **not** generated.

The above behavior occurred because that we set the RTO.inital =50ms in Scenario 1 and the preconfigured network delay in test case 6 is 50 ms. According to SCTP's RTO algorithm, the client node sent INIT messages 3 times without receiving an INIT_ACK within 50 ms, hence it terminated the negotiation and regarded this peer as not reachable (via the selected path).

For Scenario 2, the following packet capture files are generated:

scenario 2_1ms.cap

scenario 2_5ms.cap

scenario 2_20ms.cap

scenario 2_50ms.cap

scenario 2_60ms.cap

scenario 2_100ms.cap

scenario 2_499ms.cap

scenario 2_1ms_server.cap

scenario 2_5ms_server.cap

scenario 2_20ms_server.cap

scenario 2_50ms_server.cap

scenario 2_60ms_server.cap

scenario 2_100ms_server.cap

scenario 2_499ms_server.cap

Due to the RTO.init value being set to 500 ms in Scenario 2, Twopiar1 stops sending calls to Twopiar2 when the network delay is set to 500 ms, thus the files ***scenario 2_500ms.cap*** and ***scenario 2_500ms_server.cap*** will **not** be generated.

For scenario 3, the following packet capture files are generated:

scenario 3_1ms.cap	***scenario 3_1ms_server.cap***
scenario 3_5ms.cap	***scenario 3_5ms_server.cap***
scenario 3_20ms.cap	***scenario 3_20ms_server.cap***
scenario 3_50ms.cap	***scenario 3_50ms_server.cap***
scenario 3_100ms.cap	***scenario 3_100ms_server.cap***
scenario 3_500ms.cap	***scenario 3_100ms_server.cap***
scenario 3_800ms.cap	***scenario 3_800ms_server.cap***
scenario 3_1000ms.cap	***scenario 3_1000ms_server.cap***
scenario 3_2990ms.cap	***scenario 3_2990ms_server.cap***

As the RTO.init value is set to 3000 ms in Scenario 3, Twopiar1 stops sending calls to Twopiar2 when the network delay is set to 3000 ms, thus the files ***scenario 3_3000ms.cap*** and ***scenario 3_3000ms_server.cap*** are **not** generated.

5 Analysis

In this chapter, we summarize the test results from the laboratory testes described in the previous chapter and present an analysis.

5.1 Major Results

Based on the laboratory tests conducted, we summarize the major test results obtained at Diameter client and server respectively. The test cases described in Table 3-9, Table 3-10, and Table 3-11 were conducted accordingly in the lab environment and packets were captured at both Diameter client and Server side. These packet capture files were analyzed using Wiresharp[39] and the RTD of each Diameter message at the Diameter client node are calculated. Additionally, the time for the Diameter server to acknowledge a received Diameter request message and send the corresponding Diameter Answer message is calculated. The results of these calculations are presented in this section.

5.1.1 Scenario 1

The statistics of the calculated RTD of Diameter messages in all the test cases in network scenario 1 are summarized and presented as in Table 4-5. The histograms of RTD distribution for each test case can be found in Appendix B.

Table 5-1: Scenario 1 Diameter message RTD statistics

Test Number	Minimum Delay (ms)	Maximum Delay (ms)	Average Delay (ms)	Median Delay (ms)	Std.Dev* (ms)
1	0.966	2.009	1.492	1.479	0.286
2	4.674	6.345	5.586	5.654	0.461
3	19.47	21.494	20.482	20.487	0.571
4	39.452	41.530	40.423	40.293	0.576
5	48.497	50.522	49.568	49.596	0.563
6	x	x	x	x	x

The captured packets showed that no packet loss occurred during all 5 test cases. This is because that we only sent 200 Diameter messages and the network delays were less than 50 ms and packet loss rate is less than 0.2%. The average RTD of Diameter messages are very closed to the preconfigured delay and jitter values, with a standard deviation of 0.5 ms. This is considered very stable. As explained in Section 4.2.4, no Diameter message transmission occurred in test case 6. Consequently, there were no Diameter messages captured at the server.

* Standard deviation

At the Diameter server side, we evaluated the time for the server to send a corresponding Diameter Answer message. The time is calculated from the moment it receives a Diameter request message to the time it sends out the corresponding Answer message. A summary of these statistics are shown in Table 5-2.

Table 5-2: Scenario 1 Server responding time statistics

Test Number	Minimum (ms)	Maximum (ms)	Mean (ms)	Median (ms)	Std.Dev (ms)
1	0.187	0.452	0.242	0.247	0.046
2	0.182	0.403	0.239	0.242	0.035
3	0.18	0.462	0.2433	0.2425	0.042
4	0.175	0.417	0.24	0.252	0.041
5	0.132	0.43	0.244	0.246	0.036
6	x	x	x	x	x

The figures in the table above show that the server's response times for the tested Diameter message were quite rapid and stable. The average response time was ~0.24 ms with a standard deviation of ~0.04 ms. Based on the statistics in Table 5-1 and Table 5-2, we assume that the suggested modification of SCTP parameter values (Table 3-5) provides very reliable transmission performance for Diameter messages when no packet loss occurs. However, the performance when packet loss occurs remains unknown.

5.1.2 Scenario 2

The statistics of the calculated RTD of Diameter messages for all the test cases in network Scenario 2 are summarized and presented in Table 5-3.

Table 5-3: Scenario 2 Diameter Message RTD statistics

Test Number	Minimum Delay (ms)	Maximum Delay (ms)	Average Delay (ms)	Median Delay (ms)	Std.Dev (ms)
1	1.007	2.044	1.526	1.532	0.283
2	4.69	6.482	5.560	5.547	0.491
3	19.536	21.86	20.574	20.5835	0.58
4	49.536	51.586	50.591	50.671	0.582
5	59.538	61.521	60.599	60.695	0.584
6	99.505	**753.715**	103.827	100.534	**46.542**
7	498.559	**1001.183**	502.026	499.546	**35.21**
8	x	x	x	x	x

During these 8 test cases, packet loss occurred in test case 6 and 8 and the maximum delay and standard deviation values (set in bold fact and red text) increased significantly. In Test 6, we set the network to a delay of 100 ms, jitter 1 ms, and packet loss 0.5%. When looking into the captured packet file ***scenario 2_100ms.cap*** in Wireshark[39], it is quite clear to see that a total of 197 Diameter Request messages were captured. One retransmission occurred after 55.982 seconds. The Diameter Request message was sent at time 55.329, but was lost. It took the Diameter client until 652.549 ms to start retransmission. After 100.966 seconds the client node received the Diameter Answer message to this retransmitted request. Therefore, it took 753.715 ms in total to receive the Answer message to the Diameter request message that was lost.

In Test 7, where we set network delay to 499 ms, jitter 1 ms, and packet loss 0.5%. A total of 197 Diameter Request Call messages were captured and 2 retransmissions occurred due to packet loss. The first retransmission occurred after 72.044 seconds, because a Diameter Request message that was sent at 71.542 was lost. It took the client 501.218 ms to start retransmission. After 499.965 ms, the client received the Diameter Answer message to this retransmitted request. Therefore, it took 1.001183 second in total to successfully deliver the message and receive an answer. The second retransmission occurred after 158.049 seconds, because another Diameter Request message that was sent at 157.550 seconds was lost. Following this, it took the client 499.006 ms to start retransmission. At 158.049 seconds, the client received the Diameter Answer message from the server to this retransmitted request. Therefore, it took 499.623 ms in total to successfully deliver the message and receive an answer. For more details of the retransmission, please refer to the file ***scenario 2_499ms.cap.***

At the server side, the statistics summary of its response time for each test case is listed in Table 5-4. From this table, we can see that it takes more or less the same amount of time (average 0.26 ms with a standard deviation 0.04 ms) as in Scenario 1 for the server to respond to each Diameter request message with an Answer message, **independent** of the network delay. Additionally, the retransmission in tests 6 and 7 did not affect the server's response time.

Table 5-4: Scenario 2 Server responding time statistics

Test Number	Minimum (ms)	Maximum (ms)	Mean (ms)	Median (ms)	Std.Dev (ms)
1	0.187	0.445	0.246	0.252	0.037
2	0.185	0.432	0.248	0.257	0.042
3	0.184	0.428	0.254	0.261	0.043
4	0.183	0.423	0.255	0.259	0.040
5	0.207	0.382	0.2562	0.26	0.036
6	0.186	0.462	0.2589	0.2625	0.047
7	0.206	0.415	0.264	0.276	0.040
8	x	x	x	x	x

5.1.3 Scenario 3

The statistics of calculated RTD of Diameter messages for all the test cases in network Scenario 3 are summarized and presented in Table 5-5.

Table 5-5: Scenario 3 Diameter Message RTD statistics

Test Number	Minimum Delay (ms)	Maximum Delay (ms)	Average Delay (ms)	Median Delay (ms)	Std.Dev (ms)
1	1.014	2.059	1.574	1.5815	0.287
2	4.735	6.315	5.526	5.5315	0.452
3	19.568	21.68	20.592	20.607	0.579
4	49.484	3553.384	90.631	50.419	323.614
5	99.57	101.603	100.623	100.619	0.549
6	490.115	4507.36	756.262	502.884	831.034
7	799.534	801.672	800.583	800.59	0.589
8	990	5502	1124	1002	627.994
9	2980	8333	3077	2991	572.962
10	X	X	X	X	X

Among the 10 test cases, packet loss happened in tests 4, 6, 8, and 9. For the details of this packet loss and retransmission process during these tests, please refer to files ***scenario 3_50ms.cap***, ***scenario 3_500ms.cap***, ***scenario 3_1000ms.cap,*** and ***scenario 3_2990ms.cap***. Based on the statistics presented in Table 5-5, we can see that the maximum RTD and deviation values (marked in red) also increased noticeably, even more so than in Scenario 2. For example, the test case 7 in Scenario 2 and test case 6 in Scenario 3 have almost the network delay (499 ms and 500 ms respectively), however the maximum RTD (4507.36 ms) in Scenario 3 is more than 4 times longer than Scenario 2 (1001.183 ms), the standard deviation is more than 20 times higher . This indicates that the proposed SCTP parameter values in Table 3-7 caused longer retransmission time and the RTD are **not** reliable compared to Scenario 2.

At the Diameter server side, the summary of the calculated statistics is shown in Table 5-6. From these statistics we can see that maximum RTO and standard deviation values (marked in red) increased significantly when packet loss happened in those 4 tests: Test 4 (50 ms delay), Test 6 (500 ms delay), Test 8 (1000 ms delay), and Test 9 (2990 ms delay). When a packet is lost, the server needs to wait for retransmission of the lost packet to arrive before acknowledging other packets. The receiver awaits the retransmission of the missing packet. This causes the subsequent messages that are sent after the lost message to be pended until the retransmission is acknowledged. For instance, in test 4, one Diameter Request message was sent at 22.200 seconds, but got lost, it took 3.503 seconds for Diameter client to start retransmission (as described earlier), then the retransmitted packet arrived at server at 25.704 seconds and was acknowledged at 25.7044 seconds. While waiting for the retransmission, there were 3 messages received at server, but did not get acknowledged until the retransmitted packet got acknowledged. Therefore, the longest delay in test 4 (2.551 seconds) was the time it took to acknowledge the first message that were sent after the lost message. The same applies to tests 6, 8, and 9. Based on these findings, we can see that server's response time is affected by the actual network delay and retransmission behavior.

Table 5-6: **Scenario 3 Server delay measurement statistics**

Tests	Minimum (ms)	Maximum (ms)	Mean (ms)	Median (ms)	Std.Dev (ms)
Test 1	0.195	0.388	0.25865	0.271	0.047
Test 2	0.189	0.407	0.26	0.2685	0.039
Test 3	0.186	0.398	0.254	0.2605	0.047
Test 4	0.191	**2551.001**	23.742	0.2755	**214.94**
Test 5	0.188	0.469	0.2687	0.279	0.0413
Test 6	0.205	**3006.108**	181.9927	0.283	**626.02**
Test 7	0.190	0.456	0.2688	0.2765	0.041
Test 8	0.198	**3495.487**	81.2193	0.290	**454.612**
Test 9	0.196	**4361.549**	59.046	0.2895	**431.41**

5.2 Applying Suggested SCTP Parameter Values

Based on the experimental results and analysis in Section 5.1, we can see that if no packet loss and retransmission occur, then the RTD of Diameter messages were close to the preconfigured network delay and jitter values, with a very small deviation of 0.5 ms. However, when retransmission occurred, then RTD greatly increased and we can see the relation between the network delay and RTO.initial values shown in Table 5-7.

Table 5-7: **Comparison of RTD when retransmissions occur**

Scenario	Network delay (ms)	RTO.initial (ms)	Maxium RTD (ms)	Std.Dev (ms)
2	100	500	753.715	46.542
2	**499**	**500**	**1001.183**	**35.21**
3	**500**	**3000**	**4507.36**	**831.034**
3	1000	3000	5502	627.994
3	2990	3000	8333	572.962

From the table above, we can see that when the value of RTO.initial increased, the maxium RTD and standard deviation also increased, even in scenarios that have the same network delay and jitter. The red marked entries (in the second and third rows) show that even when the preconfigured network delay is only 1 ms larger, that the higher RTO.initial value can lead to much longer RTD and higher deviation values.

Therefore, the author decided to adjust the parameter values by reducing the RTO.inital values for Scenarios 2 and 3 and running further validation tests (as described in Section 3.3.5) in order to verify if the retransmission time would be shortened. For Scenario 2, the RTO.initial is changed from 500 ms to 200 ms, as shown in Table 5-8. For Scenario 3, the RTO.initial is changed from 3 seconds to 2 seconds, as shown in Table 5-9. For Scenario 2, the author increased RTO.Max value from 2 seconds to 20 seconds, because the validation tests is designed to last for 10 minutes, and author does not want the transmission to be terminated too soon. For the same reason in for Scenario 3, the author increased RTO.max value from 12 seconds to the default value of 60 seconds.

Table 5-8: Modified SCTP Parameter Values for Scenario 2

Parameter	Value
RTO.Initial (ms)	200
RTO.Min (ms)	100
RTO.Max (ms)	20000
Max.Burst	4
RTO.Alpha	1/8
RTO.Beta	1/4
Valid.Cookie.Life	60 seconds
Association.Max.Retrans	6 attempts
Path.Max.Retrans	3 attempts (per destination address)
Max.Init.Retransmits	3 attempts
HB.interval	30 seconds
HB.Max.Burst	1

Table 5-9: Modified SCTP Parameter Values for Scenario 3

Parameter	Value
RTO.Initial (ms)	2000
RTO.Min (ms)	1000
RTO.Max (ms)	60000
Max.Burst	4
RTO.Alpha	1/8
RTO.Beta	1/4
Valid.Cookie.Life	60 seconds
Association.Max.Retrans	6 attempts
Path.Max.Retrans	3 attempts (per destination address)
Max.Init.Retransmits	3 attempts
HB.interval	30 seconds
HB.Max.Burst	1

For Scenario 2, we chose to test with a network delay of 100 ms, jitter 1 ms, and packet loss rate of 0.5%. During this test 60 893 Diameter messages sent and received according to the packets captured and these were subsequently analyzed. Table 5-10 shows the statistics of these RTD measurements.

Table 5-10: Scenario 2 Diameter Message RTD statistics

Minimum Delay (ms)	Maximum Delay (ms)	Average Delay (ms)	Median Delay (ms)	Std.Dev (ms)
98.804	352.66	105.55	101.20	20.299

By comparing this table to the statistics of test case 6 of Scenario 2 shown as in Table 5-11., we can see that a lower RTO.initial value leads to better RTD and better stability.

Table 5-11: Scenario 2 Diameter Message RTD Statistics_Test Case 6

Minimum Delay (ms)	Maximum Delay (ms)	Average Delay (ms)	Median Delay (ms)	Std.Dev (ms)
99.505	**753.715**	103.827	100.534	**46.542**

For scenario 3, the author chose a network delay of 1000 ms, jitter 10 ms, and packet loss rate of 1%. As described earlier, the Diameter messages were sent at the rate of 100 messages per second for about 10 minutes. This setting means that there will be approximately 1 message lost every second, hence the Diameter node needs to retransmit lost messages all the time. After repetitive tests, we noticed that the Diameter nodes terminated their transmissions after around 20 seconds. This is due to the RTO.max value being limited to 60 seconds. If we consider the time duration a retransmission takes for a single lost message is around 3 seconds (RTO.initial=2 seconds and network delay=1 second), the 1st lost message needs to wait for 3 seconds to be acknowledged and transmitted back to the sender. The 2nd lost message occurred after 2 seconds at the sender side, but it took about 6 seconds to be retransmitted, because the receiver needs to await the completion of the acknowledgement of the 1st retransmitted message, and then it took another 3 seconds to trigger retransmission of 2nd lost message. When the 3rd message was lost, it took about 9 seconds to be retransmitted. Consequently, it took about 60 seconds for the 20th lost message to retransmitted and acknowledged. By that time, the RTO timer expired and SCTP terminated the transmission, as the failover process did not take place successfully.

In order to validate this analysis, we changed the RTO.max from 60 seconds to 30 seconds, and then we could see that the SCTP connection was aborted after about 10 seconds. With this hypothesis, I thought changing the RTO.max values to 100 seconds or 1000 seconds would prolong the Diameter association. However, our test results showed that the SCTP association still terminated after about 20 seconds. I suspect that the sctp library Seagull utilizes might only accept a maximum RTO of 60 seconds, hence higher values would not take effect. Due to the limited timeframe of this thesis project, the author did not investigate this issue further.

From the above analysis, we conclude that it will **not** be a good idea for there to be only one SCTP association available in such an unreliable network environment as tested in

Scenario 3 with a high packet loss rate of 1%. In such a case a secondary path must be established in the case of both high delay and a high packet loss ratio.

In order to verify how the parameter values suggested in Table 3-5 affect the performance in a reliable network condition, such as Scenario 1, when retransmission occurs, the author sent Diameter messages at the rate of 100 messages per second for 10 minutes in s network that has 5 ms network delay, jitter 0.5 ms, and packet loss ration of 0.1%. The results of this test are shown in Table 5-12.

Table 5-12 Scenario 1 Diameter Message RTD statistics

Minimum Delay (ms)	Maximum Delay (ms)	Average Delay (ms)	Median Delay (ms)	Std.Dev (ms)
4.9110	36.7060	5.8915	5.9170	0.936

The figures show that a reliable network (such as in Scenario 1) with the suggested SCTP parameter values can provide reliable Diameter transmission, even though packet loss occurs, while the RTD has a standard deviation of less than 1 ms.

5.3 Discussion

Retransmissions are timer-controlled and the time that it takes for a retransmission to happen is derived from measurements of the RTD between the two endpoints. Consequently, the time for this retransmission depends upon the values set for RTO.intial and the network delay. If the approximate network delay is known for a particular network setup, and there is a need to limit or reduce the time needed for retransmission timeout to a desired level, then the RTO.initial should be configured accordingly.

With regard to testing SCTP failover performance, the author used a SCTP traffic generator tool Iperf3 to generate SCTP traffic and tested failovers in our lab environment. The test results showed the failover process occurs as it was designed to occur. Since this project focused only on a single-homed association, the details results of this failover test are not presented here. The captured test trace file can be found in the appendix at the end of this report.

6 Conclusions and Future work

In this chapter, the conclusion of this master's thesis project is presented. Some future research work is also suggested. The chapter ends with some reflections on the economic, social, ethical, and sustainability aspects of this thesis project.

6.1 Conclusions

With the advent of 3GPP's LTE and 4G cellular systems, the amount of IP traffic and the number of LTE connections are constantly growing. In addition, the signaling traffic based on the Diameter protocol between network elements in LTE networks will continue to increase. From a Diameter server provider's perspective, maintaining robust Diameter connectivity availability is crucial to ensure QoS and QoE for the Diameter Signaling service. To obtain the optimal Diameter message transmission performance, its transport protocol SCTP must be considered and evaluated, since the 'One size for all' configuration recommendations defined in IETF's RFC 4960 for SCTP should not be blindly applied in network environments with different network conditions (e.g. specific delay, jitter, and packet loss rates).

In this thesis project, the author studied SCTP and Diameter protocols, as well as previous research on tuning SCTP parameter configuration values to obtain better transmission performance for signaling traffic. Based on the collected research results, some theoretically optimal SCTP parameter configuration values were summarized, suggested, and tested in our laboratory. In this thesis project, three generic network environments (see as below) are considered and laboratory tests were conducted to evaluate the Diameter message transmission performance in these three environments:

1. Reliable network with low network latency (e.g., a national network environment),
2. Semi-reliable network with medium latency (e.g., an intra-continent network, for example inside continental European Union/EU region) , and
3. An unreliable network with high latency and long geographic distance (e.g., intercontinental networks, for example European Union to/from Asia Pacific (EU-APAC) connection)

Based on the tests conducted in this thesis project, we could see that the time for a Diameter node to initiate a retransmission is largely dependent upon RTO.intial value and the actual network delay. Diameter service providers or MNOs can modify SCTP's configuration values based on the known network conditions (such as delay, packet loss) in their networks to achieve better packet loss recovery performance. Our test results also showed that the Diameter message volume can also impact retransmission and eventually will affect the reliability of their transmission. This will occur because the greater the amount of messages transmitted, the greater the number of lost messages is a specific network condition (i.e., with a certain packet loss ratio). Thus, more messages means more retransmissions, hence they are bound to happen more frequently.

Table 6-1 shows the SCPT parameter configuration values we proposed for the three network scenarios given in Table 3-1.

Table 6-1: Summary of the recommended SCTP parameter values

	Scenario 1	Scenario 2	Scenario 3
Parameter	**Value**		
RTO.Initial (ms)	50	200	2000
RTO.Min (ms)	25	100	1000
RTO.Max (ms)	500	20000	60000
Max.Burst	4	4	4
RTO.Alpha	1/8	1/8	1/8
RTO.Beta	1/4	1/4	1/4
Valid.Cookie.Life	60 seconds	60 seconds	60 seconds
Association.Max.Retrans	6 attempts	6 attempts	6 attempts
Path.Max.Retrans	3 attempts (per destination address)	3 attempts (per destination address)	3 attempts (per destination address)
Max.Init.Retransmits	3 attempts	3 attempts	3 attempts
HB.interval	30 seconds	30 seconds	30 seconds
HB.Max.Burst	1	1	1

As noted in Section 5.2, if a network environment with an overall delay is about 1 second and about 1% packet loss, such recommended values would not help improve transmission performance, the optimal solution should be switch over to a better performing link as soon as such delay and packet loss are detected.

6.2 Limitations

The laboratory tests we conducted are based on the Seagull application, which does not utilize Linux Kernel sctp library. The test results will be more convincing if the Seagull software can be modified to utilize Linux kernel sctp library instead external proprietary library, since many network operators' Diameter Agents run on top of Linux kernel.

One limitation about utilizing Seagull in our laboratory experiments to generate Diameter traffic is that the SCTP failover could not occur. During our tests, we could see that Diameter server sent HeartBeat messages on the secondary link to the client node; however, the client node could not acknowledge it, although the secondary link connection was working correctly. This causes the server to believe that the secondary link is not available, thus we could not test Diameter failover performance.

6.3 Future work

There are several immediate works author can think of and they are worth investigating further. However due to the timeframe of this thesis project, author will leave them as future work.

The first thing would be fixing the Seagull code, so that it can use the kernel SCTP module rather than the external module. The second thing that is worth doing is to replay

Diameter traffic captured in a real network into a test configuration in a lab environment, so that the test results would be much closer to the network reality. Because Seagull is only designed to send fixed rate of Diameter messages, and real life Diameter messages rates are not constant. Furthermore, during the analysis of the test results, author did not investigate how different Diameter message requests were sent on different streams within an association to avoid head of line blocking. This can be worth analyzing in future works, since it will be very desirable when scaling up the traffic load.

6.4 Required reflections

This thesis project was started with the discussion author had with his industrial advisors about ensuring QoS of their Diameter Routing Exchanging service for LTE roaming. Since commercializing LTE roaming worldwide is still at an early stage, there is still lack of standardized QoE and QoS for Diameter Service providers to offer their customers. With this relevant business background and appropriate technical support, the author studied the performance of the Diameter protocol when utilizing SCTP as its transport layer protocol. The aim was to explore whether it was possible to tune the SCTP configuration values to achieve optimal Diameter transmission availability and reliability in various network conditions, so that a set of configuration values could be provided to the author's employer to improve QoS for their Diameter Routing Exchange service.

As this thesis project is considered basic research and considering the company's polices, the practical experiments conducted in our lab did not utilize the actual Diameter equipment that is in service or the operating network environment. For this reason, only requests rates averaged over a day were given (to avoid disclosing any company confidential data). Additionally, an emulated network was set up in a LAN environment and an open-source Diameter message generator tool was used to generate traffic for my experiments; hence, there was no risk of accidentally disclosing any customer's actual Diameter traffic.

In spite of the limitations listed in Section 6.3, the research did lay a foundation for the optimal Diameter transmission performance by tuning SCTP parameter configuration values. These research results are considered valuable by author's industrial supervisors and will be used as reference to adjust SCTP parameter values in TSIC's production platform. Knowing these values could help the operator to offer better service to their customers which would have a positive impact on the company. In addition, because the customers would have a higher quality of service the delays experienced by their customer (end users) should be improved. This would have a positive value for society in that all of the end users whose MNOs use such an optimize Diameter and SCTP service should have shorter waiting times for calls to be initiated, shorter times to roaming to another network, etc.

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Appendix A: Captured packets at Diameter Client

An example of a captured packet file at the Diameter Client is presented in this appendix. The other captured packet traces are available via DiVA.

Scenario 1_1ms

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	62.115.66.250	62.115.66.251	SCTP	96	INIT
2	0.003573	62.115.66.251	62.115.66.250	SCTP	184	INIT_ACK
3	0.003809	62.115.66.250	62.115.66.251	SCTP	160	COOKIE_ECHO
4	0.005758	62.115.66.251	62.115.66.250	SCTP	62	COOKIE_ACK
5	0.006277	62.115.66.250	62.115.66.251	DIAMETER	344	cmd=Capabilities-Exchange Request(257) flags=R--- appl=Diameter Common Messages(0) h2h=0 e2e=0 |
6	0.007208	62.115.66.251	62.115.66.250	SCTP	64	SACK
7	0.007429	192.194.74.138	192.194.74.137	SCTP	80	HEARTBEAT
8	0.007542	62.115.66.251	62.115.66.250	DIAMETER	304	SACK cmd=Capabilities-Exchange Answer(257) flags=---- appl=Diameter Common Messages(0) h2h=0 e2e=0 |
9	0.007646	62.115.66.250	62.115.66.251	SCTP	64	SACK
10	0.058024	62.115.66.250	62.115.66.251	DIAMETER	320	SACK cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fa1 e2e=1389 |
11	0.059321	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fa1 e2e=1389 |
12	0.078489	62.115.66.250	62.115.66.251	SCTP	64	SACK
13	1.010999	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fa2 e2e=138a |
14	1.012257	62.115.66.251	62.115.66.250	SCTP	64	SACK
15	1.012436	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fa2 e2e=138a |
16	1.012505	62.115.66.250	62.115.66.251	SCTP	64	SACK
17	1.951511	62.115.66.250	62.115.66.251	SCTP	64	SACK
18	2.014237	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fa3 e2e=138b |
19	2.015554	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fa3 e2e=138b |
20	2.034723	62.115.66.250	62.115.66.251	SCTP	64	SACK
21	3.017344	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fa4 e2e=138c |
22	3.018720	62.115.66.251	62.115.66.250	SCTP	64	SACK
23	3.018908	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fa4 e2e=138c |
24	3.018980	62.115.66.250	62.115.66.251	SCTP	64	SACK
25	3.951985	62.115.66.250	62.115.66.251	SCTP	64	SACK
26	4.020708	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fa5 e2e=138d |
27	4.022013	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fa5 e2e=138d |
28	4.041184	62.115.66.250	62.115.66.251	SCTP	64	SACK
29	5.023854	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fa6 e2e=138e |
30	5.024884	62.115.66.251	62.115.66.250	SCTP	64	SACK
31	5.025071	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fa6 e2e=138e |
32	5.025155	62.115.66.250	62.115.66.251	SCTP	64	SACK
33	5.055248	62.115.66.250	62.115.66.251	SCTP	64	SACK

34	6.026908	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fa7 e2e=138f |
35	6.028718	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fa7 e2e=138f |
36	6.047884	62.115.66.250	62.115.66.251	SCTP	64	SACK
37	7.030649	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fa8 e2e=1390 |
38	7.032472	62.115.66.251	62.115.66.250	SCTP	64	SACK
39	7.032640	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fa8 e2e=1390 |
40	7.032712	62.115.66.250	62.115.66.251	SCTP	64	SACK
41	7.953675	62.115.66.250	62.115.66.251	SCTP	64	SACK
42	8.034440	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fa9 e2e=1391 |
43	8.036027	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fa9 e2e=1391 |
44	8.055265	62.115.66.250	62.115.66.251	SCTP	64	SACK
45	9.037881	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=faa e2e=1392 |
46	9.039397	62.115.66.251	62.115.66.250	SCTP	64	SACK
47	9.039562	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=faa e2e=1392 |
48	9.039629	62.115.66.250	62.115.66.251	SCTP	64	SACK
49	9.954587	62.115.66.250	62.115.66.251	SCTP	64	SACK
50	10.041400	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fab e2e=1393 |
51	10.043281	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fab e2e=1393 |
52	10.062446	62.115.66.250	62.115.66.251	SCTP	64	SACK
53	11.045054	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fac e2e=1394 |
54	11.046790	62.115.66.251	62.115.66.250	SCTP	64	SACK
55	11.046951	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fac e2e=1394 |
56	11.047019	62.115.66.250	62.115.66.251	SCTP	64	SACK
57	11.955969	62.115.66.250	62.115.66.251	SCTP	64	SACK
58	12.048742	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fad e2e=1395 |
59	12.050034	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fad e2e=1395 |
60	12.069190	62.115.66.250	62.115.66.251	SCTP	64	SACK
61	13.051815	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fae e2e=1396 |
62	13.053187	62.115.66.251	62.115.66.250	SCTP	64	SACK
63	13.053370	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fae e2e=1396 |
64	13.053494	62.115.66.250	62.115.66.251	SCTP	64	SACK
65	13.956466	62.115.66.250	62.115.66.251	SCTP	64	SACK
66	14.055262	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=faf e2e=1397 |
67	14.056344	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=faf e2e=1397 |
68	14.075508	62.115.66.250	62.115.66.251	SCTP	64	SACK

69	15.058135	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fb0 e2e=1398 |
70	15.059452	62.115.66.251	62.115.66.250	SCTP	64	SACK
71	15.059620	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fb0 e2e=1398 |
72	15.059688	62.115.66.250	62.115.66.251	SCTP	64	SACK
73	15.103778	62.115.66.250	62.115.66.251	SCTP	64	SACK
74	16.011318	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fb1 e2e=1399 |
75	16.012488	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fb1 e2e=1399 |
76	16.031647	62.115.66.250	62.115.66.251	SCTP	64	SACK
77	17.015400	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fb2 e2e=139a |
78	17.017131	62.115.66.251	62.115.66.250	SCTP	64	SACK
79	17.017305	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fb2 e2e=139a |
80	17.017376	62.115.66.250	62.115.66.251	SCTP	64	SACK
81	17.957366	62.115.66.250	62.115.66.251	SCTP	64	SACK
82	18.019112	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fb3 e2e=139b |
83	18.020262	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fb3 e2e=139b |
84	18.039425	62.115.66.250	62.115.66.251	SCTP	64	SACK
85	19.022061	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fb4 e2e=139c |
86	19.023695	62.115.66.251	62.115.66.250	SCTP	64	SACK
87	19.023865	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fb4 e2e=139c |
88	19.023937	62.115.66.250	62.115.66.251	SCTP	64	SACK
89	19.957918	62.115.66.250	62.115.66.251	SCTP	64	SACK
90	20.025682	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fb5 e2e=139d |
91	20.026899	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fb5 e2e=139d |
92	20.046066	62.115.66.250	62.115.66.251	SCTP	64	SACK
93	21.028667	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fb6 e2e=139e |
94	21.029790	62.115.66.251	62.115.66.250	SCTP	64	SACK
95	21.029951	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fb6 e2e=139e |
96	21.030023	62.115.66.250	62.115.66.251	SCTP	64	SACK
97	21.958018	62.115.66.250	62.115.66.251	SCTP	64	SACK
98	22.031831	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fb7 e2e=139f |
99	22.033443	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fb7 e2e=139f |
100	22.052617	62.115.66.250	62.115.66.251	SCTP	64	SACK
101	23.035204	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fb8 e2e=13a0 |
102	23.036204	62.115.66.251	62.115.66.250	SCTP	64	SACK
103	23.036394	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fb8 e2e=13a0 |
104	23.036466	62.115.66.250	62.115.66.251	SCTP	64	SACK

105	23.959456	62.115.66.250	62.115.66.251	SCTP	64	SACK
106	24.038144	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fb9 e2e=13a1 |
107	24.039791	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fb9 e2e=13a1 |
108	24.058977	62.115.66.250	62.115.66.251	SCTP	64	SACK
109	25.041579	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fba e2e=13a2 |
110	25.042619	62.115.66.251	62.115.66.250	SCTP	64	SACK
111	25.042790	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fba e2e=13a2 |
112	25.042873	62.115.66.250	62.115.66.251	SCTP	64	SACK
113	25.153022	62.115.66.250	62.115.66.251	SCTP	64	SACK
114	26.044558	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fbb e2e=13a3 |
115	26.046296	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fbb e2e=13a3 |
116	26.065470	62.115.66.250	62.115.66.251	SCTP	64	SACK
117	27.048052	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fbc e2e=13a4 |
118	27.049283	62.115.66.251	62.115.66.250	SCTP	64	SACK
119	27.049458	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fbc e2e=13a4 |
120	27.049528	62.115.66.250	62.115.66.251	SCTP	64	SACK
121	27.960492	62.115.66.250	62.115.66.251	SCTP	64	SACK
122	28.051210	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fbd e2e=13a5 |
123	28.053014	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fbd e2e=13a5 |
124	28.072181	62.115.66.250	62.115.66.251	SCTP	64	SACK
125	29.054756	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fbe e2e=13a6 |
126	29.055916	62.115.66.251	62.115.66.250	SCTP	64	SACK
127	29.056097	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fbe e2e=13a6 |
128	29.056184	62.115.66.250	62.115.66.251	SCTP	64	SACK
129	29.961142	62.115.66.250	62.115.66.251	SCTP	64	SACK
130	30.057881	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fbf e2e=13a7 |
131	30.059457	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fbf e2e=13a7 |
132	30.078640	62.115.66.250	62.115.66.251	SCTP	64	SACK
133	31.011134	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fc0 e2e=13a8 |
134	31.012951	62.115.66.251	62.115.66.250	SCTP	64	SACK
135	31.013137	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fc0 e2e=13a8 |
136	31.013208	62.115.66.250	62.115.66.251	SCTP	64	SACK
137	31.962212	62.115.66.250	62.115.66.251	SCTP	64	SACK
138	32.014896	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fc1 e2e=13a9 |
139	32.016547	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fc1 e2e=13a9 |
140	32.035712	62.115.66.250	62.115.66.251	SCTP	64	SACK

141	33.005793	192.194.74.138	192.194.74.137	SCTP	80	HEARTBEAT
142	33.018290	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fc2 e2e=13aa |
143	33.019422	62.115.66.251	62.115.66.250	SCTP	64	SACK
144	33.019607	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fc2 e2e=13aa |
145	33.019677	62.115.66.250	62.115.66.251	SCTP	64	SACK
146	33.962705	62.115.66.250	62.115.66.251	SCTP	64	SACK
147	34.021364	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fc3 e2e=13ab |
148	34.022533	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fc3 e2e=13ab |
149	34.041718	62.115.66.250	62.115.66.251	SCTP	64	SACK
150	35.024353	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fc4 e2e=13ac |
151	35.025603	62.115.66.251	62.115.66.250	SCTP	64	SACK
152	35.025772	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fc4 e2e=13ac |
153	35.025850	62.115.66.250	62.115.66.251	SCTP	64	SACK
154	35.202073	62.115.66.250	62.115.66.251	SCTP	64	SACK
155	36.027548	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fc5 e2e=13ad |
156	36.028698	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fc5 e2e=13ad |
157	36.047862	62.115.66.250	62.115.66.251	SCTP	64	SACK
158	37.030440	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fc6 e2e=13ae |
159	37.031617	62.115.66.251	62.115.66.250	SCTP	64	SACK
160	37.031788	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fc6 e2e=13ae |
161	37.031859	62.115.66.250	62.115.66.251	SCTP	64	SACK
162	37.964844	62.115.66.250	62.115.66.251	SCTP	64	SACK
163	38.033540	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fc7 e2e=13af |
164	38.035240	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fc7 e2e=13af |
165	38.054414	62.115.66.250	62.115.66.251	SCTP	64	SACK
166	39.037021	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fc8 e2e=13b0 |
167	39.038284	62.115.66.251	62.115.66.250	SCTP	64	SACK
168	39.038457	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fc8 e2e=13b0 |
169	39.038584	62.115.66.250	62.115.66.251	SCTP	64	SACK
170	39.965564	62.115.66.250	62.115.66.251	SCTP	64	SACK
171	40.040274	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fc9 e2e=13b1 |
172	40.042002	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fc9 e2e=13b1 |
173	40.061230	62.115.66.250	62.115.66.251	SCTP	64	SACK
174	41.043818	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fca e2e=13b2 |
175	41.044756	62.115.66.251	62.115.66.250	SCTP	64	SACK
176	41.044919	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fca e2e=13b2 |

177	41.044991	62.115.66.250	62.115.66.251	SCTP	64	SACK
178	41.966966	62.115.66.250	62.115.66.251	SCTP	64	SACK
179	42.046686	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fcb e2e=13b3 │
180	42.047979	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fcb e2e=13b3 │
181	42.067143	62.115.66.250	62.115.66.251	SCTP	64	SACK
182	43.049736	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fcc e2e=13b4 │
183	43.051076	62.115.66.251	62.115.66.250	SCTP	64	SACK
184	43.051264	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fcc e2e=13b4 │
185	43.051335	62.115.66.250	62.115.66.251	SCTP	64	SACK
186	43.967314	62.115.66.250	62.115.66.251	SCTP	64	SACK
187	44.053015	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fcd e2e=13b5 │
188	44.054547	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fcd e2e=13b5 │
189	44.073783	62.115.66.250	62.115.66.251	SCTP	64	SACK
190	45.056399	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fce e2e=13b6 │
191	45.058035	62.115.66.251	62.115.66.250	SCTP	64	SACK
192	45.058208	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fce e2e=13b6 │
193	45.058293	62.115.66.250	62.115.66.251	SCTP	64	SACK
194	45.251529	62.115.66.250	62.115.66.251	SCTP	64	SACK
195	46.009895	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fcf e2e=13b7 │
196	46.011335	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fcf e2e=13b7 │
197	46.030501	62.115.66.250	62.115.66.251	SCTP	64	SACK
198	47.013224	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fd0 e2e=13b8 │
199	47.014333	62.115.66.251	62.115.66.250	SCTP	64	SACK
200	47.014506	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fd0 e2e=13b8 │
201	47.014575	62.115.66.250	62.115.66.251	SCTP	64	SACK
202	47.968575	62.115.66.250	62.115.66.251	SCTP	64	SACK
203	48.016324	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fd1 e2e=13b9 │
204	48.018112	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fd1 e2e=13b9 │
205	48.037273	62.115.66.250	62.115.66.251	SCTP	64	SACK
206	49.019874	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fd2 e2e=13ba │
207	49.021679	62.115.66.251	62.115.66.250	SCTP	64	SACK
208	49.021841	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fd2 e2e=13ba │
209	49.021908	62.115.66.250	62.115.66.251	SCTP	64	SACK
210	49.969917	62.115.66.250	62.115.66.251	SCTP	64	SACK
211	50.023663	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fd3 e2e=13bb │
212	50.024838	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fd3 e2e=13bb │

213	50.044006	62.115.66.250	62.115.66.251	SCTP	64	SACK
214	51.026604	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fd4 e2e=13bc |
215	51.027546	62.115.66.251	62.115.66.250	SCTP	64	SACK
216	51.027715	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fd4 e2e=13bc |
217	51.027783	62.115.66.250	62.115.66.251	SCTP	64	SACK
218	51.970773	62.115.66.250	62.115.66.251	SCTP	64	SACK
219	52.029605	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fd5 e2e=13bd |
220	52.031227	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fd5 e2e=13bd |
221	52.050382	62.115.66.250	62.115.66.251	SCTP	64	SACK
222	53.033101	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fd6 e2e=13be |
223	53.034315	62.115.66.251	62.115.66.250	SCTP	64	SACK
224	53.034505	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fd6 e2e=13be |
225	53.034574	62.115.66.250	62.115.66.251	SCTP	64	SACK
226	53.971577	62.115.66.250	62.115.66.251	SCTP	64	SACK
227	54.036319	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fd7 e2e=13bf |
228	54.037862	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fd7 e2e=13bf |
229	54.057028	62.115.66.250	62.115.66.251	SCTP	64	SACK
230	55.039691	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fd8 e2e=13c0 |
231	55.040793	62.115.66.251	62.115.66.250	SCTP	64	SACK
232	55.040977	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fd8 e2e=13c0 |
233	55.041050	62.115.66.250	62.115.66.251	SCTP	64	SACK
234	55.301352	62.115.66.250	62.115.66.251	SCTP	64	SACK
235	56.042784	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fd9 e2e=13c1 |
236	56.044126	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fd9 e2e=13c1 |
237	56.063284	62.115.66.250	62.115.66.251	SCTP	64	SACK
238	57.045925	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fda e2e=13c2 |
239	57.047519	62.115.66.251	62.115.66.250	SCTP	64	SACK
240	57.047693	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fda e2e=13c2 |
241	57.047763	62.115.66.250	62.115.66.251	SCTP	64	SACK
242	57.972730	62.115.66.250	62.115.66.251	SCTP	64	SACK
243	58.049511	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fdb e2e=13c3 |
244	58.050487	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fdb e2e=13c3 |
245	58.069647	62.115.66.250	62.115.66.251	SCTP	64	SACK
246	59.052264	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fdc e2e=13c4 |
247	59.053715	62.115.66.251	62.115.66.250	SCTP	64	SACK
248	59.053885	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fdc e2e=13c4 |

249	59.053952	62.115.66.250	62.115.66.251	SCTP	64	SACK
250	59.973913	62.115.66.250	62.115.66.251	SCTP	64	SACK
251	60.055680	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fdd e2e=13c5 │
252	60.057488	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fdd e2e=13c5 │
253	60.076671	62.115.66.250	62.115.66.251	SCTP	64	SACK
254	61.009206	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fde e2e=13c6 │
255	61.010241	62.115.66.251	62.115.66.250	SCTP	64	SACK
256	61.010408	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fde e2e=13c6 │
257	61.010475	62.115.66.250	62.115.66.251	SCTP	64	SACK
258	61.974498	62.115.66.250	62.115.66.251	SCTP	64	SACK
259	62.012205	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fdf e2e=13c7 │
260	62.014206	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fdf e2e=13c7 │
261	62.033374	62.115.66.250	62.115.66.251	SCTP	64	SACK
262	63.015976	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fe0 e2e=13c8 │
263	63.016960	62.115.66.251	62.115.66.250	SCTP	64	SACK
264	63.017175	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fe0 e2e=13c8 │
265	63.017244	62.115.66.250	62.115.66.251	SCTP	64	SACK
266	63.976276	62.115.66.250	62.115.66.251	SCTP	64	SACK
267	64.019233	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fe1 e2e=13c9 │
268	64.021182	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fe1 e2e=13c9 │
269	64.040352	62.115.66.250	62.115.66.251	SCTP	64	SACK
270	65.022971	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fe2 e2e=13ca │
271	65.024427	62.115.66.251	62.115.66.250	SCTP	64	SACK
272	65.024595	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fe2 e2e=13ca │
273	65.024718	62.115.66.250	62.115.66.251	SCTP	64	SACK
274	65.351091	62.115.66.250	62.115.66.251	SCTP	64	SACK
275	66.026488	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fe3 e2e=13cb │
276	66.028376	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fe3 e2e=13cb │
277	66.047536	62.115.66.250	62.115.66.251	SCTP	64	SACK
278	67.030149	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fe4 e2e=13cc │
279	67.031962	62.115.66.251	62.115.66.250	SCTP	64	SACK
280	67.032155	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fe4 e2e=13cc │
281	67.032224	62.115.66.250	62.115.66.251	SCTP	64	SACK
282	67.977213	62.115.66.250	62.115.66.251	SCTP	64	SACK
283	68.033929	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fe5 e2e=13cd │
284	68.035182	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fe5 e2e=13cd │

285	68.054337	62.115.66.250	62.115.66.251	SCTP	64	SACK
286	69.006313	192.194.74.138	192.194.74.137	SCTP	80	HEARTBEAT
287	69.036958	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fe6 e2e=13ce |
288	69.037982	62.115.66.251	62.115.66.250	SCTP	64	SACK
289	69.038165	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fe6 e2e=13ce |
290	69.038235	62.115.66.250	62.115.66.251	SCTP	64	SACK
291	69.978218	62.115.66.250	62.115.66.251	SCTP	64	SACK
292	70.039993	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fe7 e2e=13cf |
293	70.041778	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fe7 e2e=13cf |
294	70.060980	62.115.66.250	62.115.66.251	SCTP	64	SACK
295	71.043588	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fe8 e2e=13d0 |
296	71.045405	62.115.66.251	62.115.66.250	SCTP	64	SACK
297	71.045556	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fe8 e2e=13d0 |
298	71.045625	62.115.66.250	62.115.66.251	SCTP	64	SACK
299	71.978600	62.115.66.250	62.115.66.251	SCTP	64	SACK
300	72.047357	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fe9 e2e=13d1 |
301	72.048399	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fe9 e2e=13d1 |
302	72.067557	62.115.66.250	62.115.66.251	SCTP	64	SACK
303	73.050169	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fea e2e=13d2 |
304	73.051449	62.115.66.251	62.115.66.250	SCTP	64	SACK
305	73.051630	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fea e2e=13d2 |
306	73.051698	62.115.66.250	62.115.66.251	SCTP	64	SACK
307	73.979694	62.115.66.250	62.115.66.251	SCTP	64	SACK
308	74.053461	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=feb e2e=13d3 |
309	74.055151	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=feb e2e=13d3 |
310	74.074316	62.115.66.250	62.115.66.251	SCTP	64	SACK
311	75.056962	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fec e2e=13d4 |
312	75.058131	62.115.66.251	62.115.66.250	SCTP	64	SACK
313	75.058303	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fec e2e=13d4 |
314	75.058422	62.115.66.250	62.115.66.251	SCTP	64	SACK
315	75.400807	62.115.66.250	62.115.66.251	SCTP	64	SACK
316	76.010053	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fed e2e=13d5 |
317	76.011641	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fed e2e=13d5 |
318	76.030798	62.115.66.250	62.115.66.251	SCTP	64	SACK
319	77.013387	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fee e2e=13d6 |
320	77.014783	62.115.66.251	62.115.66.250	SCTP	64	SACK

321	77.014960	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fee e2e=13d6 |
322	77.015030	62.115.66.250	62.115.66.251	SCTP	64	SACK
323	77.981046	62.115.66.250	62.115.66.251	SCTP	64	SACK
324	78.016792	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fef e2e=13d7 |
325	78.018621	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fef e2e=13d7 |
326	78.037791	62.115.66.250	62.115.66.251	SCTP	64	SACK
327	79.020392	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ff0 e2e=13d8 |
328	79.022182	62.115.66.251	62.115.66.250	SCTP	64	SACK
329	79.022360	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ff0 e2e=13d8 |
330	79.022428	62.115.66.250	62.115.66.251	SCTP	64	SACK
331	79.982430	62.115.66.250	62.115.66.251	SCTP	64	SACK
332	80.024177	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ff1 e2e=13d9 |
333	80.025376	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ff1 e2e=13d9 |
334	80.044541	62.115.66.250	62.115.66.251	SCTP	64	SACK
335	81.027183	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ff2 e2e=13da |
336	81.028142	62.115.66.251	62.115.66.250	SCTP	64	SACK
337	81.028318	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ff2 e2e=13da |
338	81.028391	62.115.66.250	62.115.66.251	SCTP	64	SACK
339	81.983394	62.115.66.250	62.115.66.251	SCTP	64	SACK
340	82.030153	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ff3 e2e=13db |
341	82.031590	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ff3 e2e=13db |
342	82.050754	62.115.66.250	62.115.66.251	SCTP	64	SACK
343	83.033574	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ff4 e2e=13dc |
344	83.034876	62.115.66.251	62.115.66.250	SCTP	64	SACK
345	83.035075	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ff4 e2e=13dc |
346	83.035163	62.115.66.250	62.115.66.251	SCTP	64	SACK
347	83.984177	62.115.66.250	62.115.66.251	SCTP	64	SACK
348	84.037074	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ff5 e2e=13dd |
349	84.038489	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ff5 e2e=13dd |
350	84.057655	62.115.66.250	62.115.66.251	SCTP	64	SACK
351	85.040282	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ff6 e2e=13de |
352	85.041915	62.115.66.251	62.115.66.250	SCTP	64	SACK
353	85.042097	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ff6 e2e=13de |
354	85.042179	62.115.66.250	62.115.66.251	SCTP	64	SACK
355	85.450628	62.115.66.250	62.115.66.251	SCTP	64	SACK
356	86.043894	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ff7 e2e=13df |

357	86.045817	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ff7 e2e=13df │
358	86.065001	62.115.66.250	62.115.66.251	SCTP	64	SACK
359	87.047618	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ff8 e2e=13e0 │
360	87.048736	62.115.66.251	62.115.66.250	SCTP	64	SACK
361	87.048918	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ff8 e2e=13e0 │
362	87.048988	62.115.66.250	62.115.66.251	SCTP	64	SACK
363	87.984965	62.115.66.250	62.115.66.251	SCTP	64	SACK
364	88.050702	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ff9 e2e=13e1 │
365	88.052644	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ff9 e2e=13e1 │
366	88.071800	62.115.66.250	62.115.66.251	SCTP	64	SACK
367	89.054393	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ffa e2e=13e2 │
368	89.055659	62.115.66.251	62.115.66.250	SCTP	64	SACK
369	89.055824	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ffa e2e=13e2 │
370	89.055892	62.115.66.250	62.115.66.251	SCTP	64	SACK
371	89.985862	62.115.66.250	62.115.66.251	SCTP	64	SACK
372	90.057624	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ffb e2e=13e3 │
373	90.058670	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ffb e2e=13e3 │
374	90.077834	62.115.66.250	62.115.66.251	SCTP	64	SACK
375	91.010335	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ffc e2e=13e4 │
376	91.012092	62.115.66.251	62.115.66.250	SCTP	64	SACK
377	91.012292	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ffc e2e=13e4 │
378	91.012354	62.115.66.250	62.115.66.251	SCTP	64	SACK
379	91.986374	62.115.66.250	62.115.66.251	SCTP	64	SACK
380	92.014059	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ffd e2e=13e5 │
381	92.015693	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ffd e2e=13e5 │
382	92.034855	62.115.66.250	62.115.66.251	SCTP	64	SACK
383	93.017445	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=ffe e2e=13e6 │
384	93.018692	62.115.66.251	62.115.66.250	SCTP	64	SACK
385	93.018875	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=ffe e2e=13e6 │
386	93.018944	62.115.66.250	62.115.66.251	SCTP	64	SACK
387	93.986984	62.115.66.250	62.115.66.251	SCTP	64	SACK
388	94.020749	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=fff e2e=13e7 │
389	94.022477	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=fff e2e=13e7 │
390	94.041645	62.115.66.250	62.115.66.251	SCTP	64	SACK
391	95.024304	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1000 e2e=13e8 │
392	95.025531	62.115.66.251	62.115.66.250	SCTP	64	SACK

393	95.025695	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1000 e2e=13e8 |
394	95.025766	62.115.66.250	62.115.66.251	SCTP	64	SACK
395	95.500296	62.115.66.250	62.115.66.251	SCTP	64	SACK
396	96.027515	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1001 e2e=13e9 |
397	96.029386	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1001 e2e=13e9 |
398	96.048604	62.115.66.250	62.115.66.251	SCTP	64	SACK
399	97.031207	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1002 e2e=13ea |
400	97.032906	62.115.66.251	62.115.66.250	SCTP	64	SACK
401	97.033105	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1002 e2e=13ea |
402	97.033191	62.115.66.250	62.115.66.251	SCTP	64	SACK
403	97.989193	62.115.66.250	62.115.66.251	SCTP	64	SACK
404	98.034909	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1003 e2e=13eb |
405	98.035938	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1003 e2e=13eb |
406	98.055094	62.115.66.250	62.115.66.251	SCTP	64	SACK
407	99.037689	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1004 e2e=13ec |
408	99.038723	62.115.66.251	62.115.66.250	SCTP	64	SACK
409	99.038888	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1004 e2e=13ec |
410	99.038955	62.115.66.250	62.115.66.251	SCTP	64	SACK
411	99.990530	62.115.66.250	62.115.66.251	SCTP	64	SACK
412	100.040745	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1005 e2e=13ed |
413	100.042218	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1005 e2e=13ed |
414	100.061379	62.115.66.250	62.115.66.251	SCTP	64	SACK
415	101.043976	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1006 e2e=13ee |
416	101.044955	62.115.66.251	62.115.66.250	SCTP	64	SACK
417	101.045141	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1006 e2e=13ee |
418	101.045379	62.115.66.250	62.115.66.251	SCTP	64	SACK
419	101.991378	62.115.66.250	62.115.66.251	SCTP	64	SACK
420	102.047153	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1007 e2e=13ef |
421	102.048583	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1007 e2e=13ef |
422	102.067746	62.115.66.250	62.115.66.251	SCTP	64	SACK
423	103.050344	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1008 e2e=13f0 |
424	103.051569	62.115.66.251	62.115.66.250	SCTP	64	SACK
425	103.051752	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1008 e2e=13f0 |
426	103.051820	62.115.66.250	62.115.66.251	SCTP	64	SACK
427	103.991819	62.115.66.250	62.115.66.251	SCTP	64	SACK
428	104.053555	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1009 e2e=13f1 |

429	104.055204	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1009 e2e=13f1 |
430	104.074367	62.115.66.250	62.115.66.251	SCTP	64	SACK
431	105.056982	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=100a e2e=13f2 |
432	105.058556	62.115.66.251	62.115.66.250	SCTP	64	SACK
433	105.058722	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=100a e2e=13f2 |
434	105.058791	62.115.66.250	62.115.66.251	SCTP	64	SACK
435	105.550326	62.115.66.250	62.115.66.251	SCTP	64	SACK
436	106.010413	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=100b e2e=13f3 |
437	106.012336	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=100b e2e=13f3 |
438	106.031491	62.115.66.250	62.115.66.251	SCTP	64	SACK
439	107.014078	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=100c e2e=13f4 |
440	107.015672	62.115.66.251	62.115.66.250	SCTP	64	SACK
441	107.015846	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=100c e2e=13f4 |
442	107.015916	62.115.66.250	62.115.66.251	SCTP	64	SACK
443	107.992940	62.115.66.250	62.115.66.251	SCTP	64	SACK
444	108.017667	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=100d e2e=13f5 |
445	108.019170	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=100d e2e=13f5 |
446	108.038330	62.115.66.250	62.115.66.251	SCTP	64	SACK
447	109.020936	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=100e e2e=13f6 |
448	109.022608	62.115.66.251	62.115.66.250	SCTP	64	SACK
449	109.022773	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=100e e2e=13f6 |
450	109.022844	62.115.66.250	62.115.66.251	SCTP	64	SACK
451	109.993863	62.115.66.250	62.115.66.251	SCTP	64	SACK
452	110.024628	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=100f e2e=13f7 |
453	110.025635	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=100f e2e=13f7 |
454	110.044813	62.115.66.250	62.115.66.251	SCTP	64	SACK
455	111.006909	192.194.74.138	192.194.74.137	SCTP	80	HEARTBEAT
456	111.027439	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1010 e2e=13f8 |
457	111.028610	62.115.66.251	62.115.66.250	SCTP	64	SACK
458	111.028775	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1010 e2e=13f8 |
459	111.028846	62.115.66.250	62.115.66.251	SCTP	64	SACK
460	111.994856	62.115.66.250	62.115.66.251	SCTP	64	SACK
461	112.030583	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1011 e2e=13f9 |
462	112.032114	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1011 e2e=13f9 |
463	112.051275	62.115.66.250	62.115.66.251	SCTP	64	SACK
464	113.033911	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1012 e2e=13fa |

465	113.035557	62.115.66.251	62.115.66.250	SCTP	64	SACK
466	113.035750	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1012 e2e=13fa |
467	113.035819	62.115.66.250	62.115.66.251	SCTP	64	SACK
468	113.995843	62.115.66.250	62.115.66.251	SCTP	64	SACK
469	114.037712	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1013 e2e=13fb |
470	114.038739	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1013 e2e=13fb |
471	114.057903	62.115.66.250	62.115.66.251	SCTP	64	SACK
472	115.040510	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1014 e2e=13fc |
473	115.042111	62.115.66.251	62.115.66.250	SCTP	64	SACK
474	115.042288	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1014 e2e=13fc |
475	115.042357	62.115.66.250	62.115.66.251	SCTP	64	SACK
476	115.600956	62.115.66.250	62.115.66.251	SCTP	64	SACK
477	116.044073	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1015 e2e=13fd |
478	116.045983	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1015 e2e=13fd |
479	116.065141	62.115.66.250	62.115.66.251	SCTP	64	SACK
480	117.047753	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1016 e2e=13fe |
481	117.048750	62.115.66.251	62.115.66.250	SCTP	64	SACK
482	117.048919	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1016 e2e=13fe |
483	117.048993	62.115.66.250	62.115.66.251	SCTP	64	SACK
484	117.996992	62.115.66.250	62.115.66.251	SCTP	64	SACK
485	118.050753	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1017 e2e=13ff |
486	118.051822	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1017 e2e=13ff |
487	118.070982	62.115.66.250	62.115.66.251	SCTP	64	SACK
488	119.053584	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1018 e2e=1400 |
489	119.055181	62.115.66.251	62.115.66.250	SCTP	64	SACK
490	119.055345	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1018 e2e=1400 |
491	119.055413	62.115.66.250	62.115.66.251	SCTP	64	SACK
492	119.998414	62.115.66.250	62.115.66.251	SCTP	64	SACK
493	120.057179	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1019 e2e=1401 |
494	120.058442	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1019 e2e=1401 |
495	120.077606	62.115.66.250	62.115.66.251	SCTP	64	SACK
496	121.010114	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=101a e2e=1402 |
497	121.011579	62.115.66.251	62.115.66.250	SCTP	64	SACK
498	121.011746	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=101a e2e=1402 |
499	121.011810	62.115.66.250	62.115.66.251	SCTP	64	SACK
500	121.998858	62.115.66.250	62.115.66.251	SCTP	64	SACK

501	122.013521	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=101b e2e=1403 |
502	122.014641	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=101b e2e=1403 |
503	122.033853	62.115.66.250	62.115.66.251	SCTP	64	SACK
504	123.016452	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=101c e2e=1404 |
505	123.017338	62.115.66.251	62.115.66.250	SCTP	64	SACK
506	123.017526	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=101c e2e=1404 |
507	123.017594	62.115.66.250	62.115.66.251	SCTP	64	SACK
508	124.000649	62.115.66.250	62.115.66.251	SCTP	64	SACK
509	124.019560	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=101d e2e=1405 |
510	124.021061	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=101d e2e=1405 |
511	124.040252	62.115.66.250	62.115.66.251	SCTP	64	SACK
512	125.022882	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=101e e2e=1406 |
513	125.023742	62.115.66.251	62.115.66.250	SCTP	64	SACK
514	125.023904	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=101e e2e=1406 |
515	125.023974	62.115.66.250	62.115.66.251	SCTP	64	SACK
516	125.651662	62.115.66.250	62.115.66.251	SCTP	64	SACK
517	126.025726	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=101f e2e=1407 |
518	126.027569	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=101f e2e=1407 |
519	126.046742	62.115.66.250	62.115.66.251	SCTP	64	SACK
520	127.029356	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1020 e2e=1408 |
521	127.030672	62.115.66.251	62.115.66.250	SCTP	64	SACK
522	127.030844	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1020 e2e=1408 |
523	127.030965	62.115.66.250	62.115.66.251	SCTP	64	SACK
524	128.001981	62.115.66.250	62.115.66.251	SCTP	64	SACK
525	128.032687	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1021 e2e=1409 |
526	128.034127	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1021 e2e=1409 |
527	128.053293	62.115.66.250	62.115.66.251	SCTP	64	SACK
528	129.035892	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1022 e2e=140a |
529	129.037103	62.115.66.251	62.115.66.250	SCTP	64	SACK
530	129.037271	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1022 e2e=140a |
531	129.037340	62.115.66.250	62.115.66.251	SCTP	64	SACK
532	130.002346	62.115.66.250	62.115.66.251	SCTP	64	SACK
533	130.039092	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1023 e2e=140b |
534	130.040189	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1023 e2e=140b |
535	130.059356	62.115.66.250	62.115.66.251	SCTP	64	SACK

536	131.041965	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1024 e2e=140c |
537	131.043756	62.115.66.251	62.115.66.250	SCTP	64	SACK
538	131.043925	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1024 e2e=140c |
539	131.043993	62.115.66.250	62.115.66.251	SCTP	64	SACK
540	132.003012	62.115.66.250	62.115.66.251	SCTP	64	SACK
541	132.045728	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1025 e2e=140d |
542	132.047303	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1025 e2e=140d |
543	132.066466	62.115.66.250	62.115.66.251	SCTP	64	SACK
544	133.049080	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1026 e2e=140e |
545	133.050525	62.115.66.251	62.115.66.250	SCTP	64	SACK
546	133.050718	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1026 e2e=140e |
547	133.050789	62.115.66.250	62.115.66.251	SCTP	64	SACK
548	134.003800	62.115.66.250	62.115.66.251	SCTP	64	SACK
549	134.052538	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1027 e2e=140f |
550	134.054120	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1027 e2e=140f |
551	134.073282	62.115.66.250	62.115.66.251	SCTP	64	SACK
552	135.055891	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1028 e2e=1410 |
553	135.056970	62.115.66.251	62.115.66.250	SCTP	64	SACK
554	135.057161	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1028 e2e=1410 |
555	135.057230	62.115.66.250	62.115.66.251	SCTP	64	SACK
556	135.701918	62.115.66.250	62.115.66.251	SCTP	64	SACK
557	136.058939	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1029 e2e=1411 |
558	136.060324	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1029 e2e=1411 |
559	136.079480	62.115.66.250	62.115.66.251	SCTP	64	SACK
560	137.011978	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=102a e2e=1412 |
561	137.012925	62.115.66.251	62.115.66.250	SCTP	64	SACK
562	137.013116	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=102a e2e=1412 |
563	137.013181	62.115.66.250	62.115.66.251	SCTP	64	SACK
564	138.005237	62.115.66.250	62.115.66.251	SCTP	64	SACK
565	138.014900	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=102b e2e=1413 |
566	138.016909	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=102b e2e=1413 |
567	138.036082	62.115.66.250	62.115.66.251	SCTP	64	SACK
568	139.018682	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=102c e2e=1414 |
569	139.020021	62.115.66.251	62.115.66.250	SCTP	64	SACK
570	139.020197	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=102c e2e=1414 |
571	139.020264	62.115.66.250	62.115.66.251	SCTP	64	SACK

572	140.006305	62.115.66.250	62.115.66.251	SCTP	64	SACK
573	140.021984	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=102d e2e=1415 |
574	140.023395	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=102d e2e=1415 |
575	140.042561	62.115.66.250	62.115.66.251	SCTP	64	SACK
576	141.025166	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=102e e2e=1416 |
577	141.026312	62.115.66.251	62.115.66.250	SCTP	64	SACK
578	141.026474	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=102e e2e=1416 |
579	141.026541	62.115.66.250	62.115.66.251	SCTP	64	SACK
580	142.007574	62.115.66.250	62.115.66.251	SCTP	64	SACK
581	142.028275	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=102f e2e=1417 |
582	142.029332	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=102f e2e=1417 |
583	142.048497	62.115.66.250	62.115.66.251	SCTP	64	SACK
584	143.031101	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1030 e2e=1418 |
585	143.032189	62.115.66.251	62.115.66.250	SCTP	64	SACK
586	143.032378	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1030 e2e=1418 |
587	143.032453	62.115.66.250	62.115.66.251	SCTP	64	SACK
588	144.009505	62.115.66.250	62.115.66.251	SCTP	64	SACK
589	144.034503	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1031 e2e=1419 |
590	144.035499	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1031 e2e=1419 |
591	144.054656	62.115.66.250	62.115.66.251	SCTP	64	SACK
592	145.037270	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1032 e2e=141a |
593	145.038736	62.115.66.251	62.115.66.250	SCTP	64	SACK
594	145.038898	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1032 e2e=141a |
595	145.038966	62.115.66.250	62.115.66.251	SCTP	64	SACK
596	145.752720	62.115.66.250	62.115.66.251	SCTP	64	SACK
597	146.040677	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1033 e2e=141b |
598	146.042264	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1033 e2e=141b |
599	146.061419	62.115.66.250	62.115.66.251	SCTP	64	SACK
600	147.044030	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1034 e2e=141c |
601	147.045708	62.115.66.251	62.115.66.250	SCTP	64	SACK
602	147.045882	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1034 e2e=141c |
603	147.045951	62.115.66.250	62.115.66.251	SCTP	64	SACK
604	148.010959	62.115.66.250	62.115.66.251	SCTP	64	SACK
605	148.047663	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1035 e2e=141d |
606	148.049171	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1035 e2e=141d |
607	148.068382	62.115.66.250	62.115.66.251	SCTP	64	SACK

608	149.050981	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1036 e2e=141e
609	149.051895	62.115.66.251	62.115.66.250	SCTP	64	SACK
610	149.052087	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1036 e2e=141e
611	149.052173	62.115.66.250	62.115.66.251	SCTP	64	SACK
612	150.012187	62.115.66.250	62.115.66.251	SCTP	64	SACK
613	150.053948	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1037 e2e=141f
614	150.055544	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1037 e2e=141f
615	150.074709	62.115.66.250	62.115.66.251	SCTP	64	SACK
616	151.057323	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1038 e2e=1420
617	151.058831	62.115.66.251	62.115.66.250	SCTP	64	SACK
618	151.059003	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1038 e2e=1420
619	151.059071	62.115.66.250	62.115.66.251	SCTP	64	SACK
620	152.010711	62.115.66.250	62.115.66.251	DIAMETER	320	SACK cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1039 e2e=1421
621	152.012635	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1039 e2e=1421
622	152.031792	62.115.66.250	62.115.66.251	SCTP	64	SACK
623	153.014377	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=103a e2e=1422
624	153.016172	62.115.66.251	62.115.66.250	SCTP	64	SACK
625	153.016359	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=103a e2e=1422
626	153.016480	62.115.66.250	62.115.66.251	SCTP	64	SACK
627	154.013550	62.115.66.250	62.115.66.251	SCTP	64	SACK
628	154.018229	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=103b e2e=1423
629	154.019461	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=103b e2e=1423
630	154.038634	62.115.66.250	62.115.66.251	SCTP	64	SACK
631	155.021254	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=103c e2e=1424
632	155.023074	62.115.66.251	62.115.66.250	SCTP	64	SACK
633	155.023244	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=103c e2e=1424
634	155.023317	62.115.66.250	62.115.66.251	SCTP	64	SACK
635	155.804159	62.115.66.250	62.115.66.251	SCTP	64	SACK
636	156.025045	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=103d e2e=1425
637	156.026011	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=103d e2e=1425
638	156.045179	62.115.66.250	62.115.66.251	SCTP	64	SACK
639	157.027802	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=103e e2e=1426
640	157.029416	62.115.66.251	62.115.66.250	SCTP	64	SACK
641	157.029590	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=103e e2e=1426
642	157.029658	62.115.66.250	62.115.66.251	SCTP	64	SACK
643	158.014694	62.115.66.250	62.115.66.251	SCTP	64	SACK

644	158.031366	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=103f e2e=1427 │
645	158.032604	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=103f e2e=1427 │
646	158.051795	62.115.66.250	62.115.66.251	SCTP	64	SACK
647	159.034511	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1040 e2e=1428 │
648	159.035703	62.115.66.251	62.115.66.250	SCTP	64	SACK
649	159.035883	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1040 e2e=1428 │
650	159.035953	62.115.66.250	62.115.66.251	SCTP	64	SACK
651	160.014983	62.115.66.250	62.115.66.251	SCTP	64	SACK
652	160.037681	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1041 e2e=1429 │
653	160.038894	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1041 e2e=1429 │
654	160.058051	62.115.66.250	62.115.66.251	SCTP	64	SACK
655	161.040658	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1042 e2e=142a │
656	161.042314	62.115.66.251	62.115.66.250	SCTP	64	SACK
657	161.042476	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1042 e2e=142a │
658	161.042543	62.115.66.250	62.115.66.251	SCTP	64	SACK
659	162.015560	62.115.66.250	62.115.66.251	SCTP	64	SACK
660	162.044269	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1043 e2e=142b │
661	162.045496	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1043 e2e=142b │
662	162.064652	62.115.66.250	62.115.66.251	SCTP	64	SACK
663	163.047244	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1044 e2e=142c │
664	163.048493	62.115.66.251	62.115.66.250	SCTP	64	SACK
665	163.048679	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1044 e2e=142c │
666	163.048746	62.115.66.250	62.115.66.251	SCTP	64	SACK
667	164.015783	62.115.66.250	62.115.66.251	SCTP	64	SACK
668	164.050495	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1045 e2e=142d │
669	164.051627	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1045 e2e=142d │
670	164.070788	62.115.66.250	62.115.66.251	SCTP	64	SACK
671	165.006927	192.194.74.138	192.194.74.137	SCTP	80	HEARTBEAT
672	165.053429	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1046 e2e=142e │
673	165.054866	62.115.66.251	62.115.66.250	SCTP	64	SACK
674	165.055039	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1046 e2e=142e │
675	165.055109	62.115.66.250	62.115.66.251	SCTP	64	SACK
676	165.854965	62.115.66.250	62.115.66.251	SCTP	64	SACK
677	166.056945	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1047 e2e=142f │
678	166.058879	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1047 e2e=142f │
679	166.078043	62.115.66.250	62.115.66.251	SCTP	64	SACK

680	167.010543	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1048 e2e=1430 |
681	167.011589	62.115.66.251	62.115.66.250	SCTP	64	SACK
682	167.011760	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1048 e2e=1430 |
683	167.011823	62.115.66.250	62.115.66.251	SCTP	64	SACK
684	167.031880	62.115.66.250	62.115.66.251	SCTP	64	SACK
685	168.013531	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1049 e2e=1431 |
686	168.014896	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1049 e2e=1431 |
687	168.034892	62.115.66.250	62.115.66.251	SCTP	64	SACK
688	169.016679	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=104a e2e=1432 |
689	169.017935	62.115.66.251	62.115.66.250	SCTP	64	SACK
690	169.018118	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=104a e2e=1432 |
691	169.018186	62.115.66.250	62.115.66.251	SCTP	64	SACK
692	170.016267	62.115.66.250	62.115.66.251	SCTP	64	SACK
693	170.019918	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=104b e2e=1433 |
694	170.021406	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=104b e2e=1433 |
695	170.040580	62.115.66.250	62.115.66.251	SCTP	64	SACK
696	171.023175	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=104c e2e=1434 |
697	171.024752	62.115.66.251	62.115.66.250	SCTP	64	SACK
698	171.024923	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=104c e2e=1434 |
699	171.024992	62.115.66.250	62.115.66.251	SCTP	64	SACK
700	172.017060	62.115.66.250	62.115.66.251	SCTP	64	SACK
701	172.026692	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=104d e2e=1435 |
702	172.028508	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=104d e2e=1435 |
703	172.047672	62.115.66.250	62.115.66.251	SCTP	64	SACK
704	173.030257	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=104e e2e=1436 |
705	173.031554	62.115.66.251	62.115.66.250	SCTP	64	SACK
706	173.031743	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=104e e2e=1436 |
707	173.031813	62.115.66.250	62.115.66.251	SCTP	64	SACK
708	174.017894	62.115.66.250	62.115.66.251	SCTP	64	SACK
709	174.033534	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=104f e2e=1437 |
710	174.035228	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=104f e2e=1437 |
711	174.054455	62.115.66.250	62.115.66.251	SCTP	64	SACK
712	175.037170	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1050 e2e=1438 |
713	175.038086	62.115.66.251	62.115.66.250	SCTP	64	SACK
714	175.038250	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1050 e2e=1438 |
715	175.038322	62.115.66.250	62.115.66.251	SCTP	64	SACK

716	175.906241	62.115.66.250	62.115.66.251	SCTP	64	SACK
717	176.040056	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1051 e2e=1439 |
718	176.041385	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1051 e2e=1439 |
719	176.060542	62.115.66.250	62.115.66.251	SCTP	64	SACK
720	177.043150	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1052 e2e=143a |
721	177.044123	62.115.66.251	62.115.66.250	SCTP	64	SACK
722	177.044291	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1052 e2e=143a |
723	177.044359	62.115.66.250	62.115.66.251	SCTP	64	SACK
724	178.019388	62.115.66.250	62.115.66.251	SCTP	64	SACK
725	178.046079	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1053 e2e=143b |
726	178.047964	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1053 e2e=143b |
727	178.067129	62.115.66.250	62.115.66.251	SCTP	64	SACK
728	179.049732	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1054 e2e=143c |
729	179.051159	62.115.66.251	62.115.66.250	SCTP	64	SACK
730	179.051321	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1054 e2e=143c |
731	179.051436	62.115.66.250	62.115.66.251	SCTP	64	SACK
732	180.020474	62.115.66.250	62.115.66.251	SCTP	64	SACK
733	180.053198	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1055 e2e=143d |
734	180.054478	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1055 e2e=143d |
735	180.073642	62.115.66.250	62.115.66.251	SCTP	64	SACK
736	181.056271	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1056 e2e=143e |
737	181.057416	62.115.66.251	62.115.66.250	SCTP	64	SACK
738	181.057581	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1056 e2e=143e |
739	181.057648	62.115.66.250	62.115.66.251	SCTP	64	SACK
740	182.009296	62.115.66.250	62.115.66.251	DIAMETER	320	SACK cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1057 e2e=143f |
741	182.010924	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1057 e2e=143f |
742	182.030575	62.115.66.250	62.115.66.251	SCTP	64	SACK
743	183.012693	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1058 e2e=1440 |
744	183.014173	62.115.66.251	62.115.66.250	SCTP	64	SACK
745	183.014357	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1058 e2e=1440 |
746	183.014425	62.115.66.250	62.115.66.251	SCTP	64	SACK
747	183.033577	62.115.66.250	62.115.66.251	SCTP	64	SACK
748	184.016416	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1059 e2e=1441 |
749	184.018007	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1059 e2e=1441 |
750	184.037588	62.115.66.250	62.115.66.251	SCTP	64	SACK

751	185.020588	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=105a e2e=1442 │
752	185.021766	62.115.66.251	62.115.66.250	SCTP	64	SACK
753	185.021934	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=105a e2e=1442 │
754	185.022004	62.115.66.250	62.115.66.251	SCTP	64	SACK
755	185.956993	62.115.66.250	62.115.66.251	SCTP	64	SACK
756	186.023732	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=105b e2e=1443 │
757	186.025314	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=105b e2e=1443 │
758	186.044479	62.115.66.250	62.115.66.251	SCTP	64	SACK
759	187.027074	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=105c e2e=1444 │
760	187.028621	62.115.66.251	62.115.66.250	SCTP	64	SACK
761	187.028792	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=105c e2e=1444 │
762	187.028860	62.115.66.250	62.115.66.251	SCTP	64	SACK
763	188.021902	62.115.66.250	62.115.66.251	SCTP	64	SACK
764	188.030576	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=105d e2e=1445 │
765	188.032355	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=105d e2e=1445 │
766	188.051516	62.115.66.250	62.115.66.251	SCTP	64	SACK
767	189.034147	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=105e e2e=1446 │
768	189.035196	62.115.66.251	62.115.66.250	SCTP	64	SACK
769	189.035354	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=105e e2e=1446 │
770	189.035422	62.115.66.250	62.115.66.251	SCTP	64	SACK
771	190.023468	62.115.66.250	62.115.66.251	SCTP	64	SACK
772	190.037167	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=105f e2e=1447 │
773	190.038326	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=105f e2e=1447 │
774	190.057497	62.115.66.250	62.115.66.251	SCTP	64	SACK
775	191.040128	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1060 e2e=1448 │
776	191.041043	62.115.66.251	62.115.66.250	SCTP	64	SACK
777	191.041223	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1060 e2e=1448 │
778	191.041294	62.115.66.250	62.115.66.251	SCTP	64	SACK
779	192.024318	62.115.66.250	62.115.66.251	SCTP	64	SACK
780	192.043003	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1061 e2e=1449 │
781	192.044361	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1061 e2e=1449 │
782	192.063517	62.115.66.250	62.115.66.251	SCTP	64	SACK
783	193.046127	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1062 e2e=144a │
784	193.047352	62.115.66.251	62.115.66.250	SCTP	64	SACK
785	193.047534	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1062 e2e=144a │
786	193.047602	62.115.66.250	62.115.66.251	SCTP	64	SACK

787	194.024640	62.115.66.250	62.115.66.251	SCTP	64	SACK
788	194.049344	62.115.66.250	62.115.66.251	DIAMETER	304	cmd=3GPP-Update-Location Request(316) flags=R--- appl=3GPP S6a/S6d(16777251) h2h=1063 e2e=144b |
789	194.050454	62.115.66.251	62.115.66.250	DIAMETER	292	SACK cmd=3GPP-Update-Location Answer(316) flags=---- appl=3GPP S6a/S6d(16777251) h2h=1063 e2e=144b |
790	194.069620	62.115.66.250	62.115.66.251	SCTP	64	SACK

Appendix B: Histograms of Test Cases Results

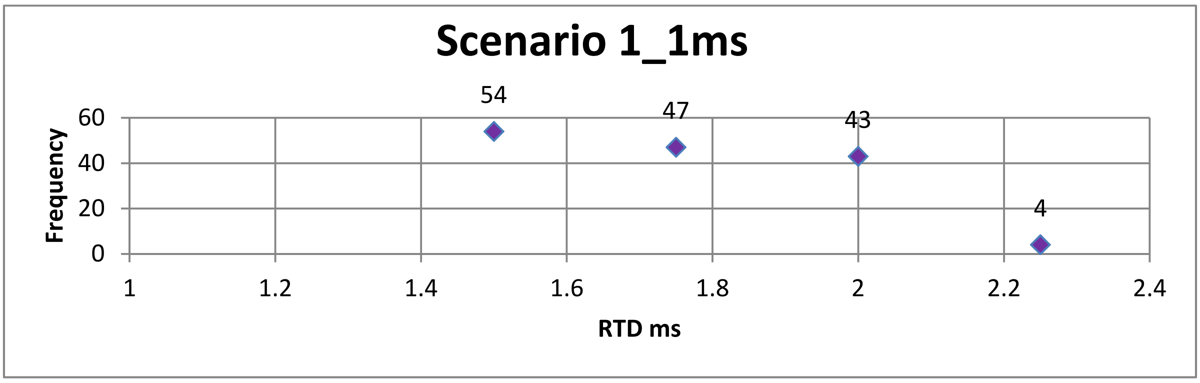

Figure 6-3 **Scenario 1_1ms**

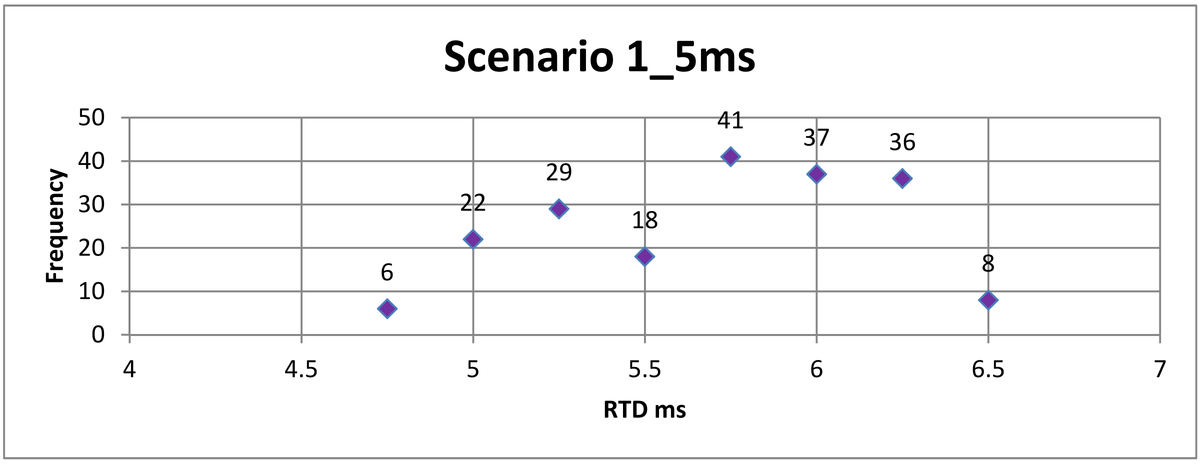

Figure 6-2 **Scenario 1_5ms**

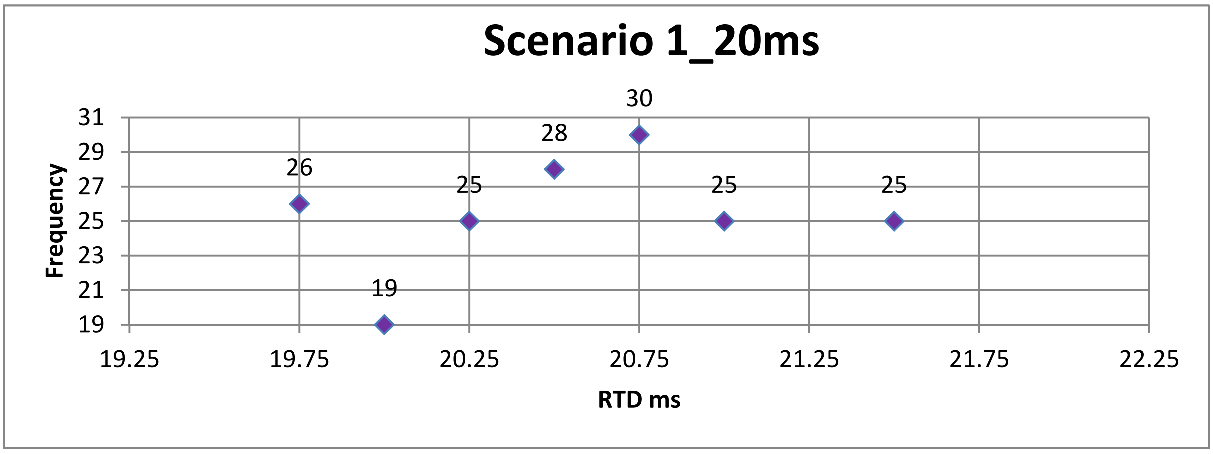

Figure 6-1: **Scenario 1_20ms**

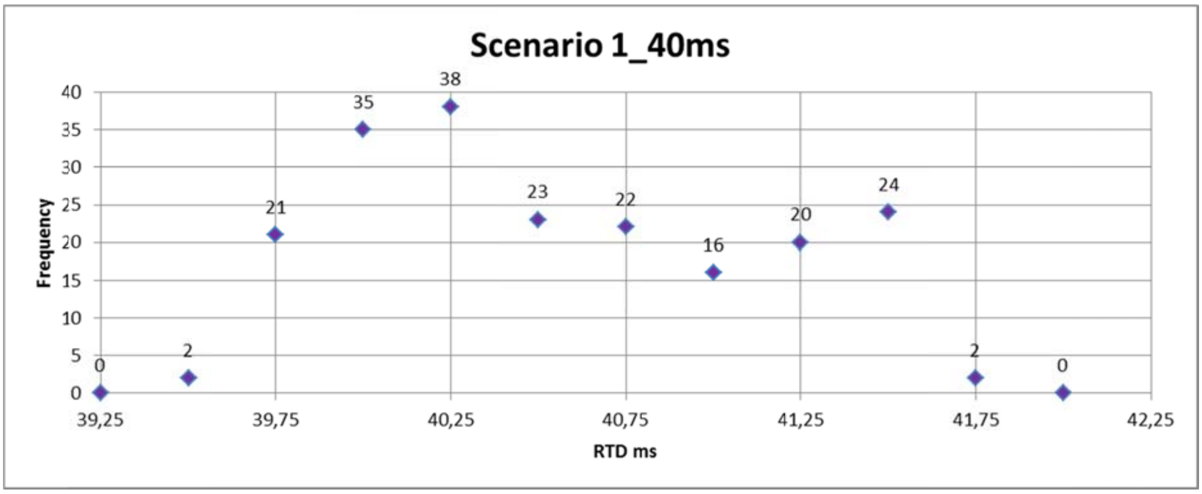

Figure 6-5: **Scenario 1_40ms**

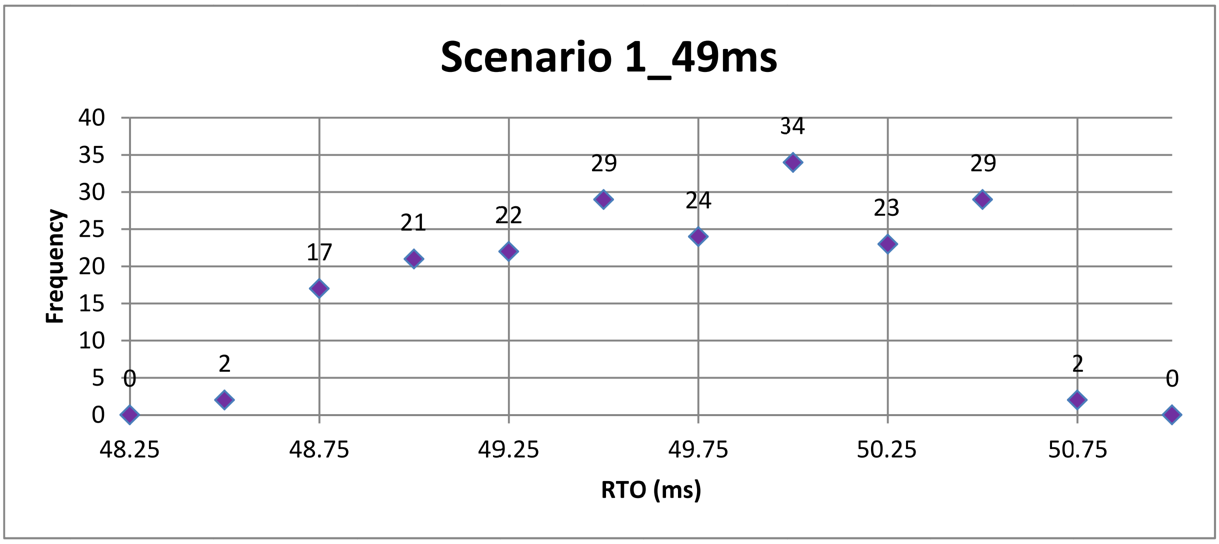

Figure 6-4: **Scenario 1_49ms**

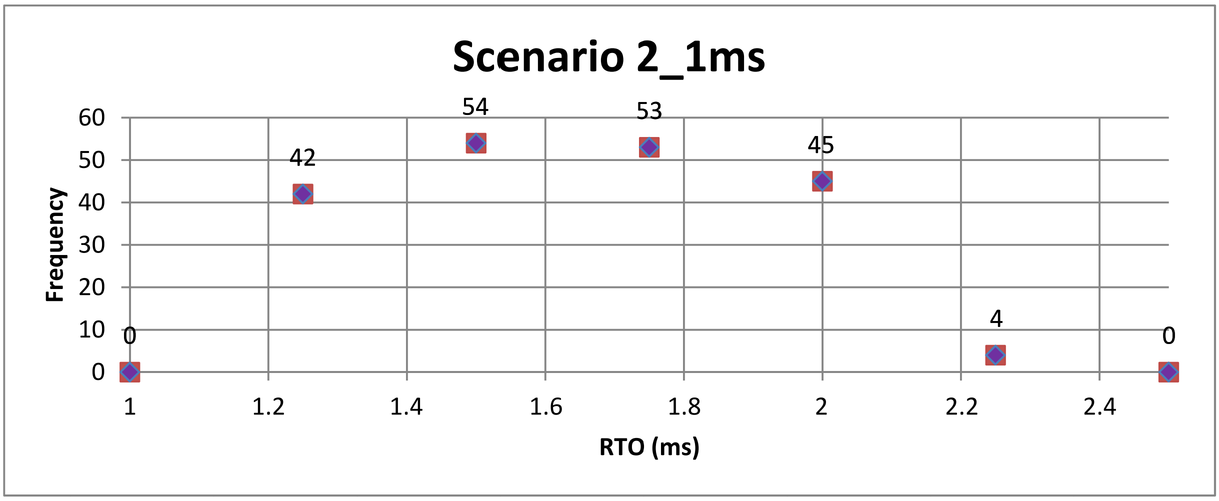

Figure 6-6: **Scenario 2_1ms**

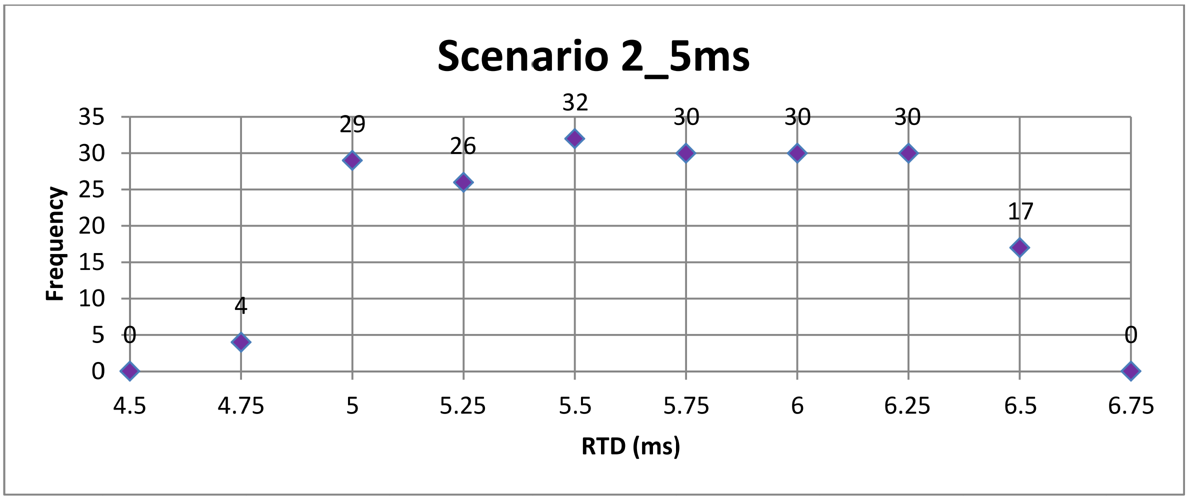

Figure 6-7: **Scenario 2_5ms**

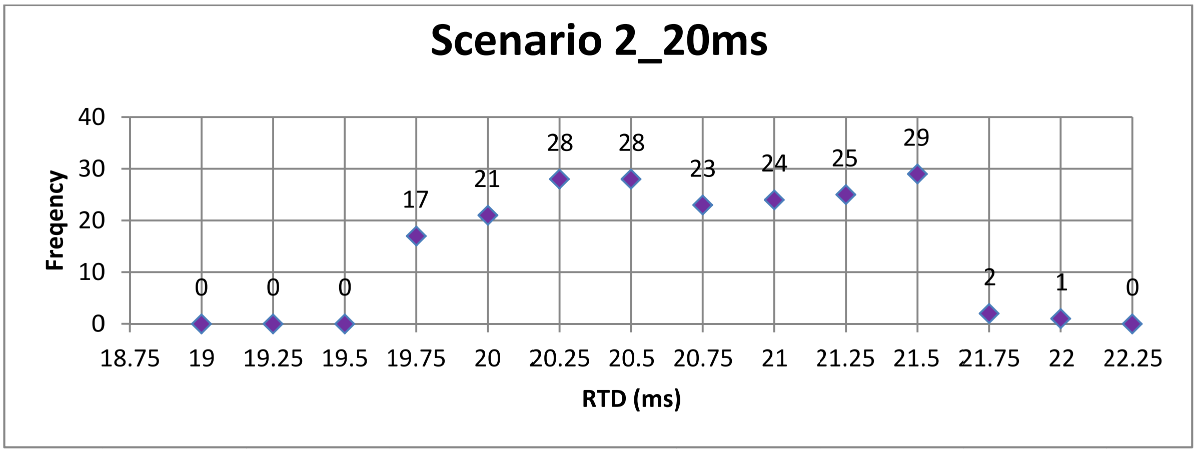

Figure 6-8: **Scenario 2_20ms**

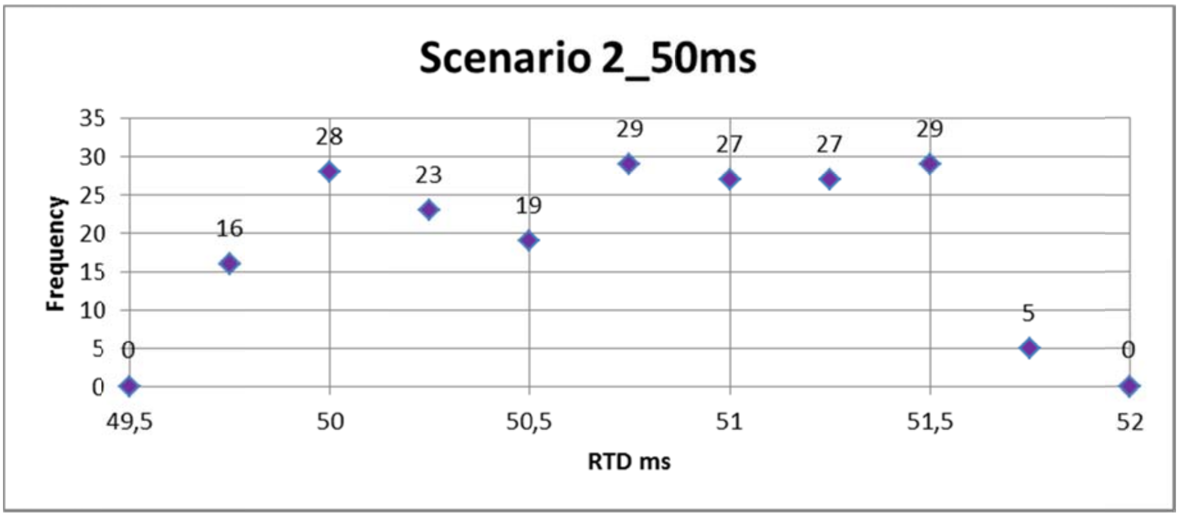

Figure 6-9: **Scenario 2_50ms**

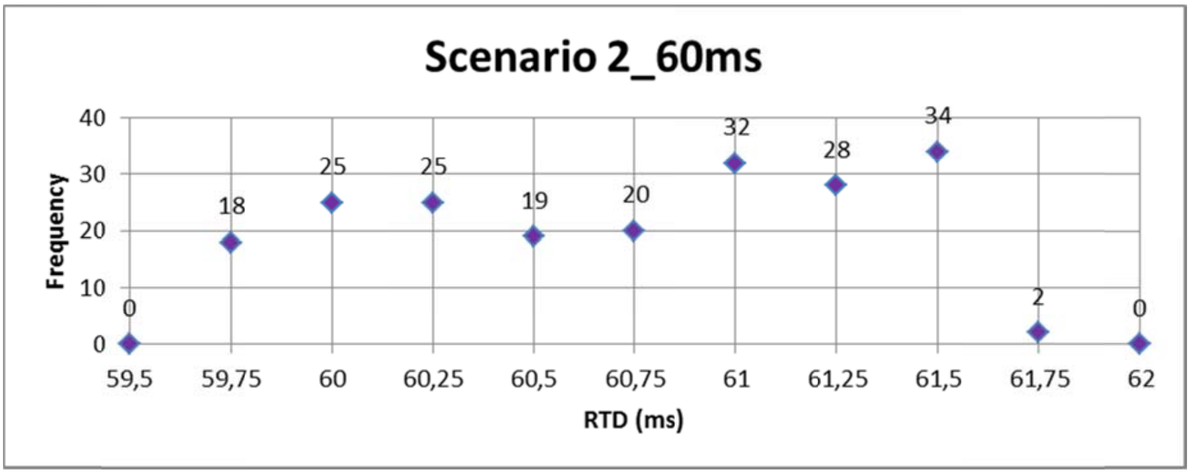

Figure 6-10: **Scenario 2_60ms**

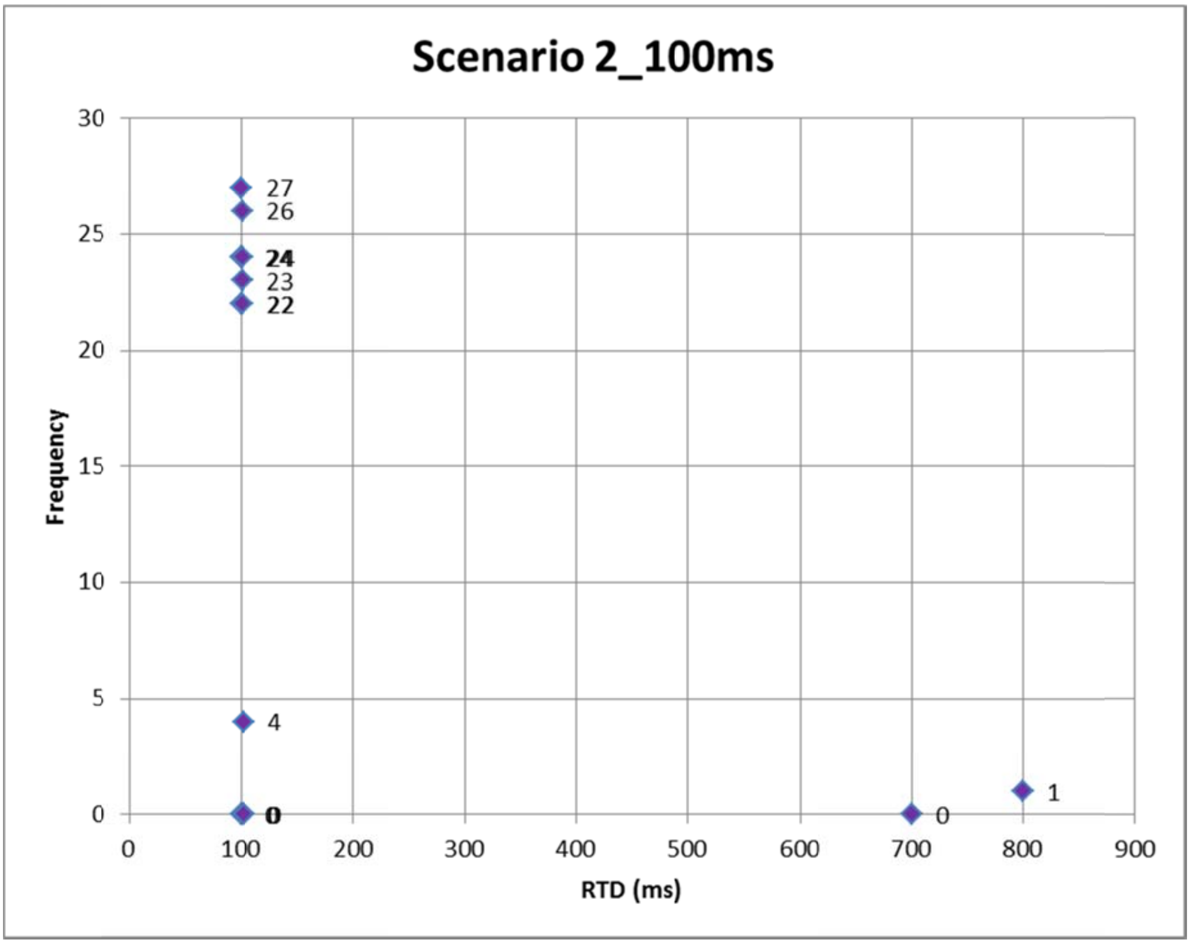

Figure 6-11: **Scenario 2_100ms**

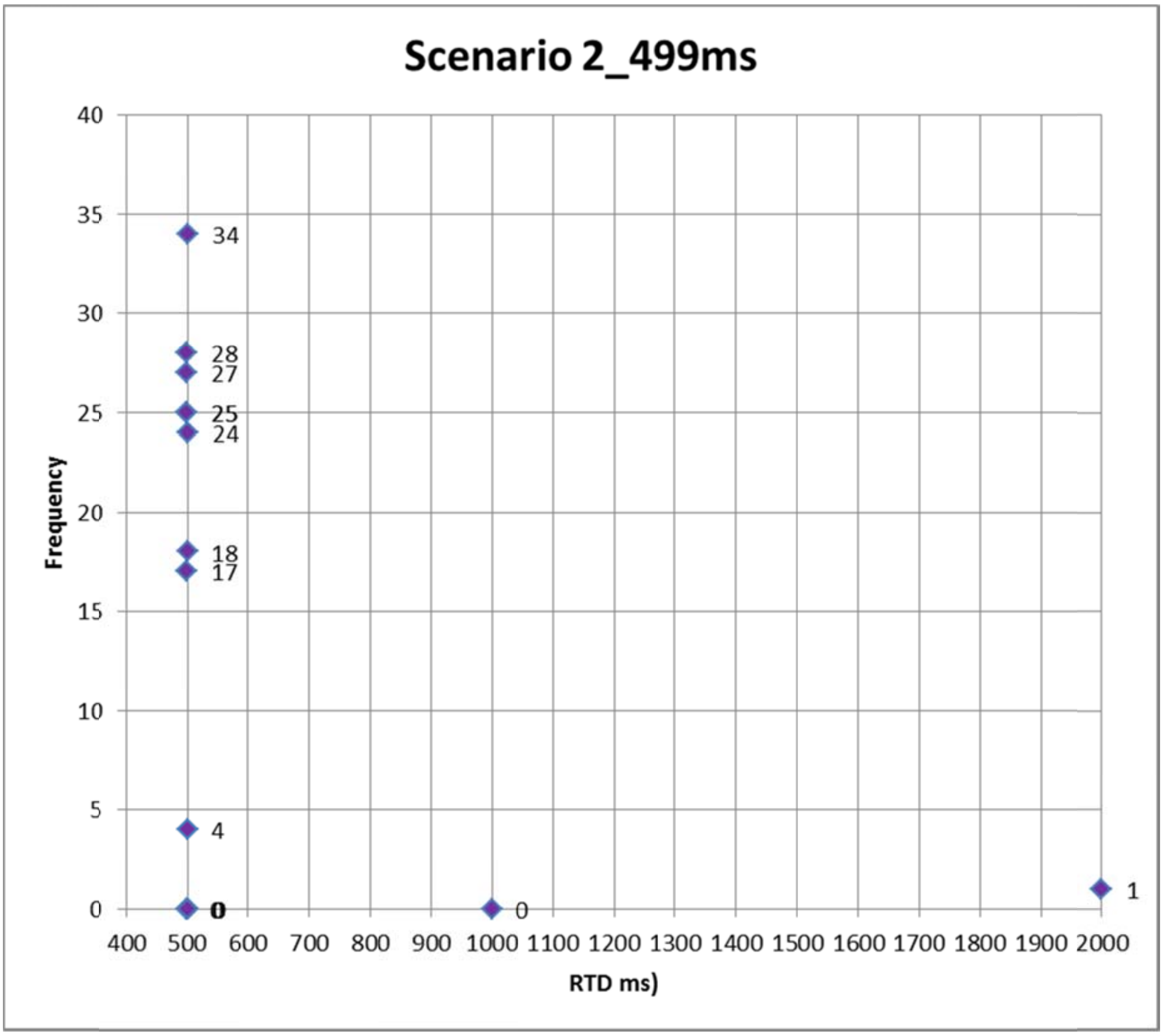

Figure 6-12: **Scenario 2_499ms**

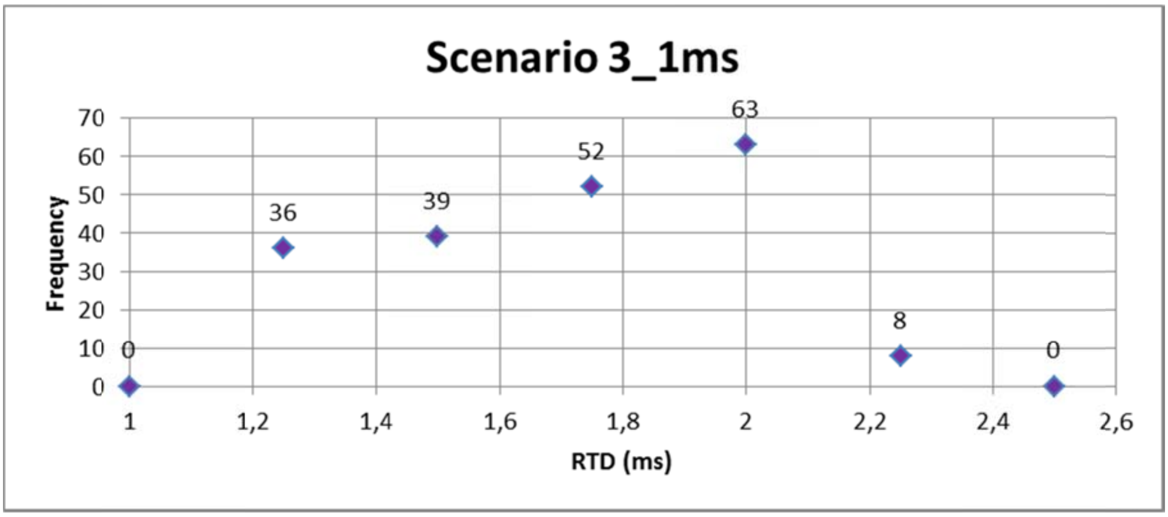

Figure 6-13: **Scenario 3_1ms**

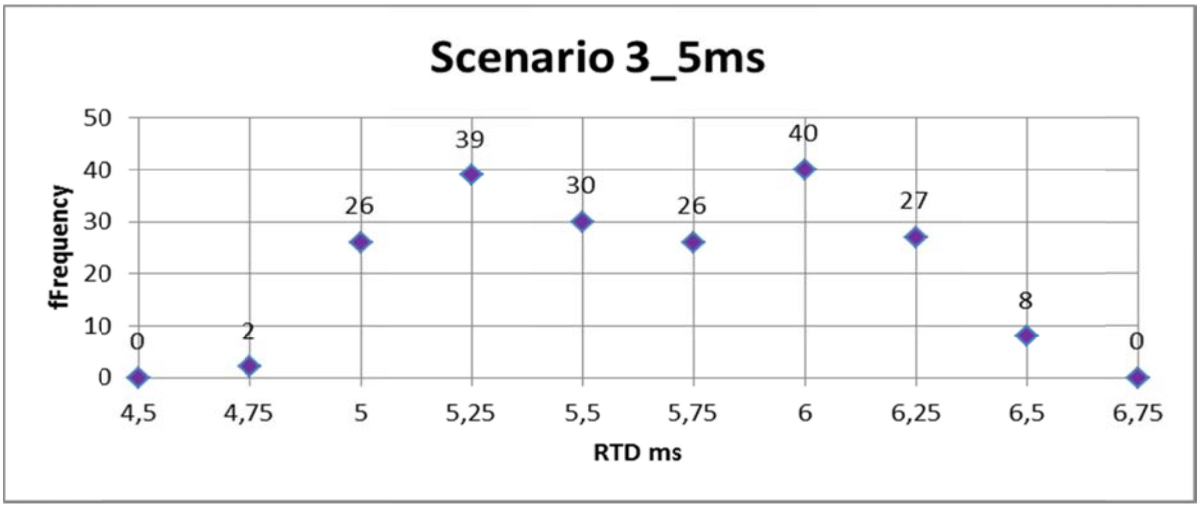

Figure 6-14: **Scenario 3_5ms**

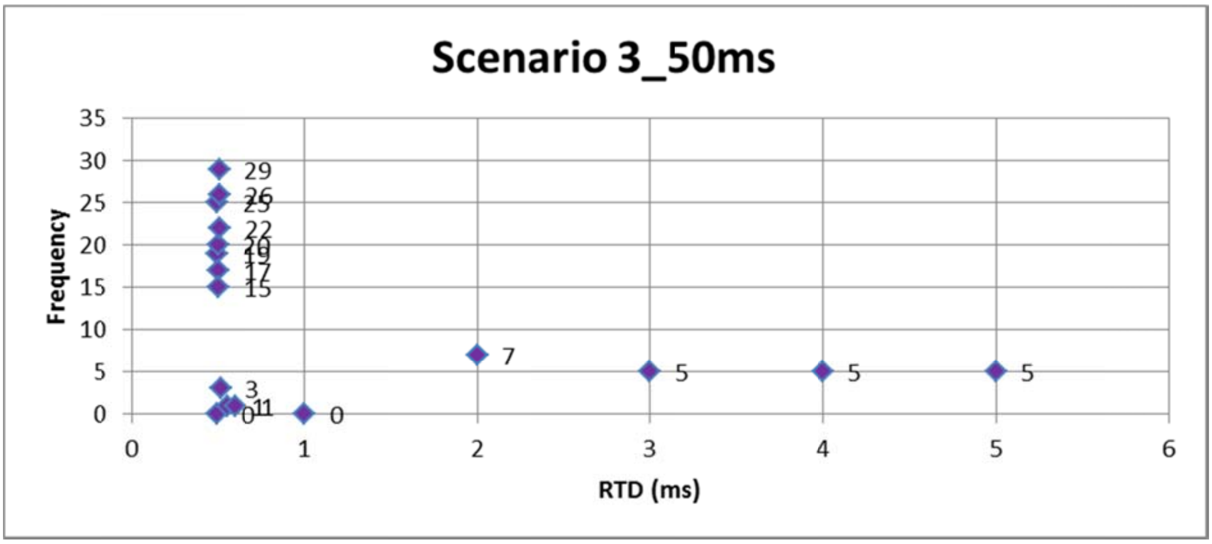

Figure 6-15: **Scenario 3_50ms**

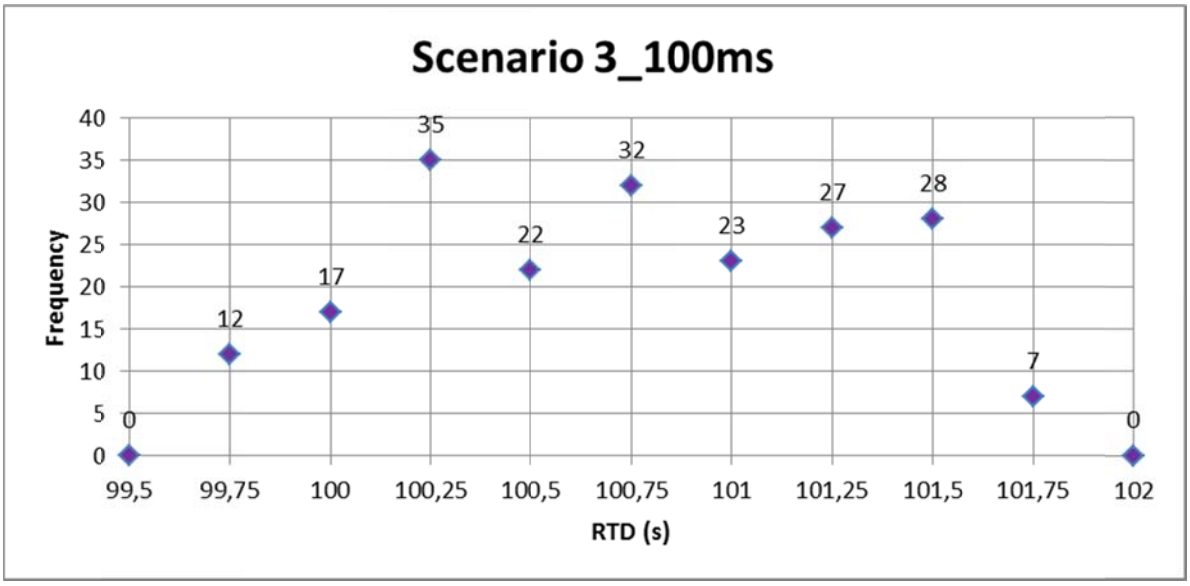

Figure 6-16: **Scenario 3_100ms**

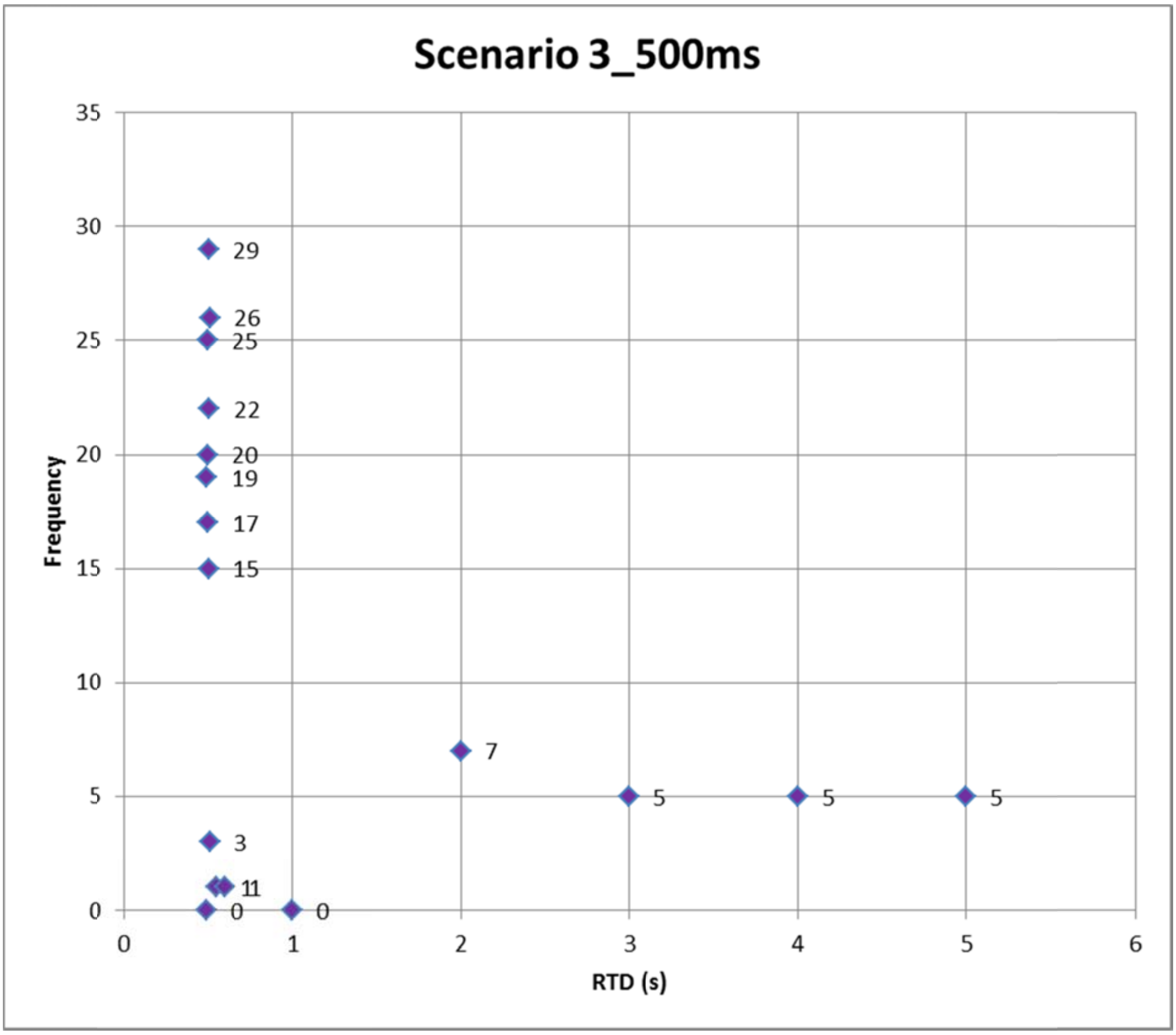

Figure 6-17: **Scenario 3_500ms**

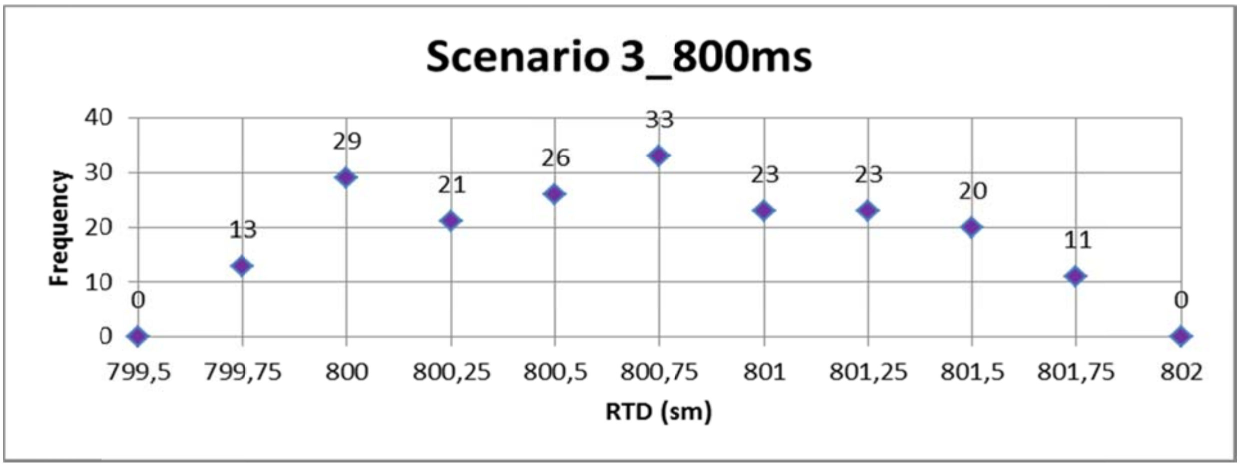

Figure 6-18: **Scenario 3_800ms**

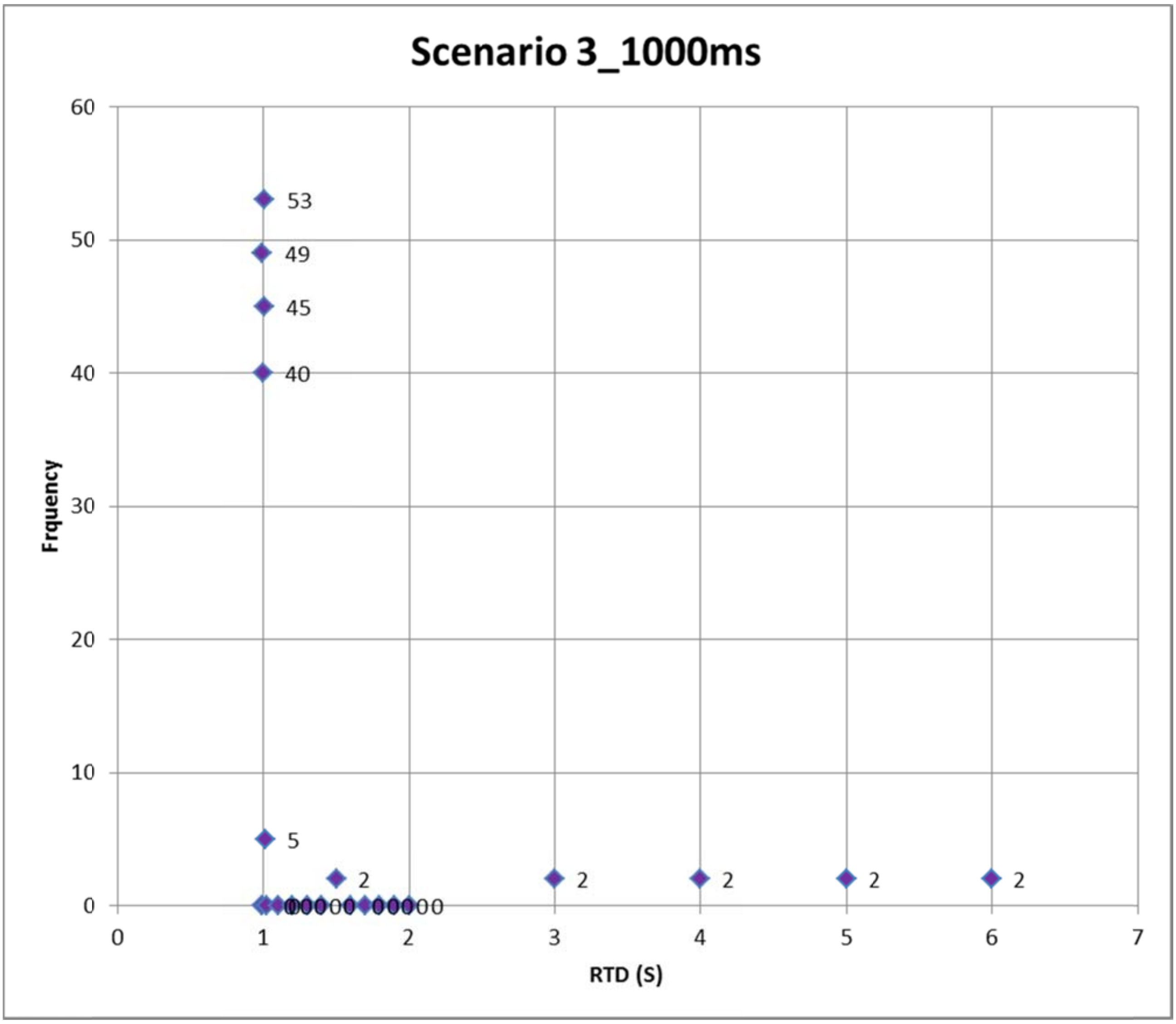

Figure 6-19: **Scenario 3_1000ms**

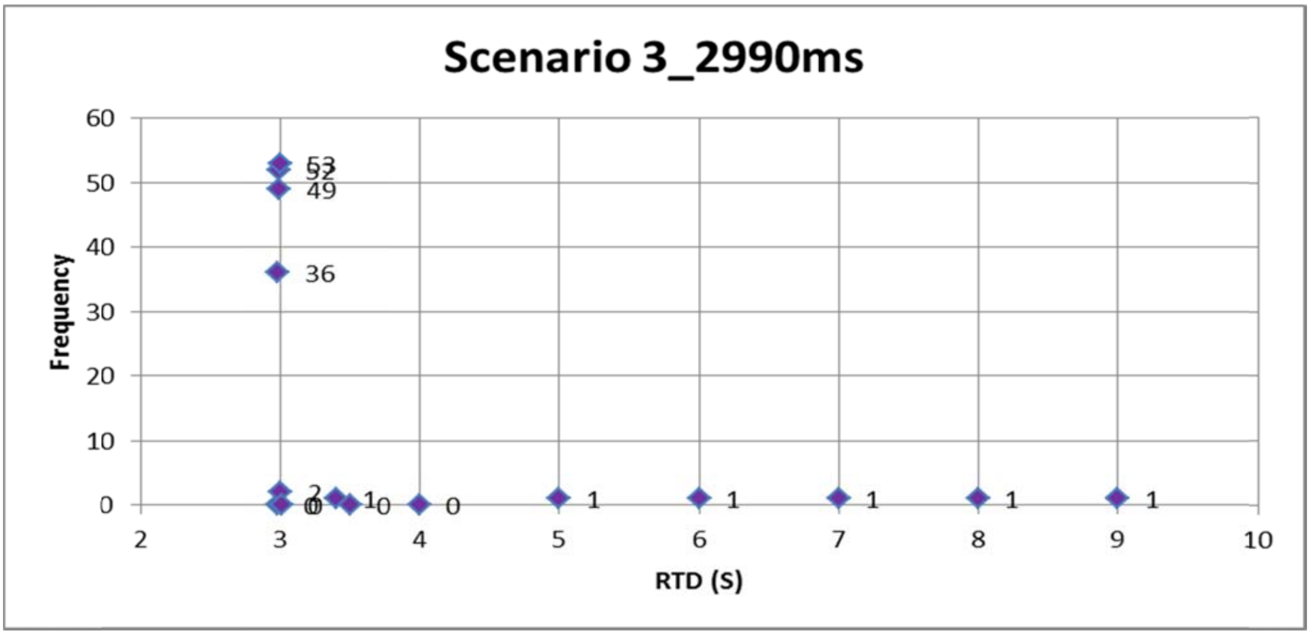

Figure 6-20: Scenario 3_2990ms

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