LTE PGW Reference Application

Functional Specification

1091419 1.12a

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1091419 1.12a

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Preface

Objective

This document provides a functional description of the LTE PGW Reference Application software (p/n 1091419 1.12a) designed by the Continuous Computing Corporation. This product is referred to as LTE PGW Application in the rest of the document.

Audience

Continuous Computing assumes that the readers of this document are familiar with telecommunication protocols, specifically LTE.

Document Organization

This document is organized into the following sections:

Section	Description
1 Introduction	Provides an overview of the product, including the product description and features.
2 Application	Describes the network architecture and protocol stacks.
3 Product Highlights	Defines Trillium Advanced Portability Architecture (TAPA) and describes the product-specific features.
4 Licensing Options	Describes the licensing information for this software.
5 Memory Size	Gives the products memory size which includes the total code sizes.

Section	Description
6 Open Source Software Usage	Gives the details about the open source software products used during the development.
Appendix A: Addendum	Describes the lists of changes for this addendum release.

Document Set

The suggested reading order of this document set is:

1. *LTE PGW Reference Application Functional Specification*

   Describes the features and highlights that the protocol and system characteristics, including the memory characteristics and conformance details.

2. *EGT Interface Service Definition*

   Describes the internal lower layer primitives for the EGT interface with Trillium eGTP Product. The Interface Primitives section describes the software services. The Interface Service Definition describes the interface procedures defined for the service provider software.

3. *eGTP Service Definition*

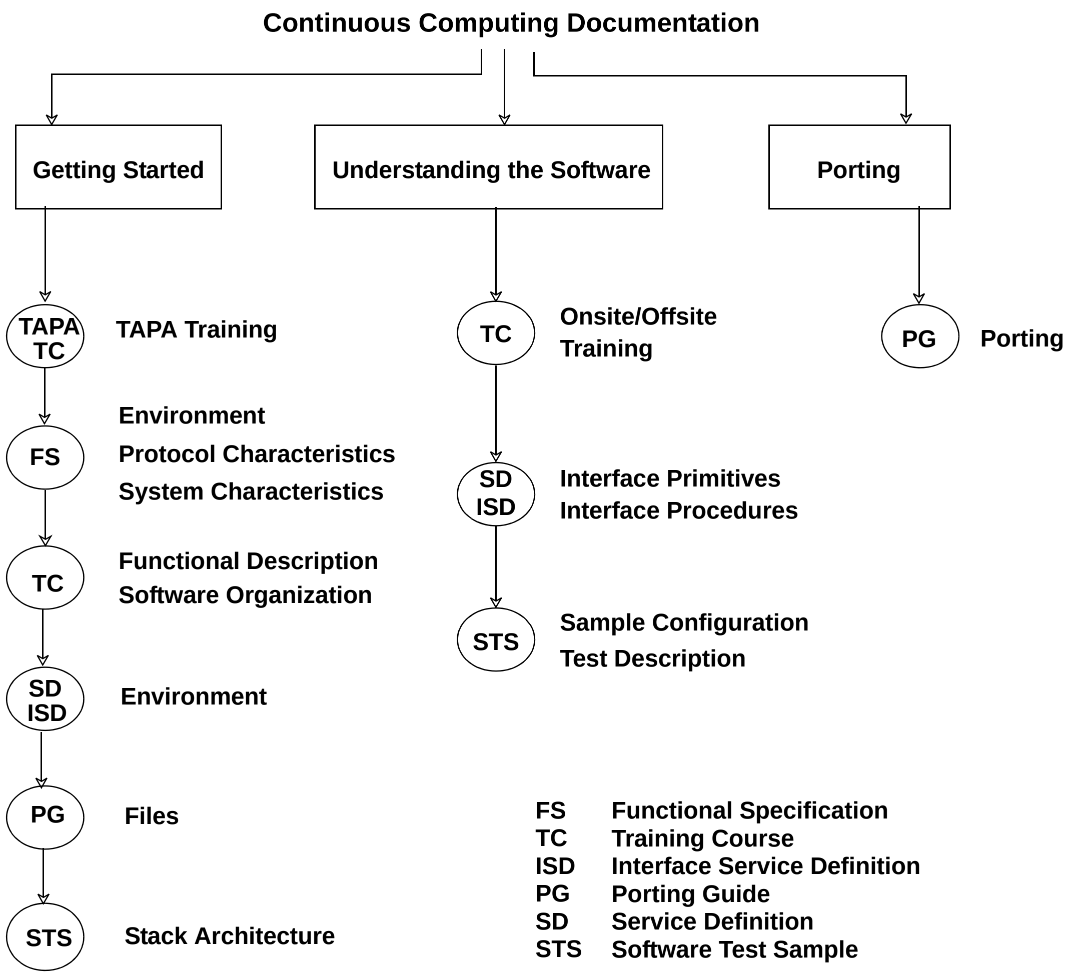
   Describes the procedures for eGTP at the layer manager interface. The layer manager interface is used to configure, control and collect the status and statistics information from the eGTP software.

4. *TUCL Service Definition*

   Describes the procedures for TUCL at the layer manager interface. The layer manager interface is used to configure, control, and collect the status and statistics information from the TUCL software.

Using Continuous Computing® Documentation

The following figure shows the various user approaches to using the software documentation. First time users must read the documents under the **Getting Started** column, where important sections and subsections are listed to the right of each document. For users familiar with the documentation, but who need to look up certain points concerning software use, **Understanding the Software** column is suggested. The **Porting** column is for users familiar with Continuous Computing Trillium software and related telecommunications protocols and wish to install the software immediately onto their development environments.



Notations

The following table displays the notations used in this document:

Notation	Explanation	Examples
Arial	**Titles**	**1.1 Title**
Book Antiqua	Body text	This is body text.
Bold	**Highlights information**	**Loose coupling, tight coupling, upper layer interface**
ALL CAPS	CONDITIONS, MESSAGES	AND, OR CONNECT ACK
Italics	Document names, emphasis	*LTE PGW Reference Application, Functional Specification* This adds *emphasis*.
`Courier New Bold`	**`Code`** **`Filenames, pathnames`**	**`PUBLIC S16`** **`AvMiLavCfgReq(pst, cfg)`** **`Pst      *pst;`** **`AvMngmt  *cfg;`**

Release History

The following table lists the history of changes in successive revisions to this document.

Version	Date	Author (S)	Description
1.12a	January 25, 2012	Manoranjan Sahu	Addendum release for CNE Feature Support upgrade.
1.11a	October 20, 2011	Naveen Dcruz H	Addendum release for Radisys logo and template upgrade.
1.1	July 20, 2010	Venumadhav Prabhu	Initial release. Conforms to LTE PGW Reference Application software release, version 1.1.

1

Introduction

1.1 Company Introduction

Continuous Computing is the only company deploying uniquely architected systems comprised of telecom platforms and Trillium software. Leveraging more than 20 years of innovation, the company enables network equipment providers to rapidly deploy carrier-class LTE, DPI, and femtocell applications with reduced risk, cost, and complexity. Only Continuous Computing combines open-standards systems, Trillium protocol software, and expert professional services to create fully-integrated solutions that empower more than 150 customers worldwide to accelerate new product delivery and maximize return on investment. Find more details at www.ccpu.com

1.1.1 Continuous Computing Trillium Product-line

Trillium® protocol software is synonymous with high quality and superior performance. Trillium originally built its strong reputation with flexible and powerful ATM, SS7, and SIGTRAN software. Trillium innovation continues today with complete and easy-to-use solutions in the Femtocell, IP Multimedia Subsystem (IMS), and Long Term Evolution (LTE) arenas.

Experts view Trillium as "the standard" for protocol stack solutions. Trillium software empowers telecom equipment manufacturers to develop reliable, high-performance 3G / 4G network nodes such as PDN GW, x-CSCF, eNodeB, xGSN, x-PCRF, ePDG, MME, Serving GW, ePDG, and many more. Key customer benefits are accelerated time-to-market, reduced development costs, and decreased project risk and complexity.

The foundation of all Trillium products is the Trillium Advanced Portability Architecture (TAPA®), which ensures complete independence from the target system's compiler, processor, operating system, or architecture. In addition, TAPA provides a consistent Application Programming Interface (API), code organization, and debugging and trace capabilities. Benefits include reliability, consistency and compressed learning curves.

Trillium software solutions also include the Distributed Fault-Tolerant / High Availability (DFT/HA) architecture, a patented model for software scalability and reliability which distributes processing loads across multiple processors and magnifies performance.

Trillium's latest innovation is a proven multi-threaded design that minimizes locking and optimizes performance in today's multi-core / multi-threaded environments. Trillium Multi-Core is a significant technology advantage which enables customers to leverage rapid advancements in silicon processing power quickly and easily.

1.1.2 Quality

The Continuous Computing Corporation is certified and registered as compliant with the CMMI Level 3 and the ISO 9001 quality system requirements. These certifications signify that the Continuous Computing Corporation processes related to the design, development, testing and distribution of communications software products and services for the next-generation network infrastructure successfully meet internationally recognized quality management systems requirements.

1.2 Product Description

This document provides functional description for LTE PGW Reference Application.

The LTE PGW Application software provides the following basic capabilities:

- Supports S5/S8 interfaces.
- PGW as integrated reference solution include:
  - Field deployable COTS - eGTP-c and eGTP-u.
  - Field deployable COTS- TUCL.
- Reference PGW data application.
- Sample Stack Manager.
- Sample Stack Manager configures all the protocol layers and Reference PGW application.
- Support of DL data generation logic for multiple UE’s at PGW application.

- Interface with external gateway (IP application) using libpcap:
  - Forwarding IP packets to SGW over eGTP-u for destined UE.
  - Forwarding IP packets received from SGW to external gateway.
- Configurable number of UE’s served by PGW.
- Unique IP allocation for UE’s starting from configured IP address.
- Support of multiple UEs and single session per UE.
- Support of tunnel management Creation, Management, and Deletion.
- Supports one bearer map per UE. Each bearer map contains:
  - One control tunnel.
  - One default data tunnel.
- Setup e-GTP signaling connection with SGW.
- Supports multiple Attach and Detach procedures.
- Extensive debugging support to ease system integration and testing.

1.3 Acronyms

The following acronyms are used in this document:

Acronyms	Expansion
ANSI	American National Standards Institute
LI	Lower Interface
LMI	Layer Manager Interface
OSI	Open Systems Interconnection
PDU	Protocol Data Unit
SAP	Service Access Point
SDU	Service Data Unit
SSI-SDK	System Services Interface - Software Development Kit
TAPA	Trillium Advanced Portability Architecture
UI	Upper Interface

For a list of commonly used terms, refer to the Engineering Glossary (part number PREN026) at http://www.ccpu.com/search/glossary/

Product-specific Glossary

Acronyms	Expansion
CNE	Core Network Emulator
eGTP/e-GTP	Evolved GTP
ENB/eNB/ eNodeB	Evolved Node B
P-GW/PGW	PDN Gateway
SG	Serving Gateway
SM	Stack Manager
LTE	Long Term Evolution
TUCL	TCP/UDP Convergence Layer
UE	User Equipment

2

Application

2.1 LTE PGW Reference Application Architecture

The architecture of LTE PGW Reference is in Figure 2-1.

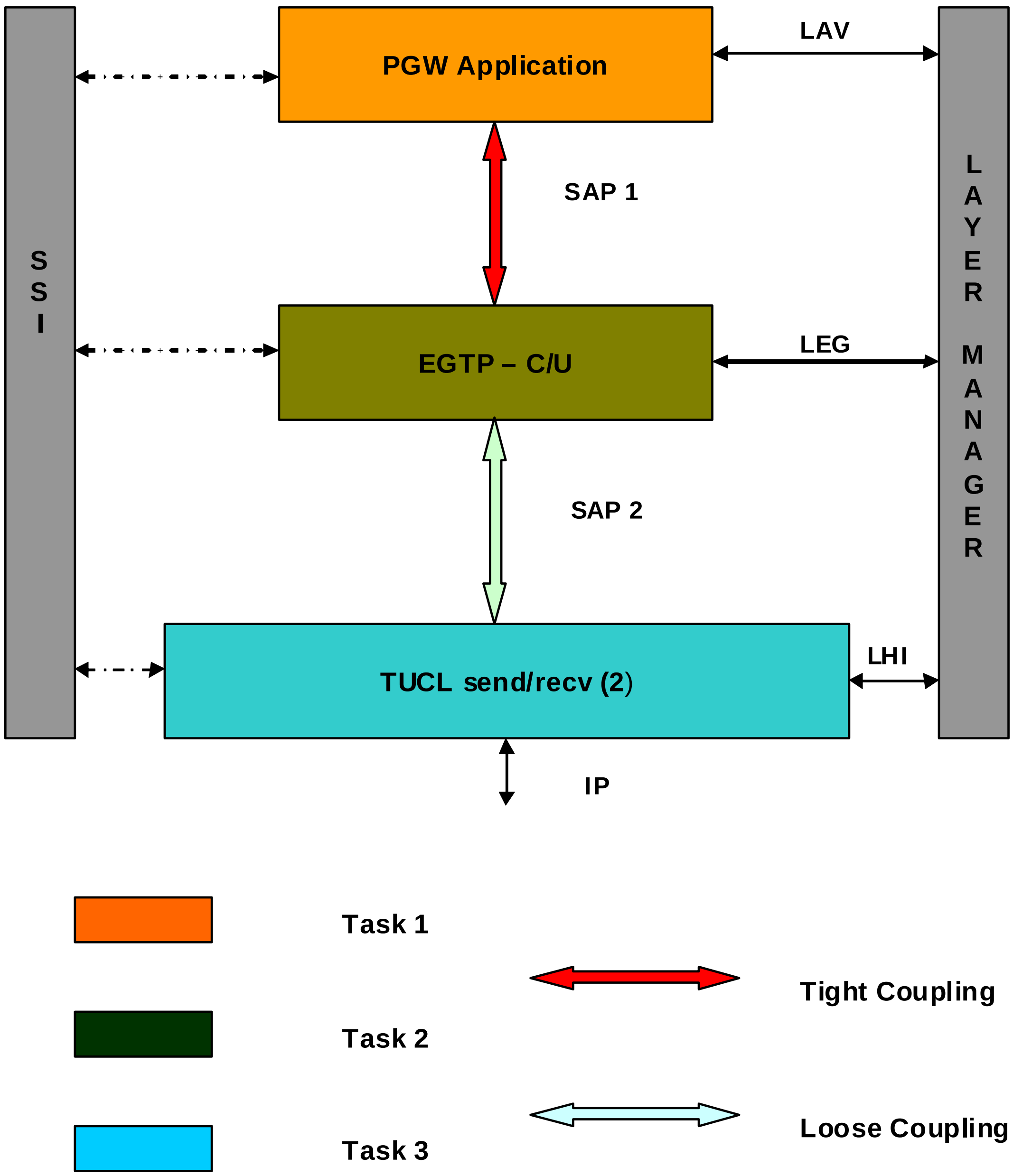


Figure 2-1: LTE PGW Reference Application Architecture

PGW Application constitutes of the following modules:

Table 2-1: PGW Application Modules

Module Name	Module Description
Layer Manager	Responsible to configure and manage all the lower layers in the PGW Protocol Stack.
eGTP	Responsible for creation/deletion of eGTP-c tunnels for UE to exchange of session request and response.
PGW Lower Interface Module (EGT)	Handles all the upper interface primitives to send the message to eGTP and receive from eGTP.
P-GW controller Module	PGW interface module has eGTP wrapper functional primitives to controlling the Tunnel management functions.

3

Licensing Options

For licensing purposes, LTE PGW Reference Application is identified by a marketing part number, 1000419. Continuous Computing Trillium supplies a base option with each license to provide core protocol functionality. Additional options can be licensed for increased functionality, as described in Table 3-1.

Table 3-1: Licensing options

Part Number	Option	Description
1000419	01	PGW Reference application - Binary of PGW Reference application and configuration files.
1000419	02	PGW Reference application - Source code of PGW Reference application, configuration files, and libraries for protocol stacks (TUCL and eGTP).

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Product Highlights

4.1 Protocol Conformance

The LTE PGW Application software complies with the basic LTE signaling and data call flow provided by the Figure 4-1.

Refer to respective lower layer (e-GTPand SCTP) *Functional Specification* documents for the protocol conformance.

4.2 Feature Support

Table 4-1 lists the features supported by the software.

Table 4-1: Features

Option	Feature	Supported
01, 02	Supports all the lower layers Configurations and Trigger binding Procedures. Supports S5/S8 interfaces. Supports path management procedure (echo procedures) between multiple core network nodes at S5/S8 interface. Supports multiple UEs and sessions [single session per UE]. Supports multiple Attach and Detach procedures of UEs. Supports eGTP tunnel management-Creation, Management, and Deletion. Supports Data Transfer between two end applications. ERAB setup release from CNE. CNE initiated Detach Procedure. Multiple UE, each with single Dedicated Bearer support. Tested PING, video-streaming (VLC player and iperf), FTP, HTML web-browsing, VNC server application in end-to-end demo setup involving ueSIM, eNodeB, and CNEs (for single UE).	Yes

Figure 4-1: LTE Control and Data

UE INITIATED DETACH (when UE is switched off)

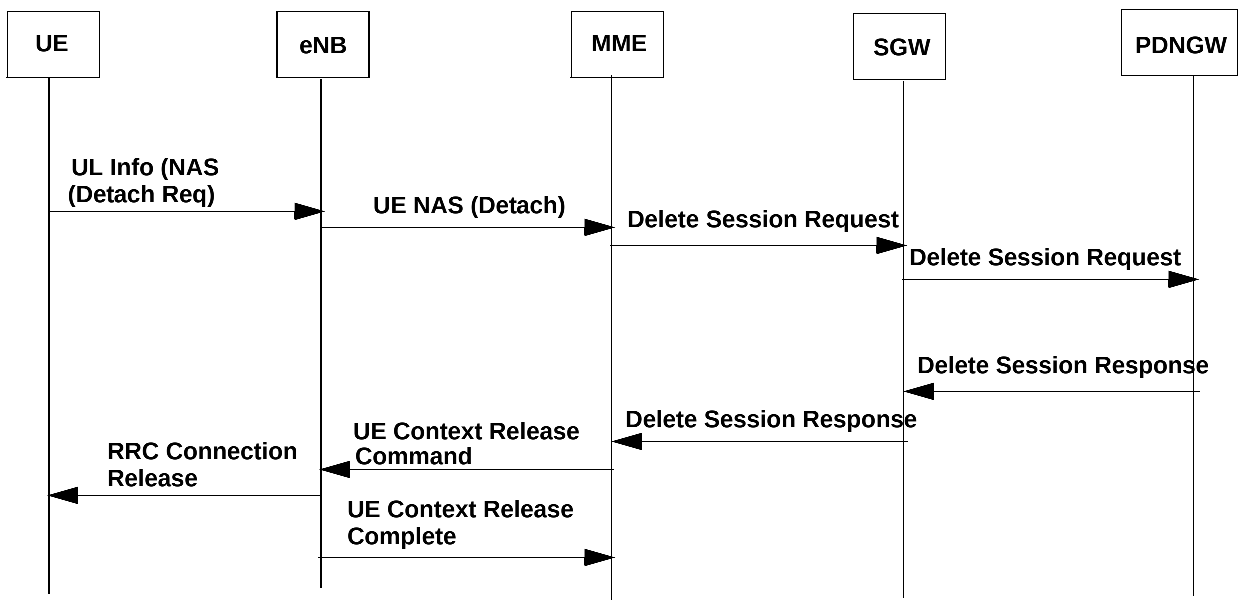

Figure 4-2: LTE Detach Call flow

4.3 TAPA

Trillium Advanced Portability Architecture (TAPA) defines the software architecture that ensures portability of Continuous Computing Trillium products across various platforms. Each Trillium product, represented by the box in the center of Figure 4-3, is equivalent to an Open Systems Interconnection (OSI) layer. The product has four interfaces that enable it to communicate with the other software modules in the system: the upper layer interface (UI), lower layer interface (LI), layer manager interface (LMI), and system services interface (SSI).

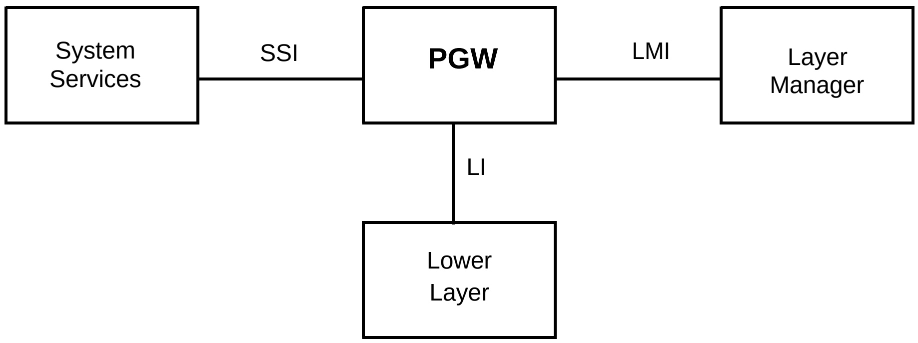

Figure 4-3: Trillium Advanced Portability Architecture (TAPA)

Interfaces

An interface is shared between two layers and used for the exchange of primitives between the layers.

Interface	Description
EGT (EGT)	Accesses the services of a lower (service provider) layer. Functions provided at this interface include binding, unbinding, connection, disconnection, data transfer, and other functions specific to the lower layer.
Layer Manager Interface (Lav)	Manages the layer resources and provides functions such as run-time configuration, control, statistics, status, alarm, and other management functions required and provided by the protocol layer.

Interface	Description
System Services Interface (SSI)	Obtains operating system services using a generic, portable interface that isolates the protocol layer from the underlying platform. Functions provided at this interface include initialization, task management, inter-task communication, timer management, memory management, message and queue management, date and time management, and resource checking.

Coupling Options

Continuous Computing Trillium software can be coupled with other layers using one of the following option.

Coupling	Description
Tight	Uses a synchronous interface, where a primitive is mapped to a direct function call into the destination layer. Control is transferred to the destination layer immediately, in a nested fashion.
Loose	Uses an asynchronous interface, where a primitive is packed into a message and posted to the destination layer. Control returns to the source layer immediately. Later, the operating system schedules the destination layer with the posted message. The destination layer retrieves the primitive from the message and processes it.
Light-weight Loose	Uses an asynchronous interface, where a pointer to the event structure is packed into a message and posted to the destination layer. This is applicable if and only if the sender and the receiver are in the same address space. Control returns to the source layer immediately, like Loose Coupling. Later, the operating system schedules the destination layer with the posted message. The destination layer retrieves the event structure by unpacking the pointer.

The system services interface is always tightly coupled.

Continuous Computing Trillium software is event-driven. It handles an event to completion, then handles the next event. Outgoing messages are generated in the same order in which the events arrived.

LTE PGW Application Primitives

Interaction between the LTE PGW Application software and the upper layer, lower layer, and layer manager takes place using a set of **primitive functions.** The primitives either initiate, or are the result of, the interactions between two layers. These primitives completely define the interaction between layers in the form of:

- Requests (service user to service provider).
- Indications (service provider to service user).
- Responses (service user to service provider).
- Confirmations (service provider to service user).

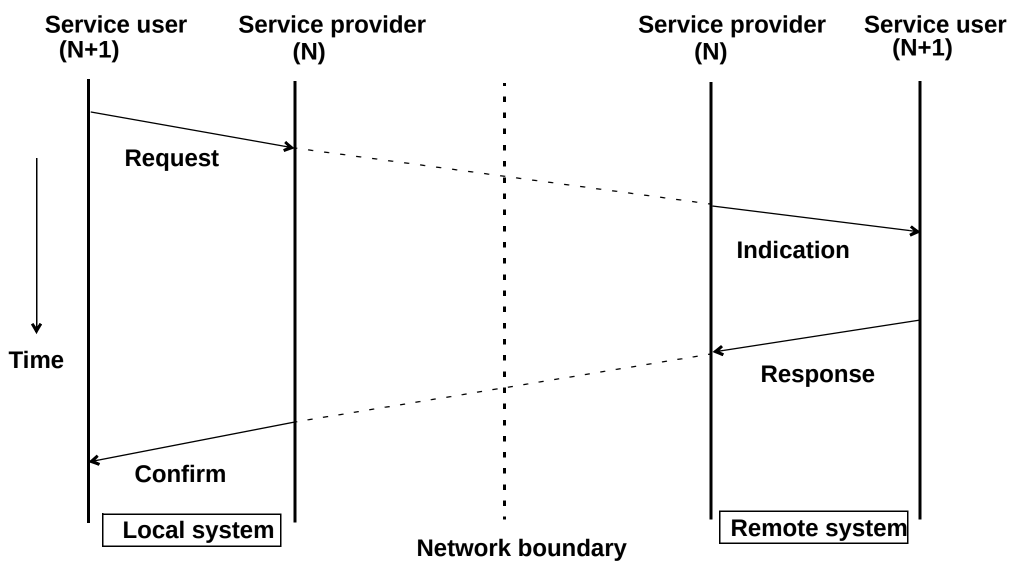

Figure 4-4: Exchange of Primitives

Service Access Points

Information flows between layers across Service Access Points (SAPs). The standardized interface of primitives and SAPs allows layers to be defined independently. Modifications can be made to the peer-to-peer protocol of one layer without affecting any upper or lower layer protocol, if the requirements of the layer interface are met.

A detailed description of the primitives used and their associated procedures can be found in the *LTE PGW Reference Application Service Definition*.

4.3.1 Portability

The software is written and delivered in the C programming language and can be compiled using any Kernighan and Ritchie or ANSI-compatible compiler.

Continuous Computing Trillium has compiled the software under native and cross compilers for many different processors. The software runs on various processors, operating systems, and architectures. While the software has not been compiled under all compilers or run on all combinations of processors, operating systems, and architectures, adherence to TAPA and its common coding and architectural standards ensures the portability of the software.

Continuous Computing Trillium has ported the software to the processors and operating systems listed as follows. This list does not constitute a recommendation for a particular operating system or processor, nor is it a complete list of operating systems and processors onto which Trillium software has been ported. It serves only to illustrate the flexibility and portability of Trillium software.

Continuous Computing Trillium provides a System Services Interface-Software Development Kit (SSI-SDK) for quick and efficient porting of the Trillium SSI to new operating system platforms.

Processors

Motorola 68xxx, Intel i960X, SPARC xxx, Intel x86, DEC Alpha, Power PC xxx, HP PA-RISC, LSI Logic LR33000.

This product is compiled and tested on Intel x86 and Octeon processor processors.

Operating Systems

This product is compiled and tested on Linux OS and Solaris environments.

4.3.2 Debugging Capabilities

Continuous Computing Trillium software provides extensive debugging capabilities. If terminal printing support is available, debug printing can be enabled, using compile-time and run-time options, to print information about the data flow through the layer.

The software can trace function calls. Every function call contains a trace macro at its entry which can be mapped to print information about the function invocation. This is useful in embedded systems for which no other symbolic debugging is available. Tracing of messages can be enabled or disabled at run-time.

4.3.3 Error Checking

Continuous Computing Trillium software provides extensive error checking and recovery mechanisms to make the software robust and enable it to deal with normal error conditions. The software enables the user to control the level of error checking using compile-time options.

Error checking is done for:

- Protocol
- Interface
- Input
- Output
- Resource

More information on error checking, refer to the *LTE PGW Reference Application Porting Guide*.

4.3.4 Run-Time Control

The layer manager interface controls many product capabilities at run-time. The configuration of the software can be changed dynamically to respond to the needs. For example, if the product supports multiple protocols, they are supported at run-time over separate SAPs. Management alarms and logging functions can be dynamically enabled and disabled. Also, where applicable, various protocol elements such as links can be enabled, disabled, deleted, or reconfigured at run-time

4.4 Product Features

This section describes the primitives that the LTE PGW Application software uses to interact with the upper layer, lower layer, and layer manager. It also describes the procedures that the primitives enable.

4.4.1 Layer Interfaces

Several sets of primitives interface the software with the upper layer, lower layer, and layer manager.

4.4.1.1 Layer Manager Interface

The layer manager interface is used for managing layer resources. It provides run-time configuration, control, statistics, status, alarm, and other management functions required and provided by the protocol layer.

Refer to the *LTE PGW Reference Application Service Definition* for details.

4.4.1.2 Upper Interfaces

PGW Application is at top most layer in the protocol stack, it does not have any upper user.

4.4.1.3 EGT Interface

The EGT interface is used by PGW Application for configuring e-GTP tunnels and transfer data to the CNE.

Refer to the *EGT Interface Service Definition* for details.

4.4.2 Configuration

Configuration procedures set parameters and environment options for the layer.

4.4.2.1 General Configuration

General configuration sets parameters for the entire LTE PGW Application layer. These parameters can be configured only once before the layer becomes operational.

4.4.2.2 Lower SAP Configuration

The Lower SAP configuration procedure allocates and configures a lower SAP. Typically, there is one lower SAP for each logical link that LTE PGW Application controls. If the SAP is already allocated, this procedure can be used to reconfigure its parameters.

4.4.3 Alarms

Alarms are generated to indicate abnormal status changes of the software or SAP. Alarms can also be advisory in nature. Alarms are sent to the layer manager as unsolicited status indications whenever a condition requiring attention is detected.

Table 4-2 lists some of the generated alarms.

Table 4-2: Alarms

Alarms	Description
SAP Binding	Generated, if the lower SAP binding is successful

4.4.4 Control

Control functions activate and deactivate layer resources. The layer manager can invoke control functions at any time. The control feature of the layer manager gives the flexibility to dynamically modify the characteristics of a stack or a resource, such as a link.

For example, by using control, user can:

- Turn tracing on or off at run-time. Once tracing is turned on, it provides the Service Data Units (SDUs) that are transmitted to the layer, and received from the layer, to the layer manager. This information can be used for debugging.
- Turn alarms on or off at run-time. When enabled, alarms provide useful information regarding the state of the protocol stack.
- Turn different debug levels on and off to aid product-specific system integration.
- Trigger Binding procedure towards lower layer.

5

Memory Size

Continuous Computing Corporation offers the industry’s leading performer LTE PGW Reference Application protocol software solution for LTE.

LTE PGW Reference Application is a cornerstone technology that provides functionality of PGW application. A key benefit of Continuous Computing’s LTE PGW Reference Application software is its capability to interwork with Continuous Computing Trillium’s SS7, IP, ATM, SIP, GTP, RRC, and ISDN protocol stacks. Continuous Computing’s LTE PGW Reference Application software is scalable and supports distributed system architectures. Continuous Computing’s LTE PGW Reference Application software offers maximum portability and flexibility based on Continuous Computing Trillium's proven TAPA™ software architecture.

Continuous Computing’s LTE PGW Reference Application software solution enables communications equipment suppliers to deliver products that meet the requirements of next-generation networks.

5.1 Code Size

The code size is the number of bytes of memory needed for the executable code. The code size includes all function calls to system services, layer manager, and the upper and lower layers, but does not include the size of the actual code provided within these functions.

The code size depends on the options delivered, compiler, linker, locator, memory model, and whether delivered features – such as error checking, management capabilities, and protocol capabilities – are used. The code size can be determined from the software link map.

A sample compile under the following conditions, tightly coupled with error checking and trace printing disabled, yields the code size in Table 5-1.

Table 5-1: Code size

Type	Condition
Product	LTE PGW Application, version 1.1
Product options	01
Compiler	gcc compiler, version 4.1.2
Compiler options	**`-Os -ansi -Wall -Wno-comment -pipe -Wshadow -Wcast-qual -Wstrict-prototypes -Wmissing-prototypes -pedantic -Wimplicit -Wunused`**
Processor	Intel(R) Core (TM) i5 CPU M 520@2.40 GHz
Total code size (in Bytes)	**1212175**

5.2 Static Data Size

The static data size is the number of bytes of memory needed for:

- Initialized variables and structures, such as state matrices or strings.
- Uninitialized variables and structures, such as anchors for control points and SAPs.

Static data is allocated at compile time and represents the global variables and structures used by the software. Static data does not include any structures allocated at run-time.

The static data size depends on the options delivered, compiler, linker, and memory model. The static data size can be determined from the software link map.

A sample compile under the following conditions, tightly coupled with error checking and trace printing disabled, yields the code size in Table 5-2.

Table 5-2: Static data size

Type	Condition
Product	LTE PGW Application, version 1.1
Product options	01
Compiler	gcc compiler, version 4.1.2
Compiler options	**`-Os -ansi -Wall -Wno-comment -pipe -Wshadow -Wcast-qual -Wstrict-prototypes -Wmissing-prototypes -pedantic -Wimplicit -Wunused`**
Processor	Intel(R) Core (TM) i5 CPU M 520@2.40 GHz
Total static data size (in Bytes)	**876916**

5.3 Dynamic Data Size

Dynamic data size is the number of bytes of memory needed for:

- Structures (for example, control points and SAPs) used to manage the interface and protocols.
- Buffers used to store messages.

Dynamic data is allocated at run-time and represents the memory managed by the operating system. Allocation of dynamic data depends on the compile-time configuration, run-time configuration, and the net flow of traffic through the software.

Dynamic data size depends on maximum allowable configuration (A), size of structures allocated for the configurable parameters (B), maximum number of messages per second (C), and the average size of a message buffer (D).

The dynamic data size can be estimated by using the formula:

$(A \times B) + (C \times D)$

The message buffer size depends on system services. The maximum allowable configuration and dynamically allocated structure size are given in Section 5.3.1 and Section 5.3.2.

5.3.1 Maximum Allowable Configuration

The maximum allowable configurations described in this section represent the capacity of the software. Actual maximums may be smaller, depending on the limitations of the system to which this software is ported, such as memory availability.

Table 5-3: Maximum allowable configurations

Entity	Maximum Number
Upper SAPs	Not applicable.
Lower SAPs	1

5.3.2 Dynamically Allocated Structure Size

This section describes the sizes of dynamically allocated structures, such as control points or SAPs.

A sample compile under the following conditions, tightly coupled with error checking and trace printing disabled, yielded the structure sizes in the following tables.

Table 5-4: Structure types

Structure Type	Condition
Product	LTE PGW Application, version 1.1
Product options	01
Compiler	gcc compiler, version 4.1.2
Compiler options	`-Os -ansi -Wall -Wno-comment -pipe -Wshadow -Wcast-qual -Wstrict-prototypes -Wmissing-prototypes -pedantic -Wimplicit -Wunused`
Processor	Intel(R) Core (TM) i5 CPU M 520@2.40 GHz

Table 5-5: Dynamically allocated structure sizes

Type	Bytes
eGTP SAP Control Block	108

6

Open Source Software Usage

Open Source Software (OSS) components were not used during the development of LTE PGW Reference Application.

Appendix A

Addendum

This section is an addendum to version 1.1 *PDN Gateway (PGW) of Core Network.*

Note: The material in this addendum is integrated into the body of the document and noted below.

Table A-1: Changes for this addendum

Description of Change	Section Reference
Updated Release History in Preface.	Preface
Updated Feature Support in Product Highlights.	Section 4.2, "Feature Support"

References

Refer to the following documents for additional information.

LTE PGW Reference Application Service Definition, Continuous Computing Corporation (p/n 1092419).

System Services Interface Service Definition, Continuous Computing Corporation (p/n 1111001).

3GPP TS 24.301 V8.2.1 (2009-06): Non-Access-Stratum (NAS) protocol for Evolved Packe System (EPS)

3G TS 29.274, version 1.3.0 (2008-10), Evolved GPRS Tunnelling Protocol for Control Plane.

3G TS 29.281, version 8.1.0 (2008-10), GPRS Tunnelling Protocol -User Plane.