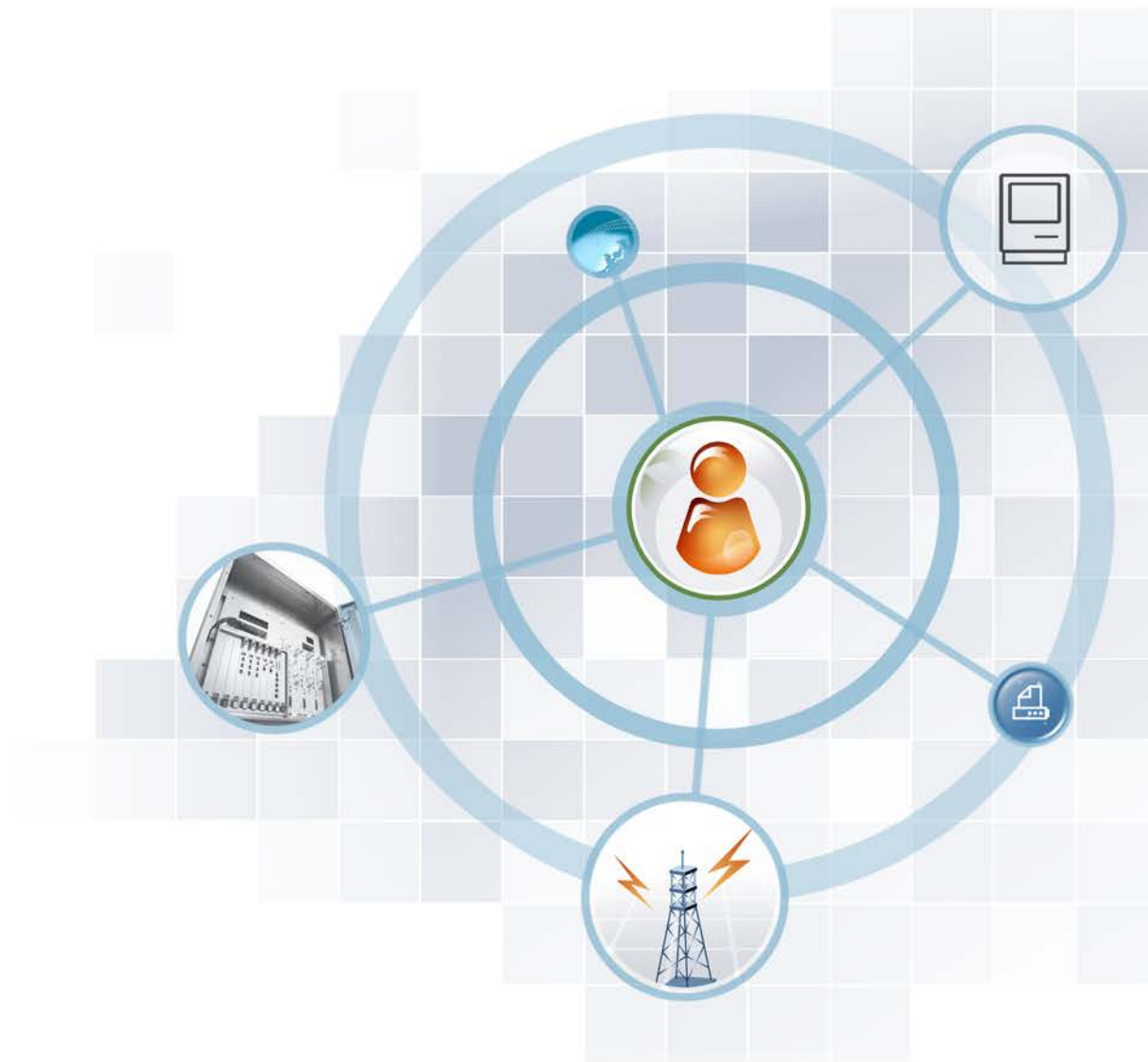


LTE 1.9 GHz Indoor Pico Cell

System Description



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INTRODUCTION

Purpose

This description describes the characteristics, features and structure of the 1.9 GHz Indoor Pico Cell, an LTE eNB.

Document Content and Organization

This manual consists of five Chapters and a list of Abbreviations.

CHAPTER 1. Samsung LTE System Overview

- Introduction to Samsung LTE System
- Samsung LTE Network Configuration

CHAPTER 2. System Overview

- Introduction to System
- Main Functions
- Specifications
- Intersystem Interface

CHAPTER 3. System Structure

- Hardware Structure
- Software Structure

CHAPTER 4. Message Flow

- Call Processing Message Flow
- Data Traffic Flow
- Network Sync Flow
- Alarm Signal Flow
- Loading Flow
- Operation and Maintenance Message Flow

CHAPTER 5. Supplementary Functions and Tools

LMT

ABBREVIATION

Describes the acronyms used in this manual.

Conventions

The following types of paragraphs contain special information that must be carefully read and thoroughly understood. Such information may or may not be enclosed in a rectangular box, separating it from the main text, but is always preceded by an icon and/or a bold title.



NOTE

NOTE

Indicates additional information as a reference.

Revision History

VERSION	DATE OF ISSUE	REMARKS
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CHAPTER 1. Samsung LTE System Overview

1.1 Introduction to Samsung LTE System

The Samsung LTE system supports 3GPP LTE (hereinafter, LTE) based services. LTE is a next generation wireless network system which solves the disadvantages of existing 3GPP mobile systems allows high-speed data service at low cost regardless of time and place.

The Samsung LTE system supports downlink Orthogonal Frequency Division Multiple Access (OFDMA), the uplink Single Carrier (SC) Frequency Division Multiple Access (FDMA), and scalable bandwidths for various spectrum allocation and provides high-speed data service. It also provides high-performance hardware for improved system performance and capacity and supports various functions and services.

**NOTE**

Compliance Standards

The Samsung LTE system is based on the Rel-8 and Rel-9 standards of the LTE 3rd Generation Partnership Project (3GPP).

The Samsung LTE system consists of the evolved UTRAN Node B (eNB), Evolved Packet Core (EPC) and LTE System Manager (LSM).

The eNB exists between the EPC and the User Equipment (UE). It establishes wireless connections with the UE and processes packet calls according to the LTE air interface standard. The eNB manages the UE in connected mode at the Access Stratum (AS) level. The EPC is the system located between the eNB and Packet Data Network to perform various control functions. The EPC consists of the Mobility Management Entity (MME), Serving Gateway (S-GW) and PDN Gateway (P-GW). The MME manages the UE in idle mode at the Non-Access Stratum (NAS) level; and the S-GW and the P-GW manage user data at the NAS level and interworks with other networks.

The LSM provides the man-machine interface; manages the software, configuration, performance and failures; and acts as a Self Organizing Network (SON) server.

The figure below shows the functional distinctions between the eNB of E-UTRAN, MME, S-GW, and P-GW according to the 3GPP standard. The eNB has a layer structure and the EPC has no layer.

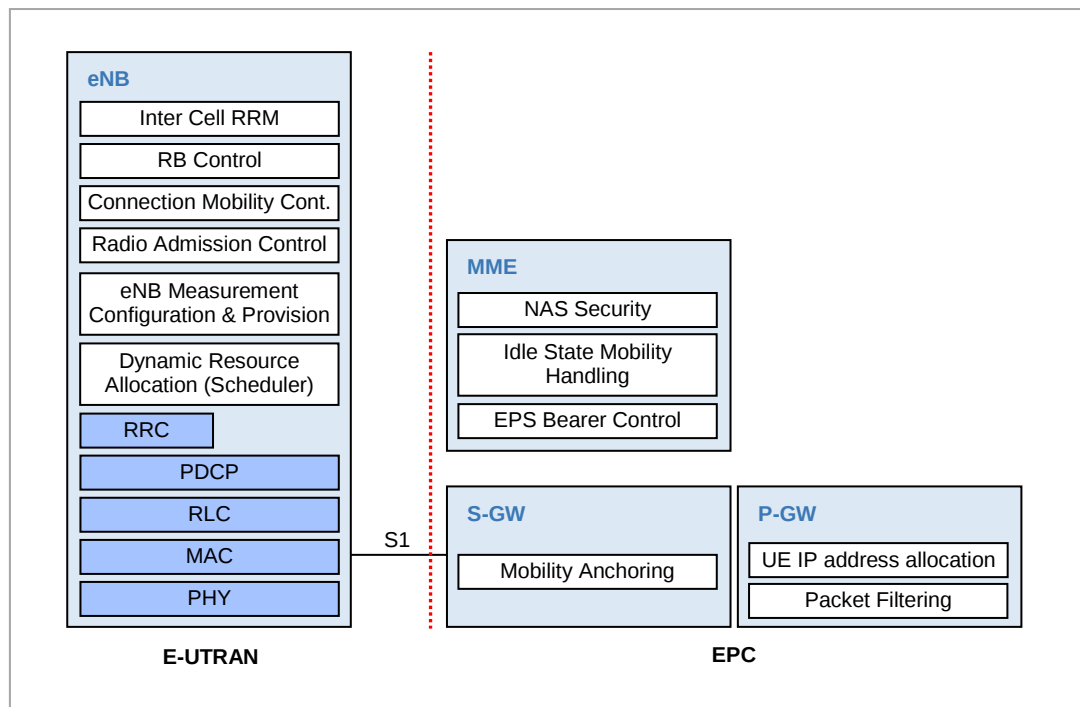


Figure 1. Functional Distinctions of E-UTRAN and EPC

eNB

An eNB is a logical network component of the Evolved UTRAN (E-UTRAN) which is on the access side in the LTE system.

eNBs can be interconnected with each other by means of the X2 interface. The eNBs are connected by means of the S1 interface to the Evolved Packet Core (EPC).

The wireless protocol layer of the eNB is divided into layer 2 and layer 3. Layer 2 is subdivided into the Media Access Control (MAC) layer, the Radio Link Control (RLC) layer, and the PDCP layer, each of which performs independent functions. Layer 3 has the RRC layer.

The MAC layer distributes air resources to each bearer according to its priority, and performs the multiplexing function and the HARQ function for the data received from the multiple upper logical channels.

The RLC layer performs the following functions.

- Segments and reassembles the data received from the PDCP layer in accordance with the size specified by the MAC layer
- Requests retransmission to recover if data transmission fails in the lower layer (ARQ)
- Reorders the data recovered by performing HARQ in the MAC layer (re-ordering)

The PDCP layer performs the following functions.

- Header compression and decompression
- Encrypts/decrypts user plane and control plane data
- Protects and verifies the integrity of control plane data
- Transmits data including sequence number related function
- Removes data and redundant data based on a timer

The RRC layer performs mobility management within the wireless access network, maintaining and control of the Radio Bearer (RB), RRC connection management, and system information transmission, etc.

MME

The MME interworks with the E-UTRAN (eNB) to process the Stream Control Transmission Protocol (SCTP)-based S1 Application Protocol (S1-AP) signaling messages for controlling call connections between the MME and the eNB and to process the SCTP-based NAS signaling messages for controlling mobility connection and call connection between the UE and the EPC.

The MME is responsible for collecting/modifying the user information and authenticating the user by interworking with the HSS. It is also responsible for requesting the allocation/release/change of the bearer path for data routing and retransmission with the GTP-C protocol by interworking with S-GW.

The MME interworks with the 2G and 3G systems, the SGSN and the MSC for providing mobility and Handover (HO), Circuit Service (CS) Fallback and Short Message Service (SMS).

The MME is responsible for inter-eNB mobility, idle mode UE reachability, Tracking Area (TA) list management, choosing P-GW/S-GW, authentication, and bearer management. The MME supports mobility during inter-eNB handover and the inter-MME handover. It also supports the SGSN selection function upon handover to a 2G or 3G 3GPP network.

S-GW

The S-GW acts as the mobility anchor during inter-eNB handover and inter-3GPP handover, and routes and forwards user data packets. The S-GW allows the operator to apply application-specific charging policies to UE, PDN or QCI and manages the packet transmission layers for uplink/downlink data.

The S-GW also supports GPRS Tunneling Protocol (GTP) and Proxy Mobile IP (PMIP) by interworking with the MME, P-GW, and SGSN.

PDN Gateway (P-GW)

The P-GW is responsible for charging and bearer policy according to the policy and manages charging and transmission rate according to the service level by interworking with the PCRF. The P-GW also performs packet filtering for each user, IP address allocation for each UE, and downlink data packet transmission layer management.

EPC

The EPC is a system located between the eNB and PDN. The subcomponents of the EPC are the MME, S-GW and P-GW.

- MME: Processes control messages using the NAS signaling protocol with the eNB and performs control plane functions such as UE mobility management, tracking area list management, and bearer and session management.
- S-GW: Acts as the anchor for the user plane between the 2G/3G access system and the LTE system, and manages and changes the packet transmission layer for downlink/uplink data.
- P-GW: Allocates an IP address to the UE, acts as the anchor for mobility between the LTE and non-3GPP access systems, and manages/changes charging and the transmission rate according to the service level.

LTE System Manager (LSM)

The LSM provides the user interface for the operator to operate and maintain the eNB. The LSM is responsible for software management, configuration management, performance management and fault management, and acts as a Self-Organizing Network (SON) server.

Core System Manager (CSM)

The CSM provides the user interface for the operator to operate and maintain the MME, S-GW, and P-GW.

Home Subscriber Server (HSS)

The HSS is a database management system that stores and manages the parameters and location information for all registered mobile subscribers. The HSS manages key data such as the mobile subscriber's access capability, basic services and supplementary services, and provides a routing function to the subscribed receivers.

Policy and Charging Rule Function (PCRF)

The PCRF server creates policy rules to dynamically apply the QoS and charging policies differentiated by service flow, or creates the policy rules that can be applied commonly to multiple service flows. The P-GW includes the Policy and Charging Enforcement Function (PCEF), which allows application of policy rules received from the PCRF to each service flow.

Online Charging System (OCS)

The OCS collects online charging information by interfacing with S-GW and P-GW. When a subscriber for whom online charging information is required makes a call, the P-GW transmits and receives the subscriber's charging information by interworking with the OCS.

Offline Charging System (OFCS)

The OFCS collects offline charging information by interfacing with S-GW and P-GW.

The OFCS uses the GTP' (Gz) or Diameter (Rf) interface to interface with the S-GW and P-GW.

CHAPTER 2. System Overview

2.1 Introduction to System

Indoor Pico Cell, an LTE eNB, is located between the UE and the EPC. It provides mobile communications services to subscribers according to the LTE air interface standard.

The Indoor Pico Cell transmits/receives radio signals to/from the UE and processes the modulation and demodulation of packet traffic signals. The Indoor Pico Cell is also responsible for packet scheduling and radio bandwidth allocation and performs handover via interface with the EPC.

The Indoor Pico Cell can be installed vertically or horizontally; and it can be installed on the wall, pole or rack by using the installation brackets. The Indoor Pico Cell is an all-in-one unit. If a fault occurs, the unit must be replaced with new one.

2.2 Main Functions

The main functions of the Indoor Pico Cell (hereinafter, eNB) are as follows:

- Physical Layer Processing
- Call Processing Function
- IP Processing
- SON Function
- Easy Operation and Maintenance



Availability of System Features and Functions

For availability and provision schedule of the features and functions described in the system manual, please refer to separate documentations.

2.2.1 Physical Layer Processing

The eNB transmits/receives data through the radio channel between the EPC and UE. To do so, the eNB provides the following functions.

- OFDMA/SC-FDMA Scheme
- Downlink Reference Signal Creation and Transmission
- Downlink Synchronization Signal Creation and Transmission
- Channel Encoding/Decoding
- Modulation/Demodulation
- Resource Allocation and Scheduling
- Link Adaptation
- HARQ
- Power Control
- MIMO

OFDMA/SC-FDMA Scheme

The eNB performs the downlink OFDMA/uplink SC-FDMA channel processing that supports the LTE standard physical layer. The downlink OFDMA scheme allows the system to transmit data to multiple users simultaneously using the subcarrier allocated to each user. Depending on the channel status and the transmission rate requested by the user, the downlink OFDM can allocate one or more subcarriers to a specific subscriber to transmit data.

In addition, when all sub-carriers are divided for multiple users, the eNB can select and assign to each subscriber a sub-carrier with the most appropriate features using the OFDMA scheme, thus to distribute resources efficiently and increase data throughput. For uplink SC-FDMA, which is similar to OFDMA modulation and demodulation, a

Discrete Fourier Transform (DFT) is applied to each subscriber in the modulation at the transmitting side. An inverse Discrete Fourier Transform (IDFT) is applied for minimizing the Peak to Average Power Ratio (PAPR) at the transmitting side, which allows continuous allocation of frequency resources available for individual subscribers. As a result, the eNB can reduce the power consumption of the UE.

Downlink Reference Signal Creation and Transmission

The UE must estimate the downlink channel to perform the coherent demodulation on the physical channel in the LTE system. The LTE uses the OFDM/OFDMA-based methods for transmitting and therefore the channel can be estimated by inserting the reference symbols from the receiving terminal to the grid of each time and frequency. These reference symbols are referred to as the downlink reference signal. The following reference signals are defined for the LTE downlink.

- Cell-specific reference signal: The cell specific reference signal is transmitted to every subframe across the entire bandwidth of the downlink cell. It is mainly used for channel estimation, MIMO rank calculation, MIMO precoding matrix selection and signal strength measurement for handover.

Downlink Synchronization Signal Creation and Transmission

The synchronization signal is used for the initial synchronization when the UE starts to communicate with the eNB. There are two types of synchronization signals: Primary Synchronization Signal (PSS) and Secondary Synchronization Signal (SSS).

The UE can obtain the cell identity through the synchronization signal. It can obtain other information about the cell through the broadcast channel. Since synchronization signals and broadcast channels are transmitted in the 1.08 MHz range, which is right in the middle of the cell's channel bandwidth, the UE can obtain the basic cell information such as cell ID regardless of the transmission bandwidth of the eNB.

Channel Encoding/Decoding

The eNB is responsible for channel encoding/decoding to correct the channel errors that occurred on a wireless channel. In LTE, the turbo coding and the 1/3 tail-biting convolutional coding are used. Turbo coding is mainly used for transmission of large data packets on downlink and uplink, while convolutional coding is used for control information transmission and broadcast channel for downlink and uplink.

Modulation/Demodulation

For the data received over the downlink from the upper layer, the eNB processes it through the baseband of the physical layer and then transmits it via a wireless channel. At this time, to transmit a baseband signal as far as it can go via the wireless channel, the system modulates and transmits it on a specific high frequency bandwidth.

For the data received over the uplink from the UE through a wireless channel, the eNB demodulates and changes it to the baseband signal to perform decoding.

Resource Allocation and Scheduling

To support multiple accesses, the eNB uses OFDMA for downlink and SC-FDMA for uplink. By allocating the 2-dimensional resources of time and frequency to multiple UEs without overlay, both methods enable the eNB to communicate with multiple UEs simultaneously.

The eNB can mux multiple UE information for the control channel and allocate signals from multiple UEs to the same time and frequency resources, which is the orthogonal resource allocation method using the cyclic shift function of the Zadoff-Chu sequence. Such allocation of cell resources to multiple UEs is called scheduling and each cell has its own scheduler for this function.

The LTE scheduler of the eNB allocates resources to maximize the overall throughput of the cell by considering the channel environment of each UE, the data transmission volume required, and other QoS elements. In addition, to reduce interferences with other cells, the eNB can share information with the schedulers of other cells over the X2 interface.

Link Adaptation

The wireless channel environment can become faster or slower, better or worse depending on various factors. The system is capable of increasing the transmission rate or maximizing the total cell throughput in response to the changes in the channel environment, and this is called link adaptation.

In particular, the Modulation and Coding Scheme (MCS) is used for changing the modulation method and channel coding rate according to the channel status. If the channel environment is good, the MCS increases the number of transmission bits per symbol using a high-order modulation, such as 64QAM. If the channel environment is bad, it uses a low-order modulation, such as QPSK and a low coding rate to minimize channel errors.

In addition, in the environment where MIMO mode can be used, the eNB operates in MIMO mode to increase the peak data rate of subscribers and can greatly increase the cell throughput.

If the channel information obtained is incorrect or modulation method of higher order or higher coding rate than the given channel environment is used, errors may occur.

In such cases, the errors can be corrected by the HARQ function.

H-ARQ

The H-ARQ is a retransmission method in the physical layer, which uses the stop-and-wait protocol. The eNB provides the H-ARQ function to retransmit or combine frames in the physical layer so that the effects of wireless channel environment changes or interference signal level changes can be minimized, which results in throughput improvement.

The LTE uses the Incremental Redundancy (IR)-based H-ARQ method and regards the Chase Combining (CC) method as a special case of the IR method.

The eNB uses the asynchronous method for downlink and the synchronous method for uplink.

Power Control

When transmitting a specific data rate, too high a power level may result in unnecessary interferences and too low a power level may result in an increased error rate, causing retransmission or delay. Unlike in other schemes such as CDMA, the power control is relatively less important in LTE. Nevertheless, adequate power control can improve performance of the LTE system.

Therefore, the UE should use adequate power levels for data transmission in order not to interfere with nearby cells. Likewise, the power level for each UE could be controlled for reducing the inter-cell interference level.

In the LTE downlink, the eNB can reduce inter-cell interference by transmitting data at adequate power levels according to the location of the UE and the MCS, which results in improvement of the entire cell throughput.

MIMO

The eNB can support the MIMO by using multiple antennas. For this purpose, the channel card of the eNB has the baseband part to process the MIMO, and individual RF paths can be processed separately. The eNB supports various types of the MIMO to provide the high-performance data service.

The eNB uses multiple antennas to support the MIMO. MIMO has the following schemes.

Direction	Item	Description
Downlink	SFBC (Space Frequency Block Coding)	This scheme implements the space-time block coding (STBC) on frequency instead of on time for increased reliability of the link. The Alamouti codes are used.
	SM (Spatial Multiplexing)	Different data are divided to multiple antenna paths for transmission so as to increase the peak data rate. (Each path uses the same time/frequency resource.) - Single User (SU)-MIMO: The SM between one eNB and one UE to increase peak data rate for one UE. - Open-loop SM: The SM that works without the Precoding Matrix Indicator (PMI) feedback of the UE when the UE's channel is unknown or changes fast due

Direction	Item	Description
		to fast movement of the UE. - Closed-loop SM: The SM that works with the Precoding Matrix Indicator (PMI) feedback of the UE when the UE's channel is known or changes slow due to slow movement of the UE.
Uplink	UL Transmit Antenna Selection	The 1 RF chain/2Tx antenna is used; and the eNB notifies the UE what Tx antenna to use. (Closed-loop selection of Tx antenna)
	Multi-User (MU) MIMO or Collaborative MIMO	The peak data rate of each UE is not increased but the cell throughput is increased. In the uplink, two different UEs use the same time/frequency resources for transmitting different data at the same time. The eNB uses a single Tx antenna for selecting two orthogonal UEs.

2.2.2 Call Processing Function

Cell Information Transmission

In a serving cell, the eNB periodically transmits a Master Information Block (MIB) and System Information Blocks (SIBs), which are system information, to allow the UE that receives them to perform proper call processing.

Call Control and Air Resource Assignment

The eNB allows the UE to be connected to or disconnected from the network.

When the UE is connected to or released from the network, the eNB transmits and receives the signaling messages required for call processing to and from the UE via the Uu interface, and to and from the EPC via the S1 interface.

When the UE connects to the network, the eNB performs call control and resource allocation required for service. When the UE is disconnected from the network, the eNB collects and releases the allocated resources.

Handover

The eNB supports intra-frequency or inter-frequency handover between intra-eNB cells, X2 handover between eNBs, and S1 handover between eNBs. It also processes signaling and bearer for handover. At intra-eNB handover, handover-related messages are transmitted via internal eNB interfaces; at X2 handover, via the X2 interface; at S1 handover, via the S1 interface.

To minimize user traffic loss during X2 and S1 handovers, the eNB performs the data forwarding function. The source eNB provides two forwarding methods to the target eNB: direct forwarding via the X2 interface and indirect forwarding via the S1 interface.

The eNB allows the UE to receive traffic without loss through the data forwarding method at handover.

**NOTE****Handover Procedure**

For more information on the handover procedure, see the 'Message Flow' section below.

Admission Control (AC)

The eNB provides capacity-based admission control and QoS-based admission control for a bearer setup request from the EPC so that the system is not overloaded.

- **Capacity-based admission control**
There is a threshold for the maximum number of connected UEs (new calls/handover calls) and a threshold for the maximum number of connected bearers that can be allowed in the eNB. Call admission is determined depending on whether the connected UEs and bearers exceed the thresholds.
- **QoS-based admission control**
The eNB determines whether to admit a call depending on the estimated PRB usage of the newly requested bearer, the PRB usage status of the bearers in service, and the maximum acceptance limit of the PRB (per bearer type, QCI, and UL/DL).

RLC ARQ

The eNB performs the ARQ function for the RLC Acknowledged Mode (AM) only. When receiving and transmitting packet data, the RLC transmits the SDU by dividing it into units of RLC PDU at the transmitting side and the packet is retransmitted (forwarded) according to the ARQ feedback information received from the receiving side for increased reliability of the data communication.

QoS Support

The eNB receives the QoS Class Identifier (QCI) in which the QoS characteristics of the bearer are defined and the GBR, the MBR, and the Aggregated Maximum Bit Rate (UE-AMBR) from the EPC. It provides the QoS for the wireless section between the UE and the eNB and the backhaul section between the eNB and the S-GW.

Via the air interface, it performs retransmission to satisfy the rate control according to the GBR/MBR/UE-AMBR values, priority of bearer defined in the QCI, and scheduling considering packet delay budget, and the Packet Loss Error Rate (PLER).

Via the backhaul interface, it performs QCI-based packet classification, QCI to DSCP mapping, and marking for the QoS. It provides queuing depending on mapping results, and each queue transmits packets to the EPC according to a strict priority, etc.

In the Element Management System (EMS), in addition to the QCI predefined in the specifications, operator-specific QCI and QCI-to-DSCP mapping can be set.

2.2.3 IP Processing

IP QoS

The eNB can provide the backhaul QoS when communicating with the EPC by supporting the Differentiated Services (DiffServ).

The eNB supports 8 class DiffServ and mapping between the services classes of the user traffic received from the MS and DiffServ classes. In addition, the eNB supports mapping between the Differentiated Services Code Points (DSCP) and the 802.3 Ethernet MAC service classes.

IP Routing

Since the eNB provides multiple Ethernet interfaces, it stores in the routing table the information on which Ethernet interface the IP packets will be routed to. The routing table of the eNB is configured by the operator. The method for configuring the routing table is similar to the standard router configuration method.

The eNB supports static routing settings, but does not support dynamic routing protocols such as Open Shortest Path First (OSPF) or Border Gateway Protocol (BGP).

Ethernet/VLAN Interface

The eNB provides Ethernet interfaces and supports the static link grouping, Virtual Local Area Network (VLAN), and Ethernet CoS functions that comply with IEEE 802.3ad for Ethernet interfaces. The MAC bridge function defined in IEEE 802.1D is not supported. The eNB allows multiple VLAN IDs to be set for an Ethernet interface. To support Ethernet CoS, it maps the DSCP value of the IP header to the CoS value of the Ethernet header for Tx packets.

2.2.4 SON Function

The SON function supports the self-configuration, self-establishment and self-optimization function.

Self-Configuration and Self-Establishment

Self-configuration and self-establishment enable automatic setup of radio parameters and automatic configuration from system 'power-on' to 'in-service', which minimizes the effort in installing the system. The detailed functions are as follows.

- Self-Configuration
 - Self-configuration of Initial Physical Cell Identity (PCI)
 - Self-configuration of initial neighbor information
 - Self-configuration of initial Physical Random Access Channel (PRACH) information
- Self-Establishment
 - Automatic IP address acquisition
 - Auto OAM connectivity

- Automatic software and configuration data loading
- Automatic S1/X2 setup
- Self-test

Self-Optimization

- PCI auto-configuration
The SON server of the LSM is responsible for allocating the initial PCI in the self-establishment procedure of a new eNB, detecting a problem automatically, and selecting, changing, and setting a proper PCI when a PCI collision/confusion occurs with the neighbor cells during operation.
- Automatic Neighbor Relation (ANR) optimization
The ANR function minimizes the network operator's effort to maintain the optimal NRT by managing the NRT dynamically depending on grow/degrow of the neighbor cells. This function automatically configures the initial NRT of each eNB and recognizes environment changes, such as cell grow/degrow or new eNB installation during operation to maintain the optimal NRT. In other words, the ANR function updates the NRT for each eNB by automatically recognizing topology changes such as new neighbor cell or eNB installation/uninstallation and adding or removing the Neighbor Relation (NR) to or from the new neighbor cell.
- Mobility robustness optimization
The mobility robustness optimization function is the function for improving handover performance in the eNB by recognizing the problem that handover is triggered at the incorrect time (e.g. too early or too late) before, after, or during handover depending on UE mobility, or handover is triggered to the incorrect target cell (handover to the wrong cell) and then by optimizing the handover parameters according to the reasons for the problem.
- Random Access Channel (RACH) optimization
The RACH Optimization (RO) function minimizes the access delay and interference through dynamic management of the parameters related to random access.
The RO function is divided into the initial RACH setting operation and the operation for optimizing parameters related to the RACH. The initial RACH setting operation is for setting the preamble signatures and the initial time resource considering the neighbor cells. The operation for optimizing parameters related to the RACH is for estimating the RACH resources, such as time resource and subscriber transmission power required for random access, that change depending on time, and for optimizing the related parameters.

2.2.5 Easy Operation and Maintenance

Through interworking with the management systems (LSM, Web-EMT, and CLI), the eNB provides the maintenance functions such as system initialization and restart, system configuration management, management of fault/status/diagnosis for system resources and services, management of statistics on system resources and various performance data and security management for system access and operation.

Graphics and Text Based Console Interfaces

The LSM manages all eNBs in the network using the Database Management System (DBMS). The eNB also interworks with the console terminal to allow the operator to connect directly to the Network Element (NE), rather than through the LSM, and perform the operations and maintenance.

The operator can use the graphics-based console interface (Web-EMT, Web-based Element Maintenance Terminal) or the text-based Command Line Interface (CLI) according to user convenience and work purposes. The operator can access the console interfaces without additional software. For the Web-EMT, the operator can log in to the system using Internet Explorer. For the CLI, the operator can log in to the system using the telnet or the Secure Shell (SSH) in the command window.

The operator can perform the management of configuration and operational information, management of fault and status, and monitoring of statistics and so on. To grow/degrow resources or configure a neighbor list that contains relation of multiple NEs, the operator needs to use the LSM.

Operator Authentication Function

The eNB provides the authentication and privilege management functions for the system operators.

The operator accesses the eNB using the operator's account and password via the CLI. At this time, the eNB grants the operator an operation privilege in accordance with the operator's level.

The eNB also logs the access successes and failures for CLI, login history, and so on.

Highly-Secured Maintenance

The eNB supports the Simple Network Management Protocol (SNMP) and SSH File Transfer Protocol (SFTP) for security during communications with the LSM, and the Hypertext Transfer Protocol over SSL (HTTPS) and Secure Shell (SSH) during communications with the console terminal.

Online Software Upgrade

When a software package is upgraded, the EPC can upgrade the existing package while it is still running.

The package upgrade is done by downloading a new package → activating of the new package.

The download and activation of a new package is performed using the Download menu and Activation menu of the LSM GUI.

When upgrading the package, the service stops temporarily at the ‘change to the new package’ step because the existing process needs to be stopped so that the new process can start. Since the operating system does not need to be restarted, the service can be resumed within several minutes. After upgrading the software, the eNB updates the package stored in the internal nonvolatile storage.

Call Trace

The eNB supports the call trace function for a specific UE.

The operator can enable trace for a specific UE through the MME. The trace execution results such as signaling messages are transmitted to the LSM.

OAM Traffic Throttling

The eNB provides the operator with the function for suppressing the OAM-related traffic that can occur in the system using the operator command. At this time, the target OAM-related traffic includes the fault trap messages for alarm reporting and the statistics files generated periodically.

For the fault trap messages, the operator can suppress generation of alarms for the whole system or some fault traps using the alarm inhibition command, consequently allowing the operator to control the amount of alarm traffic that is generated. For the statistics files, the operator can control the amount of statistics files by disabling the statistics collection function for each statistics group using the statistics collection configuration command.

2.3 Specifications

Key Specifications

The key specifications of the Indoor Pico Cell are as follows:

Item	Specifications
Radio Specifications	FDD LTE
Operating Frequency	1.9 GHz
Channel Bandwidth	5 MHz
Peak Throughput (Mbps) (with Category 3 UE)	DL: 31.7 Mbps (2x2 MIMO), UL: 10.1 Mbps (1x2 SIMO) (Calculation conditions: DL 1 % PHY error, UL 1 % PHY error)
Tx Power	250 mW/Path (Total 500 mW)
Antenna Configuration	2Tx/2Rx
Backhaul	Gigabit Ethernet 1 port (Copper)
Holdover	N/A

Input Power

The power specifications of the Indoor Pico Cell are as follows:

Item	Specifications
Indoor Pico Cell	External AC adapter (100~254 VAC)

Dimensions and Weight

The dimensions and weight of the Indoor Pico Cell are as follows:

Item	Specifications
Size (W×D×H) [in. (mm)]	9.06 (230) × 2.36 (60) × 10.63 (270)
Weight [lb (kg)]	7.72 (3.5) or less

GPSR Specifications

The specifications of the Indoor Pico Cell's GPS receiver (GPSR) are as follows:

Item	Specifications
Received Signal from GPS	GPS L1 Signal
Accuracy/Stability	±0.05 ppm (frequency)

IEEE1588v2 Specifications

The IEEE1588v2 specifications for the Indoor Pico Cell are as follows:

Item	Specifications
Clock Source	1588 Grand Master
Accuracy/Stability	±0.05 ppm (frequency)



NOTE

Synchronization Accuracy of IEEE1588v2

IEEE1588v2 satisfies the synchronization accuracy under the conditions defined in the ITU-T G.8261 Appendix VI two-way protocol (Test Case 12-17) and G.8271.

Ambient Conditions

This section describes the operating temperature, humidity level and other ambient conditions and related standard of the Indoor Pico Cell.

Item	Range
Temperature	0~50°C
Humidity	5~90 % RH
Altitude	-60~1800 m
Earthquake	Richter magnitude 7.0~8.3 (Zone 4, Telcordia GR-63 CORE)
Sound Pressure Level	45 dBA or below; 3.28 ft (1.0 m) distance from the product surface
Dust Rating	IEC60529, IP2X
EMC	FCC Part 15
Safety	UL 60950



CAUTION

Cautions for Antenna Installation

Do not use base station's antenna within the distance of ???cm from people and do not co-locate nor operate in conjunction with any other antenna or transmitters for the protection of general public from exposure to radio frequency electromagnetic fields.

2.4 Intersystem Interface

2.4.1 Interface Structure

The eNB provides the following interfaces for interworking between NEs.

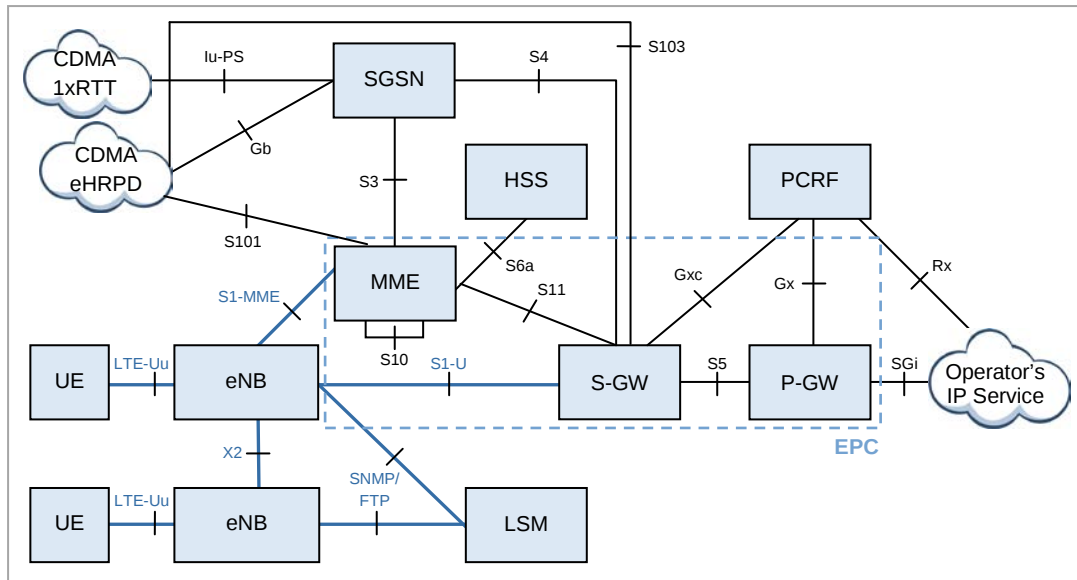


Figure 3. Inter-System Interface Structure

- Interface between eNB and UE
The eNB, in compliance with the 3GPP LTE Uu air interface standard, transmits and receives control signals and subscriber traffic to and from the UE.
- Interface between eNB and S-GW
The interface between S-GW and eNB is 3GPP LTE S1-U, and the physical access method is GE/FE.
- Interface between eNB and MME
The interface between MME and eNB is 3GPP LTE S1-MME, and the physical access method is GE/FE.
- Interface between eNB and neighbor eNB
The inter-eNB interface is 3GPP LTE X2-C/X2-U, and the physical access method is GE/FE.
- Interface between eNB and LSM
The interface between the eNB and the LSM complies with the IETF SNMPv2c/ SNMPv3 standard, the FTP/SFTP standard, and the proprietary standard of Samsung; the physical connection method is GE/FE.

2.4.2 Protocol Stack

The inter-NE protocol stack of the eNB is as follows:

Protocol Stack between UE and eNB

The user plane protocol layer consists of the PDCP, RLC, MAC, and PHY layers. The user plane is responsible for transmission of the user data (e.g. IP packets) received from the upper layer. In the User plane, all protocols are terminated in the eNB. The control plane protocol layer is composed of the NAS layer, RRC layer, PDCP layer, RLC layer, MAC layer and PHY layer. The NAS layer is located on the upper wireless protocol. It performs UE authentication between UE and MME, security control, and paging and mobility management of UE in the LTE IDLE mode. In the control plane, all protocols except for the NAS signal are terminated in the eNB.

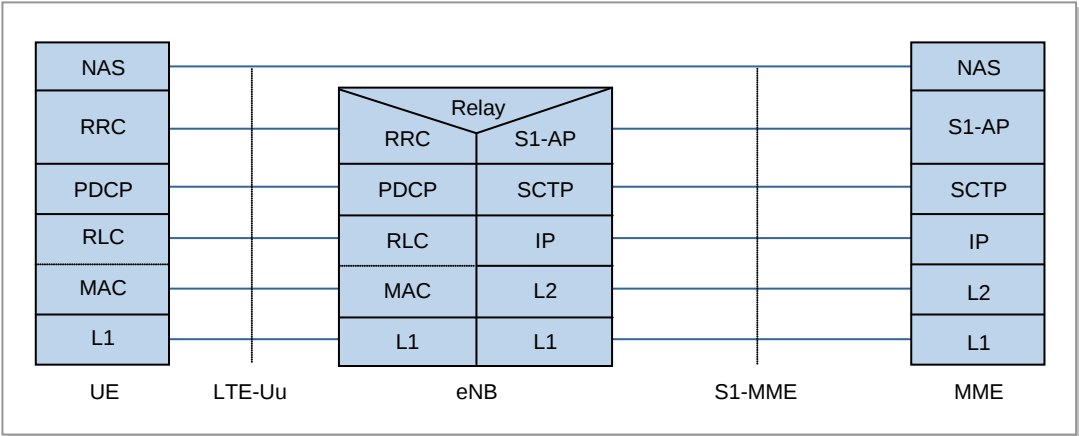


Figure 4. Protocol Stack between UE and eNB

Protocol Stack between eNB and EPC

The eNB and the EPC are connected physically through the FE and GE method, and the connection specification should satisfy the LTE S1-U and S1-MME interface. In the user plane, the GTP-User (GTP-U) is used as the upper layer of the IP layer; and in the Control plane, the SCTP is used as the upper layer of the IP layer.

The figure below shows the user plane protocol stack between the eNB and S-GW.

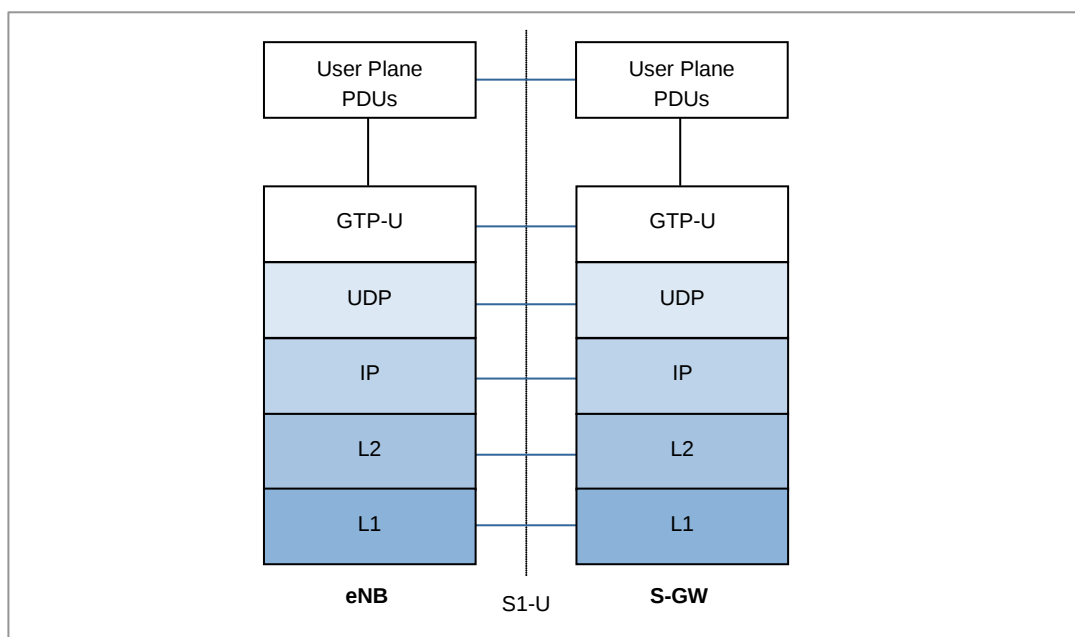


Figure 5. Protocol Stack between eNB and S-GW User Plane

The figure below shows the control plane protocol stack between the eNB and MME.

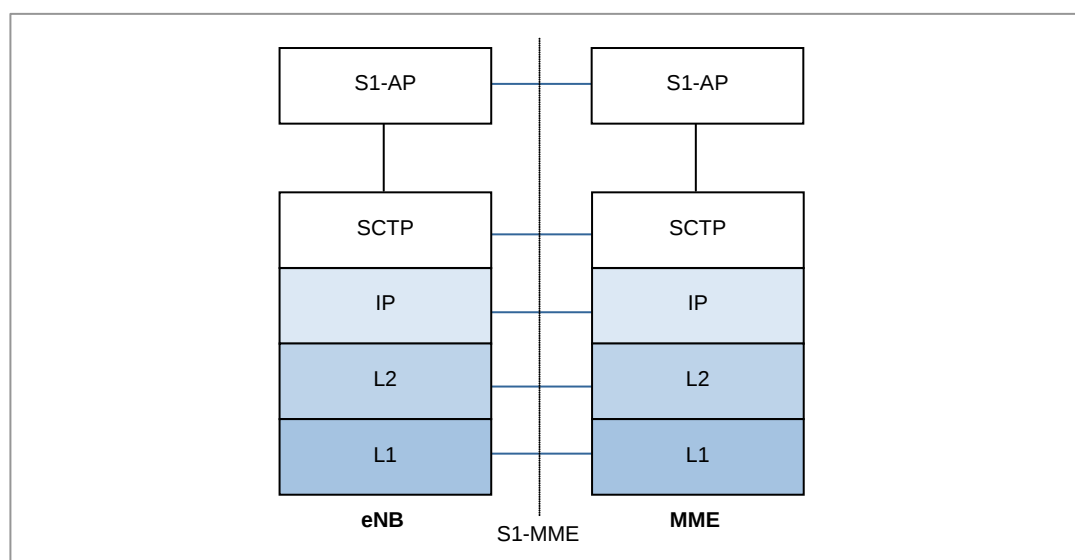


Figure 6. Protocol Stack between eNB and MME Control Plane

Inter-eNB Protocol Stack

The eNB and the eNB are connected physically through the FE and GE method, and the connection specification should satisfy the LTE X2 interface. The figure below shows the inter-eNB user plane protocol stack.

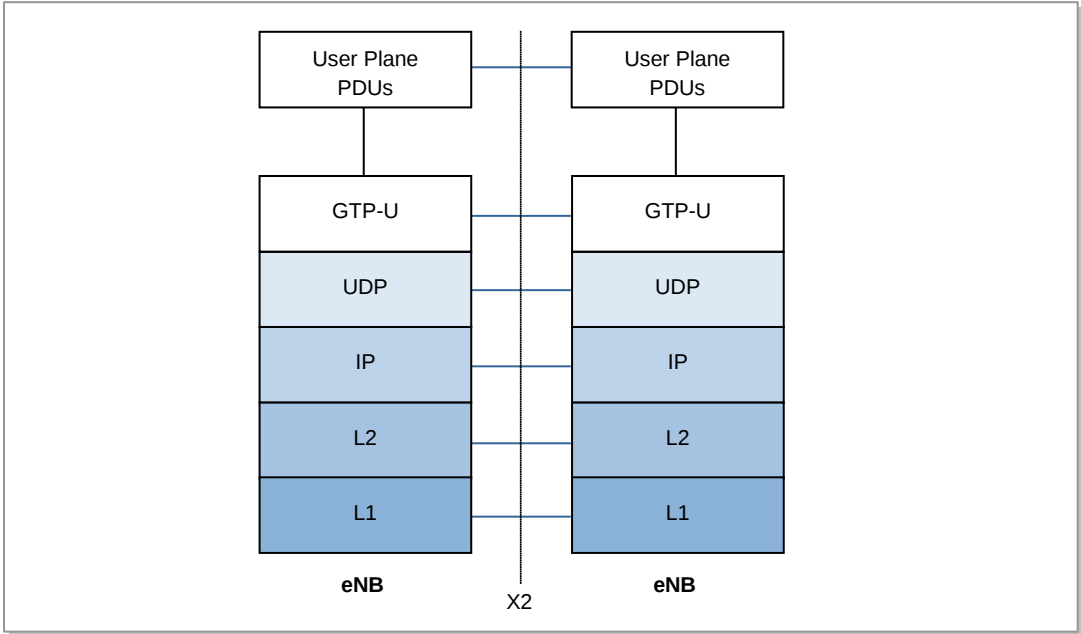


Figure 7. Inter-eNB User Plane Protocol Stack

The figure below shows the control plane protocol stack.

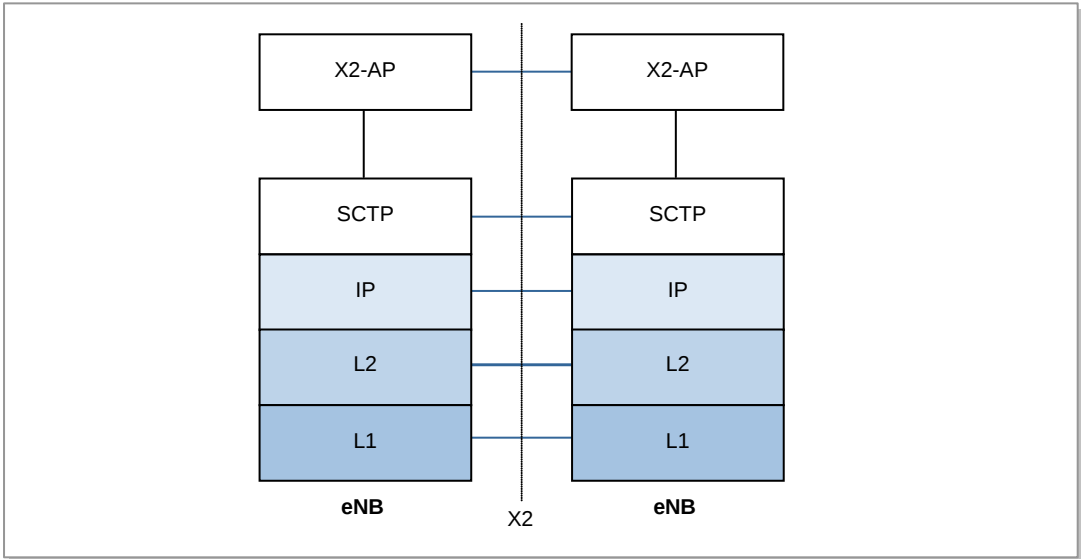


Figure 8. Inter-eNB Control Plane Protocol Stack

Protocol Stack between eNB and LSM

The FE and GE are used for the physical connection between eNB and LSM, and the connection specifications must satisfy the FTP/SNMP interface. The figure below shows the user plane protocol stack between the eNB and LSM.

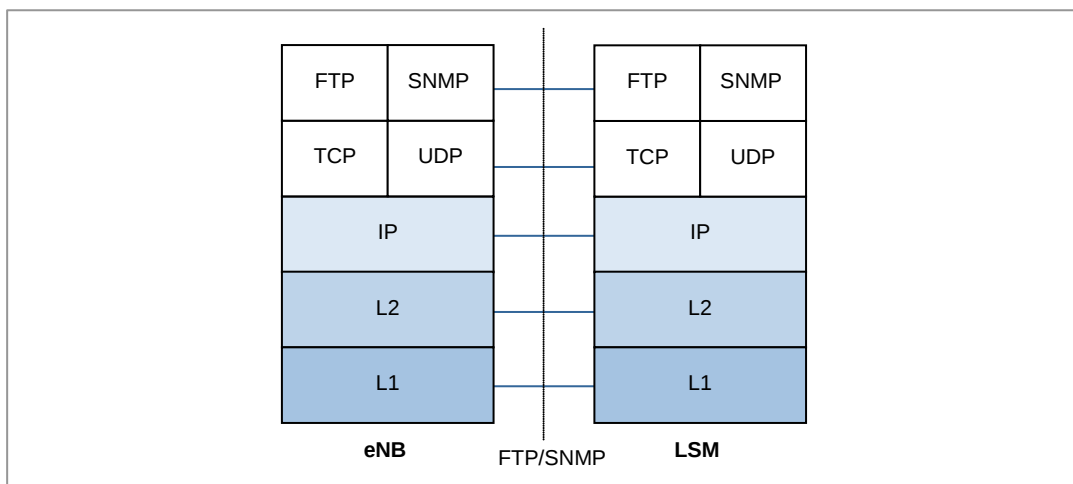


Figure 9. Interface Protocol Stack between eNB and LSM

CHAPTER 3. System Structure

3.1 Hardware Structure

The Indoor Pico Cell consists of LTE 7 baseband and transceiver Integrated board Assembly (L7IAs) which is the digital & RF board.

The L7IA performs the functions of main controller, network interface, clock generation & distribution, and modem. The transceiver performs the Digital Up Conversion (DUC)/Digital Down Conversion (DDC), Crest Factor Reduction (CFR), linearization and DAC/ADC functions. Moreover, the L7IA performs the spurious wave suppression function and has the built-in Low Noise Amplifier (LNA).

The L7IA operates with 1 Carrier/Omni 2Tx/2Rx. The maximum output of the L7IA is 250 mW/path for the output port.

The configuration of the Indoor Pico Cell is shown below:

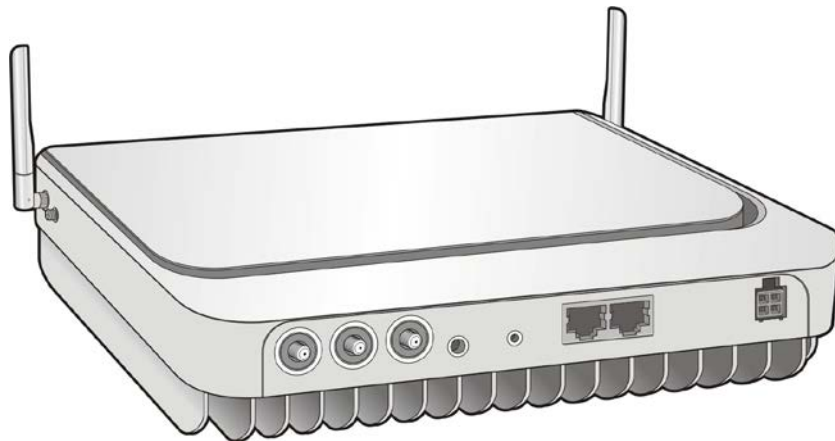


Figure 10. Indoor Pico Cell Configuration

The external interface of the Indoor Pico Cell is as follows:

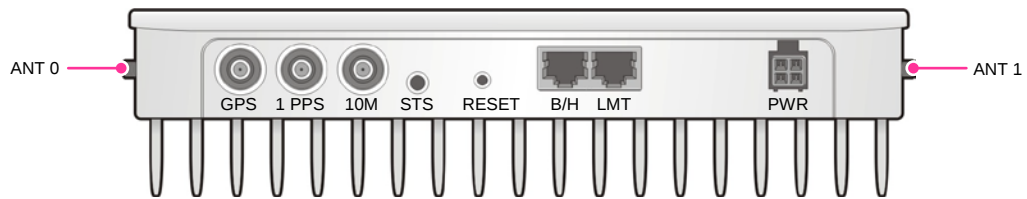


Figure 11. External Interface of Indoor Pico Cell

Name	Connector Type	Description
ANT0, ANT1	SMA	RF Antenna
GPS	SMA	GPS Antenna
1PPS	SMA	1 PPS Reference Clock
10M	SMA	Reference Frequency
B/H	RJ-45	Copper Backhaul (10 Base-T/100 Base-TX/1000 Base-T)
LMT	RJ-45	LMT connection or Daisy-chain connection port
PWR	Molex 4P	12 VDC power input

The Indoor Pico Cell shows the system operation status through the LED (STS). The table below describes the LED status.

LED Status		Description
●	Red on	- Hardware is reset. - An error occurred with the power. - Critical alarm is generated. - Backhaul link is down.
●	Orange on	Booting has been completed.
◐	Orange blinking (slow)	ROM loader is running.
◐	Orange blinking (fast)	The software download and status are being checked.
●	Green on	Software is running.
◐	Green blinking	Normal operation
◐	Red blinking	Major/Minor alarm is generated.
○	LED off	No power supply

The internal configuration of the Indoor Pico Cell is shown below.

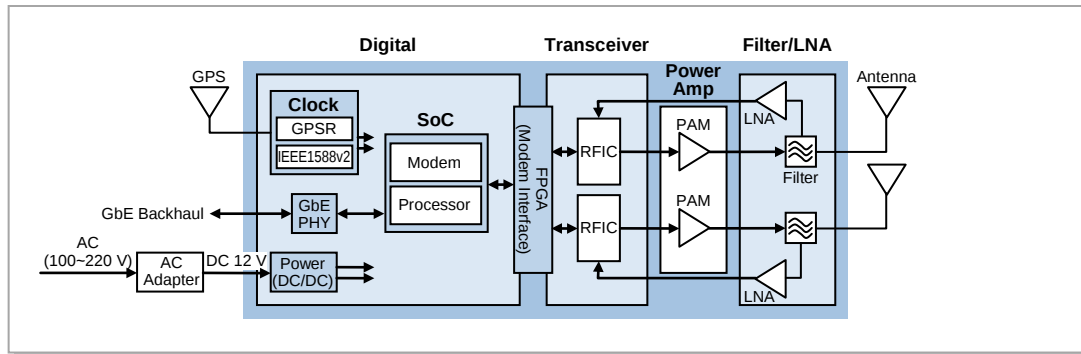


Figure 12. Internal Configuration of Indoor Pico Cell

Item	Description
Digital Processing Function	SoC function - Performs the main processor functions of the system - Performs the call processing, resource allocation, operation, and maintenance functions - Processes GTP, PDCP, OAM, RRC and RRM - Processes RLC and MAC/PHY - Processes OFDMA/SC-FDMA channel - Processes subscriber data traffic - Collects alarms and reports them to LSM - Controls IEEE1588v2 Other digital processing functions - Receives GPS signals and generates and supplies clocks - Synchronizes using IEEE 1588v2 packet - Supports backhaul (GE/FE)
Transceiver Function	- Supports 5 MHz 1 Carrier/Omni 2Tx/2Rx - Convert RF uplink/downlink
Power Amplifier Function	- Supports 5 MHz 1 Carrier/Omni 2Tx/2Rx - Max. output 250 + 250 mW (for the external antenna port of the enclosure)
Filter and LNA Function	- Filters transmitted/received RF signals - Performs LNA function for Rx signals

Main Controller Function

The main processor of the Indoor Pico Cell takes the highest role, and performs the communication path setup between UE and EPC, system operation and maintenance, etc. It also manages the status for all hardware/software in the Indoor Pico Cell, allocates and manages resources, collects alarms, and reports all status information to the LSM.

Clock Generation and Distribution Function

The L7IA is equipped with Beyond Enhanced GPS Engine Module (BEGEM) and IEEE1588v2 block. The BEGEM enables each block of the Indoor Pico Cell to operate under a synchronized clock system.

The BEGEM creates the PP2S (Even Clock) and digital 10 MHz using the synchronization signal received via the GPS antenna while the IEEE1588v2 block creates the 1 PPS and digital 10 MHz synchronized with the IEEE1588v2 Master and each delivers the created data to the Clock Generation & Distribution block of the L7IA.

The Clock Generation & Distribution block generates the system clock (30.72 MHz), PP2S (Even clock), 1 PPS, and System Frame Number (SFN) for synchronization using the signals received, and distributes them to the hardware blocks in the system.

The clock distributed in the system is used to keep the internal synchronization in the Pico Cell and operate the system.

The Clock Generation & Distribution block also generates the 1PPS which is the reference clock used for the measuring equipment or repeater. And, the BEGEM also transmits time information and location information through the TOD path.

Network Interface Function

The L7IA interfaces with the EPC via Gigabit Ethernet or Fast Ethernet.

Subscriber Channel Processing Function

The L7IA is equipped with the modem supporting the LTE standard physical layer to process the OFDMA/SC-FDMA channel, and the DSP processes the RLC/MAC.

The modem modulates the packet data received from upper level and transmits it to the transceiver. Reversely, the modem demodulates the packet data received from the transceiver, converts them to the format which is defined in the LTE standard physical layer specifications, and transmits them to the upper processor.

2Tx/2Rx MIMO Support

The RF part of the L7IA consists of transceiver and AMP, and supports the RF path of the 2Tx/2Rx. The maximum output is 250 mW/path for the external antenna port of the enclosure.

DAC/ADC and Power Amplification

For the downlink, the baseband signals are converted to analog signals through the Digital to Analog Converter (DAC). The frequency of those analog signals is up converted through the modulator and then those signals are amplified into high-power RF signals through the power amplifier.

For the uplink, the frequency of the signals where low noise is amplified at LNA of L7IA is down converted through the demodulator. These down-converted frequency signals are converted to baseband signals through the Analog to Digital Converter (ADC).

The converted baseband signals are transmitted to the modem.

Reset Function

The L7IA can reset the hardware remotely. The reset command is transmitted to the system's CPLD upon the LSM's command, and the CPLD monitors it and resets the board power.

Filter and LNA Function

The L7IA includes a filter and LNA, and suppresses the out-of-band spurious wave radiation.

The L7IA supports the RF path of 2Tx/2Rx. In the downlink path of the L7IA, the high-power amplified RF signal is transmitted to the antenna through the filter after satisfying the spectrum mask defined for each region. In the uplink path of the L7IA, the RF signal received via the filter is transmitted to the digital processing part of the L7IA through low-noise amplification in the LNA.

Power

The Indoor Pico Cell is supplied with power through the AC adapter. The L7IA uses the 12 VDC received via an external AC adapter. After receiving the 12 VDC power input, it generates the power required in the L7IA through the DC/DC converter.

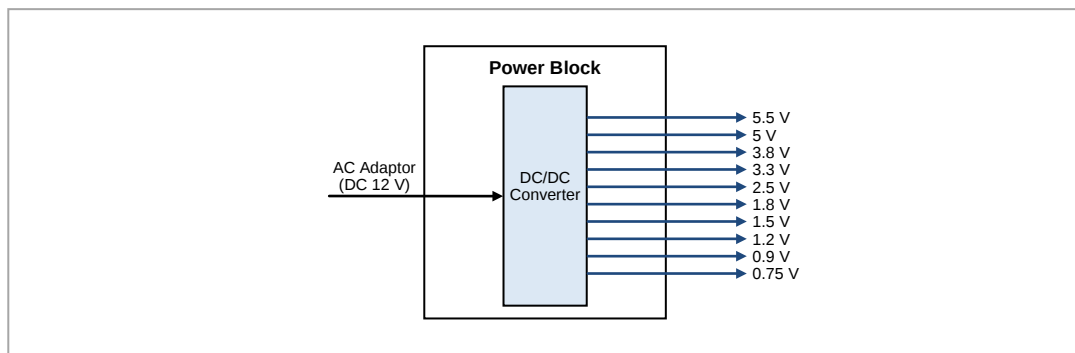


Figure 13. Power Supply Configuration

3.2 Software Structure

3.2.1 Basic Software Structure

The software of the eNB is divided into three parts: Kernel Space (OS/DD), Forwarding Space (NPC, NP) and User Space (MW, IPRS, CPS, OAM) which are described below.

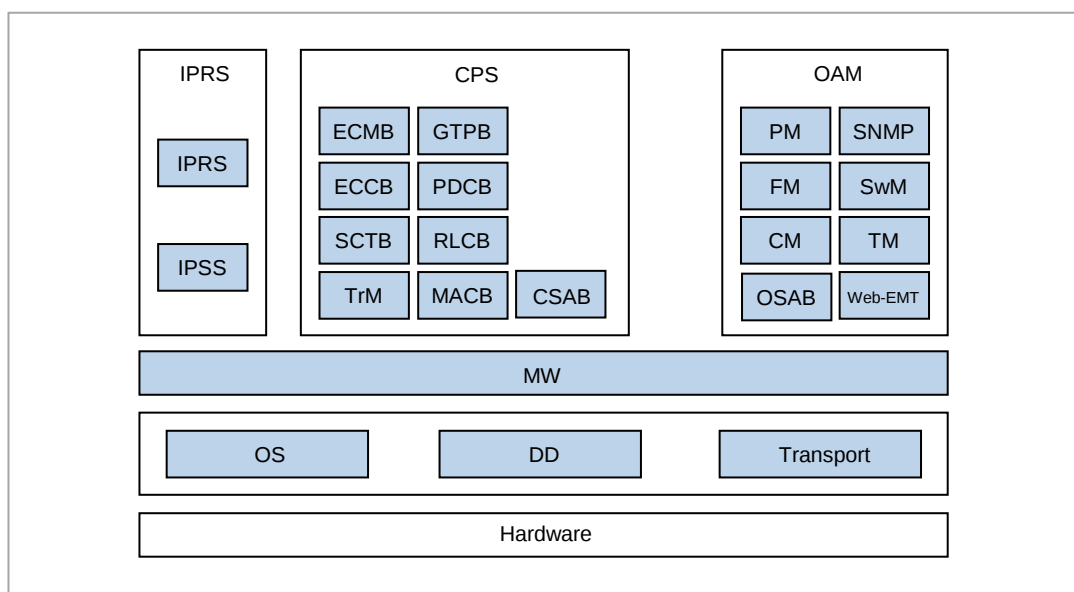


Figure 14. Indoor Pico Cell Software Structure

Operating System (OS)

The OS initializes and controls the hardware devices and ensures the software is ready to run on the hardware devices.

The OS consists of a booter, kernel, root file system (RFS) and utility.

- **Booter:** Performs initialization on boards. It initializes the CPU, L1/L2 Cache, UART, and MAC and the devices such as CPLD and RAM within each board, and runs the u-boot.
- **Kernel** Manages the operation of multiple software processes and provides various primitives to optimize the use of limited resources.
- **RFS:** Stores and manages the binary files, libraries, and configuration files necessary for running and operating the software in accordance with the File-system Hierarchy Standard 2.2 (FHS).
- **Utility:** Provides the functions for managing the complex programmable logic device (CPLD), LED, watchdog, and environment and inventory information, measuring and viewing the CPU load, and storing and managing fault information when a processor goes down.

Device Driver (DD)

The DD allows applications to operate normally on devices that are not directly controlled from the OS in the system. The DD consists of the physical DD and virtual DD.

- Physical DD: Provides the interface through which an upper application can configure, control, and monitor the external devices of the processor. (Switch device driver and Ethernet MAC driver, etc.)
- Virtual DD: For the physical network interfaces, virtual interfaces are created on the kernel so that the upper applications may control the virtual interfaces instead of controlling the physical network interfaces directly.

Transport

The NP is the software which processes the packets required for backhaul interface.

The functions of the NP are as follows:

- Packet Rx/Tx
- MAC filtering
- IP packet forwarding
- IP fragmentation/reassembly
- VLAN termination

Middleware (MW)

The MW ensures seamless communication between OS and applications on various hardware environments. It provides a Message Delivery Service (MDS) between applications, Debugging Utility Service (DUS), Event Notification Service (ENS), Task Handling Service (THS), Miscellaneous Function Service (MFS).

- MDS: Provides all services related to message transmitting and receiving.
- DUS: Provides the function for transmitting debugging information and command between the applications and the operator.
- ENS: Adds and manages various events such as timers, and provides the function for transmitting an event message to the destination at the time when it is needed.
- MFS: The MFS is responsible for all hardware-dependent functions, such as accessing physical addresses of hardware devices.
- THS: Provides the task creation/termination function, the task control function, and the function for providing task information, etc.

IP Routing Software (IPRS)

The IPRS is the software that provides the IP routing and IP security function for the eNB backhaul. The IPRS is configured with IPRS and IP Security Software (IPSS), and each of them provide the functions as follows.

- IPRS: Collects and manages the system configuration and status information necessary for IP routing. Based on this data, the IPRS provides the function for creating routing information.
 - Managing Ethernet and VLAN-TE
 - IP addresses management
 - IP routing information management

- IPSS: Provides the QoS and security function for the IP backhaul.
 - Backhaul bandwidth restriction
 - QCI to DSCP mapping
 - DSCP to CoS mapping
 - Ciphering of backhaul traffic and integrity protection by using IPsec

3.2.2 CPS Block

The Call Processing Software (CPS) block performs the resource management of the LTE eNB and the call processing function in the eNB defined in the 3GPP and performs the interface function with the EPC, UE, and neighbor eNBs. The CPS consists of the eNB control processing subsystem (ECS) which is responsible for network access and call control functions, and the eNB Data processing Subsystem (EDS) which is responsible for user traffic handling.

In addition, depending on the eNB functions defined in 3GPP, the ECS consists of ECMB, ECCB, SCTB, CSAB and TrM; and the EDS consists of GTPB, PDCB, RLCB and MACB. The following shows the CPS structure.

Stream Control Transmission protocol Block (SCTB)

The SCTB is responsible for establishing the S1 interface between the eNB and the MME, and establishes the X2 interface between neighbor eNBs.

The major functions of the SCTB are as follows:

- S1 interfacing
- X2 interfacing

eNB Common Management Block (ECMB)

The ECMB performs call processing function such as the system information transmission and the eNB overload control for each eNB and cell.

The major functions of the ECMB are as follows:

- Setting/Releasing cell
- Transmitting system information
- eNB overload control: controls the eNB overload depending on CPU load status
- Access barring control: controls the access barring parameters of SIB2
- Resource measurement control: controls the measurement of the resource status in the system, such as PRB usage and PDB
- Transmission of cell load information: Inter-system X2 load information message transmission

eNB Call Control Block (ECCB)

The ECCB performs the function to control the call procedure until exit after call setup and the call processing function for the MME and neighbor eNBs.

The major functions of the ECCB are as follows:

- Radio resource management
- Idle to Active status transition
- Setting/changing/releasing bearer
- Paging Functions
- MME selection/load balancing
- Call admission control
- Security function
- Handover control
- UE measurement control
- Statistics processing

Trace Management (TrM)

- Call Trace function
- Call Summary Log (CSL) function

GPRS Tunneling Protocol Block (GTPB)

The GTPB is the user plane call processing function of the eNB. It processes the GTP.

The major functions of the GTPB are as follows:

- GTP tunnel control
- GTP management
- GTP data transmission

PDCCP Block (PDCB)

The PDCB is the user plane call processing function of the eNB. It processes the PDCCP.

The major functions of the PDCB are as follows:

- Header compression or decompression (ROHC only)
- Transmitting user data and control plane data
- PDCCP sequence number maintenance
- DL/UL data forwarding at handover
- Ciphering and deciphering for user data and control data
- Control data integrity protection
- Timer-based PDCCP SDU discarding

Medium Access Control Block (MACB)

The MACB is the user plane call processing function of the eNB. It processes the MAC protocol.

The major functions of the MACB are as follows:

- Mapping between the logical channel and the transport channel
- Multiplexing & de-multiplexing
- HARQ
- Transport format selection
- Priority handling between UEs
- Priority handling between logical channels of one UE

Radio Link Control Block (RLCB)

The RLCB is the user plane call processing function of the eNB. It processes the RLC protocol.

The major functions of the RLCB are as follows:

- Transmission for the upper layer PDU
- ARQ function used for the AM mode data transmission
- RLC SDU concatenation, segmentation and reassembly
- Re-segmentation of RLC data PDUs
- In sequence delivery
- Duplicate detection
- RLC SDU discard
- RLC re-establishment
- Protocol error detection and recovery

CPS SON Agent Block (CSAB)

The CSAB supports the SON function which is performed in the eNB CPS.

The major functions of the CSAB are as follows:

- Collection of statistics regarding the mobility robustness optimization
- Collection of statistics regarding the RACH optimization

3.2.3 OAM Blocks

The Operation And Maintenance (OAM) is responsible for operation and maintenance in the eNB. The OAM is configured with PM, FM, CM, SNMP, SwM, TM, Web-EMT and OSAB.

The major functions of the OAM are as follows:

Performance Management (PM)

PM collects and provides performance data so that the operator of the management system can determine the performance of the LTE of eNB. The PM collects events and performance data during system operation and transmits them to the management systems.

The main functions are as follows:

- Collecting statistics data
- Storing statistics data
- Transmitting statistics data

Fault Management (FM)

The FM performs the fault and status management functions on the eNB's hardware and software. The FM applies filtering to a detected fault, notifies the management system, and reflects the fault severity and threshold changes in the fault management.

The main functions are as follows:

- Detecting faults and reporting alarms
- Viewing alarms
- Alarm filtering
- Setting alarm severity
- Setting alarm threshold
- Alarm correlation
- Status management and reporting
- Status retrieval

Configuration Management (CM)

The CM manages the eNB configuration and parameters in PLD format and provides the data that the software blocks need. Through the command received from SNMP/CLI/Web-EMT, the CM provides the functions that can grow/degrow the system configuration, and display/change the configuration data and operation parameters.

The main functions are as follows:

- Retrieval and change of configuration information, and grow/degrow function

Simple Network Management Protocol (SNMP)

The SNMP is an SNMP agent for supporting a standard SNMP. It performs interfacing with the upper management systems and interoperates with the internal subagents. When receiving a request for a standard MIB object from the LSM, the SNMP processes the request independently. When receiving a request for a private MIB object, it transmits the request to the corresponding internal subagent.

The main functions are as follows:

- Interface with SNMP Manager

Soft Ware Management (SwM)

The SwM downloads and runs the package for each board in accordance with the file list downloaded during the preloading procedure. The SwM monitors the software that has been run, provides information on the running software, and supports software restart and upgrade according to the command.

The main functions are as follows:

- Downloading and installing software and data files
- Reset of hardware unit and system
- Status monitoring of the software unit in operation
- Managing and updating the software and firmware information
- Software upgrade
- Inventory Management Functions

Test Management (TM)

The TM checks the internal and external connection paths of system or the validity of its resources. The connection paths are classified into system internal IPC path and external path to other NEs. Moreover, the TM conducts on-demand tests upon the operator's request and periodic tests according to the schedule set by the operator.

The main functions are as follows:

- Enable/disable the Orthogonal Channel Noise Simulator (OCNS)
- Setting/clearing a Model
- Ping test
- Measuring the Tx/Rx power
- Measuring the antenna Voltage Standing Wave Ratio (VSWR)

OAM SON Agent Block (OSAB)

To allow the operator of a management system to perform the LTE SON function of the eNB, the OSAB supports the automatic configuration & installation of system information, and automatic creation & optimization of a neighbor list. The OSAB operates on the master OAM board.

The main functions are as follows:

- System information, automatic configuration, and automatic installation
- Optimizing automatic neighbor relation
- Detection of PCI collision/confusion

Web-based Element Maintenance Terminal (Web-EMT)

The Web-EMT is a block used to interface with the web client of the console terminal that uses a web browser. It operates as a web server. The Web-EMT support highly secured Secure Sockets Layer (SSL) based HTTP communication.

The main functions are as follows:

- Web server function
- Interoperation with other OAM blocks for processing the command from LMT

CHAPTER 4. Message Flow

4.1 Call Processing Message Flow

Attach Procedure

The figure below shows the message flow of the Attach procedure.

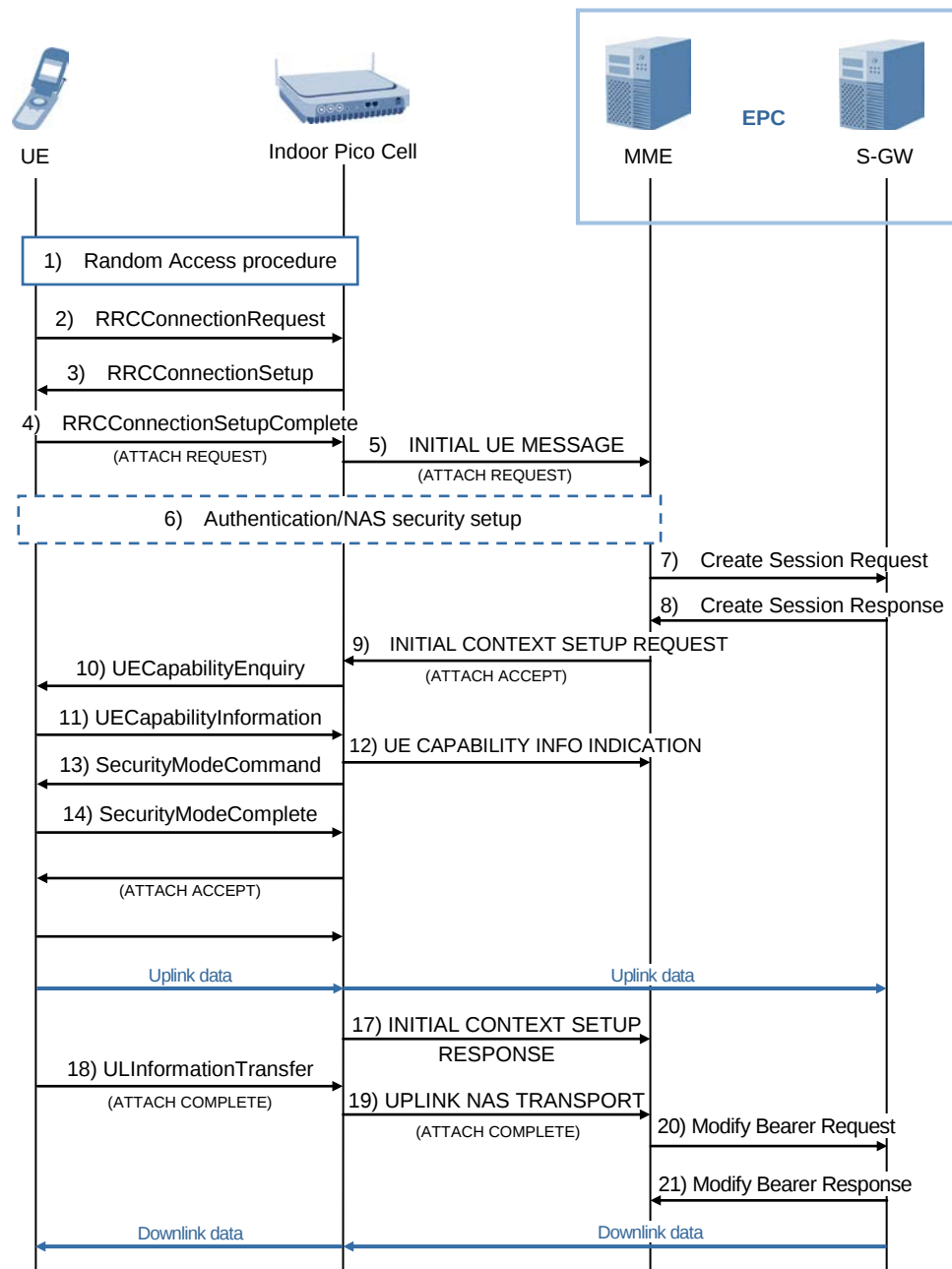


Figure 15. Attach Procedure

Step	Description
1)	The UE performs the random access procedure (TS 36.321, 5.1) with the Indoor Pico Cell.
2)~4)	The UE initializes the RRC Connection Establishment procedure (TS 36.331, 5.3.3). The UE includes the NAS ATTACH REQUEST message in the RRC RRCConnectionSetupComplete message and transmits it to the Indoor Pico Cell.
5)	The Indoor Pico Cell induces the MME from the RRC factors. The Indoor Pico Cell includes the ATTCH REQUEST message in the INITIAL UE message, which is an S1-MME Control message, and transmits it to the MME.
6)	If there is no UE context for the UE in the network, integrity is not protected for the ATTACH REQUEST message, or the integrity check fails, authentication and NAS security setup are always performed. The UE performs the EPS authentication and key agreement (AKA) procedure (TS 33.401, 6.1.1) with the MME. The MME sets up an NAS security association with the UE using the NAS security mode command (SMC) procedure (TS 33.401, 7.2.4.4).
7)~8)	The MME selects the P-GW and S-GW. The MME transmits the Create Session Request message to the S-GW. The S-GW adds a record to the EPS bearer table. From this step to step 20, the S-GW keeps the downlink packet received from the P-GW until the Modify Bearer Request message is received. The S-GW returns the Create Session Request message to the MME.
9)	The MME includes the ATTACH REQUEST message in the INITIAL CONTEXT SETUP REQUEST message, which is an S1-MME Control message, and transmits it to the Indoor Pico Cell. This S1 message also includes the AS security context information for the UE. This information starts the AS SMC procedure at the RRC level.
10)~12)	If the UE Radio Capability IE value is not contained in the INITIAL CONTEXT SETUP REQUEST message, the Indoor Pico Cell starts the procedure for obtaining the UE Radio Capability value from the UE and then transmits the execution result to the MME.
13)~14)	The Indoor Pico Cell transmits the SecurityModeCommand message to the UE, and the UE responds with the SecurityModeComplete message. In the Indoor Pico Cell, the encoding downlink must start after transmitting the SecurityModeCommand and the decoding uplink must start after receiving the SecurityModeComplete. In the UE, the uplink encryption must be started after the SecurityModeComplete message has been transmitted, and the downlink decryption must be started after the SecurityModeCommand message has been received (TS 33.401, 7.2.4.5).
15)~16)	The Indoor Pico Cell includes the ATTACH ACCEPT message in the RRCConnectionReconfiguration message and transmits it to the UE. The UE transmits the RRCConnectionReconfigurationComplete message to the Indoor Pico Cell. After receiving the ATTACH ACCEPT message, the UE can transmit uplink packets to both of the S-GW and P-GW via the Indoor Pico Cell.
17)	The Indoor Pico Cell transmits the INITIAL CONTEXT SETUP RESPONSE message to the MME.
18)~19)	The UE transmits the ULInformationTransfer message containing the ATTACH COMPLETE to the Indoor Pico Cell. The Indoor Pico Cell transmits the UPLINK NAS TRANSPORT

Step	Description
	message containing the ATTCH COMPLETE to the MME.
20)~21)	After receiving both of the INITIAL CONTEXT RESPONSE message at step 17) and the ATTACH COMPLETE message at step 19), the MME transmits the Modify Bearer Request message to the S-GW. The S-GW transmits the Modify Bearer Response message to the MME. S-GW can transmit the stored downlink packet.

Service Request Initiated by the UE

The message flow for service request procedure by UE is illustrated below.

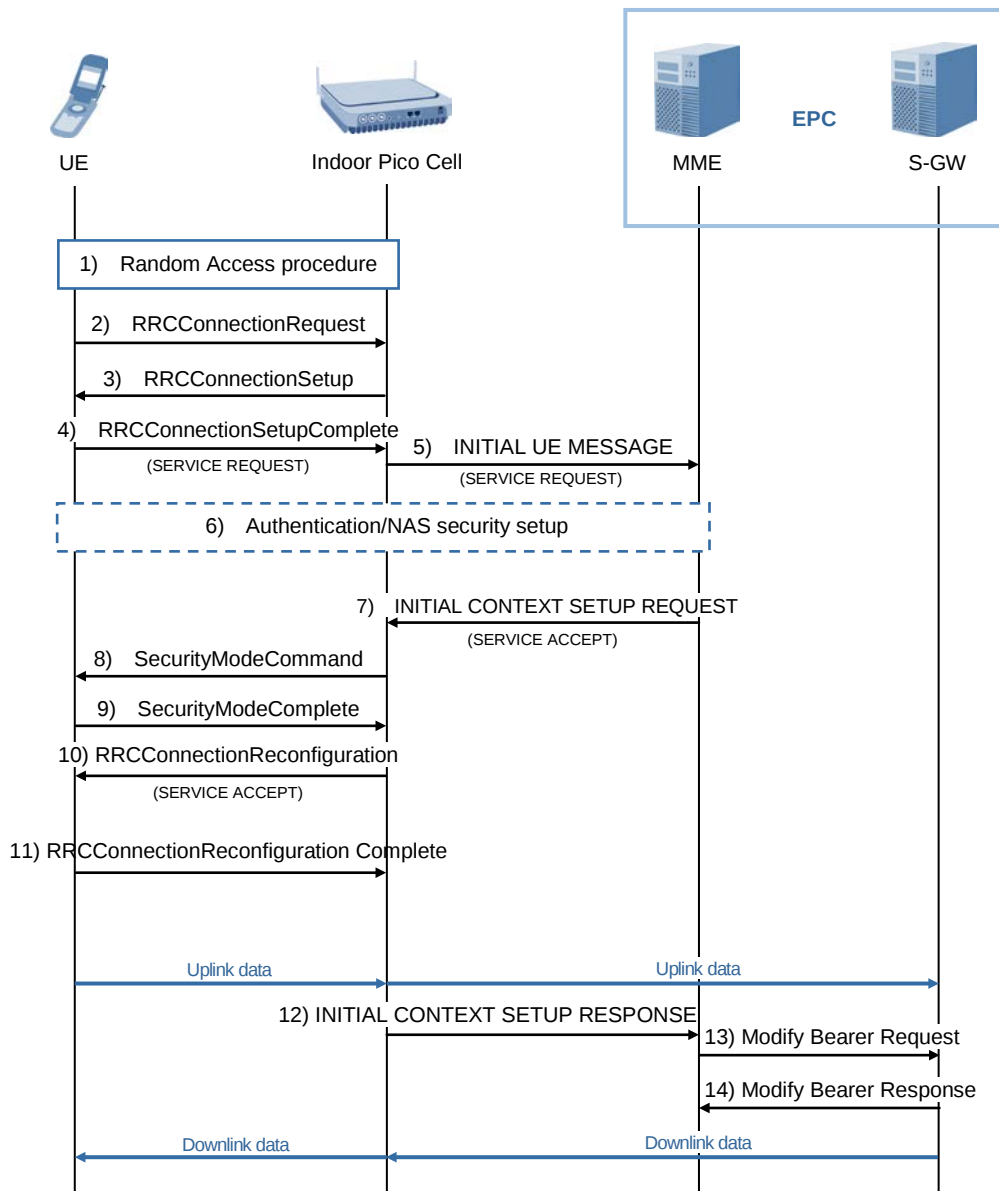


Figure 16. Service Request Procedure by UE

Step	Description
1)	The UE performs the random access procedure with the Indoor Pico Cell.
2)~4)	The UE includes the SERVICE REQUEST message (NAS) in the RRC message transmitted to the Indoor Pico Cell and transmits it to the MME.
5)	The Indoor Pico Cell includes the SERVICE REQUEST message in the INITIAL UE message, which is an S1-AP message, and transmits it to the MME.
6)	If there is no UE context for the UE in the network, integrity is not protected for the ATTACH REQUEST message, or the integrity check fails, authentication and NAS security setup are always performed. The UE performs the EPS authentication and key agreement (AKA) procedure (TS 33.401, 6.1.1) with the MME. The MME sets up an NAS security association with the UE using the NAS security mode command (SMC) procedure (TS 33.401, 7.2.4.4).
7)	The MME transmits the S1-AP Initial Context Setup Request message to the Indoor Pico Cell. In this step, radio and S1 bearer are activated for all activated EPS bearers.
8)~11)	The Indoor Pico Cell sets up the RRC radio bearers. The user plane security is set up at this step. The uplink data transmitted by the UE is relayed from the Indoor Pico Cell to the S-GW. The Indoor Pico Cell transmits the uplink data to the S-GW, and then the S-GW transmits it to the P-GW.
12)	The Indoor Pico Cell transmits the S1-AP Initial Context Setup Request message to the MME.
13)~14)	The MME transmits the Modify Bearer Request message for each PDN connection to the S-GW. Now, the S-GW can transmit the downlink data to the UE. The S-GW transmits the Modify Bearer Response message to the MME.

Service Request by Network

The message flow for service request procedure by network is illustrated below.

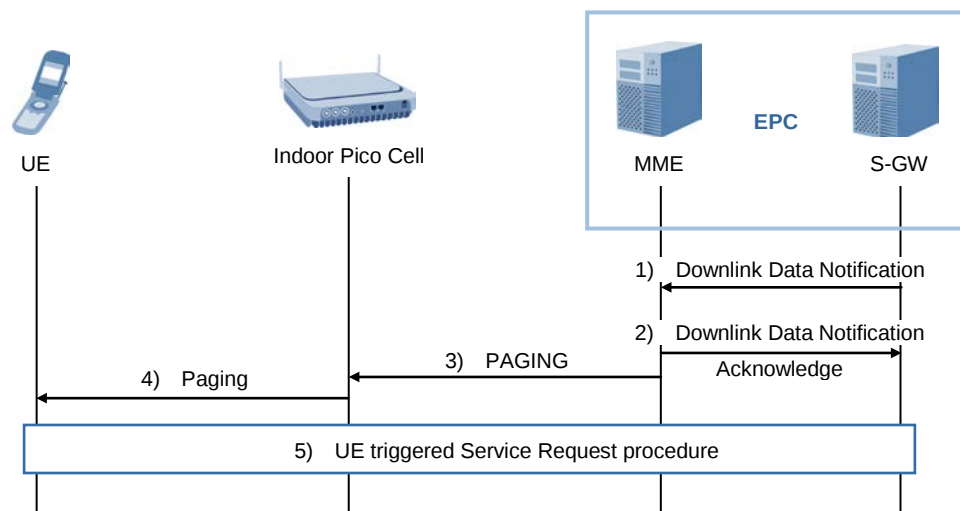


Figure 17. Service Request Procedure by Network

Step	Description
1)~2)	When receiving a downlink data packet that should be transmitted to a UE while the user plane is not connected to that UE, the S-GW transmits the Downlink Data Notification message to the MME which has the control plane connection to that UE. The MME issues the Downlink Data Notification Acknowledge message to the S-GW in response. If the S-GW receives additional downlink data packet for the UE, this data packet is stored and no new Downlink Data Notification is transmitted.
3)~4)	When the UE is registered to the MME, the MME transmits the PAGING message to all Indoor Pico Cells that belong to the TA where the UE is registered. When the Indoor Pico Cell receives the PAGING message from the MME, the Indoor Pico Cell transmits the Paging message to the UE.
5)	If the UE in idle mode is paged via the E-UTRAN connection, the Service Request procedure is initiated by the UE. The S-GW transmits the downlink data to the UE via the RAT which has performed the Service Request procedure.

Detach by UE

The figure below shows the message flow of the Detach procedure initiated by the UE.

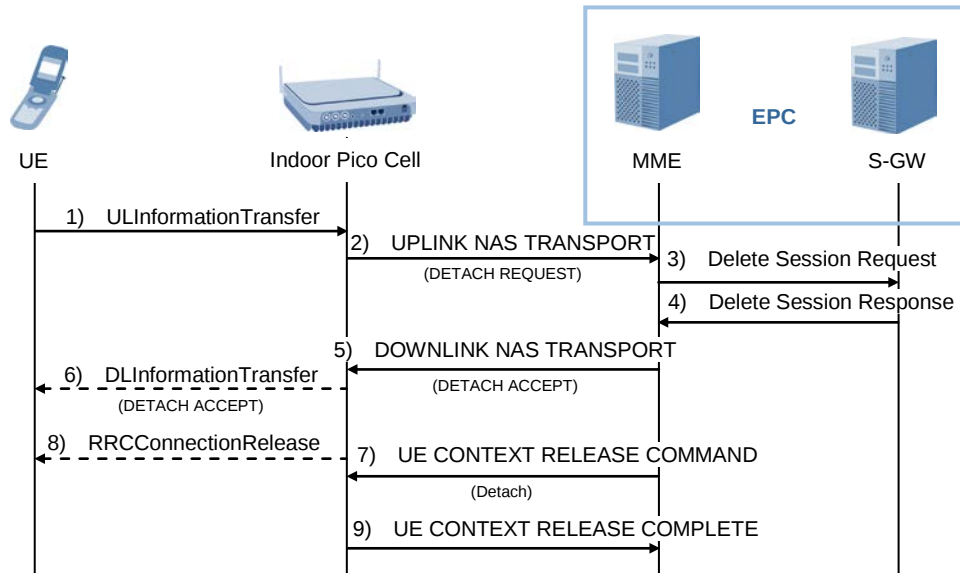


Figure 18. Detach Procedure by UE

Step	Description
1)~2)	The UE transmits the NAS DETACH REQUEST message to the MME. This NAS message is used to start setting up an S1 connection when the UE is in Idle mode.
3)	The active EPS bearers and their context information for the UE and MME which are in the S-GW are deactivated when the MME transmits the Delete Session Request message for each PDN connection.
4)	When receiving the Delete Session Request message from the MME, the S-GW releases the related EPS bearer context information and replies with the Delete Session Response message.
5)~6)	If the detachment procedure has been triggered by reasons other than disconnection of power, the MME transmits the DETACH ACCEPT message to the UE.
7)	The MME sets the Cause IE value of the UE CONTEXT RELEASE COMMAND message to 'Detach' and transmits this message to the Indoor Pico Cell to release the S1-MME signal connection for the UE.
8)	If the RRC connection has not yet been released, the Indoor Pico Cell transmits the RRCConnectionRelease message to the UE in Requested Reply mode. Once a reply to this message is received from the UE, the Indoor Pico Cell removes the UE context.
9)	The Indoor Pico Cell returns the UE CONTEXT RELEASE COMPLETE message to the MME and confirms that S1 is released. By doing this, the signal connection between the MME and Indoor Pico Cell for the UE is released. This step must be performed immediately after step 7).

Detach by the MME

The figure below shows the message flow of the Detach procedure initiated by the MME.

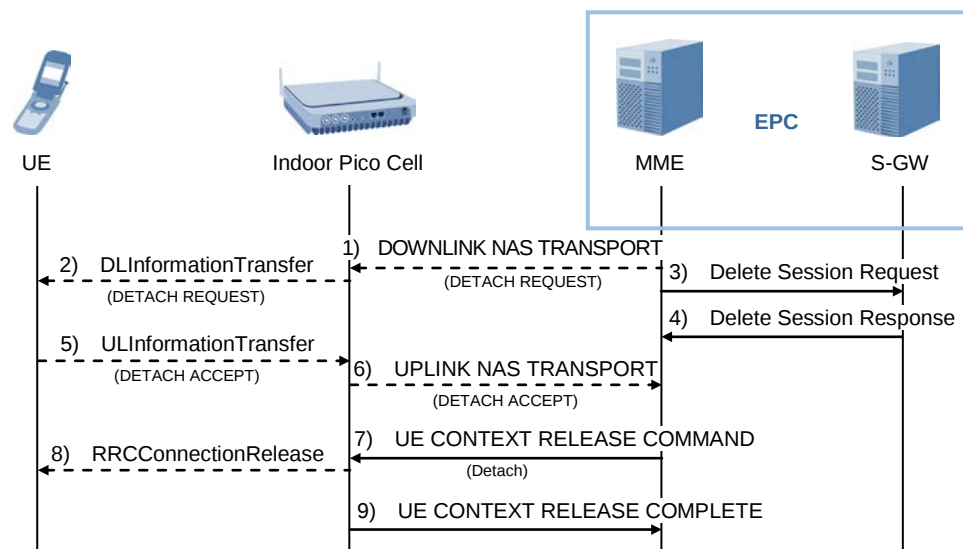


Figure 19. Detach Procedure by MME

Step	Description
1)~2)	The MME detaches the UE implicitly if there is no communication between them for a long time. In case of the implicit detach, the MME does not transmit the DETACH REQUEST message to the UE. If the UE is in the connected state, the MME transmits the DETACH REQUEST message to the UE to detach it explicitly.
3)~4)	It is the same procedure as step 3) and 4) of 'Detach Procedure by UE'.
5)~6)	When the UE receives the DETACH REQUEST message from the MME in Step 2), the UE transmits the DETACH ACCEPT message to the MME. The Indoor Pico Cell transmits this NAS message to the MME.
7)	After receiving both of the DETACH ACCEPT message and the Delete Session Response message, the MME sets the Cause IE value of the UE CONTEXT RELEASE COMMAND message to 'Detach' and transmits this message to the Indoor Pico Cell to release the S1 connection for the UE.
8)~9)	It is the same procedure as step 8) and 9) of 'Detach Procedure by UE'.

LTE Handover: X2 Based Handover

The message flow for X2 based handover procedure is illustrated below.

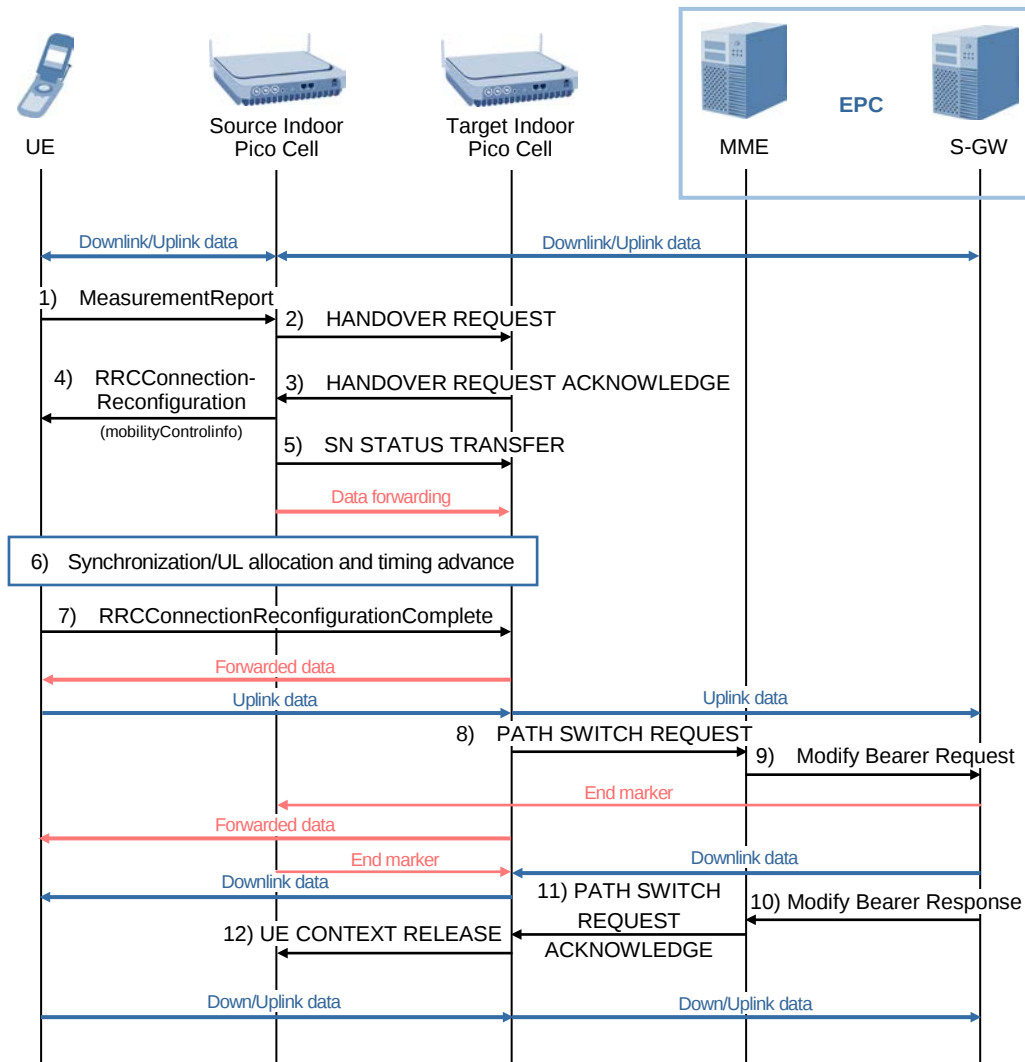


Figure 20. X2 Based Handover Procedure

Step	Description
1)	The UE transmits the MeasurementReport message according to the system information, standards and rules. The source Indoor Pico Cell determines whether to perform the UE handover based on the MeasurementReport message and the radio resource management information.
2)	The source Indoor Pico Cell transmits the HANDOVER REQUEST message and the information required for handover to the target Indoor Pico Cell. The target Indoor Pico Cell can perform management control in accordance with the E-RAB QoS information received.
3)~4)	The target Indoor Pico Cell creates the RRCConnectionReconfiguration message which contains the mobileControlInfo IE for preparing and executing the handover. The target Indoor Pico Cell includes the RRCConnectionReconfiguration message in the HANDOVER REQUEST ACKNOWLEDGE message, and transmits it to the source Indoor Pico Cell. The source Indoor Pico Cell transmits the RRCConnectionReconfiguration message and the necessary parameters to the UE to command it to perform the handover.
5)	To transmit the uplink PDCP SN receiver status and the downlink PDCP SN transmitter status of the E-RABs of which the PDCP status must be preserved, the source Indoor Pico Cell transmits the SN STATUS TRANSFER message to the target Indoor Pico Cell.
6)	After receiving the RRCConnectionReconfiguration message containing mobileControlInfo IE, the UE performs synchronization with the target Indoor Pico Cell and connects to the target cell via a RACH. The target Indoor Pico Cell responds with UL allocation and a timing advance value.
7)	After successfully connecting to the target cell, the UE uses the RRCConnection-ReconfigurationComplete message to notify the target Indoor Pico Cell that the handover procedure is complete.
8)	The target Indoor Pico Cell uses the PATH SWITCH REQUEST message to notify the MME that the UE has changed the cell.
9)~10)	The MME transmits the Modify Bearer Response message to the S-GW. The S-GW changes the downlink data path into the target Indoor Pico Cell. The S-GW transmits at least one 'end marker' to the source Indoor Pico Cell through the previous path, and releases the user plane resources for the source Indoor Pico Cell. The S-GW transmits the Modify Bearer Response message to the MME.
11)	The MME transmits the PATH SWITCH REQUEST ACKNOWLEDGE message to acknowledge the PATH SWITCH REQUEST message.
12)	The target Indoor Pico Cell transmits the UE CONTEXT RELEASE message to the source Indoor Pico Cell to notify the handover has succeeded and to make the source Indoor Pico Cell release its resources. If the source Indoor Pico Cell receives the UE CONTEXT RELEASE message, it releases the radio resources and the control plane resources related to the UE context.

LTE Handover: S1-based Handover

The message flow for S1 based handover procedure is illustrated below.

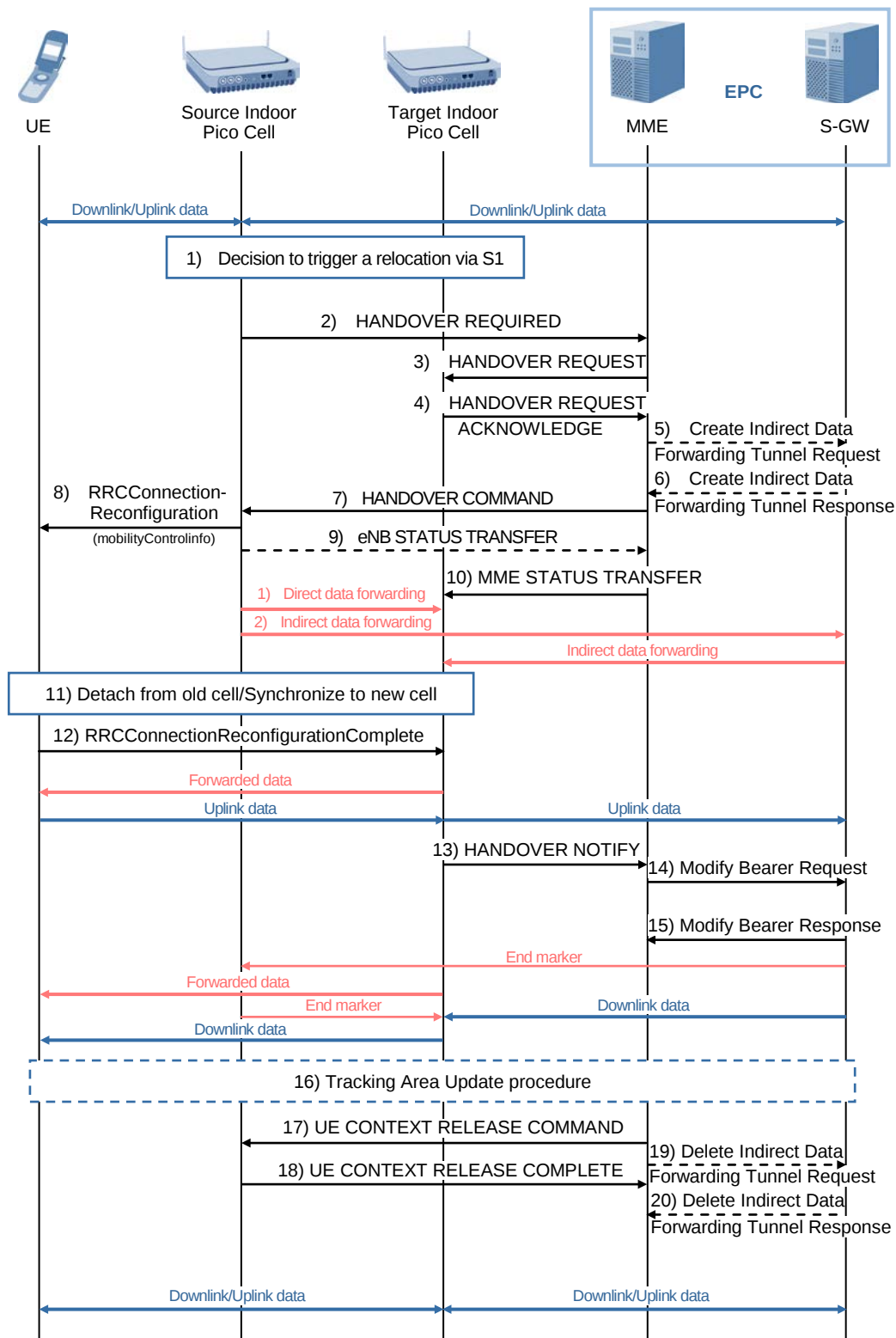


Figure 21. S1-based Handover Procedure

Step	Description
1)	The source Indoor Pico Cell determines whether to perform S1-based handover to the target Indoor Pico Cell. The source Indoor Pico Cell can make this decision if there is no X2 connection to the target Indoor Pico Cell or if an error is notified by the target Indoor Pico Cell after an X2-based handover has failed, or if the source Indoor Pico Cell dynamically receives the related information.
2)	The target Indoor Pico Cell transmits the HANDOVER REQUIRED message to the MME. The source Indoor Pico Cell notifies the target Indoor Pico Cell which bearer is used for data forwarding and whether direct forwarding from the source Indoor Pico Cell to the target Indoor Pico Cell is possible.
3)~4)	The MME transmits the HANDOVER REQUEST message to the target Indoor Pico Cell. This message makes the target Indoor Pico Cell create a UE context containing the bearer-related information and the security context. The target Indoor Pico Cell transmits the HANDOVER REQUEST ACKNOWLEDGE message to the MME.
5)~6)	If indirect forwarding is used, the MME transmits the Create Indirect Data Forwarding Tunnel Request message to the S-GW. The S-GW responds to the MME with the Delete Indirect Data Forwarding Tunnel Response message.
7)~8)	The MME transmits the HANDOVER COMMAND message to the source Indoor Pico Cell. The source Indoor Pico Cell creates the RRCConnectionReconfiguration message using the Target to Source Transparent Container IE encapsulated in the HANDOVER COMMAND message and then transmits it to the UE.
9)~10)	To transmit the PDCP and HFN status of the E-RABs of which the PDCP status must be preserved, the source Indoor Pico Cell transmits the eNB/MME STATUS TRANSFER message to the target Indoor Pico Cell via the MME. The source Indoor Pico Cell must start forwarding the downlink data to the target Indoor Pico Cell through the bearer which was determined to be used for data forwarding. This can be either direct or indirect forwarding.
11)	The UE performs synchronization with the target Indoor Pico Cell and connects to the target cell via the RACH. The target Indoor Pico Cell responds with UL allocation and a timing advance value.
12)	After successfully synchronizing with the target cell, the UE uses the RRCConnectionReconfigurationComplete message to notify the target Indoor Pico Cell that the handover procedure is complete. The downlink packets retransmitted by the source Indoor Pico Cell can be forwarded to the UE. The uplink packets can also be transmitted from the UE to the S-GW via the target Indoor Pico Cell.
13)	The target Indoor Pico Cell transmits the HANDOVER NOTIFY message to the MME. The MME starts the timer which tells when the source Indoor Pico Cell resources and the temporary resources used for indirect forwarding at S-GW will be released.
14)	The MME transmits the Modify Bearer Request message for each PDN connection to the S-GW. Downlink packets are transmitted immediately from the S-GW to the target Indoor Pico Cell.

Step	Description
15)	The S-GW transmits the Modify Bearer Response message to the MME. If the target Indoor Pico Cell changes the path for assisting packet resorting, the S-GW immediately transmits at least one 'end marker' packet to the previous path.
16)	If any of the conditions listed in section 5.3.3.0 of TS 23.401(6) are met, the UE starts the Tracking Area Update procedure.
17)~18)	When the timer started at step 13) expires, the MME transmits the UE CONTEXT RELEASE COMMAND message to the source Indoor Pico Cell. The source Indoor Pico Cell releases the resources related to the UE and replies with the UE CONTEXT RELEASE COMPLETE message.
19)~20)	If indirect forwarding is used and when the timer started by the MME at step 13) expires, the MME transmits the Delete Indirect Data Forwarding Tunnel Request message to the S-GW. This message makes the S-GW release the temporary resources allocated for indirect forwarding at step 5). The S-GW responds to the MME with the Delete Indirect Data Forwarding Tunnel Response message.

4.2 Data Traffic Flow

Sending Path

The user data received from the EPC passes through the network interface module and is transmitted through the Ethernet switch to the L7IA of Indoor Pico Cell. The transmitted user data goes through baseband-level digital processing, and transmitted to the transceiver part. The transceiver up-converts the wideband baseband signal to the RF band, and the converted signal is transmitted to the antenna through the power amplifier and filter.

Receiving Path

The RF signal received by the antenna passes through the L7IA's filter and its low noise is amplified by the LNA. This signal is converted to the data signal of baseband after the RF down-conversion in the transceiver of the L7IA. The data which passed through the SC-FDMA signaling process in the modem is converted to the Gigabit Ethernet frame and transmitted to the EPC through GE.

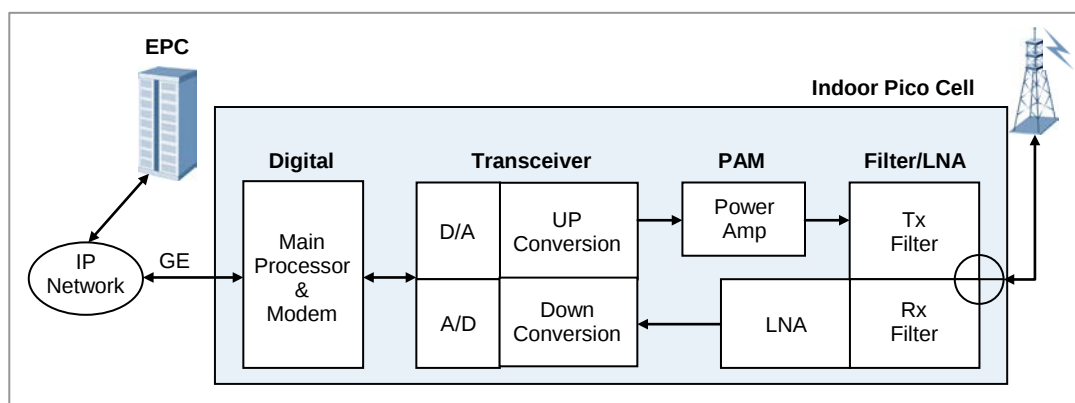


Figure 22. Data Traffic Flow

4.3 Network Sync Flow

The Indoor Pico Cell supports the GPS and IEEE1588v2 synchronization method selectively. In case of the GPS synchronization, the GPS receiver (BEGEM) receives the synchronization signal from the GPS and creates clocks. The clocks are distributed by the clock generation & distribution part.

In case of the IEEE1588v2 packet synchronization, the IEEE1588v2 packet is received from an external IEEE 1588v2 server for the synchronization.

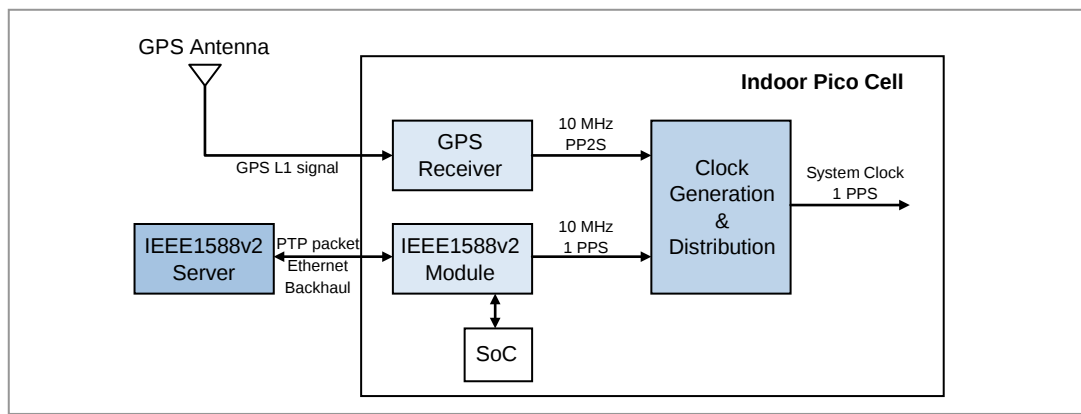


Figure 23. Network Synchronization Flow

4.4 Alarm Signal Flow

An alarm is reported as an alarm signal when a fault occurs. The L7IA collects all the alarms and report them to the LSM which is the management system.

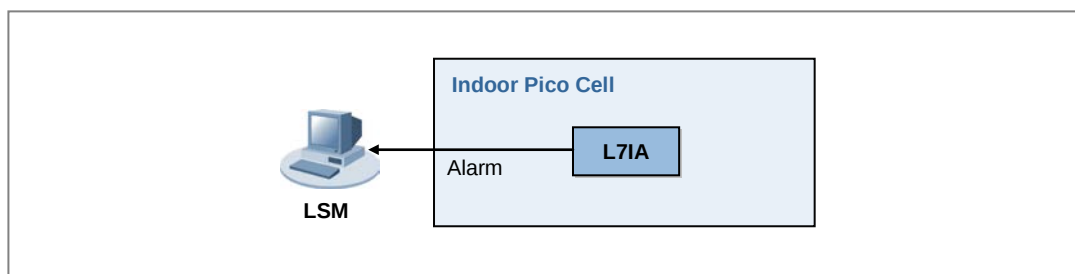


Figure 24. Alarm flow

4.5 Loading Flow

Loading is the procedure through which the processors and devices of the system can download from the LSM the software executables, data, and other elements required to perform their functions.

Loading the system is performed during the system initialization procedure. Loading is also involved when a specific board is mounted in the system, when a hardware reset is carried out, or when the operator of an upper management system restarts a specific board.

At the first system initialization, the system is loaded through the LSM. As the loading information is stored in the internal storage, no unnecessary loading is carried out afterward. After the first system initialization, it compares the software files and versions of LSM and downloads changed software files.

The loading information contains the software image and default configuration information file, etc.

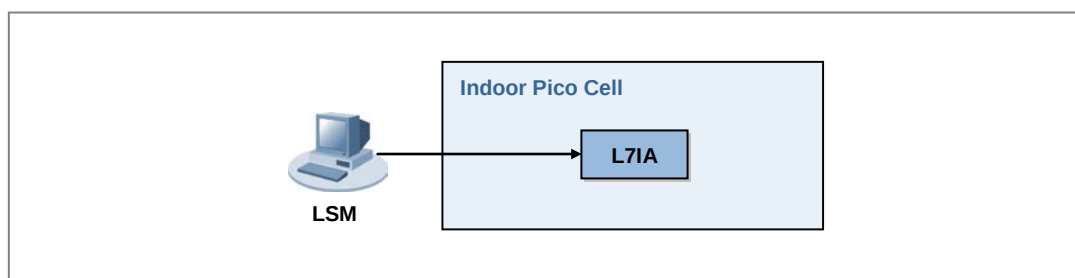


Figure 25. Loading Signal Flow

4.6 Operation and Maintenance Message Flow

The operator can check and change the status of the Indoor Pico Cell through the management system.

To accomplish this, the Indoor Pico Cell provides the SNMP agent function, and the LSM operator can carry out the operation and maintenance functions of the Indoor Pico Cell remotely through the SNMP. Moreover, the operator can carry out the maintenance function using the web browser.

The statistical information provided by the Indoor Pico Cell is given to the operator in accordance with the collection interval.

The operation and maintenance in the Indoor Pico Cell is performed using the SNMP message between the SNMP agent in the main OAM and the SNMP manager of the LSM. The LMT is a type of GUI-based console terminal which directly accesses the Indoor Pico Cell to monitor the status of, operate and maintain the equipment.

The figure below shows the operation and maintenance signal flow.

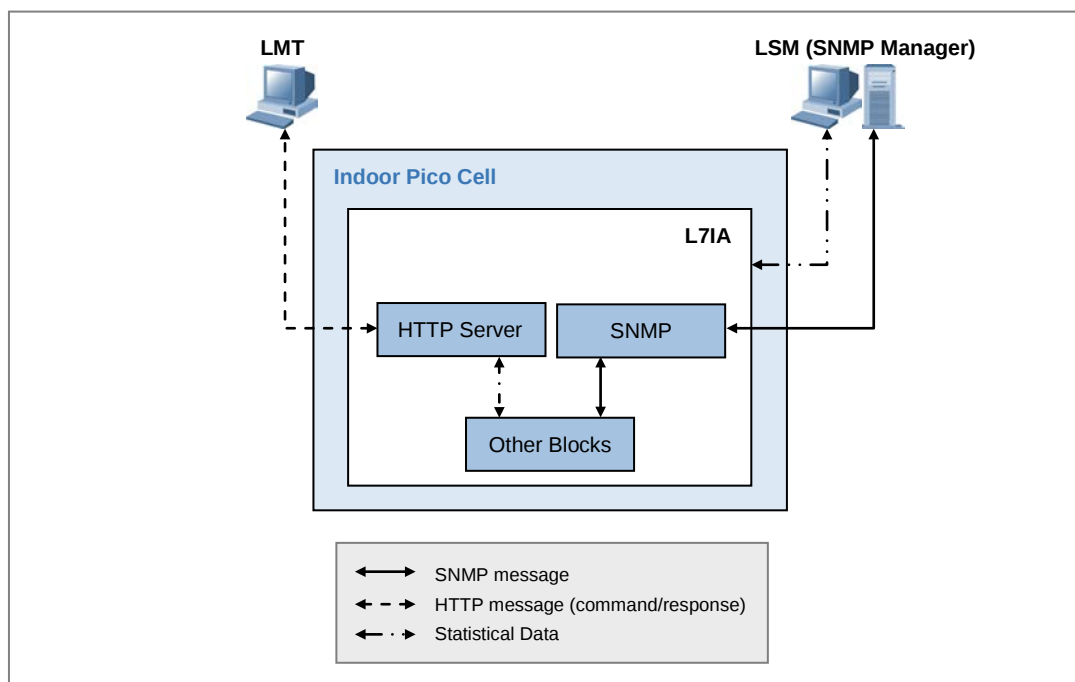


Figure 26. Operation and Maintenance Signal Flow

CHAPTER 5. Supplementary Functions and Tools

5.1 LMT

The LMT is a GUI-based console terminal. It is the tool that monitors the status of devices and performs operation and maintenance tasks by connecting directly to the Indoor Pico Cell. The operator can run the LMT using Internet Explorer, without installing separate software. The GUI is provided using the HTTPs protocol internally.

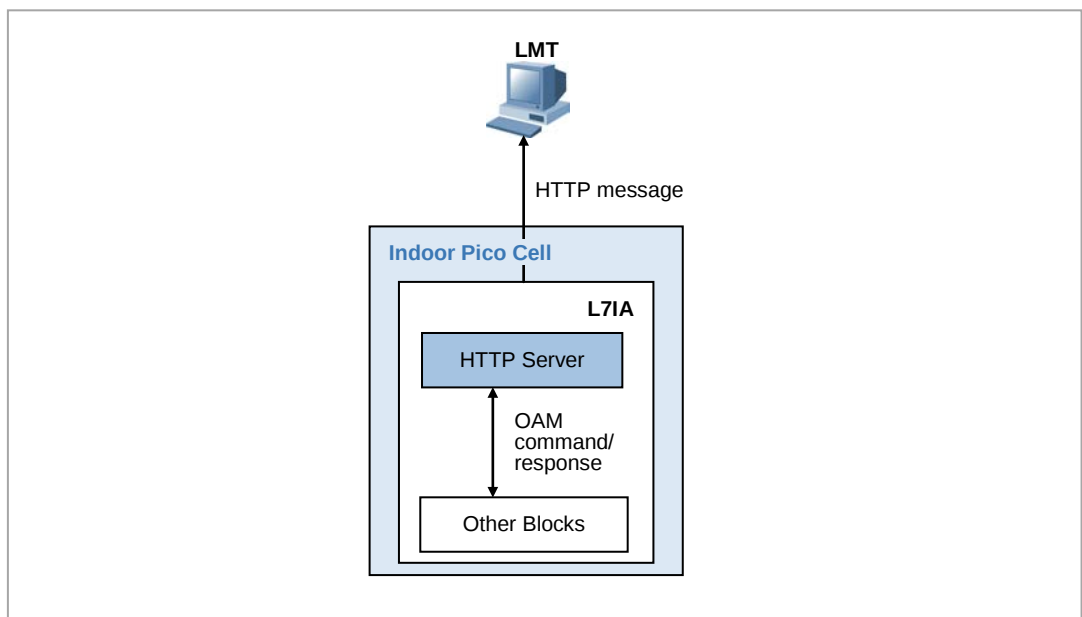


Figure 27. LMT Interface

Through the LMT, the operator can reset or restart the Indoor Pico Cell or its internal boards, view and change the configuration and operation parameter values, monitor the system status and faults, carry out diagnostic functions, and so on. But the resource grow and degrow functions and changing the operation information related to neighbor list are available from the LSM only, which manages the entire networks and the loading images.



ABBREVIATION

3GPP	3rd Generation Partnership Project
64 QAM	64 Quadrature Amplitude Modulation

A

AC	Admission Control
ADC	Analog to Digital Converter
AKA	Authentication and Key Agreement
AM	Acknowledged Mode
AMBR	Aggregated Maximum Bit Rate
ANR	Automatic Neighbor Relation
ARQ	Automatic Repeat Request
AS	Access Stratum

B

BEGEM	Beyond Enhanced GPS Engine Module
BGP	Border Gateway Protocol

C

CA	Carrier Aggregation
C & M	Control & Maintenance
CC	Chase Combining
CFR	Crest Factor Reduction
CLI	Command Line Interface
CM	Configuration Management
CoS	Class of Service
CPLD	Complex Programmable Logic Device
CPS	Call Processing Software
CS	Circuit Service
CSAB	CPS SON Agent Block
CSM	Core System Manager

D

DAC	Digital to Analog Converter
DBMS	Database Management System
DD	Device Driver
DDC	Digital Down Conversion
DFT	Discrete Fourier Transform
DHCP	Dynamic Host Configuration Protocol
DiffServ	Differentiated Services
DL	Downlink
DSCP	Differentiated Services Code Point
DSP	Digital Signal Processor
DUC	Digital Up Conversion
DUS	Debugging Utility Service

E

ECCB	eNB Call Control Block
ECMB	eNB Common Management Block
ECS	eNB Control processing Subsystem
EDS	eNB Data processing Subsystem
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMS	Element Management System
eNB	evolved UTRAN Node-B
ENS	Event Notification Service
E/O	Electric-to-Optic
EPC	Evolved Packet Core
EPS	Evolved Packet System
ES	Energy Saving
ESM	Energy Saving Management
ESM	EPC System Manager
E-UTRAN	Evolved UTRAN

F

FDD	Frequency Division Duplex
FE	Fast Ethernet
FHS	File-system Hierarchy Standard 2.2
FM	Fault Management
FSTD	Frequency Switched Transmit Diversity
FTP	File Transfer Protocol

G

GBR	Guaranteed Bit Rate
GE	Gigabit Ethernet
GPRS	General Packet Radio Service
GPS	Global Positioning System
GTP	GPRS Tunneling Protocol
GTPB	GPRS Tunneling Protocol Block
GTP-U	GTP-User
GW	Gateway

H

HARQ	Hybrid Automatic Repeat Request
HAS	High Availability Service
HO	Handover
HSS	Home Subscriber Server
HTTP	Hyper Text Transfer Protocol
HTTPS	Hyper Text Transfer Protocol over SSL

I

ICIC	Inter-Cell Interference Coordination
ICMP	Internet Control Message Protocol
IDFT	Inverse Discrete Fourier Transform
IETF	Internet Engineering Task Force
IF	Intermediate Frequency
IP	Internet Protocol
IPRS	IP Routing Software
IPSS	IP Security Software
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
IR	Incremental Redundancy

L

L7IA	LTE 7 baseband and transceiver Integrated board Assembly
LMT	Local Maintenance Tool
LNA	Low Noise Amplifier
LSM	LTE System Manager
LTE	Long Term Evolution

M

MAC	Media Access Control
MACB	Medium Access Control Block
MBR	Maximum Bit Rate
MCS	Modulation Coding Scheme
MDS	Message Delivery Service
MFS	Miscellaneous Function Service
MIB	Master Information Block
MIMO	Multiple-Input Multiple-Output
MMC	Man Machine Command
MME	Mobility Management Entity
MSS	Master SON Server
MU	Multiuser

N

NAS	Non-Access Stratum
NE	Network Element
NP	Network Processing
NPC	Network Processing Control
NR	Neighbor Relation
NRT	Neighbor Relation Table

O

OAM	Operation and Maintenance
OCNS	Orthogonal Channel Noise Simulator
OCS	Online Charging System
O/E	Optic-to-Electric
OFCS	Offline Charging System
OFD	Optic Fiber Distributor
OFDMA	Orthogonal Frequency Division Multiple Access
OS	Operating System
OSAB	OAM SON Agent Block
OSPF	Open Shortest Path First
OSS	Operating Support System

P

PAPR	Peak-to-Average Power Ratio
PCI	Physical Cell Identity
PCRF	Policy and Charging Rule Function
PD	Power Detector
PDCB	PDCH Block
PDCH	Packet Data Convergence Protocol
PDN	Packet Data Network
PDU	Protocol Data Unit

P-GW	PDN Gateway
PLER	Packet Loss Error Rate
PM	Performance Management
PMI	Precoding Matrix Indicator
PMIP	Proxy Mobile IP
PoE	Power over Ethernet
PRACH	Physical Random Access Channel
PRB	Physical Resource Block
PSS	Primary Synchronization Signal
PTP	Precision Time Protocol

Q

QCI	QoS Class Identifier
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying

R

RACH	Random Access Channel
RB	Radio Bearer
RB	Resource Block
RET	Remote Electrical Tilt
RF	Radio Frequency
RFS	Root File System
RLC	Radio Link Control
RLCB	Radio Link Control Block
RO	RACH Optimization

S

S1-AP	S1 Application Protocol
SC	Single Carrier
SC-FDMA	Single Carrier Frequency Division Multiple Access
SCTB	Stream Control Transmission protocol Block
SCTP	Stream Control Transmission Protocol
SDU	Service Data Unit
SFBC	Space Frequency Block Coding
SFN	System Frame Number
SFTP	SSH File Transfer Protocol
S-GW	Serving Gateway
SIBs	System Information Blocks
SM	Spatial Multiplexing
SMC	Security Mode Command
SMS	Short Message Service
SNMP	Simple Network Management Protocol
SON	Self Organizing Network

SSH	Secure Shell
SSS	Secondary Synchronization Signal
STBC	Space Time Block Coding
SU	Single User
SwM	Software Management

T

TA	Tracking Area
THS	Task Handling Service
TM	Test Management
TOD	Time Of Day
TrM	Trace Management

U

UDA	User Defined Alarm
UDE	User Defined Ethernet
UDP	User Datagram Protocol
UE	User Equipment
UL	Uplink
UTRAN	UMTS Terrestrial Radio Access Network

V

VLAN	Virtual Local Area Network
VSWR	Voltage Standing Wave Ratio

W

Web-EMT	Web-based Element Maintenance Terminal
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MPE Information

	Warning: Exposure to Radio Frequency Radiation The radiated output power of this device is far below the FCC radio frequency exposure limits when keeping a separation distance of 100 cm from human contact. Nevertheless, the device should be used in such a manner that the potential for human contact during normal operation is minimized. In order to avoid the possibility of exceeding the FCC radio frequency exposure limits, human proximity to the antenna should not be less than 100cm during normal operation. The gain of the antenna is 2.5 dBi. The antenna(s) used for this transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.
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LTE 1.9 GHz Indoor Pico Cell System Description

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