Chapter 1 Samsung LTE System Overview

Introduction to Samsung LTE System

Samsung LTE system supports 3GPP LTE (hereinafter, LTE) based services.

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

Samsung LTE system supports Orthogonal Frequency Division Multiple Access (OFDMA) for downlink, Single Carrier (SC) Frequency Division Multiple Access (FDMA) for uplink, 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.

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

Samsung LTE system consists of evolved UTRAN Node B (eNB), Evolved Packet Core (EPC), and Small Cell Element Management System (EMS).

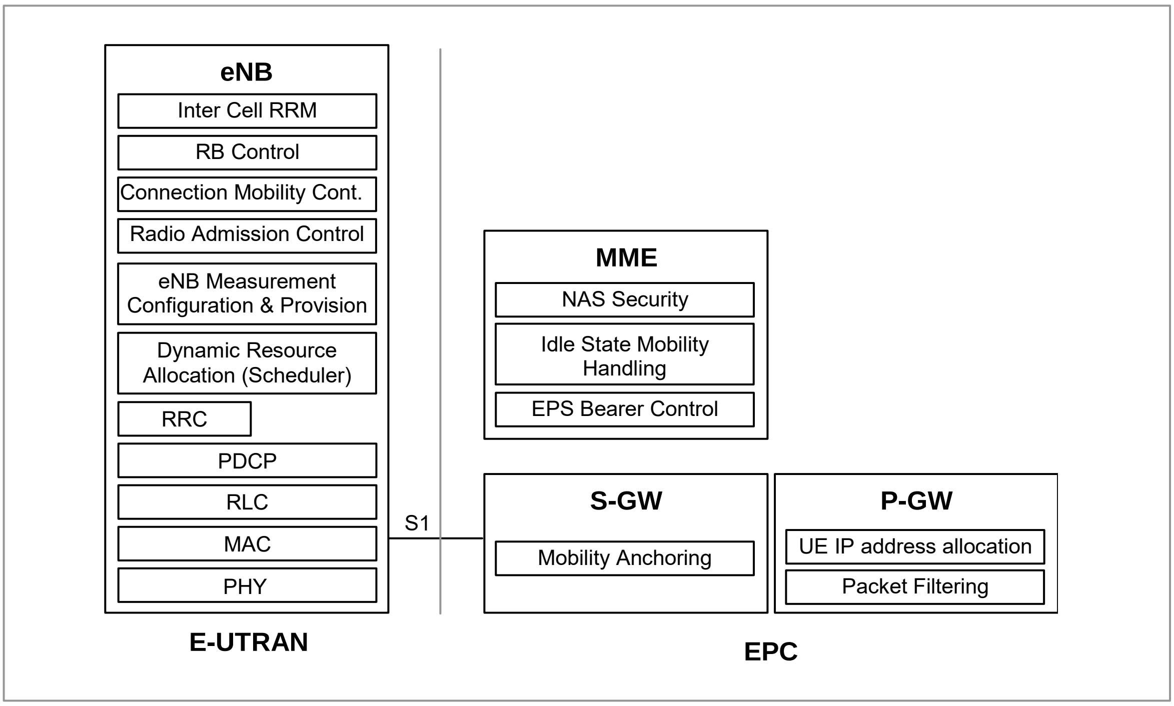
The eNB exists between an EPC and a User Equipment (UE). It establishes wireless connections with the UE and processes packet calls according to LTE air interface standard. The eNB manages the UE in connected mode at the Access Stratum (AS) level.

The EPC is the system, which is located between an eNB and a Packet Data Network (PDN) to perform various control functions. The EPC consists of Mobility Management Entity (MME), Serving Gateway (S-GW), and PDN Gateway (P-GW). The MME manages UE in idle mode at the Non-Access Stratum (NAS) level. The S-GW and the P-GW manages user data at the NAS level and interworks with other networks.

The Small Cell Management System (EMS) provides man-machine interface; manages the software, configuration, performance, and failures. Also, it acts as a Self-Organizing Network (SON) server.

The following figure shows the functional distinctions between the eNB of E-UTRAN, and the MME, S-GW, and P-GW of EPC 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

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

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

The wireless protocol layer of eNB is divided into layer 2 and layer 3. The layer 2 is subdivided into Media Access Control (MAC) layer, Radio Link Control (RLC) layer, and PDCP layer, each of which performs independent functions. Also, layer3 has Radio Resource Control (RRC) layer.

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

The RLC layer performs the following functions:

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

The PDCP layer performs the following functions:

- Compresses and decompresses a header
- 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 controlling of Radio Bearer (RB), RRC connection management, and system information transmission, and so on.

MME

The MME interworks with 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. The MME also process the SCTP-based NAS signaling messages for controlling mobility connection and call connection between UE and EPC.

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

The MME interworks with 2G and 3G systems, Mobile Switching Center (MSC), and Serving GPRS Support Node (SGSN) 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 SGSN selection function upon handover to 2G or 3G 3GPP network.

S-GW

The S-GW acts as a 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 MME, P-GW, and SGSN.

P-GW

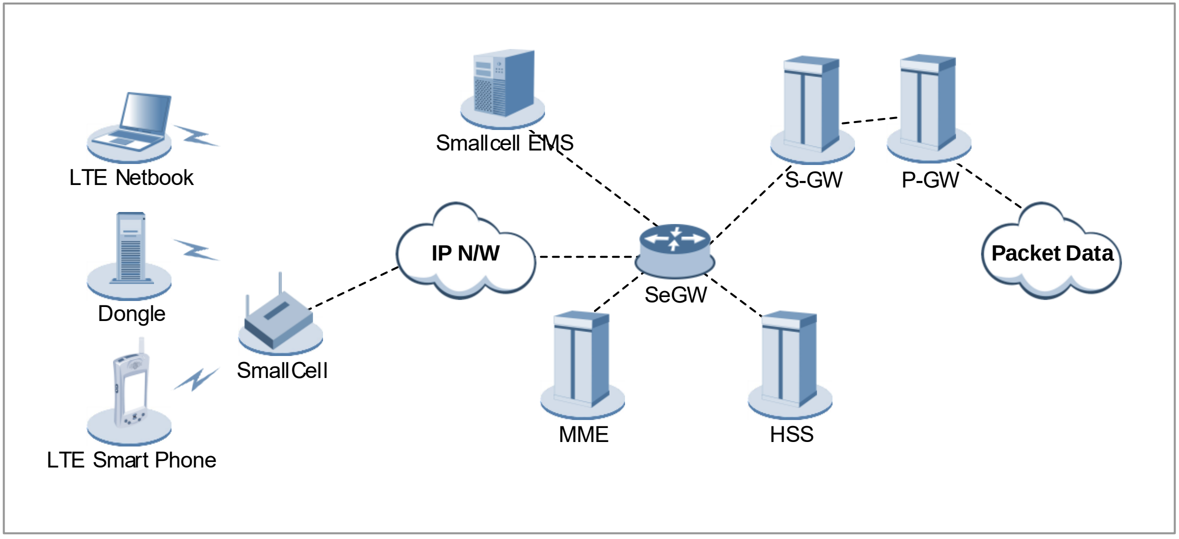
The P-GW is responsible for charging and bearer policy according to the policy and manages charging and transmission rate according to the service level by interworking with PCRF. The P-GW also performs packet filtering for each user, IP address allocation for each UE, and downlink data packet transmission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

Samsung SmallCell Network Configuration

A network with the LTE SmallCell is consists of the SmallCell, Small Cell EMS, Small Cell Gateway, Small Cell GW EMS, Evolved Packet Core (EPC), and so on. A Subnet of the Packet Data Network (PDN), which allows the User Equipment (UE) to access external networks, comprises multiple SmallCells and Small Cell Gateway/EPC (MME and S-GW/P-GW).

Figure below depicts the network configuration of the SmallCell.

Figure 2. SmallCell Network Architecture



SmallCell

The SmallCell is located between the UE and the EPC. It processes packet calls by connecting to the UE wirelessly according to the LTE air standard.

The SmallCell is responsible for transmission and reception of wireless signals, modulation and demodulation of packet traffic signals, packet scheduling for efficient utilization of wireless resources, Hybrid Automatic Repeat request (HARQ)/ARQ processing, Packet Data Convergence Protocol (PDCP) for packet header compression, and wireless resources control.

In addition, the SmallCell performs handover by interworking with EPC.

EPC

The EPC is a system, which is located between the SmallCell and the 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 SmallCell 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 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.

SmallCell EMS

The SmallCell EMS provides the user interface for the operator to operate and maintain the SmallCell. The SmallCell EMS is responsible for software management, configuration management, performance management and fault management.

The EMS also interworks with service provider's Network Management System (NMS) and carries out the Plug and Play (PnP) and SON related functions.

SeGW

Security Gateway (SeGW) provides the security tunneling to the SmallCell connected through the public IP network. To configure the tunnel, SeGW performs the authentication of the SmallCell by interworking with the AAA server and sets the IPSec security tunneling to the authenticated SmallCell only.

SeGW also provides the network protection through firewall and anti-attack features.

HSS

The Home Subscriber Server (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.

Protocol Stack between NEs

Table below outlines the inter-NE protocol stack of the SmallCell.

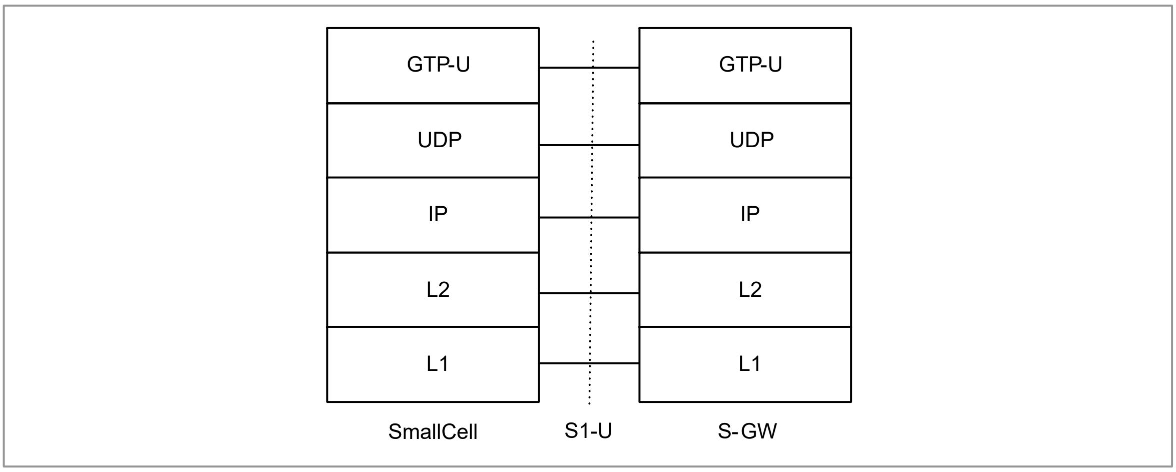
Table 1. ***SmallCell supports the following interfaces for interworking with NEs***

Target System	Interface Name	Physical Interface
S-GW	S1-U	GE/FE
SmallCell	X2-C/X2-U	GE/FE
Small Cell EMS	TR-069/FTP	GE/FE
UE	Uu	Air

S1 Interface Protocol Stack

Figure below depicts the protocol stack for the S1 interface user plane.

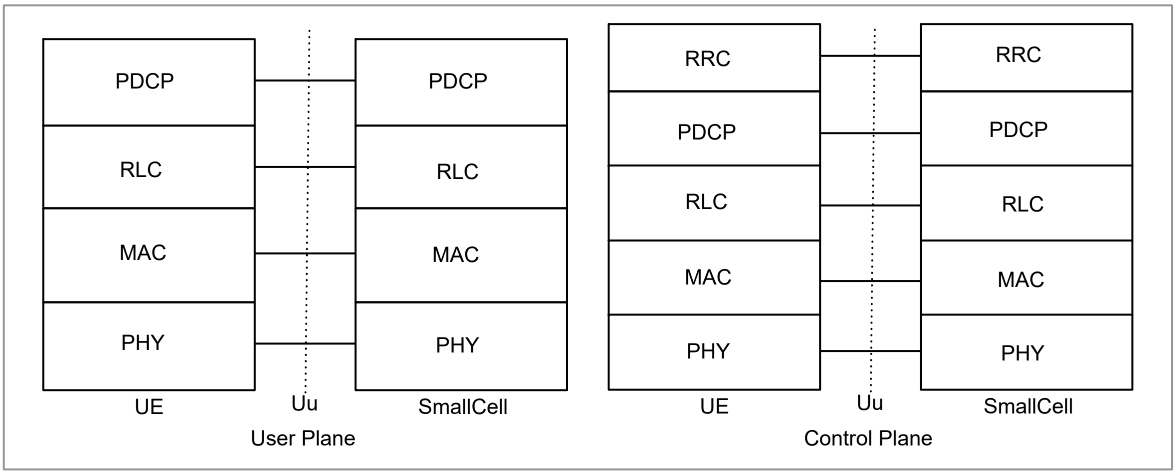
Figure 3. ***S1 Protocol Stack-Control Plane (S1-MME)***



Uu Interface Protocol Stack

The user plane protocol layer consists of the PDCP, RLC, MAC, and PHY layers, as depicted in figure below.

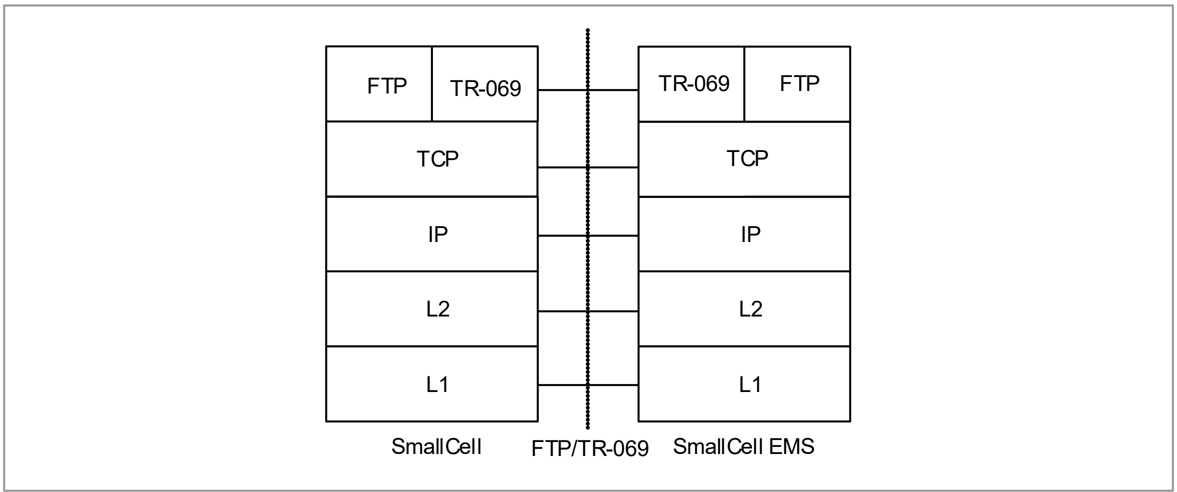
Figure 4. ***Uu Interface Protocol Stack***



Protocol Stack for Interworking with SmallCell EMS

Figure below depicts the protocol stack for the connection between the SmallCell and the SmallCell EMS.

Figure 5. ***Protocol Stack for Interworking with SmallCell EMS***



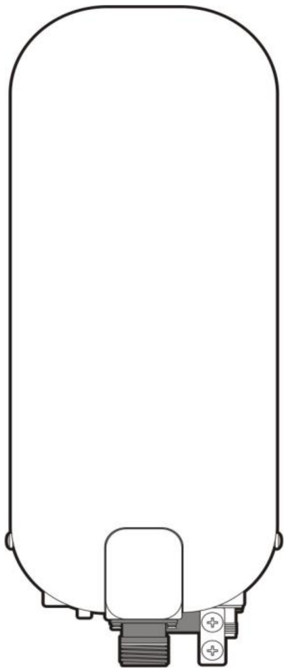
Chapter 2 SOL230 Overview

Introduction to SOL230

The SOL230 is located between the UE and the EPC. It interfaces wirelessly in accordance with the LTE air standard and provides subscribers with wireless communications service. The SOL230 transmits and receives wireless signals to and from UE and processes the modulation and demodulation of traffic signals. In addition, it allocates packet scheduling and wireless bandwidth, and performs handover by interfacing with the EPC.

The SOL230 is an all-in-one unit. If a fault occurs, the unit must be replaced.

Figure 6. *SOL230 Appearance*



Key Features

The key functions of the SOL230 are as follows:

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

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

Physical Layer Processing

The SmallCell transmits/receives data through the wireless channel between the EPC and the UE. To do so, the SmallCell 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 SmallCell 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 SmallCell 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 SmallCell can reduce the power consumption of the UE.

Downlink Reference Signal Creation and Transmission

The UE must estimate the downlink channel to perform coherent demodulation on the downlink physical channel in the LTE system. The LTE uses OFDM/OFDMA-based methods for transmission, making it possible to estimate the channel by inserting the reference symbols from the receiving terminal into the grid for each time and frequency. These reference symbols are called downlink reference signals; there is one type of reference signals defined in 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 SmallCell. 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 SmallCell.

Channel Encoding/Decoding

The SmallCell 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. The 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 SmallCell 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 UE through a wireless channel, the SmallCell demodulates and changes it to the baseband signal to perform decoding.

Resource Allocation and Scheduling

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

The SmallCell 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 SmallCell 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.

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 64 QAM. 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 SmallCell 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 HARD function.

H-ARQ

The Hybrid Automatic Repeat Request (H-ARQ) is a retransmission method in the physical layer, which uses the stop-and-wait protocol. The SmallCell 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 SmallCell uses the asynchronous method for downlink and the synchronous method for uplink.

Power Control

When transmitting a specific data rate, a too high a power level may result in unnecessary interferences and a 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 SmallCell can reduce inter-cell interference by transmitting data at adequate power levels according to the location of UE and the MCS, which results in improvement of the entire cell throughput.

MIMO

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

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

Direction	Item	Description
Downlink	Space Frequency Block Coding (SFBC)	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.
	Spatial Multiplexing (SM)	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 SmallCell 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 UE when the UE's channel is unknown or changes fast due to fast movement of the UE. • Closed-loop SM: The SM that works with the Precoding Matrix Indicator (PMI) feedback of UE when the UE's channel is known or changes slow due to slow movement of the UE.

Call Processing Function

Cell Information Transmission

In a serving cell, the SmallCell 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 SmallCell allows the UE to be connected to or disconnected from the network.

When the UE is connected to or released from the network, the SmallCell 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 SmallCell performs call control and resource allocation required for service. When the UE is disconnected from the network, the SmallCell collects and releases the allocated resources.

Handover

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

To minimize user traffic loss during S1 handovers, the SmallCell performs the data forwarding function. The source SmallCell provides a forwarding method to the target SmallCell: indirect forwarding via the S1 interface.

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

Admission Control

The SmallCell provides capacity-based and QoS-based Admission Control(AC) 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 allowed in the SmallCell. Call admission is determined depending on whether the connected UEs and bearers exceed the thresholds.

- QoS-based admission control

  The SmallCell determines whether to admit a call based 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 SmallCell performs the Automatic Repeat Request (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 SmallCell 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 SmallCell and the backhaul section between the SmallCell and the S-GW.

Via the air interface, the SmallCell 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, the SmallCell performs QCI-based packet classification, QCI to Differentiated Services Code Point (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, and so on.

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.

IP Processing

IP QoS

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

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

IP Routing

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

The SmallCell supports static routing setup. However, but it does not support dynamic routing protocols, such as Open Shortest Path First (OSPF)/Border Gateway Protocol (BGP).

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 (OTAR Based SON)
  - Self-configuration of Initial Physical Cell Identity (PCI)
  - Self-configuration of Initial neighbor information
  - Self-configuration of Initial Root Sequence Index (RSI)
  - Self-configuration of Initial Tx Power
  - Self-configuration of Initial Carrier
- 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

PCI Auto-configuration provides functions such as PCI collision/ confusion detection and PCI reallocation.

Automatic Neighbor Relation

Automatic Neighbor Relation (ANR) configures and manages the intra-LTE NRT to guarantee stable UE mobility in the LTE system. Samsung ANR fully meets the requirements of the 3GPP LTE standard. Samsung ANR provides automatic NR addition and X2 interface establishment function triggered by UE mobility and periodical NRT management function.

Random Access Channel (RACH) Optimization

After PCI Auto-Configuration is done, RSI selection gets the selected PCI and determines its index in the provisioned PCI list. RSI selection then chooses the RSI with the same index in the provisioned RSI list, and informs to OAM and stack.

Easy Operation and Maintenance

Through interworking with the management systems (SmallCell EMS and CLI), the SmallCell 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 SmallCell EMS manages all SmallCells in the network using the Database Management System (DBMS). The SmallCell also interworks with the console terminal to allow the operator to connect directly to the Network Element (NE), rather than through the SmallCell EMS, and perform the operations and maintenance.

The operator can use 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 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 add/deleteresources or configure a neighbor list that contains relation of multiple NEs, the operator needs to use the SmallCell EMS.

Operator Authentication Function

The SmallCell provides the authentication and privilege management functions for the system operators. The operator accesses the SmallCell using the operator's account and password via the CLI. At this time, the SmallCell grants the operator an operation privilege in accordance with the operator's level.

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

Highly Secured Maintenance

The SmallCell supports the Hypertext Transfer Protocol (HTTP) and the Secure Shell (SSH) for security during communications with the SmallCell EMS.

Specification

Key Specifications

Table below outlines the key specifications of the SOL230.

Item	Specification	
Air Specification	LTE TDD	802.11 a/b/g/n/ac
Operating Frequency	3.5 GHz (Band 48) • DL: 3,550~3,700 MHz • UL: 3,550~3,700 MHz	2.4 GHz, 5 GHz (Dual)
Channel Bandwidth (MHz)	10/20	-
RF Chain	2Tx/2Rx	4Tx/4Rx per band
Output Power (mW/path)	500	100 (2.4 GHz), 100 (5 GHz)
Capacity	2 Carrier	-
Backhaul	Copper GE 1port, Optic GE 1 port	
Clock solution	GPS	-
Cooling	Fanless (natural convection cooling)	-

Input Power

Table below outlines the power specifications for the SOL230.

Item	Specification
Input Power	-48 VDC

Dimensions and Weight

Table below outlines the dimensions and weight of the SOL230.

Item	Specification
Size (W × D × H, mm)	142 × 352.1 × 94.3 (without mount bracket)
Volume/Weight	• Volume: 4.715 Liter • Weight: 4 kg

Ambient Conditions

Table below outlines the ambient conditions and related specifications of the SOL230.

Category	Specifications
Operating Temperature (°C)	-30~55
Operating Humidity (RH)	10~90 %

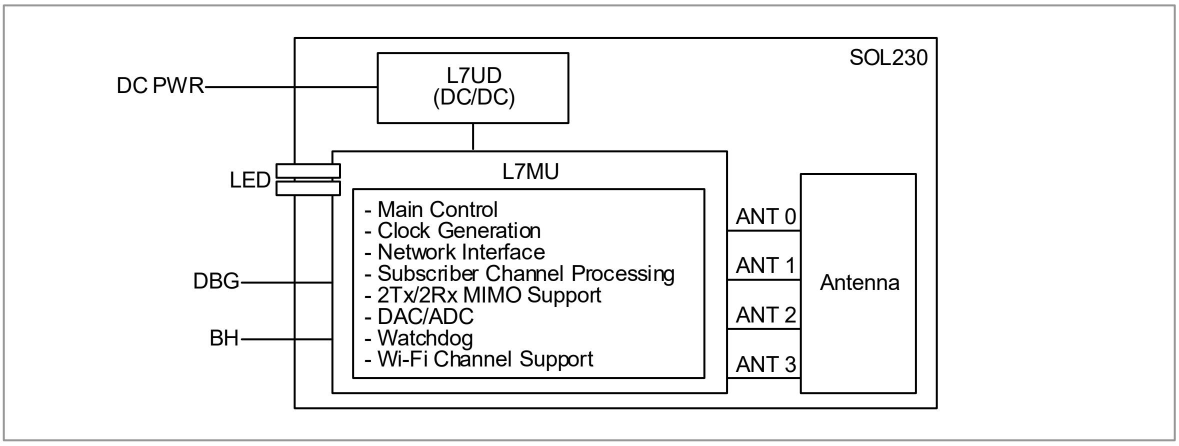
Chapter 3 SOL230 Structure

Hardware Structure

The SOL230 consists of a main block (L7MU), which is a digital and RF processing board, a DC/DC (L7UD), and antennas.

Figure below depicts the shows internal configuration of SOL230:

Figure 7. ***Internal Configuration of SOL230***



Main Block (L7MU)

The major functions of the L7MU are as follows:

- Main Control Functions
- Clock Generation Function
- Network Interface Function
- Subscriber Channel Processing Function
- 2Tx/2Rx MIMO Support
- DAC/ADC Function
- Wi-Fi Channel Support

Main Control Functions

The main processor of SOL230 takes the highest role of the system, and performs the communication path setup between the UE and the EPC, system operation and maintenance, and so on.

It also manages the status for all hardware and software in SOL230, allocates and manages resources, collects alarms, and reports all status information to the EMS.

Clock Generation Function

The SOL230 supports IEEE1588v2. The clock block allows each block of SmallCell to be operated with synchronized clock system.

The IEEE1588v2 block generates system clock by using the data, which is received from external IEEE1588v2 master. It also performs holdover function that provides normal clock for a specific time period if not receiving IEEE1588v2 packet.

Network Interface Function

The L7MU interfaces with EPC via Gigabit Ethernet. (Optic)

Subscriber Channel Processing Function

The L7MU has the modem that supports LTE standard physical layer. It also, it performs OFDMA/SC-FDMA channel processing and DSP processes RLC/MAC.

The modem modulates the packet data received from the upper processor layer and transmits it to the transceiver.

Conversely, it demodulates the data received from the transceiver and, converts the data into the type defined, for example, as indicated in the specification of physical layer in LTE standard, to transmit the data to upper processor.

2Tx/2Rx MIMO Support

The RF part of L7MU consists of a transceiver and an amplifier. It supports the 2Tx/2Rx RF path. The maximum output is 500 mW/path.

DAC/ADC Function

In downlink path, a baseband signal is converted into an analog signal through the Digital-to-Analog Converter (DAC). The frequency of those analog signals is up-converted through the modulator. Then, the signals are amplified into high-power RF signals through the power amplifier.

In uplink path, a RF signal is amplified in LNA with low noise and it is down-converted in frequency through the demodulator. These down-converted frequency signals are converted into baseband signals through the Analog-to-Digital Converter (ADC). Then, the converted baseband signal is transmitted to the modem.

Wi-Fi Channel Support

The Wi-Fi-standard physical level is supported. The wireless network environment is created by providing WLAN 802.11 a/b/g/n/ac feature. Also, 2.4 GHz and 5 GHz dual bands can be serviced simultaneously via a wireless interface.

Antenna

LTE Antenna

The integrated antenna that follows to the front surface of SOL230 is provided as the basics. Two paths are supported for transmitting and receiving RF signals.

Wi-Fi Antenna

The integrated antenna that follows to the front surface of SOL230 is provided as the basics. The Wi-Fi antenna is a dual band antenna that operates at 2.4 GHz and 5 GHz. Two paths are supported for transmitting and receiving RF signals.

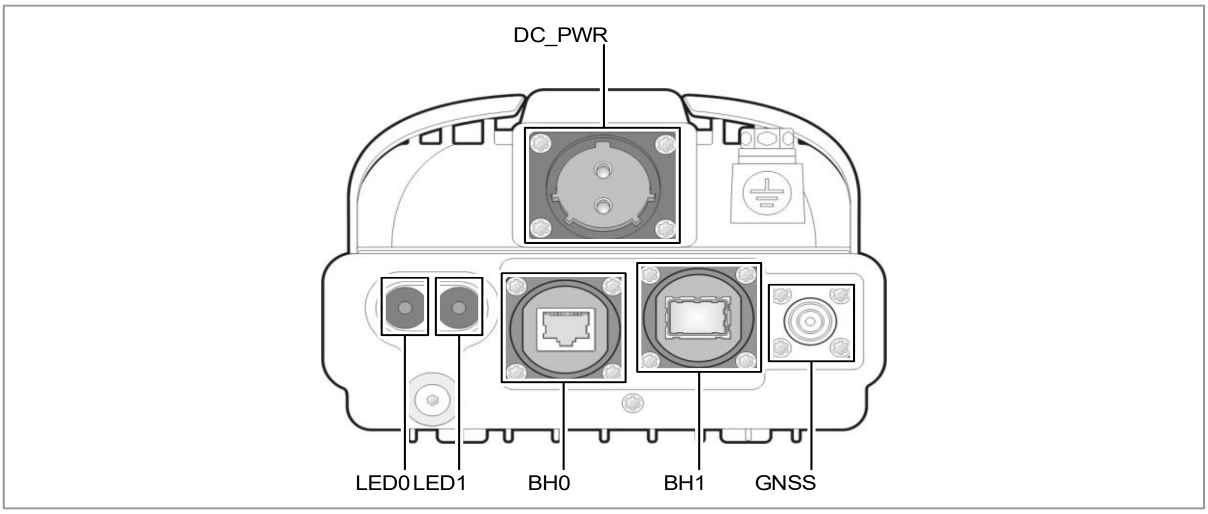
DC/DC (L7UD)

The L7UD is a customized DC/DC converter.

External Interface

Figure below depicts an external interface of SOL230.

Figure 8. ***External Interface of SOL230***



LED 0 (WiFi)

Status		Description
●	Red ON	System Initialization
◐	Green Blinking (Fast)	In Service
◐◐	Green and Amber Alternating	Alarms which do not result in the system deactivating WiFi service
◐◐	Green and Red Alternating	Alarms which result in the system deactivating WiFi service
○	LED OFF	No power supply

Status	Description

The following shows blinking period for each LED.

- Fast: On 200 ms, Off 200 ms
- Alternating: On 500 ms per each color

LED 1 (LTE)

Status		Description
●	Red ON	System initialization
●	Amber ON	• Backhaul cable open detection in progress • Acquisition of local IP address • Authentication in progress
◐	Amber Blinking (Slower)	Authentication failure
◐	Amber Blinking (Triple)	GPS Acquisition in progress
◐	Amber Blinking (Fast)	Software Package download in progress
◐	Amber Blinking (Slow)	Software Package download failure
◐	Green Blinking (Fast)	In Service
◐◐	Green and Amber Alternating	Alarms which is not the deactivating LTE services
◐◐	Green and Red Alternating	Alarms which is the deactivating LTE services
◐◐	Amber and Red Alternating	CPLD Fusing in progress
◐	Red Blinking (Fast)	Alarm occurred when Ethernet port is not connected
◐	Red Blinking (Slow)	Alarm occurred when temperature is high
○	LED OFF	No power supply

The following shows blinking period for each LED.

- Fast: On 200 ms, Off 200 ms
- Slower: On 1 s, Off 3 s
- Slow: On 1 s, Off 1 s
- Alternating: On 500 ms per each color
- Triple: On 500 ms, OFF 500 ms, On 500 ms, Off 500 ms, On 500 ms, Off 2.5 s

Connector

Interface Name	Interface Type	Description
BH 0	1Port, Copper, GbE	A port for backhaul Ethernet interfacing
BH 1	1Port, Optic (SFP), GbE	A port for backhaul Ethernet interfacing

Chapter 4 Message Flow

Data Traffic Flow

LTE Data Traffic Flow

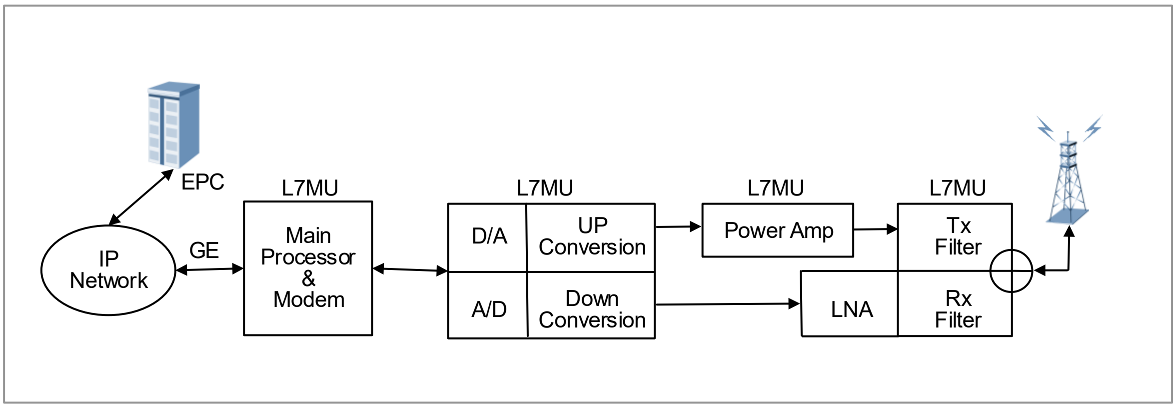
Sending Path

The user data received from the EPC passes through the IP network and is transmitted to the L7MU of SOL230. The transmitted user data goes through baseband-level digital processing (OFDMA), 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.

Receiving Path

The RF signal received by the antenna passes through the 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 L7MU. 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 9. ***SOL230 Traffic Flow (LTE)***



WiFi Data Traffic Flow

Sending Path

The signal received from the external network is transmitted to the WiFi CPU. It is transmitted to 2.4 GHz or 5 GHz Baseband chipset based on receiver's subscriber information. In case of 2.4 GHz sending signal, the signal goes through SAW filter and it is amplified in power amplifier part. Then the converted signal is then transmitted to the antenna after going through SPDT switch, 2.4 GHz LPF and

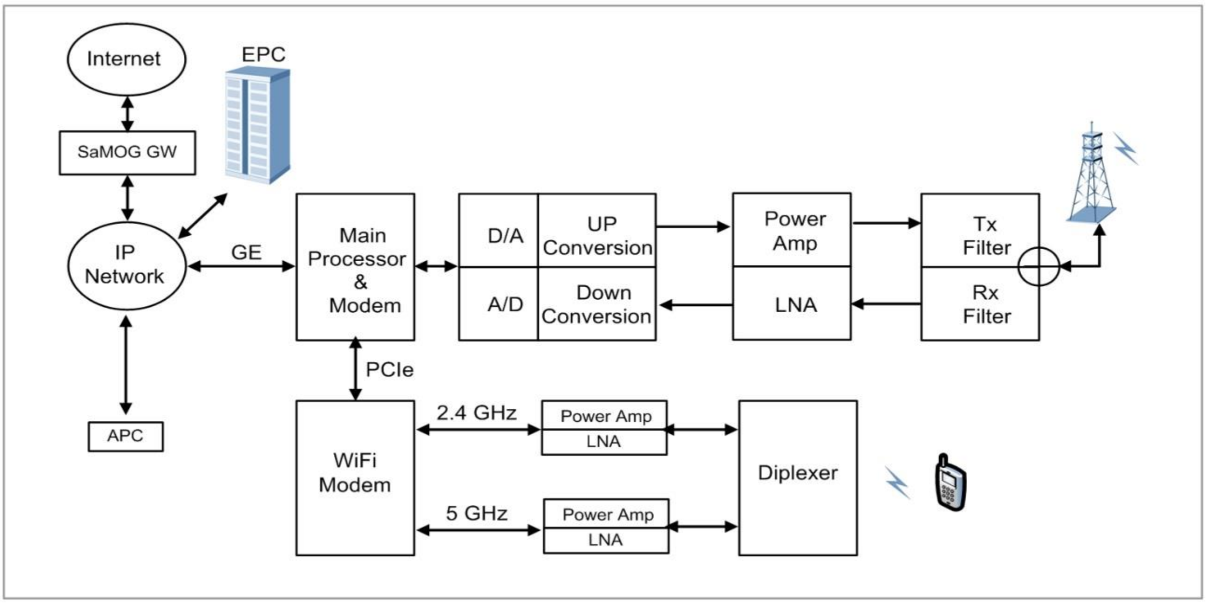
Diplexer. In case of 5 GHz sending signal, the signal goes through Notch Filter and it is amplified in power amplifier. The converted signal is then transmitted to the antenna after going through 5 GHz LPF, SPDT switch and Diplexer.

Receiving Path

The RF signal received from the antenna is transmitted to 5 GHz or 2.4 GHz receiving part through Diplexer. In case of 2.4 GHz receiving signal, the signal goes through LPF, SPDT RF switch and BPF, then it is transmitted to Baseband chipset after it is amplified in 2.4 GHz LNA part. In case of 5 GHz receiving signal, the signal goes through SPDT RF switch and Notch Filter, then it is transmitted Baseband chipset after it is amplified in 5 GHz LNA part.

The data received in Baseband chipset is demodulated and is transmitted to CPU. It is then transmitted through the Ethernet transceiver and the main processor.

Figure 10. ***SOL230 Traffic Flow (WiFi)***



Alarm Signal Flow

An alarm is reported as an alarm signal when an environmental fault occurs. The L7MU collects all the alarms and report them to the SmallCell EMS which is the management system.

Figure 11. ***SOL230 Alarm Flow (LTE)***

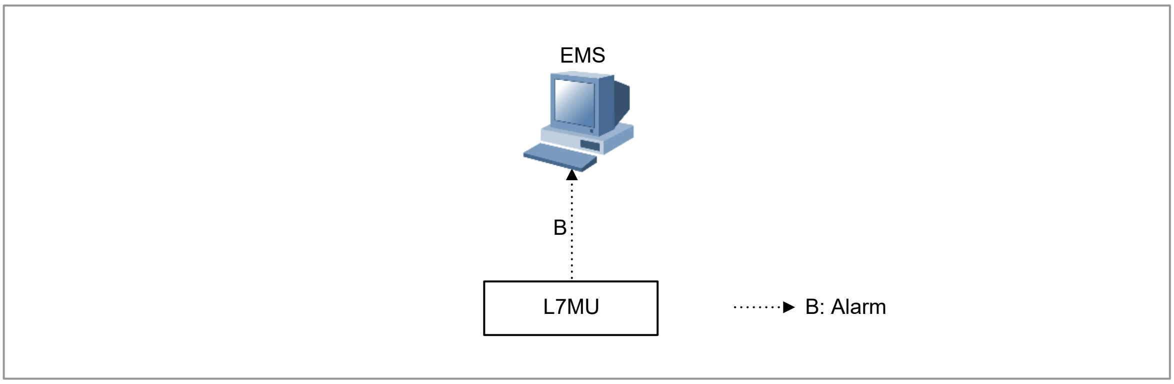
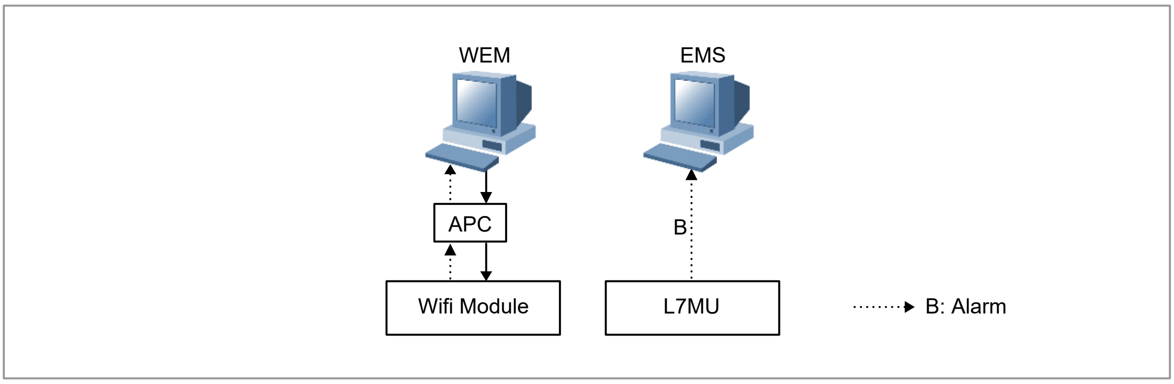


Figure 12. ***SOL230 Alarm Flow (WiFi)***

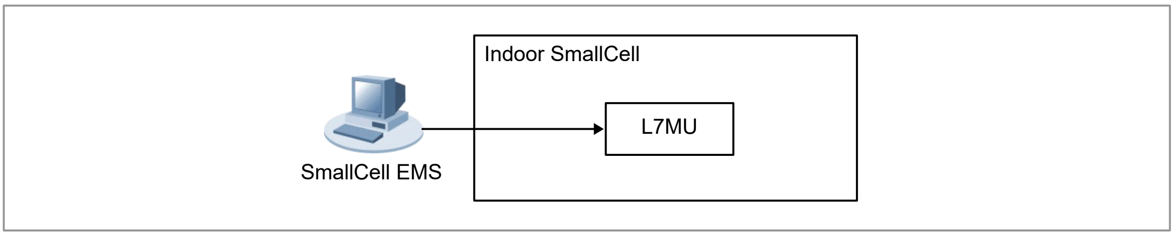


Loading Flow

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

At the first system initialization, the loading information is stored in the internal storage so that no unnecessary loading is carried out. When it is indicated to change software from the SmallCell EMS, a new file is downloaded from the SmallCell EMS.

Figure 13. ***Loading Signal Flow***



Operation and Maintenance Message Flow

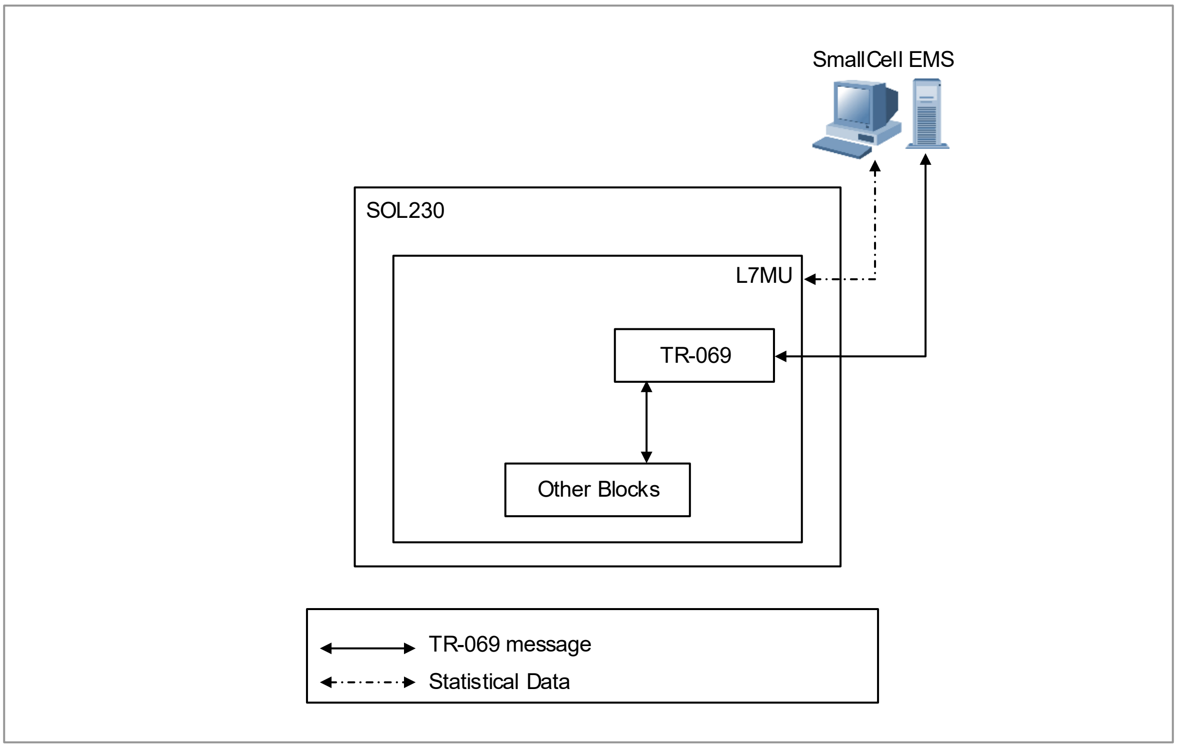
The operator can check and change the status of the SOL230 through the management system.

To do this, the SOL230 provides the TR-069 protocol interworking function, and the SmallCell EMS operator can carry out the operation and maintenance functions of the SOL230 remotely. Moreover, the operator can carry out the maintenance function using the web browser.

The statistical information provided by the SOL230 is given to the operator in accordance with the collection interval.

Figure below depicts the operation and maintenance signal flow.

Figure 14. ***Operation and Maintenance Message Flow***



■

Appendix Acronyms

3GPP	3rd Generation Partnership Project
64 QAM	64 Quadrature Amplitude Modulation
AC	Admission Control
ADC	Analog to Digital Converter
AM	Acknowledged Mode
AMBR	Aggregated Maximum Bit Rate
ANR	Automatic Neighbor Relation
ARQ	Automatic Repeat Request
AS	Access Stratum
BGP	Border Gateway Protocol
CC	Chase Combining
CLI	Command Line Interface
CPLD	Complex Programmable Logic Device
CS	Circuit Service
DAC	Digital to Analog Converter
DBMS	Database Management System
DFT	Discrete Fourier Transform
DiffServ	Differentiated Services
DL	Downlink
DSCP	Differentiated Services Code Point
DSP	Digital Signal Processor
EMS	Element Management System
eNB	evolved UTRAN Node-B
EPC	Evolved Packet Core
E-UTRAN	Evolved UTRAN
FTP	File Transfer Protocol
GBR	Guaranteed Bit Rate
GE	Gigabit Ethernet
GPRS	General Packet Radio Service
GPS	Global Positioning System
GTP	GPRS Tunneling Protocol
GW	Gateway
HARQ	Hybrid Automatic Repeat Request
HO	Handover
HSS	Home Subscriber Server
HTTP	Hyper Text Transfer Protocol
IDFT	Inverse Discrete Fourier Transform
IP	Internet Protocol
IR	Incremental Redundancy
L7MU	LTE 7 baseband and transceiver Integrated board

	Assembly
LNA	Low Noise Amplifier
LTE	Long Term Evolution
MAC	Media Access Control
MBR	Maximum Bit Rate
MCS	Modulation Coding Scheme
MIB	Master Information Block
MIMO	Multiple-Input Multiple-Output
MME	Mobility Management Entity
NAS	Non-Access Stratum
NE	Network Element
NMS	Network Management System
NR	Neighbor Relation
NRT	Neighbor Relation Table
OAM	Operation and Maintenance
OFDMA	Orthogonal Frequency Division Multiple Access
OSPF	Open Shortest Path First
PAPR	Peak-to-Average Power Ratio
PCI	Physical Cell Identity
PCRF	Policy and Charging Rule Function
PDCP	Packet Data Convergence Protocol
PDN	Packet Data Network
PDU	Protocol Data Unit
P-GW	PDN Gateway
PLER	Packet Loss Error Rate
PMI	Precoding Matrix Indicator
PMIP	Proxy Mobile IP
PnP	Plug and Play
PRB	Physical Resource Block
PSS	Primary Synchronization Signal
QCI	QoS Class Identifier
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RACH	Random Access Channel
RB	Radio Bearer
RB	Resource Block
RF	Radio Frequency
RLC	Radio Link Control
S1-AP	S1 Application Protocol
SC	Single Carrier
SC-FDMA	Single Carrier Frequency Division Multiple Access
SCTP	Stream Control Transmission Protocol
SDU	Service Data Unit
SFBC	Space Frequency Block Coding

S-GW	Serving Gateway
SIBs	System Information Blocks
SM	Spatial Multiplexing
SMS	Short Message Service
SON	Self Organizing Network
SSH	Secure Shell
SSS	Secondary Synchronization Signal
STBC	Space Time Block Coding
SU	Single User
TA	Tracking Area
UE	User Equipment
UL	Uplink
UTRAN	UMTS Terrestrial Radio Access Network