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Architecture and topology of IMT networks

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REPORT ITU-R M.2375-0

Architecture and topology of IMT networks

(2015)

1 Introduction

As traffic demand for mobile broadband communications represented by International Mobile Telecommunications (IMT), including both IMT-2000 and IMT-Advanced as defined in Resolution ITU-R 56 are increasing, the transport network in the mobile infrastructure is becoming an important application that requires special consideration.

The transport network supports the connections between one and the other of separated radio transceiver functions within one base station, between different base stations of the mobile broadband network, as well as the connections of one base station to other network elements of the mobile infrastructure.

This Report offers an overview of the architecture and topology of IMT networks and a perspective on the dimensioning of the respective transport requirements in these topologies, in order to assist relevant studies on the transport network in the mobile infrastructure. This Report covers different architectural aspects in a general level of detail.

2 Scope

This Report describes an overview of the architecture, topology/configuration, and transport requirements of IMT networks.

3 Related documents and References**3.1 Related ITU Documents**

Recommendation ITU-R M.1457	Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.2012	Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced)
Report ITU-R F.2060	Fixed service use in the IMT-2000 transport network
Recommendation ITU-T Q.1741.8	IMT-2000 references to Release 10 of GSM-evolved UMTS core network
Recommendation ITU-T Q.1742.11	IMT 2000 references (approved as of 31 December 2012) to ANSI-41 evolved core network with cdma2000 access network

3.2 References

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- [15] 3GPP2 A.S0017-D “Interoperability Specification (IOS) for cdma2000 Access Network Interfaces – Part 7 (A10 and A11 Interfaces)”, August 2012.
- [16] 3GPP2 C.S0001-F “Introduction to cdma2000 Spread Spectrum Systems”, May 2014.
- [17] 3GPP2 C.S0002-F “Physical Layer Standard for cdma2000 Spread Spectrum Systems”, May 2014.
- [18] 3GPP2 C.S0003-F “Medium Access Control (MAC) Standard for cdma2000 Spread Spectrum Systems”, May 2014.
- [19] 3GPP2 C.S0004-F “Signalling Link Access Control (LAC) Standard for cdma2000 Spread Spectrum Systems”, May 2014.
- [20] 3GPP2 C.S0005-F “Upper Layer (Layer 3) Signalling Standard for cdma2000 Spread Spectrum Systems”, May 2014.
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- [26] 3GPP2 C.S0087-A “E-UTRAN – cdma2000 HRPD Connectivity and Interworking Air Interface Specification”, January 2014.
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4 Basic elements of an IMT system based on 3GPP technical specifications

Introduction to evolved packet system (EPS)

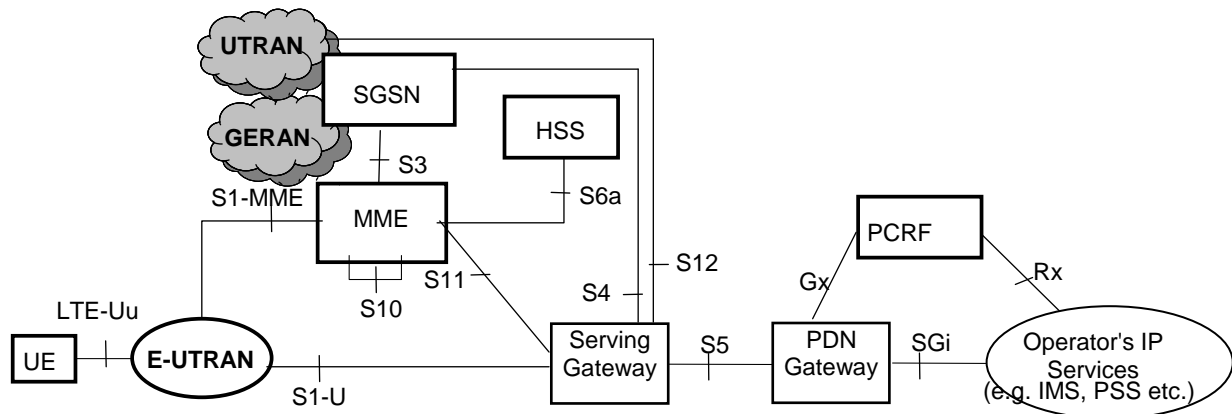
This section describes the basic elements and logical architecture of the evolved packet system (EPS) defined in 3GPP TS 23.401 [1].

The Evolved 3GPP Packet Switched Domain provides IP connectivity and comprises of the evolved packet core (EPC) and the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) defined in 3GPP TS 36.300 [2].

The Universal Terrestrial Radio Access Network (UTRAN) defined in 3GPP TS 25.401 [3] and details of the possible Core Network topologies for UTRAN can be found in Figs 2 and 2a in 3GPP TS 23.060 [4].

It must be noted that 3GPP defines a logical architecture of the network – the physical network topology is not in the scope of 3GPP and may be different in different network deployments.

FIGURE 1
Non-roaming architecture for 3GPP accesses



4.1 Core Network – EPC

The EPC comprises several network elements which are listed in the following paragraph with a brief summary of their functions.

4.1.1 MME

MME (mobility management entity) functions include:

- Non-access stratum (NAS) signalling;
- NAS signalling security;
- Inter CN node signalling for mobility between 3GPP access networks (terminating S3);
- UE reachability in ECM-IDLE state (including control and execution of paging retransmission);
- Tracking area list management;
- Mapping from UE location (e.g. TAI) to time zone, and signalling a UE time zone change associated with mobility;
- PDN GW and Serving GW selection;
- MME selection for handovers with MME change;
- Serving GPRS support node (SGSN) selection for handovers to 2G or 3G 3GPP access networks;
- Roaming (S6a towards home subscriber server (HSS));
- Authentication;
- Authorization;
- Bearer management functions including dedicated bearer establishment;
- Lawful interception of signalling traffic;
- Warning message transfer function (including selection of appropriate eNodeB);
- UE reachability procedures;
- Support relaying function (RN attach/detach).

NOTE – The Serving GW (S-GW) and the MME may be implemented in one physical node or separated physical nodes.

4.1.2 Gateway

4.1.2.1 General

Two logical Gateways exist – the S-GW and the PDN GW (P-GW). They may be implemented in one physical node or separated physical nodes.

4.1.2.2 Serving GW

The Serving GW is the gateway which terminates the interface towards E-UTRAN. For each UE associated with the EPS, at a given point of time, there is a single S-GW.

The functions of the S-GW, for both the GTP-based and the PMIP-based S5/S8, include:

- the local mobility anchor point for inter-eNodeB handover;
- sending of one or more "end marker" to the source eNodeB, source SGSN or source radio network controller (RNC) immediately after switching the path during inter-eNodeB and inter-RAT handover, especially to assist the reordering function in eNodeB;
- mobility anchoring for inter-3GPP mobility (terminating S4 and relaying the traffic between 2G/3G system and P-GW);
- ECM-IDLE mode downlink packet buffering and initiation of network triggered service request procedure;
- lawful interception;
- packet routing and forwarding;
- transport level packet marking in the uplink and the downlink, e.g. setting the DiffServ code point, based on the quality-of-service (QoS) class identifier (QCI) of the associated EPS bearer;
- accounting for inter-operator charging. For GPRS tunnelling protocol (GTP)-based S5/S8, the S-GW generates accounting data per UE and bearer;
- interfacing off-line charging system (OFCS) according to charging principles and through reference points specified in 3GPP TS 32.240.

Additional S-GW functions for the proxy mobile IP (PMIP)-based S5/S8 are captured in 3GPP TS 23.402 [5].

Connectivity to a gateway GPRS support node (GGSN) is not supported.

4.1.2.3 PDN GW

The PDN GW is the gateway which terminates the SGi interface towards the PDN. If a UE is accessing multiple PDNs, there may be more than one P-GW for that UE, however a mix of S5/S8 connectivity and G_n/G_p connectivity is not supported for that UE simultaneously.

P-GW functions include for both the GTP-based and the PMIP-based S5/S8:

- per-user based packet filtering (by e.g. deep packet inspection);
- lawful interception;
- UE IP address allocation;
- transport level packet marking in the uplink and downlink, e.g. setting the DiffServ code point, based on the QCI of the associated EPS bearer;
- accounting for inter-operator charging;
- UL and DL service level charging as defined in 3GPP TS 23.203 (e.g. based on service data flows (SDFs) defined by the PCRF, or based on deep packet inspection defined by local policy);

- interfacing OFCS through according to charging principles and through reference points specified in 3GPP TS 32.240;
- UL and DL service level gating control as defined in 3GPP TS 23.203;
- UL and DL service level rate enforcement as defined in 3GPP TS 23.203 (e.g. by rate policing/shaping per SDF);
- UL and DL rate enforcement based on access point name – aggregate maximum bit rate (APN-AMBR) (e.g. by rate policing/shaping per aggregate of traffic of all SDFs of the same APN that are associated with non-guaranteed bit rates (GBR QCI)s);
- DL rate enforcement based on the accumulated maximum bit rates (MBRs) of the aggregate of SDFs with the same GBR QCI (e.g. by rate policing/shaping);
- DHCPv4 (server and client) and DHCPv6 (client and server) functions;
- the network does not support PPP bearer type in this version of the specification. Pre-Release 8 PPP functionality of a GGSN may be implemented in the P-GW;
- packet screening.

Additionally the P-GW includes the following functions for the GTP-based S5/S8:

- UL and DL bearer binding as defined in 3GPP TS 23.203;
- UL bearer binding verification as defined in 3GPP TS 23.203;
- functionality as defined in IETF RFC 4861;
- accounting per UE and bearer.

The P-GW provides PDN connectivity to both GERAN/UTRAN only UEs and E-UTRAN capable UEs using any of E-UTRAN, GERAN or UTRAN. The P-GW provides PDN connectivity to E-UTRAN capable UEs using E-UTRAN only over the S5/S8 interface.

4.1.3 SGSN

In addition to the functions described in 3GPP TS 23.060 [4], SGSN functions include:

- inter EPC node signalling for mobility between 2G/3G and E-UTRAN 3GPP access networks;
- P-GW and S-GW selection: the selection of S-GW/P-GW by the SGSN is as specified for the MME;
- handling UE time zone as specified for the MME;
- MME selection for handovers to E-UTRAN 3GPP access network.

4.1.4 Policy and charging rule function

The policy and charging rule function (PCRF) is the policy and charging control element. PCRF functions are described in more detail in 3GPP TS 23.203. In non-roaming scenario, there is only a single PCRF in the HPLMN associated with one UE's IP-CAN session. The PCRF terminates the Rx interface and the Gx interface.

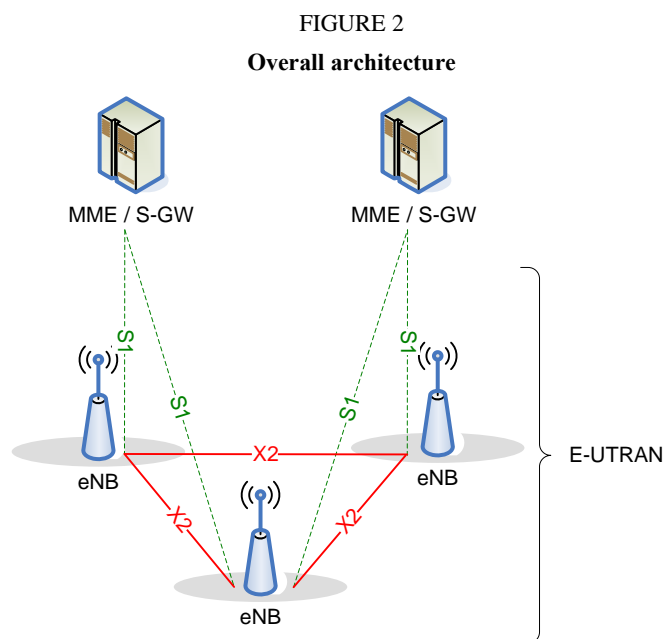
4.2 Access Network

4.2.1 Access Network – E-UTRAN

The Evolved Universal Terrestrial Radio Access Network (E-UTRAN) defined in 3GPP TS 36.300 [2] consists of eNodeBs, providing the E-UTRA user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNodeBs are interconnected with each other by means of the X2 interface. The eNodeBs are also connected by means of the S1 interface to the

EPC, more specifically to the MME by means of the S1-MME interface and to the S-GW by means of the S1-U interface. The S1 interface supports a many-to-many relation between MMEs/S-GW and eNodeBs.

The E-UTRAN architecture is illustrated in Fig. 2 below.



The eNodeB hosts the following functions:

- functions for radio resource management: radio bearer control, radio admission control, connection mobility control, dynamic allocation of resources to UEs in both uplink and downlink (scheduling);
- IP header compression and encryption of user data stream;
- selection of an MME at UE attachment when no routing to an MME can be determined from the information provided by the UE;
- routing of user plane data towards S-GW;
- scheduling and transmission of paging messages (originated from the MME);
- scheduling and transmission of broadcast information (originated from the MME or O&M);
- measurement and measurement reporting configuration for mobility and scheduling;
- scheduling and transmission of PWS (which includes ETWS and CMAS) messages (originated from the MME);
- closed subscriber group (CSG) handling;
- transport level packet marking in the uplink.

A stage-2 level description of the E-UTRAN can be found in 3GPP TS 36.300 [2].

4.2.2 Access Network – UTRAN

The Universal Terrestrial Radio Access Network (UTRAN) defined in 3GPP TS 25.401 [3] consists of a set of Radio Network Subsystems (RNS) connected to the Core Network through the I_u interface. An RNS consists of a Radio Network Controller (RNC) and one or more NodeBs connected to the RNC through the I_{ub} interface.

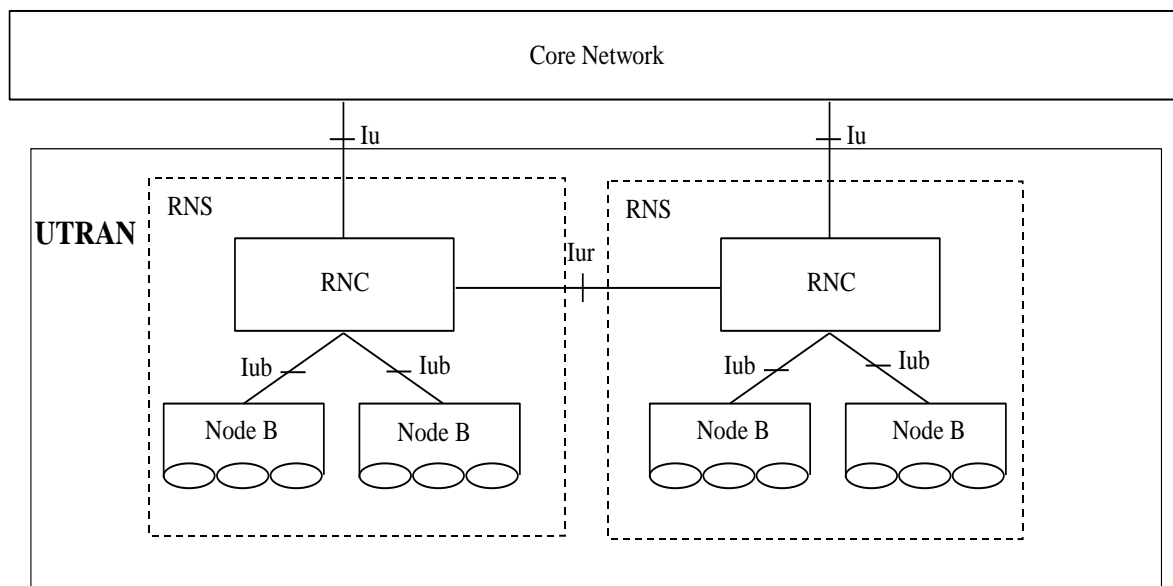
A Node B can support FDD mode, TDD mode or dual-mode operation.

Inside the UTRAN, the RNCs of the Radio Network Subsystems can be interconnected together through the I_{ur} . $I_u(s)$ and I_{ur} are logical interfaces. I_{ur} can be conveyed over direct physical connection between RNCs or virtual networks using any suitable transport network.

The UTRAN architecture is shown in Fig. 3.

Details of the possible Core Network topologies for UTRAN can be found in Figs 2 and 2a in 3GPP TS 23.060 [4].

FIGURE 3
UTRAN architecture



5 Basic elements of an IMT system based on 3GPP2 technical specifications

5.1 Core Network elements

5.1.1 cdma2000^{®1} Core Network

The following is abstracted from 3GPP2 S.R0005-B v2.0 [40].

5.1.1.1 Wireless Network reference model

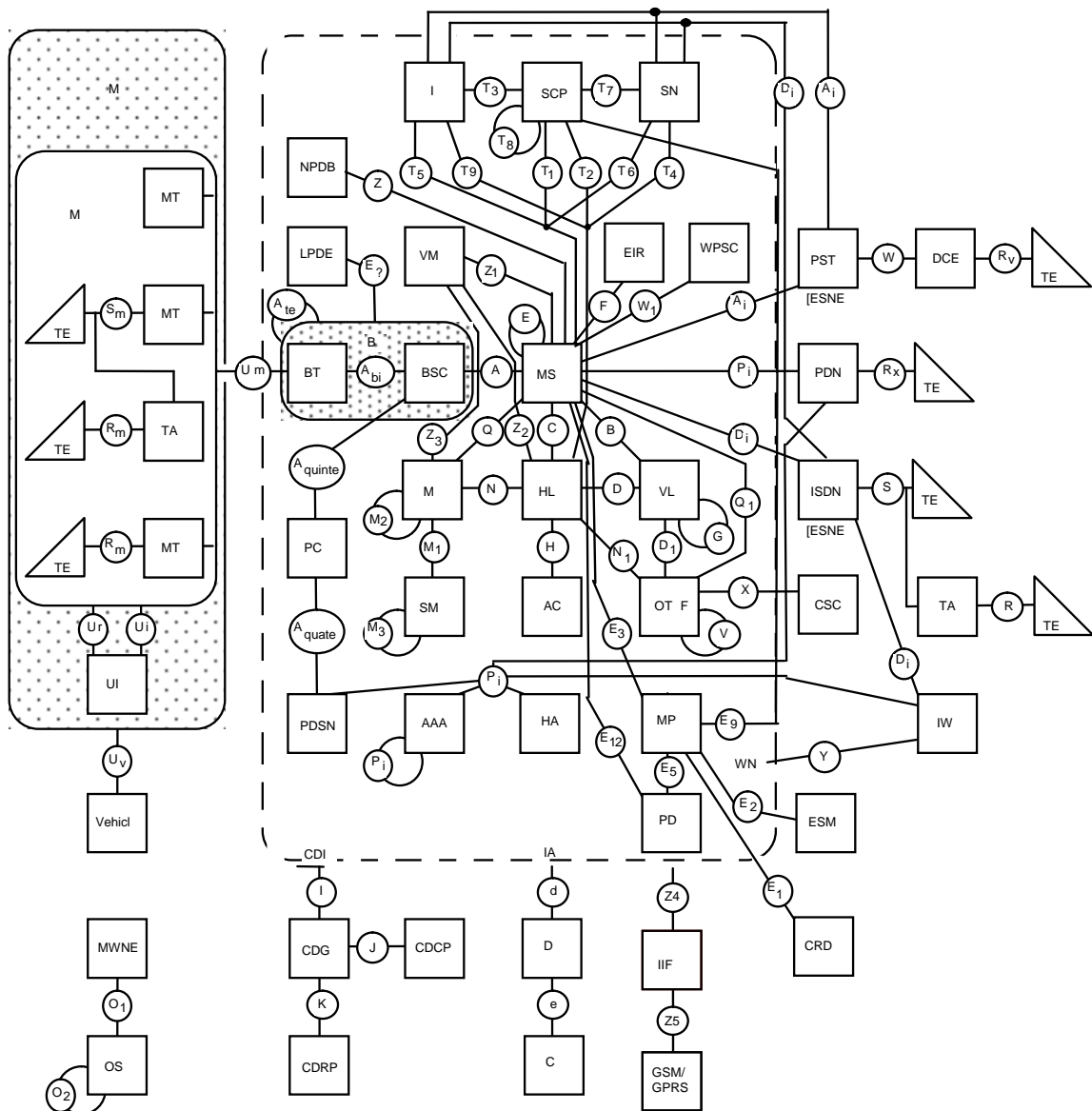
Figure 4 presents the network entities and associated reference points that comprise a wireless network. The network entities are represented by squares, triangles and rounded corner rectangles; the reference points are represented by circles. The network reference model in this Report is the compilation of several reference models currently in use in wireless standards.

¹ cdma2000[®] is the trademark for the technical nomenclature for certain specifications and standards of the organizational partners (OPs) of 3GPP2. Geographically (and as of the date of publication), cdma2000[®] is a registered trademark of the Telecommunications Industry Association (TIA-USA) in the United States of America.

Note the following:

- The network reference model is a functional block diagram.
- A network entity represents a group of functions, not a physical device. For example, a mobile switching center (MSC) is a physical device; it comprises frames, shelves, circuit packs, etc. The physical device may comprise a single network entity such as the MSC, or it may comprise some combination such as the MSC, the visitor location register (VLR), the home location register (HLR), and the authentication center (AC). The physical realization is an implementation issue; a manufacturer may choose any physical implementation of network entities, either individually or in combination, as long as the implementation meets the functional requirements. Sometimes, for practical reasons, the functional network entity is a physical device. The mobile station (MS) is an excellent example.
- A reference point is a conceptual point that divides two groups of functions. It is not necessarily a physical interface. A reference point only becomes a physical interface when the network entities on either side of it are contained in different physical devices.
- A “Collective Entity” contains encompassed network entities that are an instance of the collective.
- A “Composite Entity” contains encompassed network entities that are part of the composite.

FIGURE 4
Wireless network reference model in 3GPP2



Key

		Specific Network		Collective		Interface to Another Instance of Same Network
		Composite		Interface Reference Point		Line Intersection

AAA	Authentication, Authorization and Accounting	MC	Message Center
AC	Authentication Center	ME	Mobile Equipment
BS	Base Station	MPC	Mobile Position Center
BSC	Base Station Controller	MS	Mobile Station
BTS	Base Transceiver System	MSC	Mobile Switching Center
CDCP	Call Data Collection Point	MT	Mobile Terminal
CDGP	Call Data Generation Point	MWN	Managed Wireless Network Entity
CDIS	Call Data Information Source	NPDB	Number Portability DataBase
CDRP	Call Data Rating Point	OSF	Operations System Function
CF	Collection Function	OTAF	Over-The-Air Service Provisioning Function
CRDB	Coordinate Routing Data Base	PCF	Packet Control Function
CSC	Customer Service Center	PDE	Position Determining Entity
DCE	Data Circuit Equipment	PDN	Packet Data Network
DF	Delivery Function	PDSN	Packet Data Serving Node
EIR	Equipment Identity Register	PSTN	Public Switched Telephone Network
ESME	Emergency Services Message Entity	SCP	Service Control Point
ESNE	Emergency Services Network Entity	SN	Service Node
HA	Home Agent	SME	Short Message Entity
HLR	Home Location Register	TA	Terminal Adapter
IAP	Intercept Access Point	TE	Terminal Equipment
IIF	Interworking and Interoperability Function	UIM	User Identity Module
IP	Intelligent Peripheral	VLR	Visitor Location Register
ISDN	Integrated Services Digital Network	VMS	Voice Message System
IWF	Interworking Function	WNE	Wireless Network Entity
LPDE	Local Position Determining Entity	WPSC	Wireless Priority Service Center
LNS	L2TP Network Server		

5.1.1.2 Network entities

Each network entity may be a physical device, may form part of a physical device, or may be distributed over a number of physical devices. See § 5.1.1.3 for the definition of the reference points associated with each network entity.

Authentication, authorization and accounting (AAA)

The AAA is an entity that provides Internet Protocol functionality to support the functions of authentication, authorization and accounting.

Authentication center (AC)

The AC is an entity that manages the authentication information related to the MS. The AC may, or may not be located within, and be indistinguishable from an HLR. An AC may serve more than one HLR.

Base station (BS)

A BS is an entity that provides the means for MSs to access network services using radio. It includes a BSC and a BTS.

Base station controller (BSC)

The BSC is an entity that provides control and management for one or more BTSs. The BSC exchanges messages with both the BTS and the MSC. Traffic and signalling concerned with call control, mobility management, and MS management may pass transparently through the BSC.

Base transceiver system (BTS)

The BTS is an entity that provides transmission capabilities across the U_m reference point. The BTS consists of radio devices, antenna and equipment.

Call data collection point (CDCP)

The CDCP is the entity that collects the Data Message Handler (DMH) format call detail information as defined in 3GPP2 X.S0014-E [29].

Call data generation point (CDGP)

The CDGP is an entity which provides call detail information to the CDCP in DMH format as defined in 3GPP2 X.S0014-E [29]. This may be the entity which converts call detail information from a proprietary format into the DMH format. All information from the CDGP to the CDCP should be in DMH format.

Call data information source (CDIS)

The CDIS is an entity that can be the source of call detail information as defined in 3GPP2 X.S0014-E [29]. This information may be in proprietary format. It is not required to be in DMH format.

Call data rating point (CDRP)

The CDRP is the entity that takes the unrated DMH format call detail information as defined in 3GPP2 X.S0014-E [29] and applies the applicable charge and tax related information. The charge and tax information is added using DMH format as defined in 3GPP2 X.S0014-E [29].

Collection function (CF) – [intercept]

The CF is an entity that is responsible for collecting intercepted communications for a lawfully authorized law enforcement agency.

The CFs typically include:

- the ability to receive and process call contents information for each intercept subject;
- the ability to receive information regarding each intercept subject (e.g. call associated or non-call associated) from the delivery function and process it.

Coordinate routing data base (CRDB)

The CRDB is an entity which stores information to translate a given position expressed as a latitude and longitude to a string of digits.

Customer service center (CSC)

The CSC is an entity where service provider representatives receive telephone calls from customers wishing to subscribe to initial wireless service or request a change in the customer's existing service. The CSC interfaces proprietarily with the over-the-air service provision function (OTAF) to perform network and MS related changes necessary to complete the service provisioning request.

Data circuit equipment (DCE)

A termination that provides a non-ISDN user-network interface.

Delivery function (DF) – [intercept]

The DF is an entity that is responsible for delivering intercepted communications to one or more collection functions.

The DFs typically include:

- the ability to accept call contents for each intercept subject over one or more channels from each Access function;
- the ability to deliver call contents for each intercept subject over one or more channels to a Collection function as authorized for each law enforcement agency;
- the ability to accept information over one or more data channels and combine that information into a single data flow for each intercept subject;
- the ability to filter or select information on an intercept subject before delivery to a Collection function as authorized for a particular law enforcement agency;
- the optional ability to detect audio in-band DTMF digits for translation and delivery to a Collection function as authorized for a particular law enforcement agency;
- the ability to duplicate and deliver information on the intercept subject to one or more Collection functions as authorized for each law enforcement agency;
- the ability to provide security to restrict access.

Emergency service message entity (ESME)

The ESME routes and processes the out-of-band messages related to emergency calls. This may be incorporated into selective routers (also known as Routing, Bridging and Transfer switches), public safety answering points, emergency response agencies, and automatic location information (ALI) data base engines. The structure of the emergency service network is beyond the scope of this Report.

Emergency service network entity (ESNE)

The ESNE routes and processes the voice band portions of the emergency calls. This is composed of selective routers (also known as Routing, Bridging and Transfer switches), public safety answering points and emergency response agencies.

Equipment identity register (EIR)

The EIR is an entity that is the register to which user equipment identity may be assigned for record purposes. The nature, purpose, and utilization of this information is an area for further study.

Global System for mobile communications (GSM) mobile application part (MAP)

The network supporting GSM and Wideband CDMA radio systems.

Home agent (HA)

The HA is an entity that:

- authenticates Mobile IP registrations from the MS.
- redirects packets to the foreign agent component of the PDSN, and optionally receives and routes reverse packets from the foreign agent component of the PDSN.
- may establish, maintain and terminate secure communications to the PDSN.
- receives provisioning information from the AAA Function for users.
- may assign a dynamic home IP address.

Home location register (HLR)

The HLR is the location register to which a user identity is assigned for record purposes such as subscriber information (e.g. electronic serial number (ESN), mobile directory number (MDN), profile information, current location, authorization period).

Integrated services digital network (ISDN)

The ISDN is defined in accordance with the appropriate ANSI Standards.

Intelligent peripheral (IP)

The IP is an entity that performs specialized resource functions such as playing announcements, collecting digits, performing speech-to-text or text-to-speech conversion, recording and storing voice messages, facsimile services, data services, etc.

Intercept access point (IAP)

The IAP is an entity that provides access to the communications to, or from, the equipment, facilities, or services of an intercept subject.

Interworking and interoperability function (IIF)

The network entity that interfaces between a GSM MAP network and a MAP network.

Interworking function (IWF)

The IWF is an entity that provides information conversion for one or more wireless network entity (WNEs). An IWF may have an interface to a single WNE providing conversion services. An IWF may augment an identified interface between two WNEs, providing conversion services to both WNEs.

L2TP network server (LNS)

LNS manages secure L2TP tunnels/sessions with the L2TP Access Concentrator and PPP sessions with the MS. It may authenticate the MS and assigns it an IP address.

Local position determining entity (LPDE)

The LPDE facilitates determination of the position or geographical location of a wireless terminal. Each LPDE supports one or more position determining technologies. Multiple LPDEs using the same technology may serve the coverage area of an mobile position center (MPC) and the multiple LPDEs each using a different technology may serve the same coverage area of an MPC. Local-PDEs (LPDEs) reside at the base station (BS).

Managed wireless network entity (MWNE)

A WNE or any specific network entity having operations system wireless management needs, including another operations system.

Message center (MC)

The MC is an entity that stores and forwards short messages. The MC may also provide supplementary services for short message service (SMS).

Mobile equipment (ME)

A MS without a UIM. The ME is only capable of accessing the network for a locally defined service configuration (e.g. emergency services, service center).

Mobile position center (MPC)

The MPC selects a PDE to determine the position of a mobile station. The MPC may restrict access to position information (e.g. require that the MS be engaged in an emergency call or only release position information to authorized network entities).

Mobile station (MS)

A wireless terminal used by subscribers to access network services over a radio interface. MSs include portable units (e.g. hand-held units), units installed in vehicles, and somewhat paradoxically, fixed location MSs. The MS is the interface equipment used to terminate the radio path at the subscriber. A MS is a ME with a programmed user identity module (UIM).

Mobile switching center (MSC)

The MSC switches circuit mode MS originated or MS terminated traffic. An MSC is usually connected to at least one BS. It may connect to the other public networks (PSTN, ISDN, etc.), other MSCs in the same network, or MSCs in different networks. The MSC may store information to support these capabilities.

Mobile terminal 0 (MT0)

A self-contained data capable ME termination that does not support an external interface.

Mobile terminal 1 (MT1)

A ME termination that provides an ISDN user-network interface.

Mobile terminal 2 (MT2)

A ME termination that provides a non-ISDN user-network interface.

Number portability DataBase (NPDB)

The NPDB is an entity which provides portability information for portable Directory Numbers.

Operations system function (OSF)

The OSF is defined by the telecommunications management network (TMN) OSF (see ITU M.3100). OSF functions include element management layer (EML), network management layer (NML), service management layer (SML), and business management layer (BML) functions spanning across all operations systems functions (e.g. fault management, performance management, configuration management, accounting management, and security management).

Over-the-air service provisioning function (OTAF)

The OTAF is an entity that interfaces proprietarily to CSCs to support service provisioning activities. The OTAF interfaces with the MSC to send MS orders necessary to complete service provisioning requests.

Packet control function (PCF)

The PCF is an entity in the radio access network that manages the relay of packets between the BS and the PDSN.

Packet data network (PDN)

A PDN, such as the Internet, provides a packet data transport mechanism between processing network entities capable of using such services.

Packet data serving node (PDSN)

The PDSN routes MS originated or MS terminated packet data traffic. The PDSN establishes, maintains, and terminates link layer sessions to MSs. The PDSN may interface to one or more BSs and may interface to one or more PDNs.

Position determining entity (PDE)

The PDE facilitates determination of the position or geographical location of a wireless terminal. Each PDE supports one or more position determining technologies. Multiple PDEs using the same technology may serve the coverage area of an mobile position center (MPC) and the multiple PDEs each using a different technology may serve the same coverage area of an MPC.

Public switched telephone network (PSTN)

The PSTN is defined in accordance with the appropriate ANSI Standards.

Service control point (SCP)

The SCP is an entity that acts as a real-time database and transaction processing system that provides service control and service data functionality.

Service node (SN)

The SN is an entity that provides service control, service data, specialized resources and call control functions to support bearer-related services.

Short message entity (SME)

The SME is an entity that composes and decomposes short messages. A SME may, or may not be located within, and be indistinguishable from, an HLR, MC, VLR, MS, or MSC.

Terminal adapter (TA)

An entity that converts signalling and user data between a non-ISDN and an ISDN interface.

Terminal adapter m (TAm)

An entity that converts signalling and user data between a non-ISDN and an ISDN interface.

Terminal equipment 1 (TE1)

A data terminal that provides an ISDN user-network interface.

Terminal equipment 2 (TE2)

A data terminal that provides a non-ISDN user-network interface.

User identity module (UIM)

The UIM contains subscription information such as the NAM (number assignment module) and may contain subscription feature information. The UIM may be integrated into the ME or the UIM may be removable.

Vehicle

The Vehicle is an entity in which the ME may be installed. The Vehicle may provide power, audio, antenna connections to the ME along with a control and user data gateway to vehicle based data networks.

Visitor location register (VLR)

The VLR is the location register other than the HLR used by an MSC to retrieve information for handling of calls to or from a visiting subscriber. The VLR may, or may not be located within, and be indistinguishable from an MSC. The VLR may serve more than one MSC.

Voice message system (VMS)

The VMS stores received voice messages, data messages (e.g. email), or both message types and supports a method to retrieve previously stored messages. A VMS may also support (on a directory number basis) notification of the presence of stored messages and notification of a change in the number of voice messages, data messages, or both message types that are waiting retrieval.

Wireless network entity (WNE)

A network entity in the wireless collective entity.

Wireless priority service center (WPSC)

The WPSC is an entity that stores and facilitates the management of the WPS priority level information for the WPS Users. The WPSC authorizes the WPS User and provides the priority level information for a WPS User call origination upon request from an MSC. The WPSC serves multiple MSCs. The WPSC is only applicable to the WPSC-based solution for WPS.

5.1.1.3 Reference points

The U_m reference point is the only reference point that is by definition a physical interface. The other reference points are physical interfaces if network entities on either side of them are contained in different physical devices.

An interface exists when two network entities are interconnected through exactly one reference point.

Reference point A

Reference point A is the interface between the BSC and the MSC. See 3GPP2 A.S0011-D [9] through 3GPP2 A.S0017-D [15].

Reference point A_i

Reference point A_i is the interface between the IP and the PSTN, plus the interface between the MSC and the PSTN [ESNE], plus the interface between the SN and the PSTN.

Reference point A_{bis}

Reference point A_{bis} is the interface between the BSC and the BTS.

Reference point A_{quater}

Reference point A_{quater} is the interface between the PDSN and the PCF. See 3GPP2 A.S0011-D [9] through 3GPP2 A.S0017-D [15].

Reference point A_{quinter}

Reference point A_{quinter} is the interface between the BSC and the PCF. See 3GPP2 A.S0011-D [9] through 3GPP2 A.S0017-D [15].

Reference point A_{ter}

Reference point A_{ter} is the BS to BS interface. See 3GPP2 A.S0011-D [9] through 3GPP2 A.S0017-D [15].

Reference point B

Reference point B is the interface between the MSC and the VLR. See 3GPP2 X.S0004-E [27].

Reference point C

Reference point C is the interface between the MSC and the HLR. See 3GPP2 X.S0004-E [27].

Reference point D

Reference point D is the interface between the VLR and the HLR. See 3GPP2 X.S0004-E [27].

Reference point d

Reference point d is the interface between an IAP and the DF.

Reference point D

Reference point D₁ is the interface between the OTAF and the VLR. See 3GPP2 X.S0004-E [27].

Reference point D_i

Reference point D_i is the interface between:

- the IP and the ISDN,
- the IWF and the ISDN,
- the MSC and the ISDN [ESNE], plus
- the SN and the ISDN.

Reference point E

Reference point E is the interface between the MSC and the MSC. See 3GPP2 X.S0004-E [27].

Reference point E₂

Reference point E₂ is the interface between the MPC and the ESME.

Reference point E₃

Reference point E₃ is the interface between the MSC and the MPC.

Reference point E₅

Reference point E₅ is the interface between the MPC and the PDE.

Reference point E₉

Reference point E₉ is the interface between the SCP and the MPC. See 3GPP2 X.S0004-E [27].

Reference point E₁₁

Reference point E₁₁ is the interface between the CRDB and the MPC.

Reference point E₁₂

Reference point E₁₂ is the interface between the MSC and the PDE.

Reference point E?

Reference point E? is the interface between the BS and the Local-PDE (LPDE).

Reference point e

Reference point e is the interface between the CF and the DF.

Reference point F

Reference point F is the interface between the MSC and the EIR.

Reference point G

Reference point G is the interface between the VLR and the VLR. See 3GPP2 X.S0004-E [27].

Reference point H

Reference point H is the interface between the HLR and the AC. See 3GPP2 X.S0004-E [27].

Reference point I

Reference point I is the interface between the CDIS and the CDGP. The operations supported by this interface are described in 3GPP2 X.S0014-E [29].

Reference point J

Reference point J is the interface between the CDGP and the CDCP. The operations supported by this interface are described in 3GPP2 X.S0014-E [29].

Reference point K

Reference point K is the interface between the CDGP and the CDRP. The operations supported by this interface are described in 3GPP2 X.S0014-E [29].

Reference point L

Reserved.

Reference point M₁

Reference point M₁ is the interface between the SME and the MC. See 3GPP2 X.S0004-E [27].

Reference point M₂

Reference point M₂ is the MC to MC interface. See 3GPP2 X.S0004-E [27].

Reference point M₃

Reference point M₃ is the SME to SME interface. See 3GPP2 X.S0004-E [27].

Reference point N

Reference point N is the interface between the HLR and the MC. See 3GPP2 X.S0004-E [27].

Reference point N₁

Reference point N₁ is the interface between the HLR and the OTAF. See 3GPP2 X.S0004-E [27].

Reference point O₁

Reference point O₁ is the interface between an MWNE and the OSF.

Reference point O₂

Reference point O₂ is the interface between an OSF and an another OSF.

Reference point P_i

Reference point P_i is the interface between:

- the AAA and the AAA,
- the AAA and the PDN,
- the IWF and the PDN,

- the MSC and the PDN, plus
- the PDSN and the PDN.

See 3GPP2 X.S0011-E [28].

Reference point Q

Reference point Q is the interface between the MC and the MSC. See 3GPP2 X.S0004-E [27].

Reference point Q₁

Reference point Q₁ is the interface between the MSC and the OTAF. See 3GPP2 X.S0004-E [27].

Reference point R

Reference point R is the interface between the TA and the TE2.

Reference point R_m

Reference point R_m is the interface between the TE2 and the TA_m plus the interface between the TE2 and the MT2.

Reference point R_v

Reference point R_v is the interface between the DCE and the TE2.

Reference point R_x

Reference point R_x is the interface between the PDN and the TE2.

Reference point S

Reference point S is the interface between the ISDN and the TE1.

Reference point S_m

Reference point S_m is the interface between the TE1 and the MT1 plus the interface between the TE1 and the TAM.

Reference point T₁

Reference point T₁ is the interface between the MSC and the SCP. See 3GPP2 X.S0004-E [27].

Reference point T₂

Reference point T₂ is the interface between the HLR and the SCP. See 3GPP2 X.S0004-E [27].

Reference point T₃

Reference point T₃ is the interface between the IP and the SCP. See 3GPP2 X.S0004-E [27].

Reference point T₄

Reference point T₄ is the interface between the HLR and the SN. See 3GPP2 X.S0004-E [27].

Reference point T₅

Reference point T₅ is the interface between the IP and the MSC. See 3GPP2 X.S0004-E [27].

Reference point T₆

Reference point T₆ is the interface between the MSC and the SN. See 3GPP2 X.S0004-E [27].

Reference point T₇

Reference point T₇ is the interface between the SCP and the SN. See 3GPP2 X.S0004-E [27].

Reference point T₈

Reference point T₈ is the interface between the SCP and the SCP. See 3GPP2 X.S0004-E [27].

Reference point T₉

Reference point T₉ is the interface between the HLR and the IP. See 3GPP2 X.S0004-E [27].

Reference point U_i

Reference point U_i is the interface between the integrated UIM and the ME.

Reference point U_m

Reference point U_m is the interface between the BS and the MS, which corresponds to the air interface.

Reference point U_r

Reference point U_r is the interface between the Removable-UIM and the ME. See CDMA_UIM and TDMA_UIM. See 3GPP2 C.S0023-D [22] and 3GPP2 C.S0065-B [25].

Reference point U_v

Reference point U_v is the interface between a the ME and the Vehicle.

Reference point V

Reference point V is the interface between the OTAF and the OTAF. See 3GPP2 X.S0004-E [27].

Reference point W

Reference point W is the interface between the DCE and the PSTN.

Reference point W₁

Reference point W₁ is the interface between the MSC and the WPSC.

Reference point X

Reference point X is the interface between the CSC and the OTAF. See 3GPP2 X.S0004-E [27].

Reference point Y

Reference point Y is the interface between a wireless network entity (WNE) and the IWF. See 3GPP2 A.S0011-D v5.0 [9] through 3GPP2 A.S0017-D v5.0 [15].

Reference point Z

Reference point Z is the interface between the MSC and the NPDB. See 3GPP2 X.S0004-E [27].

Reference point Z₁

Reference point Z₁ is the interface between the MSC and the VMS. See 3GPP2 X.S0004-E [27].

Reference point Z₂

Reference point Z₂ is the interface between the HLR and the VMS. See 3GPP2 X.S0004-E [27].

Reference point Z₃

Reference point Z₃ is the interface between the MC and the VMS. See 3GPP2 X.S0004-E [27].

Reference point Z₄

The interface between the MSC, HLR, MC, AAA, PDSN, etc. and the IIF.

Reference point Z₅

The interface between the GSM/GPRS networks and the IIF.

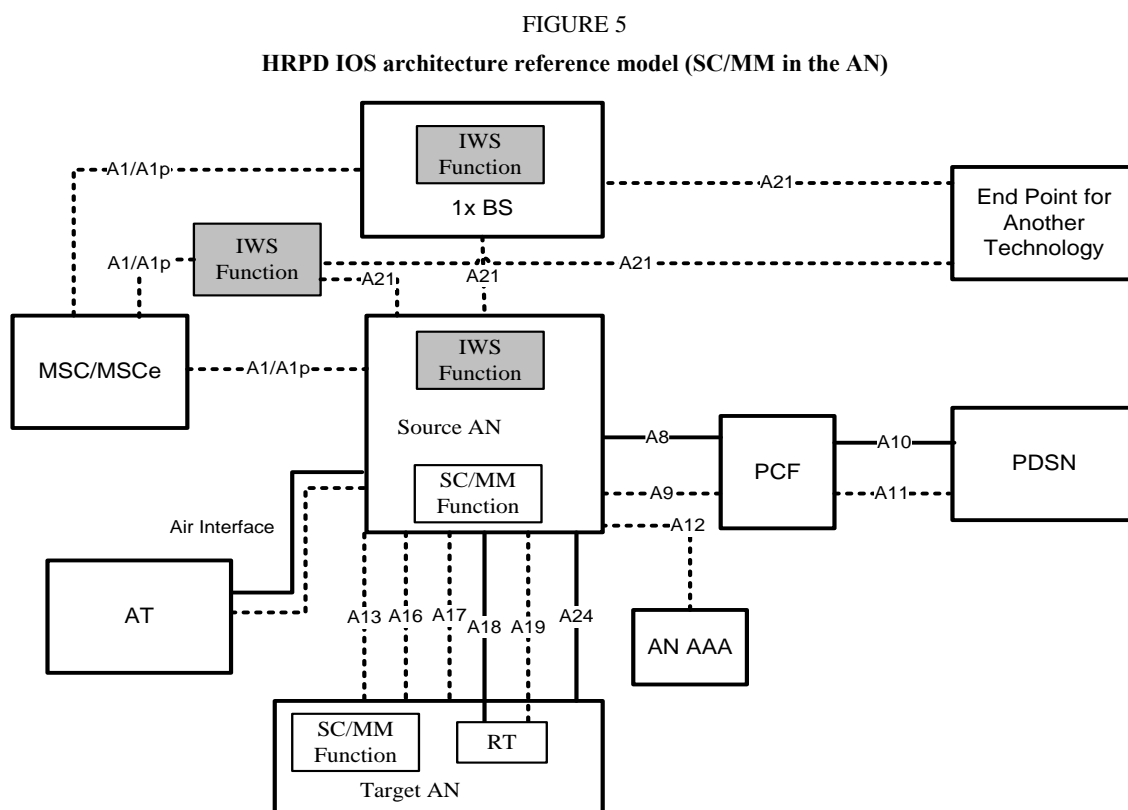
5.1.2 HRPD IOS architecture reference model

The following is extracted from 3GPP2 A.S0008-D [7].

The interfaces defined in this specification are described as follows:

- A1** The A1 interface carries signalling information between the call control and mobility management functions of the circuit-switched MSC and the IWS function.
- A1p** The A1p interface carries signalling information between the call control and mobility management functions of the MSCe and the IWS function. It is recommended that the A1p interface, instead of the A1 interface, be applied for interworking between the 1x and HRPD systems.
- A8** The A8 interface carries user traffic between the access network (AN) and the packet control function (PCF).
- A9** The A9 interface carries signalling information between the AN and the PCF.
- A10** The A10 interface carries user traffic between the PCF and the PDSN.
- A11** The A11 interface carries signalling information between the PCF and the PDSN.
- A12** The A12 interface carries signalling information related to access authentication between the SC/MM function in the AN and the AN-AAA (authentication, authorization and accounting entity).
- A13** The A13 interface carries signalling information between the SC/MM function in the source AN and the SC/MM function in the target AN for dormant state session transfer and inter-AN paging when the AT is in idle state.
- A16** The A16 interface carries signalling information between the source AN and the target AN for HRPD Inter-AN connected state session transfer (hard handoff or with cross-connectivity support).
- A17** The A17 interface carries signalling information between a source AN and a target AN to manage resources in support of inter-AN cross-connectivity (soft/softer handoff). The A17 interface establishes dedicated endpoints for the A18 and A19 interfaces. Additionally, the A17 interface tunnels air interface forward control channel signalling messages from the source AN to a target AN that has sectors in the AT's active set to be transmitted to the AT.
- A18** The A18 interface transports user traffic (i.e. air interface traffic channel data) for an AT between the source AN and a target radio transceiver (RT) during cross-connectivity. The A18 interface endpoints are set up using the A17 interface.
- A19** The A19 interface carries RT-specific bearer-related cross-connectivity control messages for an AT between the source AN and a target RT. The A19 interface endpoints are set up using the A17 interface.
- A21** The A21 interface carries signalling information between the HRPD AN and the IWS or between the end point for another technology and the IWS.
- A24** The A24 interface carries buffered user data from the source AN to the target AN for an AT, during A13 session transfer. The target AN interface endpoint is transmitted to the source AN in the A13-Session Information Request message.

The HRPD IOS messaging and call flows are based on the Architecture Reference Model shown in Fig. 5. In the Figure, solid lines indicate signalling and bearer and dashed lines indicate only signalling.



NOTE – The IWS Function may be collocated at either the 1x BS or may be a standalone entity. When providing support for HRPD interworking, the IWS may be collocated at the HRPD AN. When the IWS function is collocated at the 1x BS, the A21 interface is supported between the 1x BS and the HRPD AN or between the 1x BS and the end point for another technology, and the A1/A1p interface is supported between the MSC and the 1x BS. When the IWS function is part of the HRPD AN, the A1/A1p interface between the MSC and the HRPD AN exists, and the A21 interface is internal to the HRPD AN. When the IWS is a standalone entity, the A1/A1p interface is supported between the MSC and the IWS, and the A21 interface is supported between the IWS and the HRPD AN or between the IWS and the end point for another technology.

5.1.3 cdma2000 attachment to the 3GPP enhanced packet core (EPC)

The following is abstracted from 3GPP2 X.S0057-B [31].

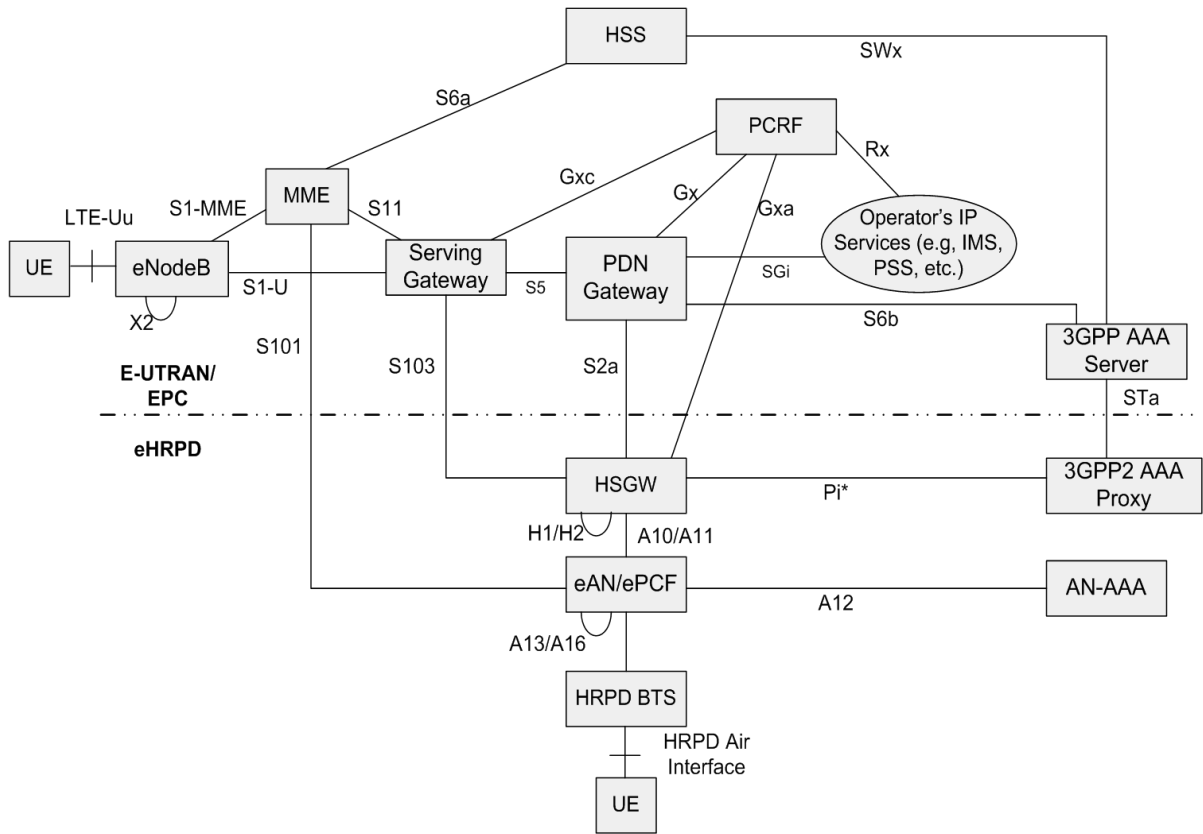
E-UTRAN – eHRPD interworking non-roaming architecture

Figure 6 shows the architecture for interworking between the 3GPP evolved universal terrestrial radio access network (E-UTRAN) and the 3GPP2 evolved high rate packet data (eHRPD) network. This architecture supports the interworking interfaces defined in 3GPP TS 23.402 [5], including the following interfaces:

- S101: the signalling interface between the EPC mobility management entity (MME) and the evolved HRPD access network (eAN/ePCF) (ref. 3GPP TS 29.276 [6]). Note that the eAN/ePCF functions are defined in 3GPP2 A.S0022-B [33],
- S103: the bearer interface between the evolved packet core (EPC) serving gateway (S-GW) and the HSGW (ref. 3GPP TS 29.276 [6]).

FIGURE 6

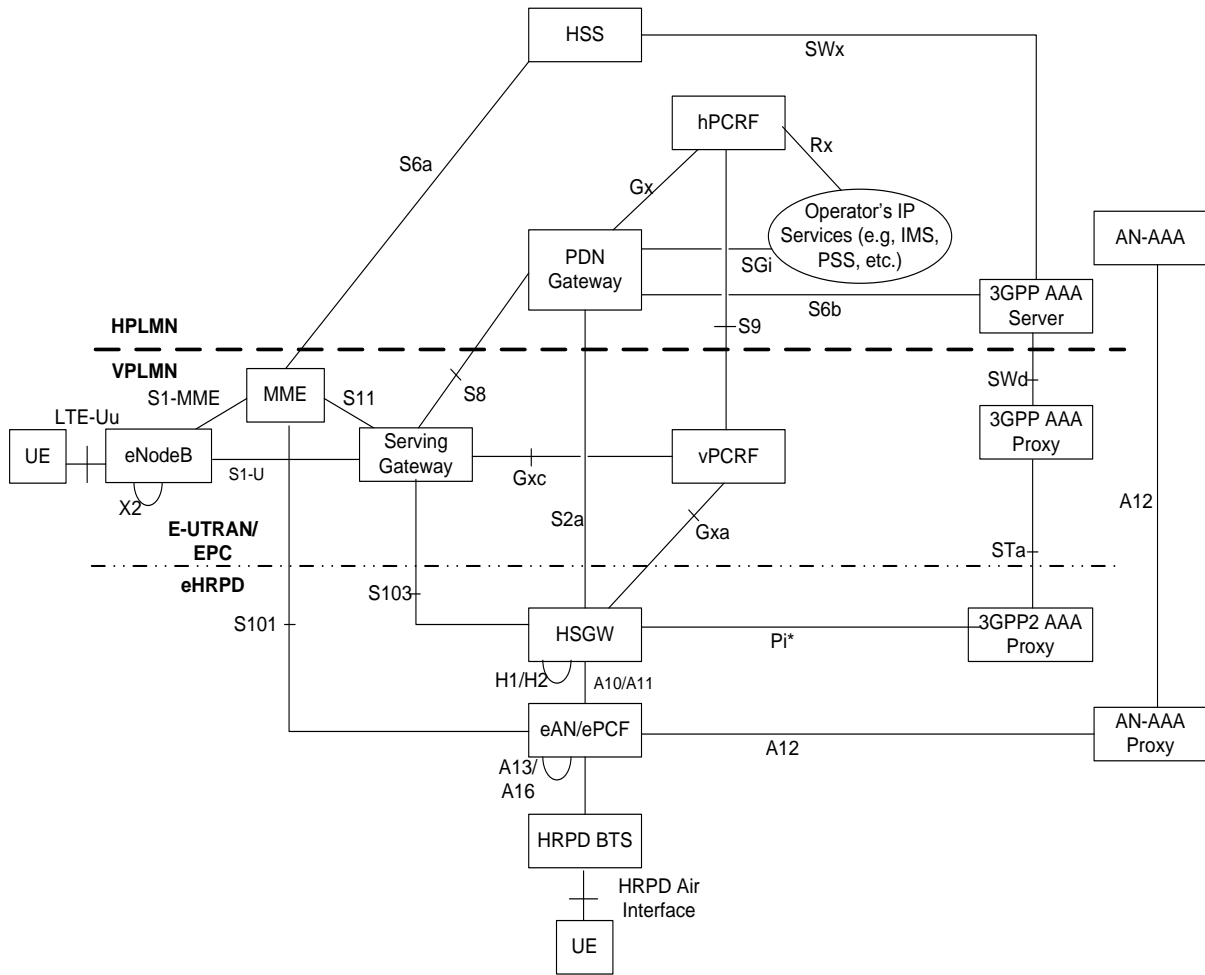
E-UTRAN – eHRPD interworking non-roaming architecture



E-UTRAN – eHRPD interworking roaming architecture (home-routed traffic)

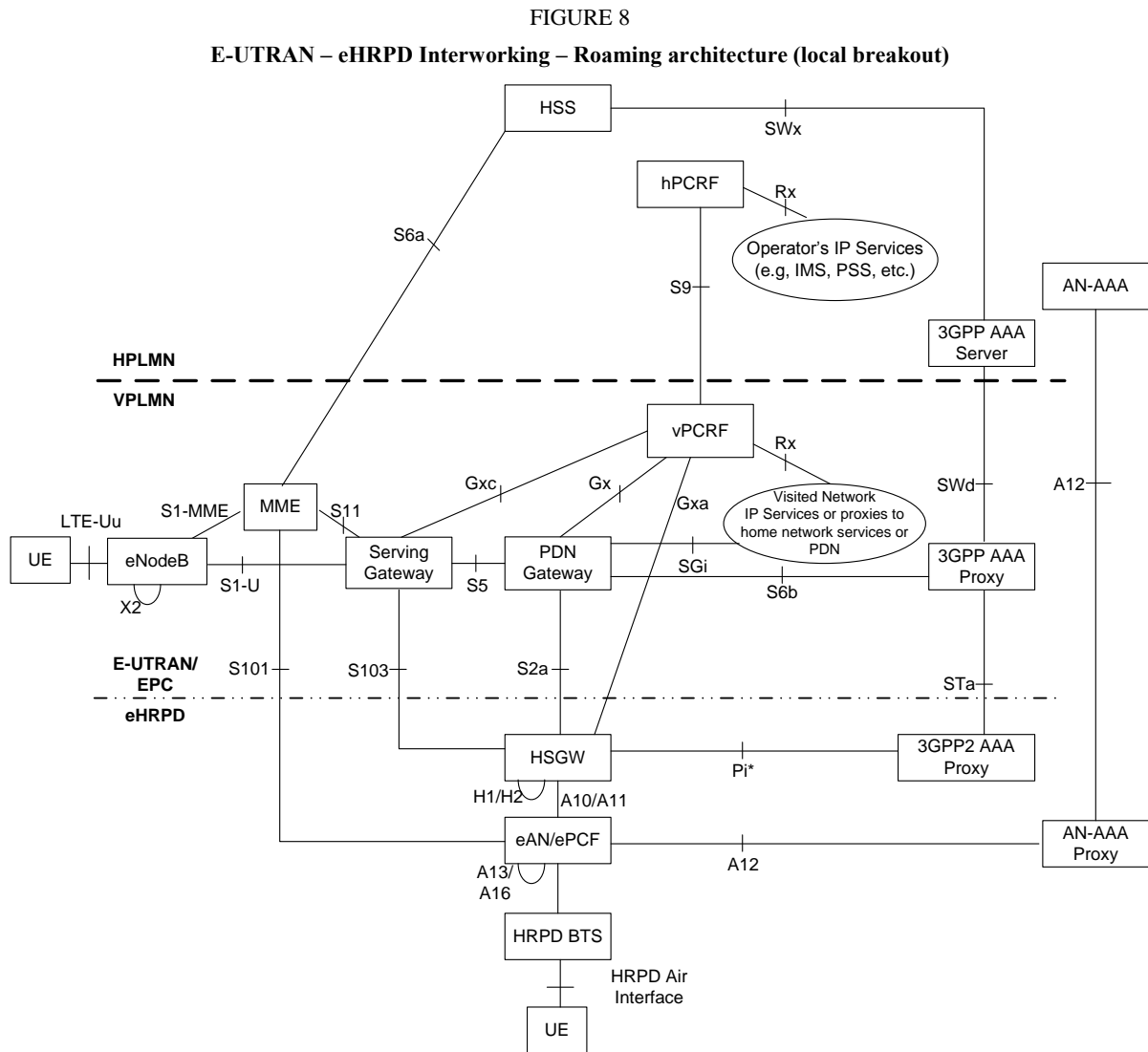
Figure 7 illustrates the E-UTRAN – eHRPD interworking architecture for home-routed traffic. In this case the anchor point (i.e. the P-GW) is located in the home network.

FIGURE 7
E-UTRAN – eHRPD interworking – Roaming architecture (home-routed traffic)



E-UTRAN – eHRPD interworking roaming architecture (local breakout)

Figure 8 illustrates the E-UTRAN – eHRPD interworking architecture for local breakout traffic. In this case the anchor point (i.e. the P-GW) is located in the visited network.



Reference points

As shown in Fig. 6 through Fig. 8, for the interworking between E-UTRAN and eHRPD, the following reference points are defined:

H1/H2 reference points

The H1 reference point carries signalling information between a source HSGW (S-HSGW) and a target HSGW (T-HSGW) for optimized inter-HSGW handoff.

The H2 reference point carries user traffic, both uplink and downlink, from a source HSGW (S-HSGW) to a target HSGW (T-HSGW) for optimized inter-HSGW handoff.

Gxa reference point

The Gxa reference point connects the policy and charging rules function (PCRF) in the 3GPP EPC to the BBERF in the HSGW in the 3GPP2 eHRPD access network.

Detailed requirements and operation of this interface is defined in 3GPP TS 23.203, 3GPP TS 29.212 and 3GPP TS 29.213.

Pi* reference point

The protocol used on the Pi* reference point connects the HSGW to the 3GPP2 AAA Proxy. The requirements for this interface to support the Pi*3GPP2 diameter application are as defined in 3GPP2

X.S0057-B [31]. If the Pi*3GPP2 diameter application is not supported, the Pi* reference point is identical to that used on the STa reference point.

S101 reference point

The S101 reference point connects the MME in the 3GPP EPS to the eAN/ePCF in the 3GPP2 eHRPD access network per 3GPP2 A.S0022-B [33]. This reference point provides tunneling of signalling and data between the UE and the target access network via the source/serving access network.

The detailed operation of this interface is defined in 3GPP TS 23.402 [5] and 3GPP TS 29.276 [6].

S103 reference point

The S103 reference point connects the serving gateway (S-GW) in the 3GPP EPC to the HSGW in the 3GPP2 eHRPD network. Its function is to forward downlink data between the S-GW and the HSGW to minimize packet losses in mobility from E-UTRAN to eHRPD.

Detailed requirements and operation of this interface is defined in 3GPP TS 23.402 [5] and 3GPP TS 29.276 [6].

S2a reference point

The S2a reference point connects the PDN Gateway in the 3GPP EPC to the HSGW in the 3GPP2 eHRPD network. This reference point provides the user plane with related control and mobility support between eHRPD access and the P-GW.

Detailed requirements and operation of this interface is defined in 3GPP TS 23.402 [5], 3GPP TS 29.275 [35], and § 5.

STa reference point

The STa reference point connects the AAA server/proxy in the 3GPP EPC to the AAA proxy in the 3GPP2 eHRPD network. This reference point is used to authenticate and authorize the UE and carries PMIPv6 mode related diameter parameters between the 3GPP AAA server/proxy and the 3GPP2 AAA proxy.

Detailed requirements and operation of this interface is defined in 3GPP TS 23.402 [5] and 3GPP TS 29.273 [34].

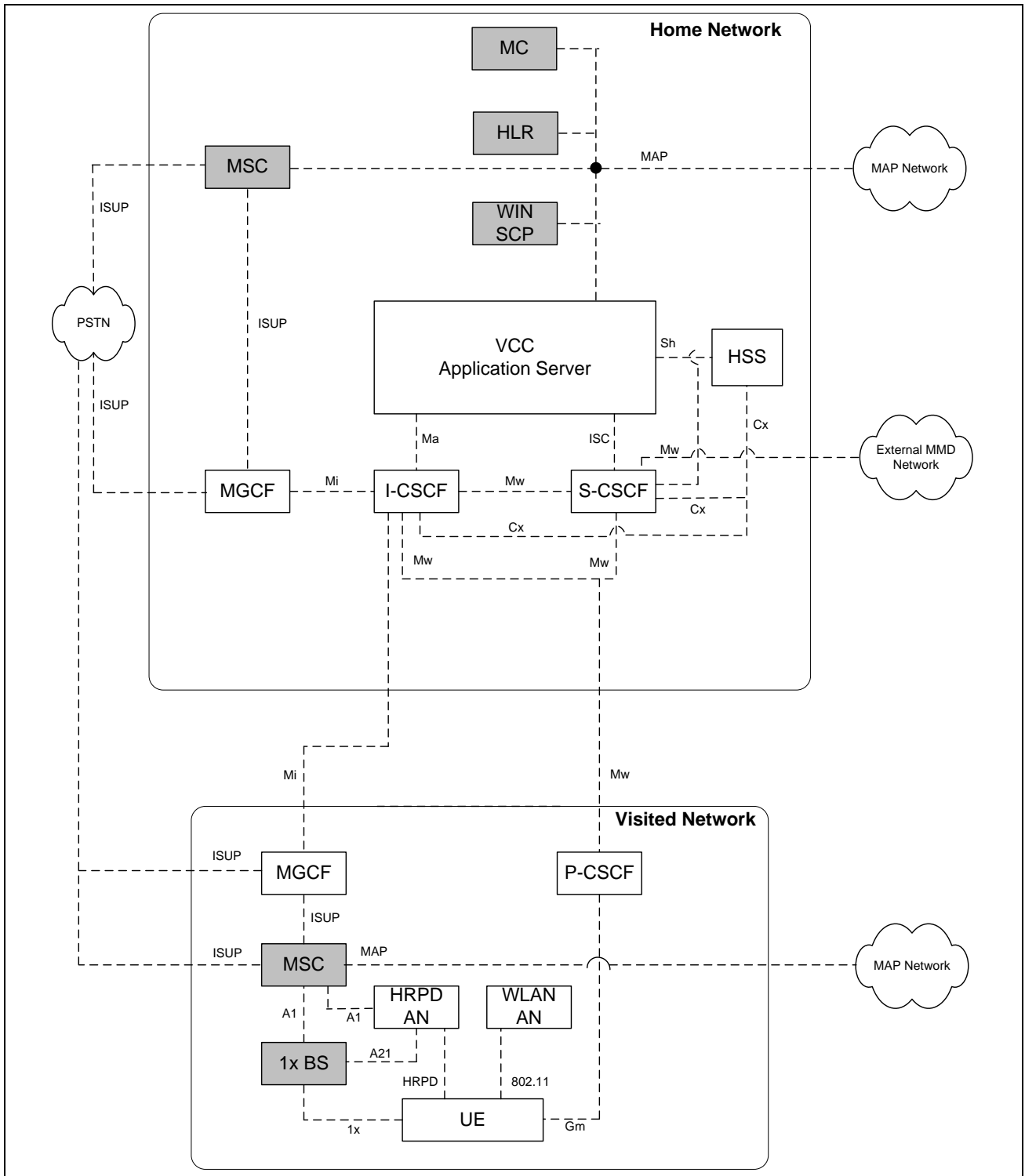
5.1.4 cdma2000 architecture for voice call continuity (VCC)

The following is abstracted from 3GPP2 X.S0042-B [30].

Architecture reference model

The following Figure illustrates the architecture reference model to support voice call continuity, including IMS-CS DTs, call origination and call termination. Only those MMD or CS network entities or interfaces supporting VCC are shown.

FIGURE 9
VCC architecture reference model



Voice call continuity introduces a new VCC application server (VCC AS) functional entity in the MMD network and relevant reference points for communication with the CS and IMS functional entities. The VCC AS makes use of existing CS and IMS functional entities and reference points.

The VCC application server comprises two main functions:

- assists in terminating services to a terminal that is 1x CS registered and/or IMS registered;

- is involved in voice call setup signalling to facilitate HRPD/WLAN VoIP-to-1x CS voice call DTs and 1x CS voice call to WLAN VoIP DTs.

The VCC AS is anchored in the call signalling path of all voice calls originated from, or terminated to, a VCC UE that is IMS registered and tuned to HRPD/WLAN, or 1x CS registered and tuned to 1x. It has the following signalling interfaces:

- VCC AS / S-CSCF (ISC)

The VCC AS serves as a SIP back-to-back user agent (B2BUA) that interfaces to the S-CSCF via an ISC SIP signalling interface.

- VCC AS / I-CSCF (Ma)

The VCC AS interfaces to an I-CSCF via an 'Ma' SIP signalling interface. This interface is used to anchor the VCC AS in the call path by sending SIP request from I-CSCF directly to the VCC AS.

- VCC AS / HLR (MAP)

The VCC AS interfaces to the 1x CS HLR using MAP in order to obtain routing information for terminating voice calls to a UE via the 1x CS network.

- VCC AS / HSS (Sh)

The VCC AS also interfaces to the HSS via an Sh interface [MMD Part-10] using the Diameter protocol to transfer data between the VCC AS and HSS.

- VCC AS / WIN SCP (MAP)

The VCC AS interfaces to the WIN SCP using the MAP protocol in order to provide routing information for 1x voice call originations and terminations and to anchor the VCC AS in these calls. The WIN SCP may be integrated with the VCC AS or may be a standalone network element.

5.2 Access network elements

5.2.1 cdma2000 1xRTT and HRPD access network architecture

The following is abstracted from 3GPP2 A.S0011-D [9].

Interface reference model

The interfaces defined in this standard are described below.

- A1 The A1 interface carries signalling information between the call control and mobility management functions of the circuit-switched MSC and the call control component of the BS (BSC).
- A1p The A1p interface carries signalling information between the call control and mobility management functions of the MSCe and the call control component of the BS (BSC).
- A2 The A2 interface is used to provide a path for user traffic. The A2 interface carries 64/56 kbit/s PCM information (for circuit-oriented voice) or 64 kbit/s unrestricted digital information (UDI, for ISDN) between the switch component of the circuit-switched MSC and the selection/distribution unit (SDU) function of the BS.
- A2p The A2p interface provides a path for packet-based user traffic sessions. The A2p interface carries voice information via IP packets between the MGW and the BS.
- A3 The A3 interface is used to transport user traffic and signalling for inter-BS soft/softer handoff when a target BS is attached to the frame selection function within the source BS. The A3 interface carries coded user information (voice/data) and signalling information between the source BS SDU function and the channel element component (BTS) of the target BS. This is a logical description of the endpoints of the A3 interface. The physical endpoints

are beyond the scope of this specification. The A3 interface is composed of two parts: signalling and user traffic. The signalling information is carried across a separate logical channel from the user traffic channel, and controls the allocation and use of channels for transporting user traffic.

- A5 The A5 interface is used to provide a path for user traffic for circuit-oriented data calls between the source BS and the circuit-switched MSC. The A5 interface carries a full duplex stream of bytes between the switch component of the circuit-switched MSC and the SDU function of the BS.
- A7 The A7 interface carries signalling information between a source BS and a target BS for inter-BS soft/softer handoff.
- A8 The A8 interface carries user traffic between the BS and the PCF.
- A9 The A9 interface carries signalling information between the BS and the PCF.
- A10 The A10 interface carries user traffic between the PCF and the PDSN.
- A11 The A11 interface carries signalling information between the PCF and the PDSN.

This is a logical architecture that does not imply any particular physical implementation. For this standard the IWF for circuit-oriented data calls is assumed to be located at the circuit-switched MSC, and the SDU function is considered to be co-located with the source BSC. Figures 9 and 10 show the relationship among network components in support of MS originations, MS terminations, and direct BS-to-BS soft/softer handoff operations.

FIGURE 9
Reference model for circuit-switched cdma2000 access network interfaces

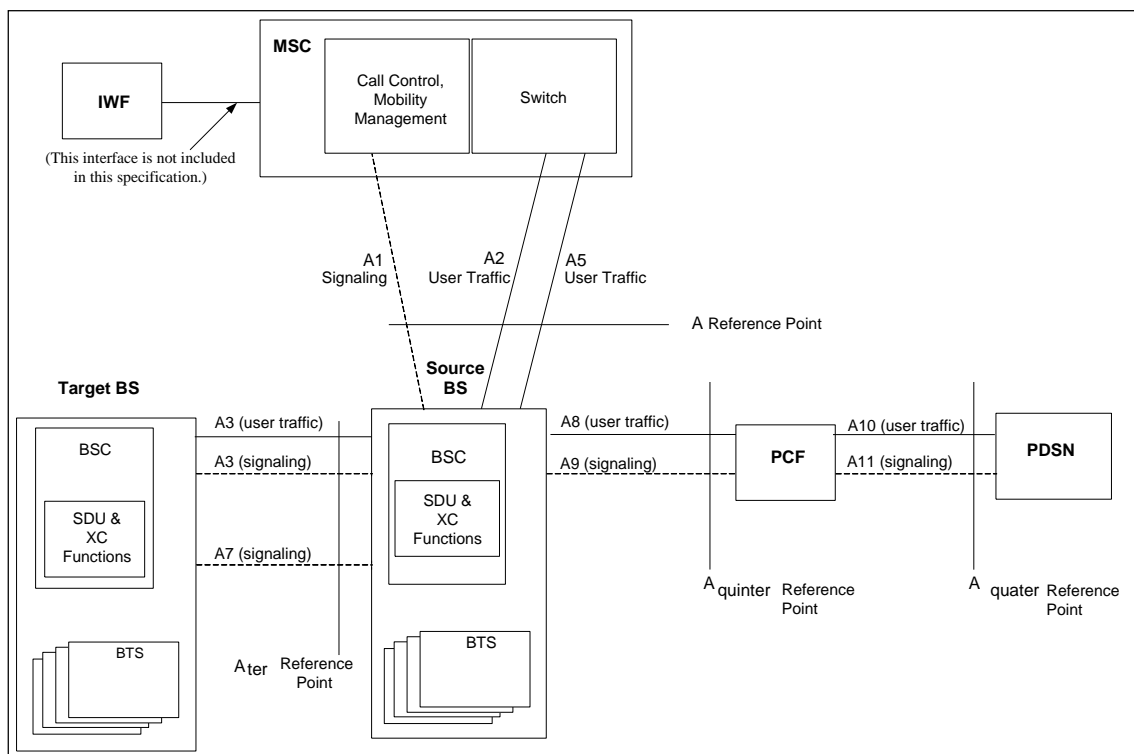
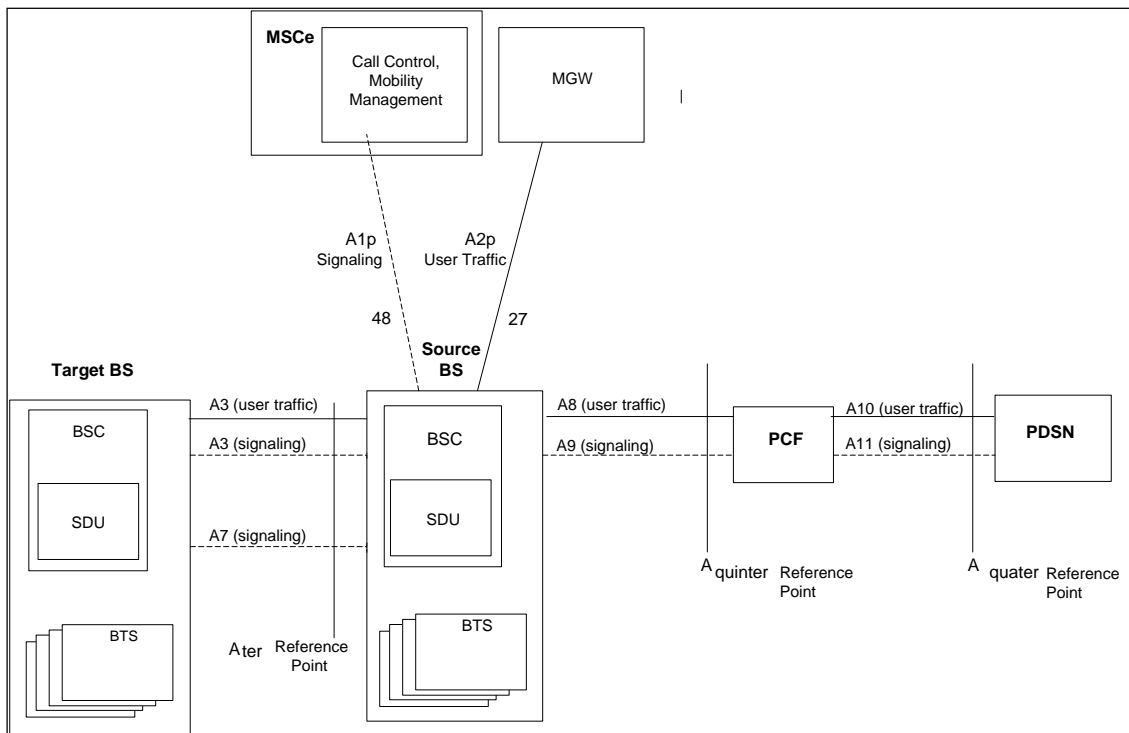


FIGURE 10
Reference model for packet-based cdma2000 access network interfaces



5.2.2 cdma2000 eHRPD access network architecture

The following is abstracted from 3GPP2 A.S0022-B [33].

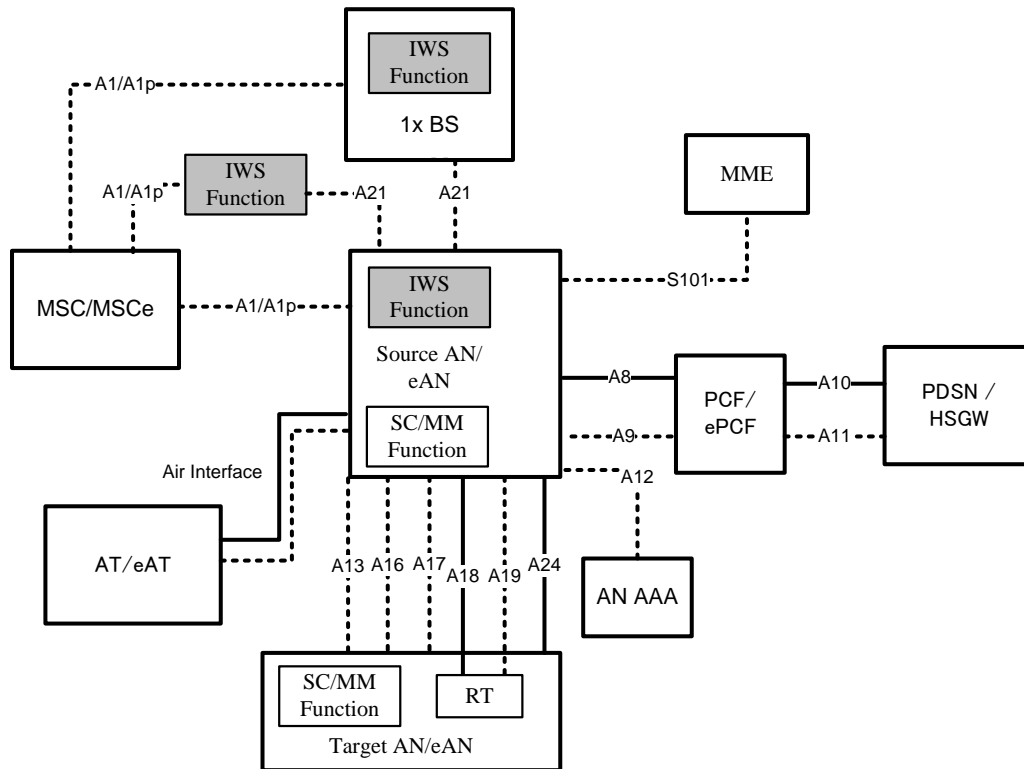
HRPD IOS architecture reference model

The eHRPD IOS messaging and call flows are based on the architecture reference model shown in Fig. 11 (session control and mobility management in the evolved access network) and in Fig. 12 (session control and mobility management in the evolved packet control function). In the figures, solid lines indicate signalling and bearer and dashed lines indicate only signalling.

The eHRPD call flows include the E-UTRAN and other 3GPP access entities (S-GW, P-GW, HSS and PCRF). Refer to 3GPP TS 23.402 [5] for the architecture model and descriptions of these network entities and associated interfaces.

FIGURE 11

E-UTRAN – eHRPD IOS architecture reference model (SC/MM in the eAN)

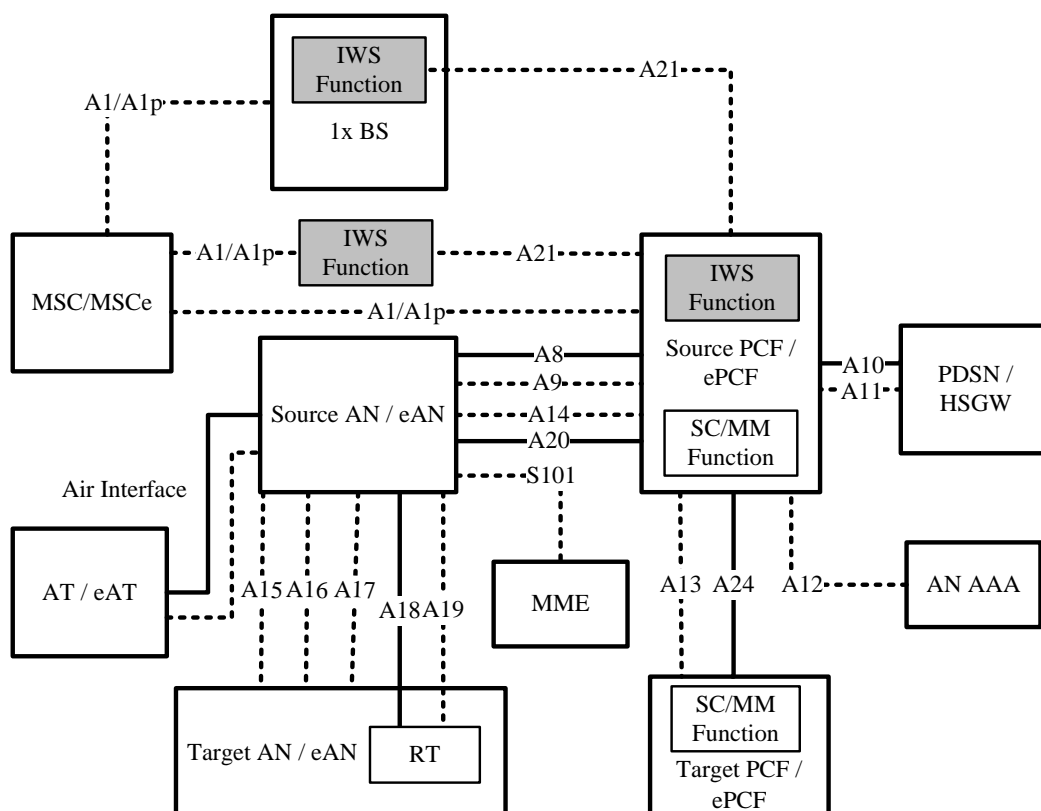


NOTE – The interworking solution (IWS) function in Fig. 11 may be collocated at either the 1x base station (BS) or at the HRPD eAN, or may be a standalone entity. When the IWS function is collocated at the 1x BS, the A21 interface is supported between the 1x BS and the HRPD eAN, and the A1/A1p interface is supported between the mobile switching center (MSC) and the 1x BS. When the IWS function is part of the HRPD eAN, the A1/A1p interface between the MSC and the HRPD eAN exists, and the A21 interface is internal to the HRPD eAN. When the IWS is a standalone entity, the A1/A1p interface is supported between the MSC and the IWS, and the A21 interface is supported between the IWS and the HRPD eAN.

NOTE – PDSN and HSGW functions may not be in the same physical entity.

FIGURE 12

E-UTRAN – eHRPD IOS architecture reference model (SC/MM in the ePCF)



NOTE – The IWS function in Fig. 12 may be collocated at either the 1x BS or at the HRPD ePCF, or may be a standalone entity. When the IWS function is collocated at the 1x BS, the A21 interface is supported between the 1x BS and the HRPD ePCF, and the A1/A1p interface is supported between the MSC and the 1x BS. When the IWS function is part of the HRPD ePCF, the A1/A1p interface between the MSC and the HRPD ePCF exists, and the A21 interface is internal to the HRPD ePCF. When the IWS is a standalone entity, the A1/A1p interface is supported between the MSC and the IWS, and the A21 interface is supported between the IWS and the HRPD ePCF.

NOTE – PDSN and HSGW functions may not be in the same physical entity.

eHRPD IOS Interfaces

The interfaces defined in this specification are described as follows.

- A1** The A1 interface carries signalling information between the call control and mobility management functions of the circuit-switched MSC and the IWS function. For A1 descriptions, refer to § 2.1. The A1 interface required for eHRPD is specified in 3GPP2 A.S0008-D [7] and 3GPP2 A.S0009-D [8].
- A1p** The A1p interface carries signalling information between the call control and mobility management functions of the mobile switching center emulation (MSCe) and the IWS function. It is recommended that the A1p interface, instead of the A1 interface, be applied for interworking between the 1x and HRPD systems. For A1p descriptions, refer to § 2.1. The A1p interface required for eHRPD is specified in 3GPP2 A.S0008-D [7] and 3GPP2 A.S0009-D [8].
- A8** The A8 interface carries user traffic between the access network and the PCF. For A8 descriptions, refer to § 5.2.1.

- A9 The A9 interface carries signalling information between the AN and the PCF. For A9 descriptions, refer to § 5.2.1.
- A10 The A10 interface carries user traffic between the PCF and the PDSN/HSGW. For A10 descriptions, refer to § 5.2.1.
- A11 The A11 interface carries signalling information between the PCF and the PDSN/HSGW. For A11 descriptions, refer to § 5.2.1.
- A12 The A12 interface carries signalling information related to access/terminal authentication between the SC/MM function and the AN-AAA.
- A13 For A.S0008 architecture, the A13 interface carries signalling information between the SC/MM function in the source AN and the SC/MM function in the target AN for dormant state session transfer and inter-AN paging when the AT is in idle state. For A.S0009 architecture, the A13 interface is between the SC/MM function in the source PCF and the SC/MM function in the target PCF.
- A14 For A.S0009 architecture, the A14 interface carries signalling information between the SC/MM function in the PCF and the AN. The A14 interface is not applicable to A.S0008 architecture.
- A15 For A.S0009 architecture, the A15 interface carries signalling information between ANs when inter-AN paging is used. The A15 interface is not applicable to A.S0008 architecture.
- A16 The A16 interface carries signalling information between the source AN and the target AN for HRPD Inter-AN connected state session transfer (hard handoff or with cross-connectivity support).
- A17 The A17 interface carries signalling information between a source AN and a target AN to manage resources in support of inter-eAN cross-connectivity (soft/softer handoff). The A17 interface establishes dedicated endpoints for the A18 and A19 interfaces. Additionally, the A17 interface tunnels air interface forward control channel signalling messages from the source AN to a target AN that has sectors in the AT's active set to be transmitted to the AT.
- A18 The A18 interface transports user traffic (i.e. air interface traffic channel data) for an AT between the source AN and a target RT during cross-connectivity. The A18 interface endpoints are set up using the A17 interface.
- A19 The A19 interface carries RT-specific bearer-related cross-connectivity control messages for an AT between the source AN and a target RT. The A19 interface endpoints are set up using the A17 interface.
- A20 For A.S0009 architecture, the A20 interface carries user traffic between the SC/MM function in the PCF and the AN. The A20 interface is not applicable to A.S0008 architecture.
- A21 The A21 interface carries signalling information between the HRPD AN and the IWS.
- A24 The A24 interface carries buffered user data from the source AN/PCF to the target AN/PCF for an AT, during A13 session transfer. The target AN/PCF interface endpoint is transmitted to the source AN/PCF in the A13-session information request message.
- S101 The S101 interface carries signalling information between the HRPD eAN and the mobility management entity (MME). Refer to 3GPP TS 29.276 [6].

eHRPD IOS Network entities

- 1x base station A 1x base station (1x BS) operates on the cdma2000 1x air interface defined by 3GPP2 C.S0001 [16] through 3GPP2 C.S0006 [21] and also supports the 1x IOS specified in 3GPP2 A.S0011 [9] through 3GPP2 A.S0017 [15].
- Access network A logical entity in the RAN used for radio communications with the AT. An AN contains one or more RTs and is equivalent to a base station in 1x systems. AN in

this specification refers to both legacy AN and evolved AN. Refer to the definition of legacy access network and evolved access network.

Access terminal	A device providing data connectivity to a user. An AT may be connected to a computing device such as a laptop personal computer or it may be a self-contained data device such as a personal digital assistant. An AT is equivalent to a mobile station in 1x systems. The term AT applies to both an evolved access terminal (eAT) and a legacy AT.
AN-AAA	An entity that performs access/terminal authentication functions for the RAN.
Evolved access network	Access network that supports operations for EPS – eHRPD RAN interworking specified in this specification, in addition to legacy access network capabilities.
Evolved access terminal	AT that supports both evolved mode (refer to 3GPP2 C.S0087-A [26]) and legacy mode operation (refer to 3GPP2 C.S0024-B [23] and 3GPP2 C.S0063-B [24]). An eAT is referred to as a UE in 3GPP TS 23.402 [5], 3GPP TS 29.276 [6] and 3GPP2 X.S0057-B [31].
Evolved packet control function	Packet control function that supports operations for EPS – eHRPD RAN interworking specified in this specification, in addition to legacy packet control function capabilities.
HRPD serving gateway	The HSGW is the HRPD serving gateway that connects the evolved HRPD access network with the EPC as a trusted non-3GPP access network.
IWS function	<p>IWS function is logically collocated at the 1x BS or the AN, or as a standalone entity. In this standard the term IWS is used without regard to the location of the IWS. When it is necessary to make a distinction with regard to the location of the IWS, that is explicitly stated. IWS provides the following functions:</p> <ul style="list-style-type: none"> • Message translation: This function translates between IOS A1/A1p messages received from/sent to an MSC and 1x air interface signalling messages sent/received over the HRPD air interface. • 1x parameters storage: This function stores 1x radio parameters required for circuit services notification application (CSNA) support. • 1x PN Offset and BTS Cell ID mapping: This function enables to map a pair of 1x PN pilot information and HRPD sector information into BTS cell ID. • RAND Generation: This optional function provides the RAND used for 1x authentication. This function may be in the HRPD AN. When several nodes in the RAN have this function, the RAND value provided by the IWS is used.
Legacy access network	An access network that complies to the specifications in 3GPP2 A.S0008-D [7] and/or 3GPP2 A.S0009-D [8] and does not support evolved mode operation in this specification.
Legacy access terminal	An AT that does not support evolved mode is referred to as a legacy AT.

Legacy packet control function

A packet control function that complies to the specifications in 3GPP2 A.S0008-D [7] and/or 3GPP2 A.S0009-D [8] and does not support evolved mode operation in this specification.

Mobile station	In 1x systems, the mobile station (MS) is an entity in the public cellular radio telecommunications service intended to be used while in motion or during halts at unspecified points. In this specification, the term MS may
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also refer to an AT where text that is applicable to 1x systems has been extended to apply to HRPD and/or eHRPD systems.

Mobile switching center The MSC switches MS/AT-originated or MS/AT-terminated traffic. An MSC connects to one or more ANs. It may connect to other public networks (PSTN, ISDN, etc.), other MSCs in the same network, or MSCs in different networks. (It has been referred to as Mobile Telephone Switching Office, MTSO.) It provides the interface for user traffic between the wireless network and other public switched networks, or other MSCs.

In this Report, for signalling, the term MSC refers to either a circuit-switched MSC or an MSCe. In situations where a statement applies to either the circuit-switched or packet-based MSC exclusively, the type of MSC is specifically identified (i.e. “circuit-switched MSC” or “MSCe”).

Mobility management entity

The MME is defined in 3GPP TS 23.402 [5].

MSC emulation (MSCe) The MSCe provides processing and control for calls and services. The MSCe provides signalling capabilities equivalent to a circuit-switched MSC on the A1p interface. The MSCe connects to an AN via IP based protocols.

Packet control function An entity in the radio access network that manages the relay of packets between the AN and the PDSN/HSGW. PCF in this specification refers to both legacy PCF and evolved PCF. Refer to the definition of legacy packet control function and evolved packet control function.

Packet data serving node An entity that routes AT originated or AT terminated packet data traffic. A PDSN establishes, maintains and terminates link layer sessions to ATs. PDSN in this specification refers to legacy PDSN that supports legacy HRPD session with AT or eAT.

Radio access network The network entities providing data connectivity between the packet switched data network (typically the Internet) and the AT. The RAN may be divided into the following logical entities: ANs, AN-AAAs, and PCFs. The interfaces between these entities, the interfaces between the PCF and the PDSN, and the interfaces between the AN and the MSC are considered parts of the RAN. Refer to § 5.1.

RT An RT is a component of an AN comprising a collection of sectors that transmit the same power control command to an AT. An RT is also referred to as a cell on the air interface (refer to 3GPP2 C.S0087-A [26]).

SC/MM function SC/MM is logically located in the AN for the A.S0008 architecture or the PCF for the A.S0009 architecture and includes the following functions:

- Storage of HRPD session related information: This function keeps HRPD session related information (e.g. keep alive timer, MNID, mapping between MNID and UATI, etc.) for idle ATs.
- Assignment of UATI: This function assigns a new UATI to an AT.
- Access authentication for the A.S0008 architecture: This function performs the access authentication procedure. This function

judges whether an AT should be authenticated or not when the AT is accessing the HRPD RAN. The SC/MM performs PPP procedures for access authentication.

- Terminal authentication for the A.S0009 architecture: This function performs the terminal authentication procedure. This function judges whether an AT should be authenticated or not when the AT is accessing the HRPD RAN. The SC/MM performs point-to-point protocol (PPP) procedures for terminal authentication.
- Mobility management: This function manages the location of an AT.

6 Basic elements of an IMT system based on TDMA-SC technical specifications

The IMT-2000 TDMA single-carrier radio interface specifications contain two variations depending on whether a TIA/EIA-41 circuit switched network component or a GSM evolved UMTS circuit switched network component is used. In either case, a common enhanced GSM general packet radio service (GPRS) packet switched network component is used.

Radio interface use with TIA/EIA-41 circuit switched network

The IMT-2000 radio interface specifications for TDMA single-carrier technology utilizing the TIA/EIA-41 circuit switched network component are developed by TIA TR45.3 with input from the Universal Wireless Communications Consortium. This radio interface is called universal wireless communication-136 (UWC-136), which is specified by American National Standard TIA/EIA-136. It has been developed with the objective of maximum commonality between TIA/EIA-136 and GSM EDGE GPRS.

This radio interface was designed to provide a TIA/EIA-136 (designated as 136)-based radio transmission technology that meets ITU-R requirements for IMT-2000. It maintains the TDMA community's philosophy of evolution from 1st to 3rd Generation systems while addressing the specific desires and goals of the TDMA community for a 3rd Generation system.

Radio interface used with GSM evolved UMTS circuit switched network component

This radio interface provides an evolution path for an additional pre-IMT-2000 technology (GSM/GPRS) to IMT-2000 TDMA single-carrier. The IMT-2000 radio interface specifications for TDMA single-carrier technology utilizing the GSM evolved UMTS circuit switched network component are developed by 3GPP and transposed by ATIS wireless technologies and systems committee (WTSC). The circuit switched component uses a common 200 kHz carrier as does the GSM EDGE enhanced GPRS phase 2 packet switched component, as used by 136EHS, to provide high speed data (384 kbit/s). In addition a new dual carrier configuration is supported.

TIA/EIA-41 circuit switched network component

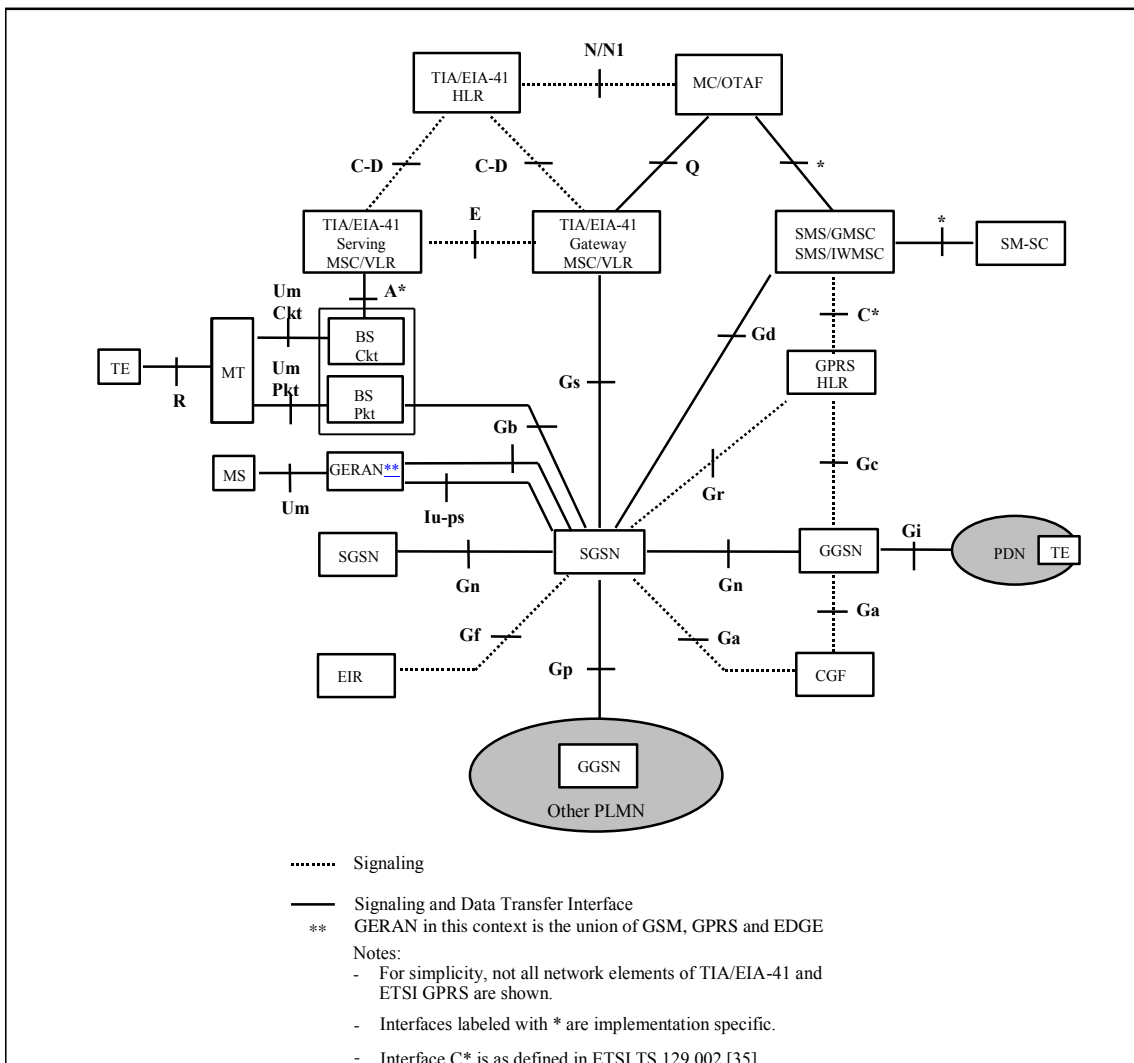
Figure 13 presents the network elements and the associated reference points that comprise a system utilizing the TIA/EIA-41 circuit switched network component. The primary TIA/EIA-41 network node visible to the serving GPRS support node (SGSN) is the gateway mobile switching center (MSC)/visitor location register (VLR). The interface between the TIA/EIA-41 gateway MSC/VLR and the SGSN is the Gs' interface, which allows the tunnelling of TIA/EIA-136 signalling messages between the MS and the gateway MSC/VLR. The tunnelling of these signalling messages is performed transparently through the SGSN. Between the MS and the SGSN, the signalling messages are transported using the tunnelling of messages (TOM) protocol layer. TOM uses the LLC

unacknowledged mode procedures to transport the signalling messages. Between the SGSN and the gateway MSC/VLR, the messages are transported using the BSSAP+ protocol.

Upon receiving a TIA/EIA-136 signalling message from a MS via the TOM protocol, the SGSN forwards the message to the appropriate gateway MSC/VLR using the BSSAP+ protocol. Upon receiving a TIA/EIA-136 signalling message from a gateway MSC/VLR via the BSSAP+ protocol, the SGSN forwards the message to the indicated MS using the TOM protocol.

MS supporting both the TIA/EIA-41 circuit switched network component and packet services (Class B136 MS) perform location updates with the circuit system by tunnelling the registration message to the gateway MSC/VLR. When an incoming call arrives for a given MS, the gateway MSC/VLR associated with the latest registration pages the MS through the SGSN. The page can be a hard page (no Layer 3 information included in the message), in which case, the Gs' interface paging procedures are used by the MSC/VLR and the SGSN. If the circuit page is not for a voice call or, if additional parameters are associated with the page, a Layer 3 page message is tunnelled to the MS by the MSC/VLR. Upon receiving a page, the MS pauses the packet data session and leaves the packet data channel for a suitable DCCH. Broadcast information is provided on the packet control channel to assist the MS with a list of candidate DCCHs. Once on a DCCH, the MS sends a page response. The remaining call setup procedures, such as traffic channel designation, proceed as in a normal page response situation.

FIGURE 13

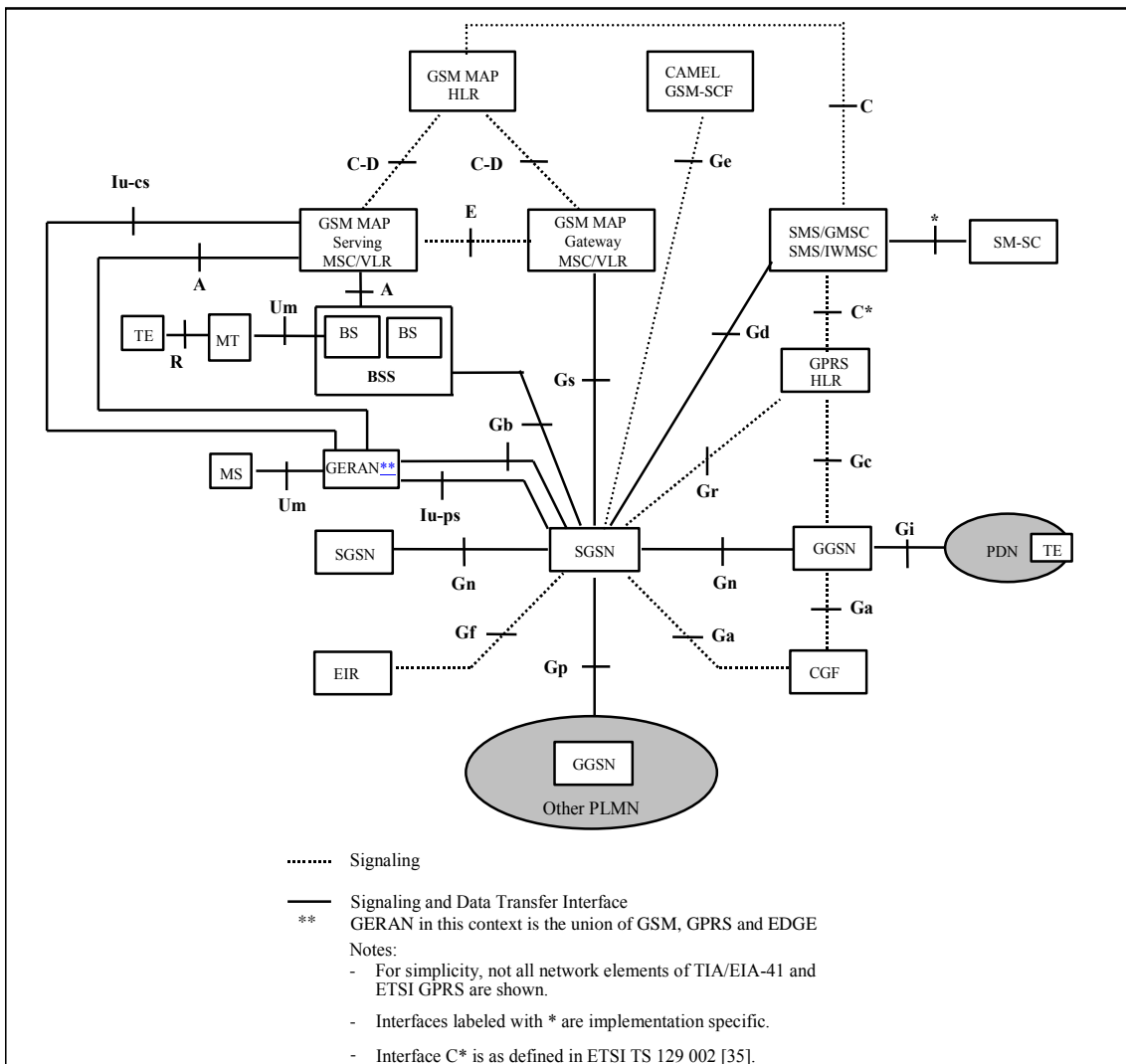


GSM evolved UMTS circuit switched network component

Figure 14 presents the network elements and the associated reference points that comprise a system utilizing the GSM evolved UMTS circuit switched network component along with the common GSM EDGE enhanced GPRS or EGPRS2 packet switched component.

Since the TDMA-SC network supports a common EDGE 136EHS bearer connected to a core enhanced GPRS backbone network or a GSM EDGE radio access network, along with either circuit switched component, GSM EDGE Release 5, Release 6, Release 7, Release 8, and Release 9 mobile stations and functions are supported. In addition to the Gs interface, GSM SMS functionality is also supported through the Gd interface².

FIGURE 14



² NOTE 7 – For simplicity, not all network elements of this system are shown in Fig. 15 below.

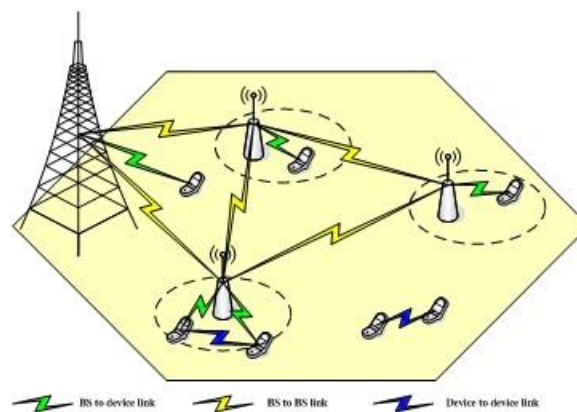
7 Transport operational requirements for IMT networks

7.1 Key features of transport solutions

For mobile operators, transport might become more complex and more flexibility might be required to provide high quality services with reasonable cost, especially when networks deployment are becoming denser.

It is expected that in the next-generation IMT networks, many different types of base stations/devices are likely to be deployed, with different transportation requirements and targets. As shown in Fig. 15, the transport in future IMT network would involve base station (BS) to device, device to device, and furthermore, BS to BS (or BS to dedicated relaying node) to transport the data traffic back to/from the core network.

FIGURE 15
Illustration of different transport links in future IMT networks



For the last category, the transport purely relying on optical fibre and microwave transmission may be inefficient and costly to provide the end-to-end transport service in the future dense deployment due to economic and/or propagation condition constraint. Wireless transport in this category would be introduced for its inherent flexibility, low cost, and ease of deployment. It is therefore expected that the hybrid deployment, including optical fibre, microwave, wireless and other medias/technologies would be the case for BS to BS (or BS to dedicated relaying node) transport.

On the other hand, statistics show that in dense and heterogeneous networks, traffics of different BSs at different locations vary quite a lot, which is due to the non-uniform traffic distribution, and time-varying traffic that results in high peak-to-mean data traffic ratio at a given location [32]. It in turn indicates that statistical multiplexing of radio resources become possible. By flexible use and assignment of the radio resources (including spatial-, frequency- and time-domain resources), the hybrid fibre/microwave/wireless deployment for BS to BS transport could meet the multiple requirements on achieving high capacity, while maintaining low cost and ease of deployment. Furthermore, the flexible use of radio resources among BS to device, device to device, and BS to BS transport might show more significant benefit to meet the different transportation requirements and targets with specific traffic distributions and propagation environments. Therefore, new transport solutions must be flexible enough to make sure that the scarce radio resources among the network could be multiplexed statistically to match the required service traffic distribution and the related propagation environments.

The flexibility requirement includes the capability of flexible topology and the capability of flexible resource assignment or sharing. The former refers to the capability of flexible use of spatial-domain

resources, i.e. the deployed devices, and flexible configuration of the connection of the network nodes. The latter refers to the capability of flexible sharing and use of the time- and frequency-domain resources with the flexible configuration of the topology.

Besides, such flexibility needs also to improve other issues, such as reliability, co-existence with other solutions, fast deployment, support of multiple applications with different QoSs, network level energy efficiency, etc. In the following, detailed descriptions on the above key features are presented.

7.1.1 Reliability

Reliable communication is the basic requirement of end-to-end data delivery for users. However, in real systems, some network equipments such as BSs may become non-operable due to irresistible reasons (e.g. natural disaster, accidents). In this situation, if the transport system is configured statically, communication reliability may thus become hard to achieve, e.g. the transport from one BS to another BS might break down due to non-operability of one of the BSs, in a static topology configuration. Therefore, resilience and redundancy are important features for transport systems to maintain high reliability, which can be achieved with flexible topology adaptation through advanced routing algorithms.

7.1.2 Compatibility with existing transport

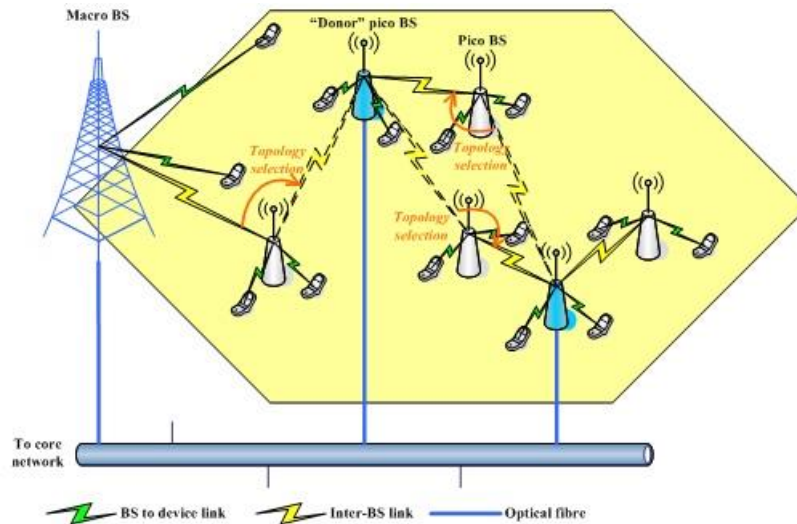
The new transport solution should be compatible or could co-exist with the legacy transport, e.g. the legacy BS to device transport. The requirement is two-fold. On one hand, the new transport solution must have no impact on the existing ones, especially for the wireless transport links among BS to devices. On the other hand, multiplexing of different kinds of transport resources, even among new and existing ones, should be considered in order to maximize the efficiency of current transport resources.

7.1.3 Flexibility

The new transport solution needs to be flexible in topology configuration, resource use, and sharing. This is especially important for BS to BS (or BS to dedicated relaying node) transport, and in turn has impact on the other two categories of transport. In future IMT systems with dense deployment of BSs having hybrid transport capability to core networks (e.g. some with optical fibre, some with microwave, and some with wireless module only), the flexible configuration of topology and resource assignment is the key to adapt the spatial-, time-, and frequency-domain resource to the traffic variations and distributions. For example, the flexible topology configuration could appropriately switch the connection path of one BS with wireless-only module to idle “donor” BSs/relays that have fibre or microwave connection to core network, rather than a pre-defined BS/relay which might be in heavy load and could not assign any more resource to the target BS. The flexible resource allocation, on the other hand, would fully enable the resource sharing with different BS to BS transports. And resource sharing may include BS to device transport, device to device transport, and BS to BS transport, such that the resource utilization efficiency could be maximized. One example of flexible topology is shown in Fig. 16.

FIGURE 16

Illustration of flexible topology



7.1.4 Fast deployment

The typical IMT system provides continued coverage for urban, suburban, and rural scenarios. However, in particular cases such as assembly, sports event, or equipment failure, coverage holes or capacity gaps may exist. In this situation, it is important to quickly deploy temporary transport resources to recover the network's capability to satisfy users' requirements. Fast transport deployment requires quick installation and configuration, which must be facilitated with advanced self-configuration and self-optimization features, and therefore, aggregation of adjacent resources and avoidance of co-channel interference must be supported.

7.1.5 QoS of multiple applications

Diverse applications and multiple different QoS should be supported at the same time even for a particular user, as the requirements of end users are becoming more complicated. In traditional IMT systems, this could be assured with advanced resource allocation and scheduling in the BS to device link (or referred to as access link). However, if the BS to BS (or BS to dedicated relaying node) capability becomes the bottleneck of end-to-end transmission, smarter transport technology is necessary, since the efficiency of inter-BS/relaying is equivalently important to that of access. Therefore, different transport links must be scheduled intelligently to match the QoS of end-to-end users, even in a mobility environment, which may be possible if joint optimizations of different transport categories are implemented.

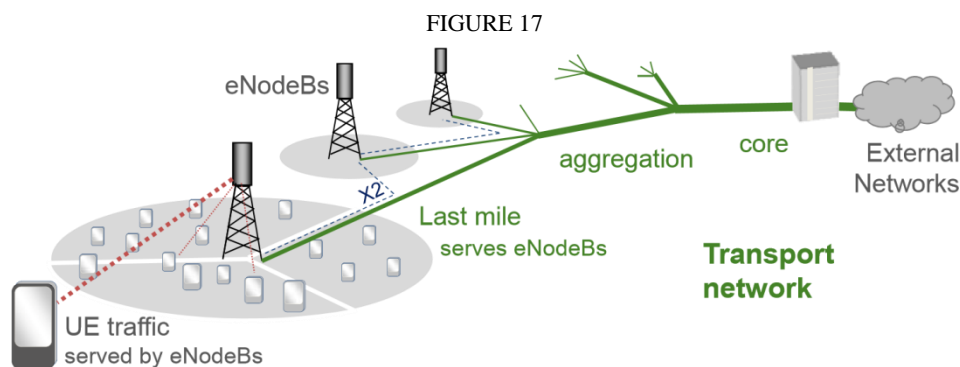
7.1.6 Higher network energy efficiency

Network energy consumption significantly influences the environment and operators, and is regarded as an important issue in future IMT systems especially when the base station density becomes higher. Transport technology is a key factor in network energy efficiency improvement, since it not only impacts the end-to-end transmission performance such as throughput and number of connections, but also contributes to the total energy consumption as many network devices are activated for transport communications. Therefore, new transport technology must be able to provide significant increases in energy efficiency while providing the equivalent quality of service, which can be achieved through dynamic high energy efficient node selection and advanced cell on/off schemes.

In addition, new transport architectures where more small cells with low energy consumption and simple functions are deployed to enhance the inter-BS/relaying links should be considered.

8 Transport capacity requirements for IMT networks³

For the case of an LTE network, the total backhaul traffic from a multi-cell base station supporting tens of users is analysed by considering the total user traffic that LTE base stations can handle both during the busy hours and in the quiet times. To this other components of backhaul traffic are added including signalling, transport overheads and the new X2 interface. This provides figures for the total backhaul traffic per eNodeB, representing the provisioning needed in the ‘last mile’ of the transport network, illustrated in Fig. 17. Provisioning for the ‘aggregation’ and ‘core’ parts of the transport network is then derived by combining traffic from multiple eNodeBs, using simple assumptions for the statistical multiplexing gains.



The traffic levels in the transport network are calculated using a theoretical modelling approach. This is needed in the early years of LTE roll out when network sizes and device penetration are too low to be able to perform useful measurements of backhaul traffic. Once loading levels in LTE networks increase, empirical methods can be used to validate, adjust and ultimately replace the theoretical models described.

The backhaul traffic figures produced by this analysis represent mature LTE networks with a sufficient number of subscribers to fully load eNodeBs during busy times. In practice, it may take several years after roll out to reach this state, and even then, only some of the eNodeBs in the network will be fully loaded. Backhaul traffic may also be impacted by the type of deployment. For example, sites near motorways may see higher levels of handover signalling, and isolated sites may generate higher traffic levels due to a lack of other cell interference. In many cases, LTE will be deployed on sites supporting other RAN technologies such as GSM or HSPA, which will generate their own backhaul traffic. In summary, the provisioning figures given for mature LTE eNodeBs may need to be adjusted to suit the particular conditions of an operator’s network. It should be understood that different operators may have different provisioning strategies.

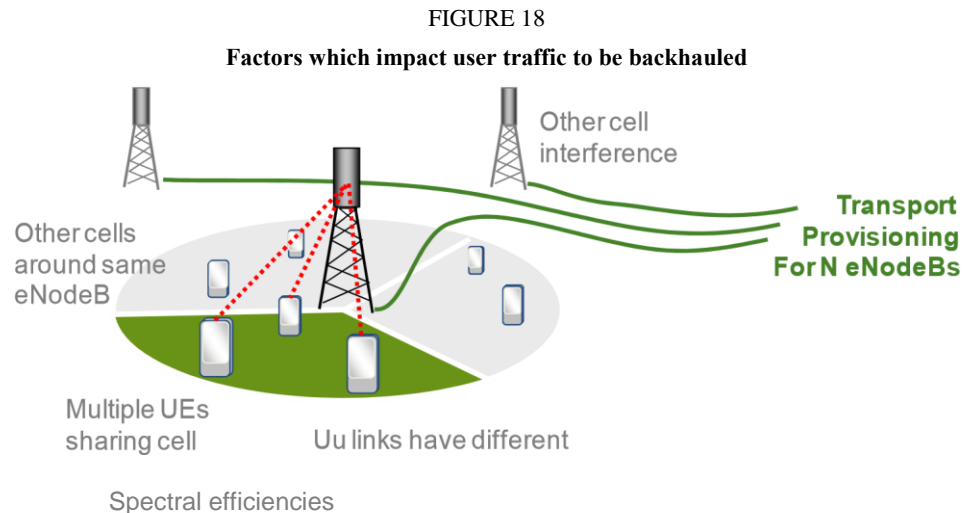
8.1 Amount of traffic we expect

Since backhaul is predominantly user plane traffic, this will be the first analysis. Subsequent analysis goes on to describe the other components of backhaul which must be considered when provisioning for each eNodeB. These include X2 traffic overheads and security. Then the analysis considers how to aggregate traffic generated a number of eNodeBs.

³ Material in this section is extracted from “[NGMN Whitepaper Guidelines for LTE Backhaul Traffic Estimation](#)” by NGMN Alliance, July 2011.

8.1.1 User plane traffic

Figure 18 illustrates the key concepts in evaluating the total user traffic carried by an eNodeB. The terms ‘cell’, ‘cell site’ and ‘base station’ are often used interchangeably, however in this report, they follow the 3GPP convention: user equipments (UEs) are served by one of many ‘cells’ in the coverage area. A “macro” LTE base station (eNodeB) typically controls three cells, ‘micro’ and ‘pico’ eNodeBs typically only control one cell and some city centre eNodeBs are starting to use six cells. Backhaul traffic per eNodeB is the total of all cells controlled by that eNodeB. Cell throughput is the sum of traffic for each of the UEs served by that cell. Each UE’s throughput varies depending on the quality of their radio link to the eNodeB, and the amount of spectrum resource assigned to them.



8.1.1.1 Calculating cell and user throughput

LTE transceivers use ‘adaptive modulation and coding’ to adjust their data rate to the radio conditions. In good conditions where the UE is close to the eNodeB and there is little interference, more bits of information can be carried without error for each unit of spectrum. This metric is spectrum efficiency measured in bits per second, per Hz (bits/s/Hz). Radio conditions are characterized by the signal to interference plus noise ratio, or SINR.

64QAM modulation can send 6 bits/s/Hz, but requires high SINR, whereas QPSK only sends 2 bits/s/Hz, but can still be received without error in the poor signal conditions found near the ‘cell edge’ during busy hour when interference is high. Variable rate coding is also used to provide finer tuning to match the data rate to the SINR.

The LTE RAN (radio access network) operates at $N = 1$ reuse, which means that each cell in the network can (re)use the entire bandwidth of the spectrum block owned by the operator. Apart from some overheads, most of this bandwidth is shared amongst the served UEs to carry their data. Clearly when there are more users, each UE is assigned a smaller share.

UE throughput (bits/s) is the product of its spectral efficiency (bits/s/Hz) and the assigned share of the cell’s spectrum (Hz). Cell throughput is the sum of all UE throughputs served by that cell. Since the total spectrum cannot change (i.e. the system bandwidth), cell throughput is the total spectrum multiplied by the cell average spectral efficiency of UEs served by that cell.

8.1.1.2 Busy and quiet times calculation

Figures 19 and 20 illustrate the variation in cell average spectral efficiency during busy and quiet times in the network. During busy times (Fig. 19), there are many UEs being served by each cell. The UEs have a range of spectrum efficiencies, depending on the quality of their radio links. Since there

are many UEs, it is unlikely that they will all be good or all be bad, so the cell average spectral efficiency (and hence cell throughput) will be somewhere in the middle.

During quiet times however, there may only be one UE served by the cell. The cell spectrum efficiency (and throughput) will depend entirely on that of the served UE, and there may be significant variations. Figure 20 shows the scenario under which the highest UE and cell throughputs occur: One UE with a good link has the entire cell’s spectrum to itself. This is the condition which represents the “headline” figures for peak data rate. Peak download rates of 150 Mbit/s have been demonstrated for LTE with 20 MHz bandwidth (and 2×2 MIMO) [36], and peak rates beyond 1 Gbit/s are proposed in later releases of the standard.

FIGURE 19

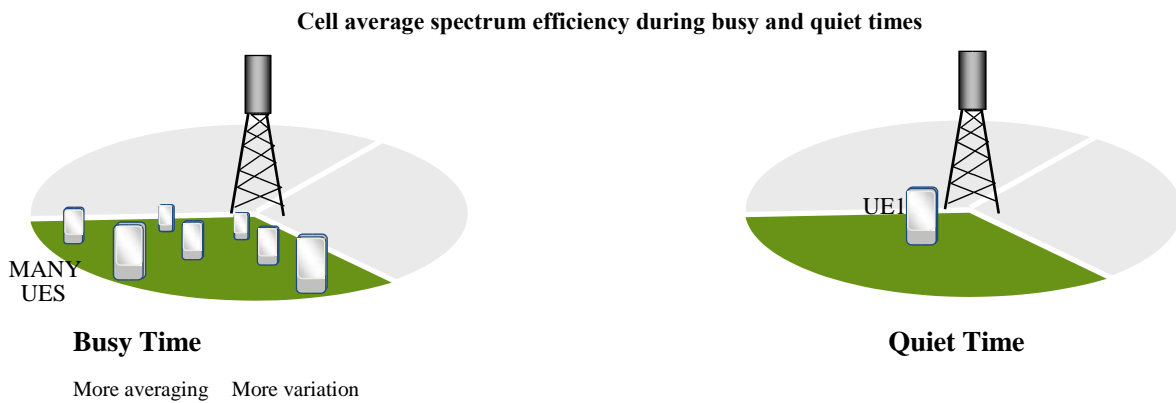


FIGURE 20

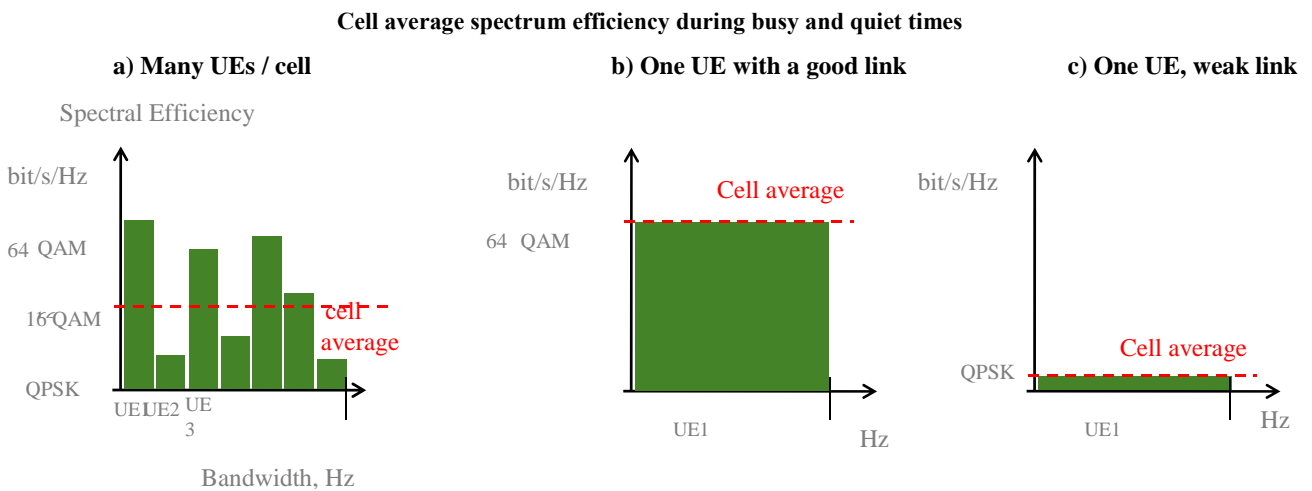
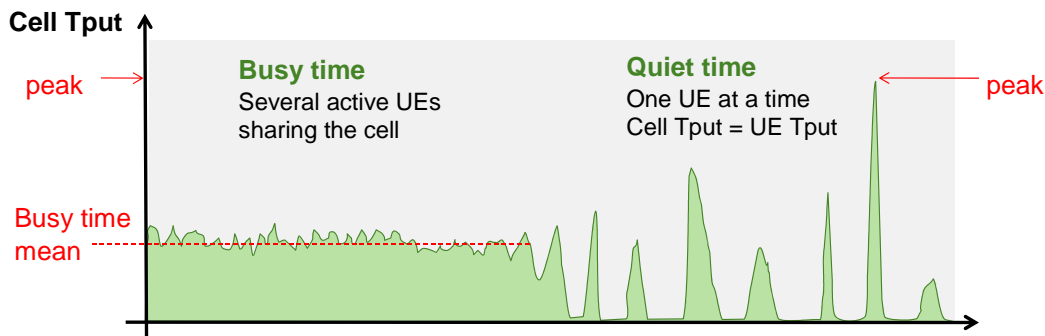


Figure 21 shows the resulting cell throughput: Throughput varies little about the ‘busy time mean’ due to the averaging effect of the many UEs using the network. Surprisingly, it is during the quiet times that *peak* cell (and thus backhaul) throughputs will occur, when one UE with a good link has the entire cell to themselves.

FIGURE 21

Illustration of cell throughput during busy and quiet times



8.1.1.3 Resulting backhaul provisioning for user data

Radio spectrum for mobile broadband is an expensive and limited resource, so backhaul should be generously provisioned to exceed cell throughput in most cases. At the same time, operators need to maintain low cost of operation, so operators cannot afford to over-provision. In this analysis, it is assumed that backhaul will be provisioned to cope with all but the top 5% of cell throughputs (i.e. the 95%-ile of the cell throughput distribution).

Provisioning for a single cell should be based on the quiet time peak rate of that cell. However, when provisioning for a Tri-cell eNodeB, or multiple eNodeBs, it is unlikely that the quiet time peaks will occur at the same time. However, the busy time mean *will* occur in all cells simultaneously – it's busy time after all. A common approach to multi-cell transport provisioning, is:

$$\text{Backhaul provisioning for } N \text{ cells} = \max(N \times \text{busy time mean, peak})$$

Peak cell throughputs are most applicable to the 'last mile' of the transport network, for backhauling of a small number of eNodeBs. Towards the core the traffic of many cells are aggregated together, and the busy hour mean is the dominant factor.

8.1.1.4 Simulating peak and mean cell throughput

Ideally and in the future, LTE backhaul provisioning will be based on measurements of real traffic levels in live commercial networks. However, it will be some time before networks are deployed and operating at full load. Whilst early trial results have confirmed the single user peak rates are achievable in the field [36], it is not so easy to create trial conditions representing busy hour.

Many LTE simulation studies assume that UEs will continuously download at whatever data rate they can achieve using the 'Full buffer' traffic model. This analysis assumes, a more sophisticated 'FTP' traffic model where each UE downloads a fixed sized file. In the full buffer model, 'near-in' UEs with good links consume more data than 'cell edge' UEs with lower data rates. Favouring UEs with good links gives higher UE and Cell throughputs. In the file transfer model, all UEs consume the same volume of data, regardless of their location or data rate. This analysis uses simulation results based on the fixed file transfer traffic model as it is considered to be more representative of real user traffic.

Other aspects of the simulations such as cell layouts and propagation models are generally consistent with 3GPP case 1 used for LTE development [37]. A summary of key assumptions is as follows:

- Urban environment (interference limited)
- Inter site distance (ISD) 500 m
- UE Speed: 3 km/h

- 2 GHz Path loss model: $L = I + 37.6 \cdot \log(R)$, R in kilometres, $I = 128.1$ dB for 2 GHz
- Multipath model: SCME (urban macro, high spread)
- eNodeB antenna type: cross polar (closely spaced in case of 4×2)

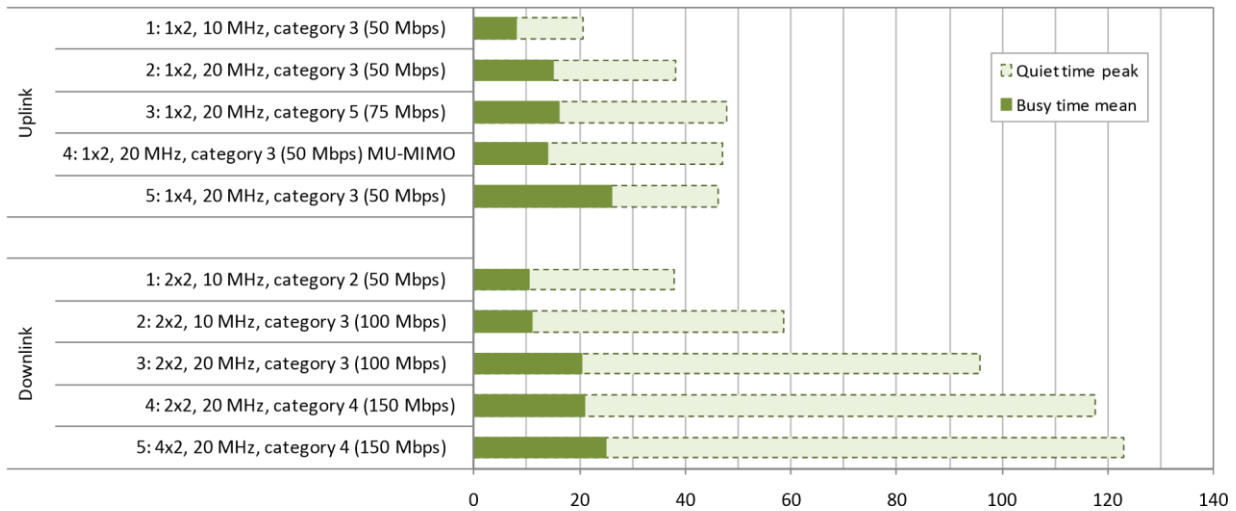
‘Interference limiting’ is when the interference from adjacent cells is significantly higher than thermal noise, which occurs when cell spacing is small. As cell spacing increases, thermal noise becomes significant for some users, and the deployment becomes ‘coverage limited’. Interference limited deployments produce higher cell throughputs than coverage limited deployments. A deployment using an 800 MHz carrier can be interference limited with a larger cell spacing than one at 2 GHz. Provided the deployment is interference limited, the carrier frequency has little impact on cell throughputs – and thus transport provisioning. The simulation results were for a 2 GHz deployment with 500 m cell spacing and were found to be interference limited in both DL and UL. They are therefore considered to be representative of an interference limited scenario at other carrier frequencies.

8.1.1.5 Simulation results for peak and mean cell throughput

Figure 22 shows cell throughputs for a variety of downlink and uplink configurations. The peak cell throughput is based on the 95%-ile user throughput under light network loads corresponding to fewer than one UE per cell. The uplink peak is around 2-3x the mean, and the downlink peak is 4-6x the mean. These high peak to mean ratios suggest that significant aggregation gains are available with LTE cell traffic.

FIGURE 22

Mean and peak (95%-ile) user plane traffic per cell for different LTE configurations

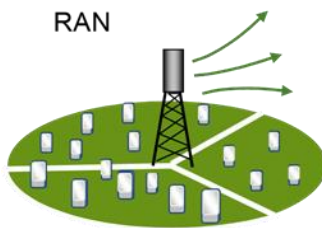
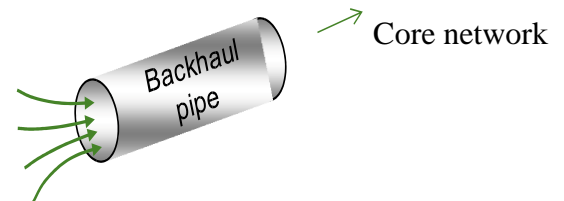


8.1.2 Backhaul traffic for single eNodeB

FIGURE 23

Components of backhaul traffic

- +X2 U and C-plane
- +OA&M, Sync, etc.
- +Transport protocol overhead
- +IPsec overhead (optional)



Backhaul traffic comprises a number of components in addition to the user plane traffic as illustrated in Fig. 23.

8.1.2.1 X2 Traffic

The new X2 interface between eNodeBs is predominantly user traffic forwarded during UE handover between eNodeBs. Further analysis of X2 functionality and traffic requirements can be found in [38]. The volume of X2 traffic is often expressed as a volume of S1 traffic, with stated figures of between 1.6 and 5% . This analysis uses 4% as a cautious average of these figures. X2 traffic only applies to the mean busy time, as the ‘peak’ cell throughput figure can only occur when there is one UE in good signal conditions – away from where a handover may occur. It should be noted that the actual volume of traffic depends on the amount of handover, so cells on motorways for example would see a higher proportion of X2 traffic than an eNodeB covering an office. It was suggested that an X2 overhead around 10% is appropriate for sites serving highly mobile users.

8.1.2.2 Control plane, OAM and synchronization signalling

Control plane signalling on both S1 (eNodeB to Core) and X2 (eNodeB to eNodeB) is considered to be negligible in comparison to associated user plane traffic, and can be ignored. The same is true for OAM (operations, administration and maintenance) and synchronization signalling.

8.1.2.3 Transport protocol overhead

Backhaul traffic is carried through the Evolved Packet Core in ‘tunnels’, which enable the UE to maintain the same IP address as it moves between eNodeBs and gateways. LTE uses either GTP (GPRS tunnelling protocol), which is also used in GSM and UMTS cores, or mobile IP tunnels. The relative size of the tunnel overhead depends on the end user’s packet size distribution. Smaller packets (like VoIP) incur larger overheads. An overhead of 10% represents the general case.

8.1.2.4 IPsec

User plane data on the S1-U interface between the eNodeB and serving gateway is not secure, and could be exposed if the transport network is not physically protected. In such situations, 3GPP specifies that IPsec encapsulated security payload (ESP) in tunnel mode should be used. This adds further overhead to the user data. This analysis assumes that IPsec ESP adds an additional 15% on top of the transport protocol overhead (making 25% in total).

8.1.2.5 Summary of single eNodeB traffic

Table 8.1.2-1 shows the calculation of eNodeB backhaul including S1 and X2 user traffic as well as transport and IPsec overheads. Figure 24 shows a graph of the resulting backhaul traffic per Tricell eNodeB. In most of the uplink cases, the busy time mean of the three cells is greater than the single cell peak.

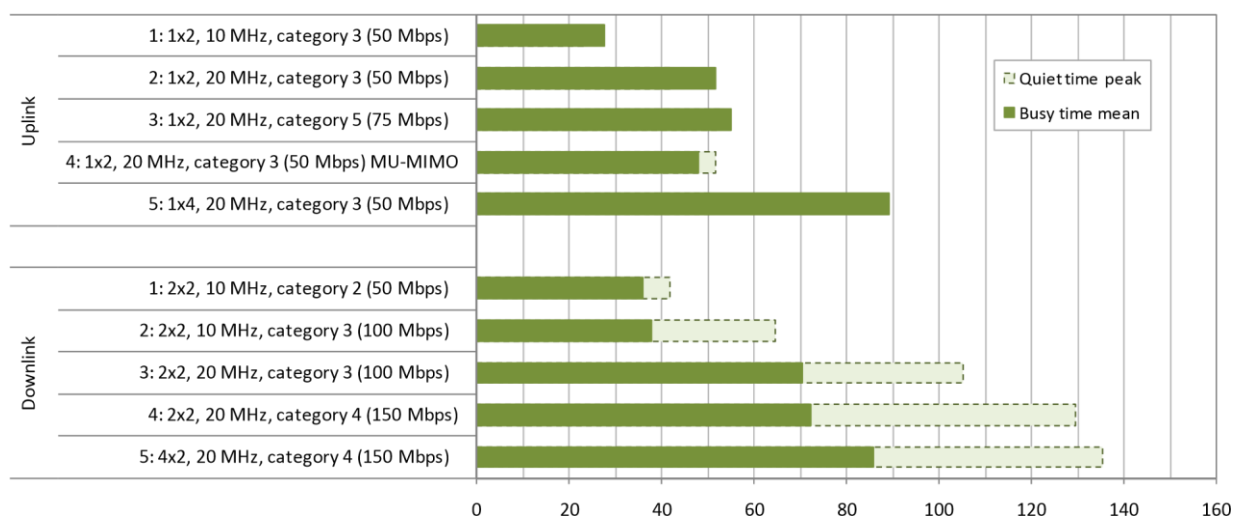
TABLE 8.1.2-1

Transport provisioning for various configurations of Tri-cell LTE eNodeB

All values in Mbit/s								Total U-plane + Transport overhead			
Scenario	Single Cell		Single base station		X2 Overhead		No IPsec		IPsec		
	Mean	Peak	Tri-cell Tput		Overhead	4%	Overhead	10%	Overhead	25%	
	(as load-> infinity)	(95%ile @ low load)	Busy time mean	Peak (95%ile)	Busy time mean	Peak	Busy time mean	Peak (95%ile)	Busy time mean	Peak (95%ile)	
DL 1: 2x2, 10 MHz, cat2 (50 Mbps)	10.5	37.8	31.5	37.8	1.3	0	36.0	41.6	41.0	47.3	
DL 2: 2x2, 10 MHz, cat3 (100 Mbps)	11.0	58.5	33.0	58.5	1.3	0	37.8	64.4	42.9	73.2	
DL 3: 2x2, 20 MHz, cat3 (100 Mbps)	20.5	95.7	61.5	95.7	2.5	0	70.4	105.3	80.0	119.6	
DL 4: 2x2, 20 MHz, cat4 (150 Mbps)	21.0	117.7	63.0	117.7	2.5	0	72.1	129.5	81.9	147.1	
DL 5: 4x2, 20 MHz, cat4 (150 Mbps)	25.0	123.1	75.0	123.1	3.0	0	85.8	135.4	97.5	153.9	
UL 1: 1x2, 10 MHz, cat3 (50 Mbps)	8.0	20.8	24.0	20.8	1.0	0	27.5	22.8	31.2	26.0	
UL 2: 1x2, 20 MHz, cat3 (50 Mbps)	15.0	38.2	45.0	38.2	1.8	0	51.5	42.0	58.5	47.7	
UL 3: 1x2, 20 MHz, cat5 (75 Mbps)	16.0	47.8	48.0	47.8	1.9	0	54.9	52.5	62.4	59.7	
UL 4: 1x2, 20 MHz, cat3 (50 Mbps) MU-MIMO	14.0	46.9	42.0	46.9	1.7	0	48.0	51.6	54.6	58.6	
UL 5: 1x4, 20 MHz, cat3 (50 Mbps)	26.0	46.2	78.0	46.2	3.1	0	89.2	50.8	101.4	57.8	

FIGURE 24

Busy time mean and quiet time peak (95%ile) backhaul traffic for a tricell eNodeB (No IPsec)



8.1.3 Backhaul traffic for multi-eNodeBs

The previous section evaluated the busy time mean and peak backhaul traffic for single cell and tricell eNodeBs, which is applicable to provisioning of ‘last mile’ backhaul. Figure 25 shows how these figures can be used to estimate backhaul capacity in the ‘aggregation’ and ‘core’ parts of the transport

network for any number of eNodeBs by considering the correlation between the peak cell throughputs across a number of aggregated eNodeBs.

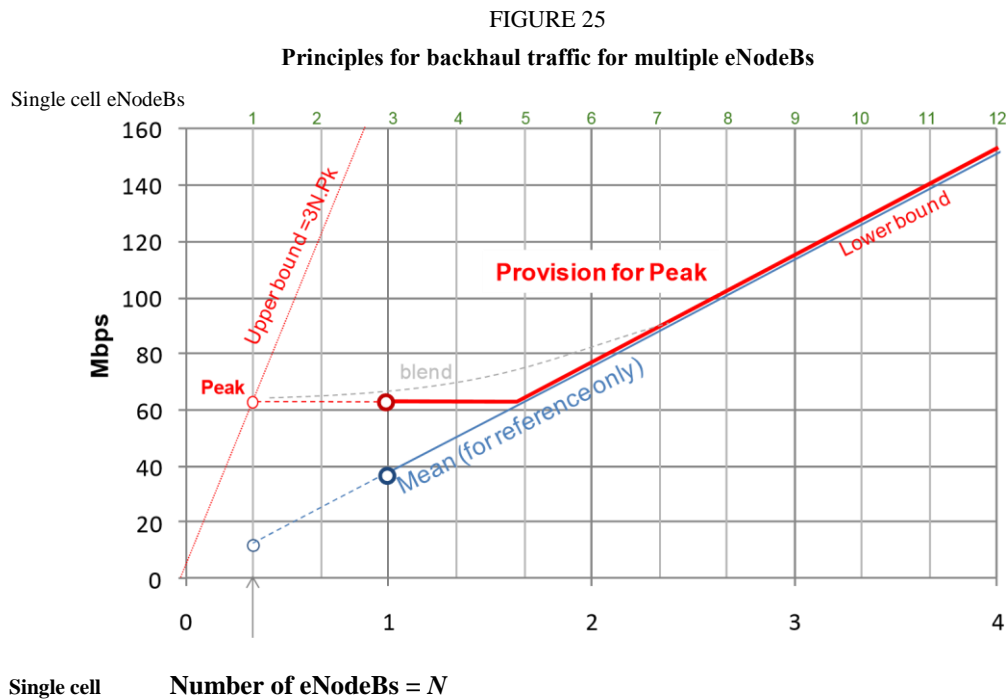


Figure 25 illustrates two bounds: An upper bound assumes that peak throughputs occur at the same moment in all cells. This is a worst case scenario, is highly unlikely to occur in practice, and would be an expensive provisioning strategy. The lower bound assumes peaks are uncorrelated but that the busy time mean applies to all cells simultaneously. The provisioning for N eNodeBs is therefore the larger of the single cell peak or $N \times$ the busy time mean, thus:

$$\text{Lower provisioning bound for } N \text{ cells} = \text{Max} (\text{peak}, n \times \text{busy time mean})$$

This lower bound assumes zero throughputs on all but the cell which is peaking during quiet times. This is based on the assumption that the peak rates only occur during very light network loads (a single UE per cell, and little or no interference from neighbouring cells). An improvement on this approach would be to consider the throughput on all aggregated cells during the quiet time peak. This would produce a curve of the form of the dotted line labelled 'blend' in Fig. 25. A yet more conservative approach would be to assume that whilst one cell is peaking, the others are generating traffic at the mean busy time rate, thus:

$$\text{Conservative Lower Bound for } N \text{ cells} = \text{Max} [\text{peak} + (N - 1) \times \text{busy time mean}, N \times \text{busy time mean}]$$

Note that the busy time mean figures are taken as the average over 57 cells in the simulation, so any aggregation benefit for slight variations in mean cell throughput has already been taken into account. When provisioning for small numbers of eNodeBs, it may be prudent to add a margin to accommodate variations in cell throughput about the busy time mean.

8.1.4 Provisioning backhaul traffic for multi-eNodeBs

Figures 26 and 27 show transport provisioning for any number of eNodeBs, for downlink and uplink configurations, respectively. Both log and linear version of the same graph are included to illustrate provisioning for small and large numbers of eNodeBs.

The x – axis is labelled for the *Tricell* eNodeBs commonly used to provide macro layer coverage across a wide area. This scale can easily be converted to represent single cell eNodeBs such as micro and pico cells used to provide capacity infill.

The provisioning curves comprise a plateau to the left, representing single cell peak, and a linear slope to the right, with a gradient representing the busy time mean. The plateaux illustrate the benefit of aggregating small numbers of cells together (up to about 5). For two or more tricell eNodeBs, provisioning is proportional to the number of eNodeBs, and no further aggregation gains are available. In reality, aggregation gains depend on the degree of correlation between traffic sources, which in turn depend on the services being demanded and complex socio-environmental factors. As LTE networks mature, traffic measurements will become available to help improve understanding in this area.

It can be seen that provisioning is most impacted by the system bandwidth and the MIMO antenna configuration, whereas UE capability makes little difference.

FIGURE 26

Downlink transport provisioning (No IPsec)

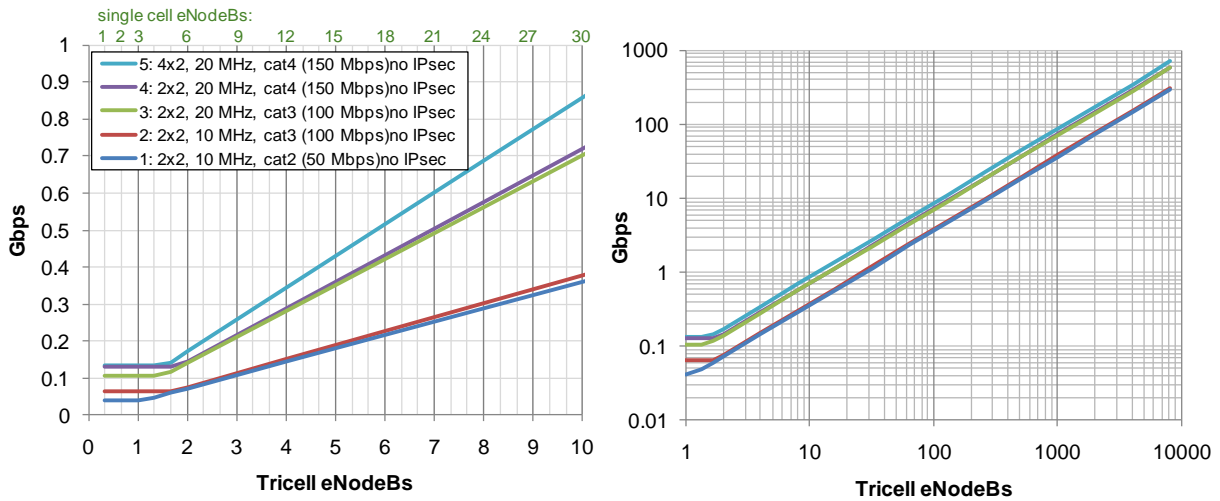
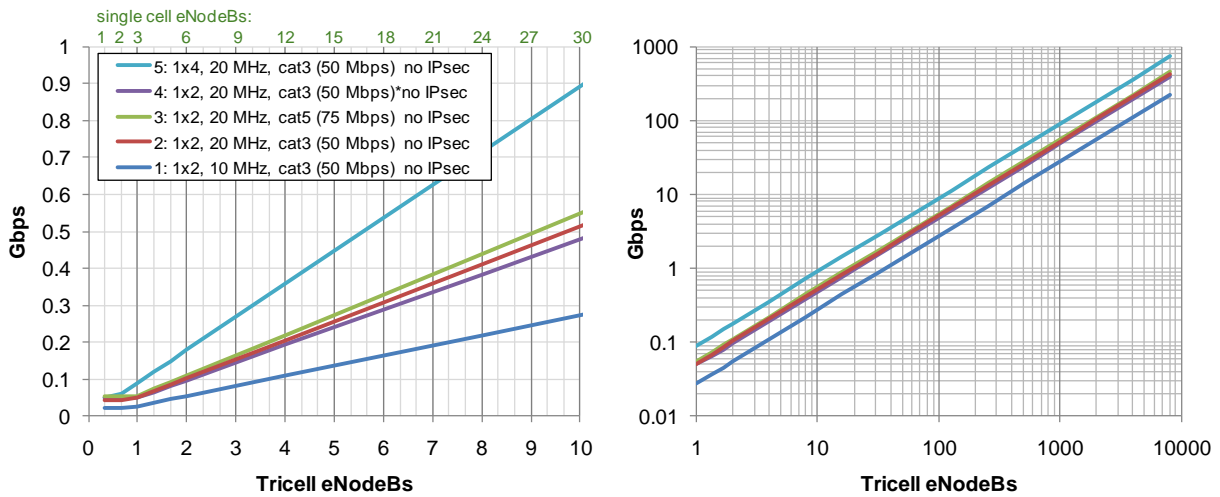


FIGURE 27

Uplink transport provisioning (No IPsec)



*UL case 4 assumes Multi User MIMO

8.1.5 Adaptation of results to real world networks

There is no ‘one size fits all’ rule for backhaul provisioning. The analysis used in this report is based on mature macro-cellular LTE networks, where user traffic demands are sufficient to reach an ‘interference limited’ state on all cells during busy times. Interference (as opposed to coverage) limited networks are those that have reached full capacity. In real world networks however, there are several factors which impact the actual traffic levels generated by eNodeBs. The following sections highlight some of these factors and describe their impact on busy time mean and quiet time peak characteristics. It is recommended that operators take these factors into account and adapt the mature network provisioning figures to fit their unique deployment conditions.

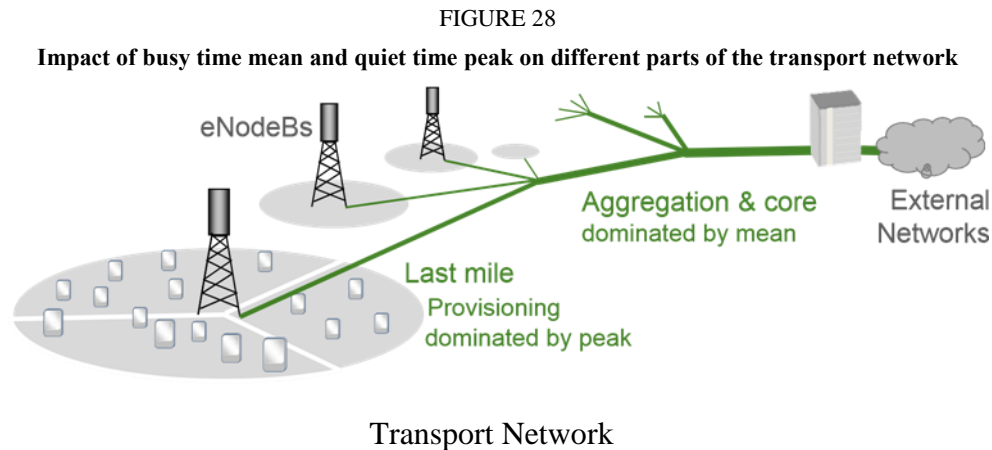


Figure 28 shows how different parts of the transport network are impacted by the different characteristics of the proposed traffic model. The peak tends to be dominant in last mile provisioning, whereas the busy time mean, because it is assumed to occur simultaneously across the network, impacts provisioning towards the core.

8.1.5.1 Network maturity and device penetration

The eNodeB traffic characteristics given above represent mature networks, where cells will be simultaneously serving multiple UEs during busy times. ‘Busy time’ can be viewed as when the offered load from UEs approaches the cell’s capacity. In the early days after rollout, there may not be sufficient device penetration for this to occur anywhere in the network. During this period, although ‘busy time’ load may not be reached, the generally light network loading conditions will still be conducive to achieving high peak rates for the few ‘early adopter’ UEs. Interpreting this to the backhaul, the last mile will still need to be provisioned for the chosen peak rate from day one. On the other hand, provisioning in the aggregation and core of the transport network can initially be reduced, and then gradually ramped up as the loading increases towards the levels described in this report.

8.1.5.2 Load variation between sites

It has been observed that a large proportion of backhaul traffic is generated by a small proportion of sites, suggesting wide variation in traffic levels across the sites. Since the figures in this report assume all cells are equally busy, they may overestimate traffic levels in the aggregation and core of the transport network. A network covering a wide area may operate at average cell loads of around 50% of the full loads given in this report. As previously mentioned, last mile provisioning will be dictated by the quiet time peak rate and which should be the same for all cells.

8.1.5.3 High mobility sites

Sites serving motorways or railway tracks will have higher handover rates than most other sites. As described in § 8.1.2.1, this will result in a higher level of mobility signalling over the X2 interface. This additional overhead applies only to the busy time mean, as peak rates do not occur during handovers.

8.1.5.4 Small or isolated cells

Where cells benefit from some isolation from their neighbours, the reduced levels of interference can lead to higher levels of backhaul traffic. It is anticipated this may occur in small cells ‘down in the clutter’ near street level or indoors. An isolated site with no near neighbours will also benefit for the same reasons. As well as increases to the busy time mean, there will be an increased likelihood of the quiet time peaks occurring at such sites

8.2 Summary of backhaul requirements

This section proposes a model for predicting traffic levels in transport networks used to backhaul mature, fully loaded LTE eNodeBs. Guidance is also given on how results can be adapted to suit other conditions, such as light loading in the early days after roll out. This theoretical approach based on simulations provides a useful stop gap until real world networks are sufficiently loaded to be able to perform measurements to characterize backhaul traffic.

Backhaul traffic comprises several components, of which user plane data is by far the largest. This was evaluated on a per cell basis and there are often multiple cells per eNodeB. LTE network simulations revealed the characteristics of cell throughput: During busy times, the many users sharing the cell have an averaging effect, and cell throughput is characterized by the cell average spectral efficiency.

Surprisingly, it is during quiet times that the highest cell throughputs occur, when one UE with a good radio link has the entire cell’s spectrum resource to itself. A typical 2×2 10 MHz cell provides up to 11Mbit/s of downlink user traffic during busy times, but during quiet times can supply an individual user with up to 59 Mbit/s.

This peak rate represents that achieved by the top 5% of users in a simulation with a low offered load. In practice, peak provisioning might also be influenced by the need to advertise a particular rate to attract consumers.

The backhaul traffic for eNodeB contains user data for one or more cells, plus traffic forwarded over the “X2” interface during handovers, plus overheads for transport protocols and security. Signalling for control plane, system management and synchronization were assumed to be negligible. When calculating traffic provisioning for multiple eNodeBs, it is assumed that the quiet time peaks do not occur at the same moment across all eNodeBs, but that the busy time mean traffic does.

The resulting analysis shows the need of 700 Mbit/s for 30 single-cell eNodeBs or 10 tri-cell eNodeBs for the case of 2x2 MIMO DL using 20 MHz bandwidth with no IPsec

The degree of traffic aggregation is smallest in the ‘last mile’ of the transport network, and greatest in the ‘core’. Since the ‘last mile’ typically backhauls only a small number of eNodeBs, provisioning tends to be dominated by the peak rate required individual cells. Towards the ‘core’ it is the busy time mean rate occurring simultaneously across all cells which determines provisioning.

Overall, this study shows that although LTE is capable of generating some very high peak rates, when the traffic of multiple cells and/or eNodeBs are aggregated together, the transport provisioning requirements are more reasonable.

9 Challenges of future network topology and network

9.1 Characteristics of future network

Though accurate prediction of future network is difficult, four key features of future network are expected, including denser and more diverse hotspot, non-uniform traffic distribution but uniform user experience, various application services and better support of emergency communications. Since mobile data explosion (e.g. 1000 times traffic improvement in the next 10 years) could happen and the traffic may appear in any possible locations, there will be a large amount of hotspots among the network whose location may vary during time and space domain. However, from the point of view of end-users, same high quality service and experience is expected no matter where and when the communication is triggered. Besides, more and more innovative services are designed and proposed, which make QoS more complicated and diverse. Furthermore, for emergency situation such as natural disaster, quick and reliable basic communication should be provided even some of the network equipments are broken down.

9.2 Future impact of cloud

Cloud is another significant trend of future network, especially in terms of computing, storage and network service. As the development of cloud technology, network topology would definitely become more diverse. One major example is the decoupling of physical equipments and network functions, which makes ubiquitous service possible. To be specific, network devices may be flexibly connected with each other and dynamically share own capability to provide high quality service and amazing experience when needed. It is expected that many different kinds of topologies, including star, ring, mesh, and even arbitrary mixtures of them may exist.

Therefore, how to jointly optimize the overall network performance under such complicated topology is an open issue, to all categories of transportations.

9.3 Challenges to reach the future

In order to make the future IMT system come true, great effort must be made especially considering the severe challenges. One major concern about future IMT system is the cost, which is composed of two parts, i.e. CAPEX and OPEX. On one hand, excessive traffic improvement needs more and more equipments together with more advanced technologies, which contributes the increase of CAPEX. On the other hand, if network resources cannot be dynamically allocated, huge waste of resources or severe resource conflict may occur, which could obviously worsen the end-to-end performance and leads to higher OPEX to network optimization. Furthermore, if network topology is statically configured, network reliability might be a problem especially when some equipment failure happens.

Flexibility is the key to address the performance achievement requirements while maintaining an affordable network cost. By flexible topology configuration, the network could offload the heavy data traffic with appropriately selected transport paths. By flexible radio resource assignment and sharing, the deployed time- and frequency-domain resource (either for BS-to-device, or for device-to-device, or for BS-to-BS, etc.) could be fully utilized, and waste of resource could be avoided.

10 Conclusion

This Report describes the architecture and topology/configuration of IMT networks, especially for E-UTRAN, cdma2000 and TDMA-SC, operational requirements and capacity requirements of the transport network in the mobile infrastructure, and future challenges.

Section 8 of this Report proposes a model for predicting traffic levels in transport networks used to backhaul mature and fully loaded LTE eNodeBs.

The user plane data, which is by far the largest, was evaluated on a per cell basis and there are often multiple cells per eNodeB. LTE network simulations revealed the following characteristics of cell throughput:

- During busy times, the many users sharing the cell have an averaging effect, and cell throughput is characterized by the cell average spectral efficiency.
- It is during quiet times that the highest cell throughputs occur, when one UE with a good radio link has the entire cell's spectrum resource to itself.
- A typical 2×2 10MHz cell provides up to 11Mbit/s of downlink user traffic during busy times, but during quiet times can supply an individual user with up to 59Mbit/s.

When calculating traffic provisioning for multiple eNodeBs, it is assumed that the quiet time peaks do not occur at the same moment across all eNodeBs, but that the busy time mean traffic does.

The resulting analysis shows the need for 700 Mbit/s for 30 single-cell eNodeBs or 10 tri-cell eNodeBs for the case of 2×2 MIMO DL using 20 MHz bandwidth with no IPsec.

The degree of traffic aggregation is smallest in the 'last mile' of the transport network, and greatest in the 'core'. Since the 'last mile' typically backhauls only a small number of eNodeBs, provisioning tends to be dominated by the peak rate required individual cells. Towards the 'core' it is the busy time mean rate occurring simultaneously across all cells which determines provisioning.

11 Terminology, abbreviations

3GPP	Third (3 rd) Generation Partnership Project
AAA	Authentication, authorization and accounting
AC	Authentication center
APN	Access point name
AMBR	Aggregate maximum bit rate
CDCP	Call data collection point
CDGP	Call data generation point
CSC	Customer service center
CSG	Closed subscriber group
DL	Down link
ECM	EPS connection management
EIR	Equipment identity register
eNodeB	Evolved NodeB
EPS	Evolved packet system
EPC	Evolved packet core
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
GBR	Guaranteed bit rate
GERAN	GSM EDGE radio access network
GGSN	Gateway GPRS support node
GTP	GPRS tunnelling protocol

HA	Home agent
HLR	Home location register
HSS	Home subscriber server
HRPD	High rate packet data
IOS	Interoperability specification
IWF	Interworking function
MBR	Maximum bit rate
MC	Message center
MME	Mobility management entity
MSC	Mobile switching center
NAS	Non-access stratum
OFCS	Off-line charging system
OTAF	Over-the-air service provision function
PCF	Packet control function
PCRF	Policy and charging rule function
PMIP	Proxy mobile IP
PWS	Public warning system
QCI	QoS class identifier
RNC	Radio network controller
RNS	Radio network subsystem
SDF	Service data flow
SGSN	Serving GPRS support node
UE	User equipment
UIM	User identity module
UL	Up link
UTRAN	Universal Terrestrial Radio Access Network
VLR	Visitor location register
