Mobile Wireless Internet Forum

OpenRAN Architecture

in 3rd Generation Mobile Systems

Technical Report MTR-007

Release v1.0.0

Adopted and Ratified

September 4, 2001

Contribution Reference Number: mwif2001.094.

Mobile Wireless Internet Forum

Contribution Reference Number:	**MWIF 2001.094**
Last Saved:	**September 4, 2001**
Title:	**OpenRAN Architecture in 3rd Generation Mobile Systems**
Working Group:	**MWIF WG4 (IP in the RAN – OpenRAN Task Force)**
Editor	**James Kempf**
Status:	**Approved and Ratified**
IPR Acknowledgement:	**Attention is called to the possibility that use or implementation of this MWIF Technical Report may require use of subject matter covered by intellectual property rights owned by parties who have not authorized such use. By publication of this Technical Report, no position is taken by MWIF or its Members with respect to the infringement, enforceability, existence or validity of any intellectual property rights in connection therewith, nor does any warranty, express or implied, arise by reason of the publication by MWIF of this Technical Report. Moreover, the MWIF shall not have any responsibility whatsoever for determining the existence of IPR for which a license may be required for the use or implementation of an MWIF Technical Report, or for conducting inquiries into the legal validity or scope of such IPR that is brought to its attention. This Technical Report is offered on an "as is" basis. MWIF and its members specifically disclaim all express warranties and implied warranties, including warranties of merchantability, fitness for a particular purpose and non-infringement.**

For addition information contact:

Mobile Wireless Internet Forum

39355 California Street, Suite 307, Fremont, CA 94538

+1 (510) 608-5930

+1 (510) 608-5917 (fax)

info@mwif.org

www.mwif.org

Abstract:

The purpose of this technical report is to promote a single open mobile wireless internet architecture which enables seamless integration of mobile telephony and internet based services (voice, video, data etc.) and is independent of the wireless access technology.

Table of Contents

1 INTRODUCTION

The vision of the OpenRAN architecture is to design a radio access network architecture with the following characteristics:

- Open,
- Flexible,
- Distributed,
- Scalable.

Such an architecture would be open because it defines open, standardized interfaces at key points that in past architectures were closed and proprietary. It would be flexible because it admits of several implementations, depending on the wired network resources available in the deployment situation. It would be distributed because monolithic network elements in past architectures would have been broken down into their respective functional entities, and the functional entities would have been grouped into network elements that can be realized as a distributed system. The architecture would define an interface with the core network that allows the core network to be designed independently from the RAN, preserving access network independence in the core. Finally, the architecture would not require changes in radio link protocols, in particular, a radio link protocol based on IP would not be necessary. This document presents the first steps in developing the OpenRAN vision.

In its first phase, the subject of this document, the OpenRAN architecture is purely concerned with distributing RAN functions to facilitate achieving open interfaces and flexible deployment. The transport substrate for implementing the architecture is assumed to be IP but no attempt is made to optimize the use of IP protocols, nor are specific interfaces designated as open. The architecture could as well be implemented on top of existing functional architectures that maintain a strict isolation between the transport layer and radio network layer, by splitting an existing radio network layer into control and bearer parts. In addition, interoperation with existing core and RAN networks is supported via interworking functions. Chapters 7 through 11 in this report are exclusively concerned with this first phase of the architecture, and it is possible that the architecture may change as the actual implementation of the OpenRAN is considered and For Further Study items are resolved.

In its second phase, consideration of protocols for the interfaces leads to considering how IP can be used more efficiently in the radio access network. This may lead to the use of IETF protocols in areas that are currently handled by radio network layer control protocols, such as micromobility, QoS, and security, and a designation of which interfaces should be open and which should be implementation-specific. In addition, the architecture currently has a CDMA focus, since CDMA radio access networks tend to be the most demanding in terms of functionality. In the second phase, how the architecture applies to radio-link protocols based on other principles will be considered. Finally, the second phase is expected to resolve all For Further Study items from phase 1 and to generate a requirements tracability analysis. This analysis is necessary to validate that the architecture does, in fact, meet the principles and requirements laid out in Chapters 5 and 6 of this document.

In its third phase, the addition of a radio access network protocol general enough to support multiple radio link types and an operations and maintenance protocol based on standard IP operations and maintenance protocols may allow a forward looking, truly global RAN to emerge, customizable to a particular radio link protocol and able to run multiple radio link types simultaneously.

It is expected that the first phase of this report could serve as input into the advanced architecture planning activities of 3GPP and 3GPP2. The architecture work in this document should allow the 3G SDOs to move more quickly to the kind of distributed architecture embodied in the OpenRAN by applying the functional decomposition in this document to the specifics of their radio access network protocols and radio link protocols, should they feel such an architecture is desirable. The second and third phases of this report are expected to be topics for research and further investigation before they are ready for 3G SDO action. The OpenRAN is primarily a research project into how to architect and implement an all-IP based radio access network, and, as with any research project, there are likely to be some areas that prove fruitful and valuable and others that are dead ends. It is not intended that the contents of this document be introduced directly to standards bodies for acceptance, but rather that the ideas stimulate thinking and provide a starting point and proof of concept for the 3G SDOs and others.

1.1 Motivations

In this section, some of the motivations behind the OpenRAN effort are explained. While the OpenRAN work has been motivated by perceived shortcomings in current RAN architectures, many of the issues raised in this section may be addressed by compatible changes to existing architectures or even through particular implementations of existing architectures. The intent of the OpenRAN work is to see whether all of these issues can be addressed in a comprehensive fashion, by starting from scrach and redesigning the RAN completely.

By deploying a radio access network based on the OpenRAN architecture, public network operators could achieve **independence of their core networks from the access network** technology. This is intended to allow public network operators to leverage their core, service-based network, including support for mobility, across a variety of access technologies, achieving the potential of a larger market for their services.

Because the OpenRAN architecture is designed to allow the co-existence of multiple radio technologies within a single RAN infrastructure, deployment of OpenRAN-based radio access networks is intended to allow an operator to achieve **cost-effective utilization of their expensive spectrum assets** by selecting the most appropriate radio protocol. Also, duplicate wire-line infrastructure for different radio technologies is unnecessary.

The OpenRAN could also contribute to **cost-efficiency** in other ways. By allowing the separation of the control and bearer plane functio ns onto different servers the control plane functions could be implemented on all-purpose server platforms while the specific real-time bearer plane functions could be implemented on highly specialized hardware. When connected to an all-IP core, the applic ation of existing IP protocols, interfaces, and modules, e.g. IP mobility management and AAA infrastructure, is intended to allow standard routers and servers to be used in both the RAN and core, allowing for exploitation of their economies of scale. Load sharing could reduce the cost of redundancy by avoiding duplication of each network entity.

The distributed nature of the OpenRAN could increase reliability by **removing any single points of failure**. Functions that in past RAN architectures were clustered into monolithic nodes are distributed in the OpenRAN. The result improves the potential for redundancy, because the cost of deploying multiple instantiations for particular RAN network elements is reduced. In past architectures, the cost of deploying redundant network elements was prohibitive and difficult because of centralization, depending on implementation. Distribution also improves scalability. Because new services are expected to become an important means for 3G operators to win over customers from competitors, the unpredictable requirements of these services on network resources and their typical introduction in hot spots call for an incremental infrastructure growth capability. In the OpenRAN, the control plane, bearer plane and transport plane infrastructure are intended to scale independently, increasing the deployment flexibility.

Because the OpenRAN admits flexible deployment scenarios, operators could select a **deployment that matches the available backhaul network resources**. Past RAN architectures, based on a star topology, were optimized for cases where rich, high-bandwidth backhaul network resources were not available. As growth in Internet connectivity has occurred, many metropolitan areas now support a rich variety of wire-line and fixed wireless backhaul options. Increasing backhaul bandwidth is generally coupled with lower costs for backhaul. Operators could deploy with a star topology where bandwidth is limited, or a mesh topology where richer bandwidth resources are available, the OpenRAN is compatible with both.

The ability to handle multiple radio link protocols with a single radio network layer protocol facilitates **interoperability between radio link protocols**. In its more advanced version, some functions (mobility management, wire-line QoS, security) that today are handled at the radio network layer are planned to move into the IP transport layer. As a result, these functions could be shared between radio link protocols. This has the potential to allow load balancing between different radio link protocols. For example, an operator could arrange to hand off a data call from GSM to WCDMA if the over-the-air bandwidth requirements became large enough.

Finally, the OpenRAN design could allow **more flexible business models** to evolve around provision of wireless Internet access. The separation between core and RAN allows separation between the business entities providing core services and wireless access. For example, a public network operator could decide to organize their service-based core network and wireless access networks into separate business units. This would allow the core unit to solicit business from other access businesses, and the access business to solicit business from other service suppliers. The potential is also available for new wireless ISPs to arise. A wireless ISP would supply wireless access only, and depend on existing service-based core suppliers for services. If the RAN is based on Internet protocols and mechanisms, ISPs are more likely to become potential customers because they already understand Internet protocols and already have existing equipment based in Internet protocols, and so they do not have as steep a learning curve nor a difficult integration operation if they want to provide wireless access.

1.2 Objectives

The long term vision of the OpenRAN architecture is to extend the peer-to-peer and distributed Internet architecture to radio access networks, so a radio access network becomes just another access network, like cable, DSL, Ethernet, etc.. The first step toward this goal is to gather requirements. The second step is to determine the basic functionality of a radio access network as a collection of functional entities in a functional architecture, identifying the interfaces between the functional entities. The third step is to describe which interfaces are open and how they can be implemented using IETF protocols, or protocols based on IP but designed specifically for the radio access network functions. The fourth step is to trace back the architecture to validate that it does, in fact, meet the requirments. The objectives of the first version of this report are to address steps one and two in the above process, future versions of this report will address the remaining steps.

1.3 Architectural Approach

The OpenRAN architecture described in this document was constructed using a formal, step-by-step approach. The approach used by the working group to define the OpenRAN architecture is the following:

- Gather principles, assumptions, and requirements;
- Define the atomic functions required to provide RAN functionality for the canonical radio protocols;
- Define the logical functional entities in the OpenRAN;
- Allocate the atomic functions to functional entities;
- Identify the interconnections between the functional entities;
- Define a network architecture model and define reference points by grouping the functional entities into network elements and grouping their interconnections into reference points[1];
- Define the nature of the traffic over the reference points[1];
- Determine which reference points are candidates for open interfaces[2];
- Validate the model via message flows[2].
- Establish a requirements tracability analysis to assure that the architecture does, in fact, meet the requirements[2].

In Version 1, the functional architecture consists of basic building blocks, called functional entities. These entities provide definitions of functions needed to support wireless radio access in the RAN. Each entity may contain one or more atomic functions. The functional architecture makes no recommendation about how functional entities should be grouped into network elements for implementation purposes. Interfaces between functional entities are defined and traffic over them characterized. Future versions of this report will complete the architectural program outlined above.

---

[1] This activity was only partially completed in Version 1, in that the interconnections between functional entities were identified as reference points, rather than the interfaces between network elements, and the traffic on these was characterized.

[2] This activity was not completed in Version 1.

1.4 Overview

This document defines the MWIF OpenRAN Reference Architecture. This architecture interacts with the MWIF Core Network Reference Architecture (NRA) [4] via the Access Gateway (AGW).

The scope of Version 1 includes the following topics:

- Principles and requirements for the OpenRAN architecture;
- The atomic functions, functional entities, and their interaction involved in providing wireless access network service;
- A discussion of the conceptual model presented by the OpenRAN, and how it might be implemented;
- A discussion of how the OpenRAN interfaces with the MWIF Core NRA via the Access Gateway;
- Brief discussions of how to map the OpenRAN onto existing RAN architectures, specifically the 3GPP UTRAN and the 3GPP2 IOS 4 RAN.

The interfaces defined in this document are capable of supporting the services offered to mobile subscribers operating under a variety of standards, but the architecture was specifically designed with WCDMA [12] and cdma2000 [13] in mind. Additional radio protocols may be explicitly considered in a future revision. The architecture is designed to inter-work with existing core networks as well as future all-IP core networks, such as the MWIF core NRA. In addition, there are provisions for interoperating with existing radio access networks of the same radio link technology that support inter-RAN interfaces. The architecture is not specified to inter-operate with radio access networks having different radio link technologies or where inter-RAN interfaces do not exist.

1.5 Release plan

It is the objective of the MWIF to provide timely industry direction for mobile wireless Internet. In order to accomplish this, the MWIF will periodically release Technical Reports. The period in which Technical Report will be released will be frequent enough to meet the objective of timely industry direction.

This Technical Report is one of a series intended to specify the MWIF architecture. At the time of release of this report, the following MWIF Technical Reports are scheduled:

MTR-001	MWIF Architectural Principles
MTR-002	MWIF Architecture Requirements
MTR-003	MWIF Layered Functional Architecture
MTR-004	MWIF Network Reference Architecture
MTR-005	MWIF Gap Analysis
MTR-006	MWIF IP Transport in the RAN
MTR-007	MWIF OpenRAN Architecture

1.6 Structure of this Report

Chapter 1: **Introduction** to the content and purpose of this report.

Chapter 2: **References** to relevant papers, specifications and reports

Chapter 3: **Definitions, Symbols and Abbreviations**

Chapter 4: **Scope of the Architecture**

Chapter 5: **Architectural Principles**

This chapter contains all agreed architecture principles and other assumptions being relevant for the OpenRAN architecture.

Chapter 6: **Requirements**

This chapter captures the architectural, functional, operator and handoff requirements.

Chapter 7: **Functional Entities**

This chapter captures the definitions of atomic functions (building blocks) that must be supported by OpenRAN architecture and presents a grouping of these functions into functional elements.

Chapter 8: **Functional Architecture**

This chapter captures the OpenRAN functional architecture, characterizing reference points and the traffic on them.

Chapter 9: **Conceptual Model**

This chapter describes the OpenRAN conceptual model, based on the architecture.

Chapter 10: **Integration with MWIF Core Architecture**

This chapter shows integration of the OpenRAN architecture with the MWIF Core architecture.

Chapter 11: **Mapping to 3G Architectures**

This chapter maps the OpenRAN architecture to the current 3G architectures defined by 3GPP and 3GPP2.

Chapter 12: **Future Work**

This chapter discusses plans for future work on the OpenRAN architecture. These are areas that the working group considered during the discussion of Version 1 and laid aside either because they were not well understood or due to time constraints.

Annexes: (as appropriate)

2 REFERENCES

Within this chapter only references specifically referred to in this report are listed:

1. MTR-001, Release 1.0/July 6, 2000, “MWIF Architectural Principles”, MWIF Requirements Working Group.
2. MTR-002, Release 0.6/August 30, 2000, “MWIF Architecture Requirements”, MWIF Requirements Working Group.
3. MTR-003, Version 1.0/August 2, 2000, “MWIF Layered Functional Architecture”, MWIF Architecture Working Group.
4. MTR-004, Version 0.6/August 10, 2000, “MWIF Network Reference Architecture”, MWIF Architecture Working Group.

5. MTR-006, Release 1.0.0, "IP in the RAN as a Transport Options in 3rd Generation Mobile Systems", MWIF IP in the RAN WG.
6. MWIF2000.108, May 10,2000, "A Study of Open RAN Architecture", Telcordia Technologies and Toshiba.
7. MWIF2000.112, June 5, 2000, "MWIF IP in RAN: Open RAN Architecture – Architecture Proposal & Migration Aspects", Siemens & NEC.
8. 3GPP2 SC.P000X, August 23, 2000/V0.6.0, "Requirements for a 3G Network Based on Internet Protocol (All-IP) with Support for TIA/EIA-41 Interoperability", 3GPP2.
9. MWIF2000.116, May 16, 2000, "All IP Network Architecture: Conceptual Framework and Functional Model", Motorola & Siemens.
10. OpenRAN Architecture Task Force Contribution, September 29, 2000, "RAN Architecture Requirements", Jean Casimir, Lucent Technologies.
11. MWIF2000.215, September 29, 2000, "Requirements for Open RAN", Siemens & NEC.
12. Holma, H., and Toskala, A., "WCDMA for UMTS", John Wiley and Sons, New York, NY, 2000.
13. Garg, V., "IS-95 CDMA and cdma2000", Prentice-Hall, Upper Saddle River, NJ, 2000.
14. 3GPP TS 25.401 v3.3.0, R-99, RAN WG3, UTRAN Overall Description
15. Calhoun, P., et. al., "The Diameter Base Protocol," draft-ietf-aaa-diameter-xx.txt, a work in progress.
16. Rigney, C., et. al., "Remote Authentication Dial In user Service (RADIUS)," RFC 2865, June 2000.
17. Blunk, L., and Vollbrecht, J., "PPP Extensible Authentication Protocol (EAP)," RFC 2284, March 1998.
18. Schulzrinne, H., et. al., "RTP: A Transport Protocol for Real-Time Applications," RFC 1889, January 1996.
19. 3GPP2 Network Reference Model, TSB-100.
20. Inter-operability Specification (IOS) for CDMA 2000 Access Network Interfaces, PN-4545-RV Ballot Version (to be published as TIA/EIA-IS-2001 (3GPP2 A.S0001-0.1) December 2000.
21. BTS-BSC Inter-operability (Abis Interface), SP-4604 (to be published as TIA/EIA/IS-828), Ballot Version December 4, 2000.

3 DEFINITIONS, SYMBOLS AND ABBREVIATIONS

This chapter provides definitions, symbols and abbreviations relevant to the application of IP as a transport option within the 3GPP-UTRAN, 3GPP2-RAN, IP work in IETF, and other mobile systems. Comments are provided on the alignment of definitions, symbols and abbreviations between different systems, e.g. 3GPP-UTRAN and 3GPP2-RAN.

3.1 Abbreviations

2G	2nd Generation
3G	3rd Generation
3GPP	3rd Generation Partnership Project
3GPP2	3rd Generation Partnership Project-2
AAA	Authentication, Authorization, and Accounting

AAL	ATM Adaptation Layer
AAL2	ATM Adaptation Layer type 2
ATM	Asynchronous Transfer Mode
BS	Base Station
BSC	Base Station Controller
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
CN	Core Network
CRNC	Controlling Radio Network Controller
DCA	Dynamic Channel Allocation
DRNC	Drift Radio Network Controller
FDD	Frequency Division Duplex
GSM	Global System for Mobile communications
IETF	Internet Engineering Task Force
IP	Internet Protocol
IWF	Interworking Function
L1	Layer 1 (physical layer)
L2	Layer 2 (data link layer)
OA&M	Operations, Administration, and Maintenance
PPP	Point to Point Protocol
QoS	Quality of Service
RAN	Radio Access Network
RNC	Radio Network Controller
RNS	Radio Network Subsystem
TDD	Time Division Duplex
TNL	Transport Network Layer
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UTRA	UMTS Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
WAN	Wide Area Network
WCDMA	Wideband Code Division Multiple Access

3.2 Glossary of terms

A Interface: Interconnection point between BSC and core network. Designated by **Iu** in 3GPP Specifications.

A3 and A7: Logical interface between two BSCs. A3 consists of both a control component and a bearer component. A3-control and A7 interfaces are both TCP/IP connections over

ATM. A3-bearer is currently defined using an AAL2/ATM protocol stack. Identified as **Iur** in 3GPP Specifications.

Access Network: An access network is composed of all functions that enable a user to access services. It can be used to hide all access-specific peculiarities from the core network.

Admission control: The process by which the network assures that sufficient resources are available to support the requested service before authorizing/granting access to the requested service. Admission control may occur at the access network and within the core network.

Anchor: A function in the RAN that relays control or bearer plane traffic to and from a UE, is temporarily assigned to a physical node and then stays put, independent of the mobility of that UE.

Bearer: A subscriber information transmission path of defined capacity, delay, and bit error rate.

Bearer Plane: The collection of functional entities and interfaces through the RAN implementing a bearer path.

Base Station (BS): An entity in the public radio telecommunications system used for radio telecommunications with mobile stations. Origin is 3GPP2. In 3GPP, the BS is called the RNS.

Base Station Controller (BSC): The control portion of the base station that includes call control logic and interconnections to the MSC, the BTSs that are part of the BS, other BSCs, and BTSs of neighboring BSs for purposes of soft/softer handoff. Origin is 3GPP2. In 3GPP, the BSC is called an RNC.

Base Transceiver Station (BTS): A component of a base station that includes radio equipment. A BTS is sometimes equated with the physical cell site of a wireless network. Origin is 3GPP2. In 3GPP, the BTS is called a Node B.

Bearer connection: A connection intended to provide a path for user traffic.

Best effort service: A service model that provides an unspecified QoS.

Cell: The unit of a base station having the ability to radiate in a given geographic area; a “sector” or “face” of a physical radio equipment implementation.

Common channel: A radio resource (logical channel or physical channel) that can be shared dynamically between several UEs.

Connection: An logical association between two endpoints. This definition does not imply anything about the transport protocol or physical implementation.

Control connection: A connection intended to provide a path for control traffic.

Context: A collection of radio resources and/or state information used as the basis for establishing an active connection. A UE in dormant mode does not have a context active.

Control Plane: The collection of functional entities, interfaces, and network elements involved in controlling the transport of bearer packets between the core network and the UE through the RAN.

Controlling RNC (CRNC): A role an RNC can take with respect to a specific set of Node Bs. There is only one Controlling RNC for any Node B. The Controlling RNC has the overall control of the logical resources of its Node Bs. CRNC is a 3GPP term [14].

Core network: A core network is composed of the set of equipment under the control of an operator that provides service access to and from the terminal. It includes all the functions related to call and bearer control.

Dedicated channel: A channel dedicated to a specific UE.

Downlink: The direction of core network to mobile device. Origin is 3GPP. The equivalent 3GPP2 term is forward link.

Dormant mode: A mobility management state of the UE in which it does not have any context with the RAN though it periodically listens to a paging channel in order to be alerted. In this state the UE only issues location updates when moving between paging areas (groups of cells) and the location of the UE is tracked by the core network. Origin is 3GPP2. The equivalent 3GPP term is mobility management "idle" state.

Drift RNC (DRNC): The role an RNC can take with respect to a specific connection between an UE and the RAN. The Drift RNC supports the Serving RNC with radio resources when the connection between the RAN and the UE needs to use cell(s) controlled by this RNC. DRNC is a 3GPP term [14].

Entity: Functional element composed of a set of functions and responsible for performing its allocated tasks.

Flow control: Mechanism(s) used to prevent the network from becoming overloaded by regulating the input rate transmissions. It is a continuous process and if the load increases from the pre-defined value, the network takes appropriate action (bit rate reduction, transmission delay, dropping low priority calls, etc.) as per the service contract, traffic type, or QoS requirements per user.

Guaranteed service: A service model that provides highly reliable performance, with little or no variance in the measured performance criteria.

Handover: The transfer of a UE radio connection (layer 3 and/or layer 2) from one radio access network entity to another. Handover is a 3GPP term, the corresponding 3GPP2 term is handoff.

Hard handover/handoff: Handover/handoff in which the connection is not maintained with the old radio access network entity while a connection is made with the new entity.

Interface: The common boundary between two associated systems (Source ITU-T I.113).

Interworking function (IWF): A functional entity that provides translation between the OpenRAN and a legacy core network or legacy RAN.

Iu: Interconnection point between an RNC and a core network. It is also considered as a reference point. Origin is 3GPP. In 3GPP2 Specifications it is called A interface.

Iub: Interface between an RNC and Node B. Origin is 3GPP. It is designated by A-bis in 3GPP2 Specifications.

Iur: A logical interface between two RNC. While logically representing a point to point link between RNCs, the physical realization may not be a point to point link. Origin is 3GPP. It is designated by A-3, A-7 in 3GPP2 Specifications.

Logical channel: A logical path that can carry control, user traffic, or a combination of the two between two entities such as the network and the mobile. A logical channel can be instantiated over one or more physical channels. Logical channels may also share physical channels.

Logical radio resource: A virtual radio resource dedicated to a specific type of information or application use that could get mapped into one or another physical radio resource. For example, code channels are physical radio resources, each could be used for multiple applications. One physical channel could cover multiple logical channels, and vice versa.

Node B: A logical node responsible for radio transmission/reception to/from the User Equipment in one or more cells. It terminates the Iub interface towards the RNC. Origin is 3GPP. In 3GPP2 Specifications it is designated as BTS or BS.

Macrodiversity: An operation state in which a UE simultaneously has radio links with two or more BTSs/Node Bs in order to reduce its emitted power and increase the reliability of the radio connection against fast fades. Macrodiversity results in multiple simultaneous physical transport packet streams between the BTSs/Node Bs and the respective network controllers (RNC/BSC) that must be resolved to generate a single packet/voice stream coming out of the RAN. Macrodiversity is resolved on the UE through a signal processing technique at layer 1.

Macromobility: Mobility management between RANs. From the point of view of an IP-based core network, this only involves a change in the Mobile IPv6 care of address, since the UE changes its globally visible subnet. For the RAN point of view, however, this will involve relocating control and bearer plane functions from one RAN to another.

Micromobility: Mobility management within the RAN that maintains the actual location of the UE and the corresponding transport path towards the UE. It breaks down in the mobility management of the bearer plane, dealing with the down-link path from the core network access point up to the point where IP is segmented into radio frames, and radio layer mobility, dealing with the transport path of the radio frames up to the base station. In addition it may include the mobility management of the control entity of a UE in the RAN, or control plane relocation. In this document version it is only used as a synonym for referring to the mobility management of the bearer plane.

Mobile Station (MS): A mobile device capable of utilizing a radio link for network access. Network access may include voice, multimedia, and/or data. MS is a 3GPP2 term, the equivalent 3GPP term is User Equipment (UE).

Mobile Switching Center (MSC): In a legacy core network, the MSC switches mobile-originated or mobile-terminated traffic. An MSC is usually connected to at least one base station. 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.

Packet: An information unit identified by a label at Layer 3 of the OSI reference model (Source: ITU-T I.113). A network protocol data unit (NPDU).

Packet Control Function (PCF): An entity in the radio access network that manages the relay of packets between the BS and the PDSN. Origin is 3GPP2.

Packet Data Serving Node (PDSN): Routes mobile-originated or mobile-terminated packet data traffic. A PDSN establishes, maintains and terminates link layer sessions to mobile stations. Origin is 3GPP2.

Physical channel: A physical path between the point of macrodiversity combining/splitting and the mobile that consists of any connecting RAN channel(s) and radio channel(s). Depending on the radio technology in use, a physical channel may be in soft handoff between the mobile station and the macrodiversity selection/combining point.

Physical radio resource: Attribute that defines a physical radio channel like spreading codes, Walsh codes, timeslots, etc.

Protocol: A formal set of procedures that are adopted to ensure communication between two or more functions within the same layer of a hierarchy of functions (Source: ITU-T I.112).

Quality of Service (QoS): The quality of networking service performance, including data loss, delay, jitter, and bandwidth experienced by packets within a network. QoS breaks down into application QoS, transport network QoS, and radio QoS. Application QoS applies to the QoS specified by the application software. Transport QoS applies to QoS applied in the transport network where radio frames are carried in IP packets. Radio QoS applies to QoS specified for radio frames transmitted over the air.

Radio Access Network (RAN): Collection of subnets under the same administrative domain that interface between a wired backbone (the core network) and a set of radio access points, for example BTSs. The RAN may include multiple radio technologies, and it has well-defined QoS requirements that partially derive from the radio link. A RAN may consist of multiple IP subnets, and each subnet interfaces with the core through an access gateway. There may be multiple access gateways per RAN subnet and multiple RAN subnets per access gateway. The RAN topology is independent from the core. UE movement between RANs implies movement from one administrative domain to another.

RAN resources: Attributes that are required by IP packet flows within t he RAN. Examples are macrodiversity combining/splitting units, segmentation/reassembly units, available bandwidth.

Radio bearer: The service provided by the radio layer 2 protocol for transfer of user data between User Equipment and the radio access network.

Radio channel: The physical, layer 1 connection between a single User Equipment and a single access point of the radio access network.

Radio bearer packet flow : A flow of IP packets between the Radio Layer 1 and the User Radio Gateway.

Radio directed packet flow: A flow of packets between the Access Gateway and the User Radio Gateway (and, ultimately, to the UE application layer). Corresponds to the radio access bearer in 3GPP terminology. In 3GPP2, corresponds to a link layer connection.

Radio frame: From 3GPP, a radio frame is a numbered time interval of 10 ms duration used for data transmission on the radio physical channel. A radio frame is divided into 15 time slots of 0.666 ms duration. The unit of data that is mapped to a radio frame (10 ms time interval) may also be referred to as radio frame From 3GPP2, a radio frame is a basic timing interval in the system. For the Sync Channel, a frame is 26.666. ms long. For the Access Channel, the Paging Channel, the Broadcast Channel, the Forward Supplemental Channel, the Forward Supplemental Code Channel, the Reverse Supplemental Channel, and the Reverse Supplemental Code Channel, a frame is 20 ms long. For the Enhanced Access Channel, the Forward Common Control Channel, and the Reverse Common Control Channel, a frame is 5, 10, or 20 ms long. For the Forward Fundamental Channel, Forward Dedicated Control Channel, Reverse Fundamental Channel, and Reverse Dedicated Control Channel, a frame is 5 or 20 ms long. For the Common Assignment Channel, a frame is 5 ms long.

Radio interface: The “radio interface” is the wireless interface between User Equipment and Node B or BTS (i.e., access point in radio access network). This term encompasses all the functionality required to maintain such interfaces.

Radio link: The logical association between a single User Equipment and a single access point of the radio access network.

Radio Network Controller (RNC): The equipment in RNS, which is in charge of controlling the use and the integrity of the radio resources. Origin is 3GPP. In 3GPP2 it is designated by BSC (Base station controller).

Radio Network Subsystem (RNS): Radio Network Subsystem is a network part is responsible for the radio directed IP packet flow and the control traffic flow (including the radio path) as well as the control of these flows. Origin is 3GPP. In 3GPP2, this is called the Base Station (BS).

Release A: A particular version of standard produced by the 3GPP2. Release B and so would be the following versions. In context with 3GPP Specifications, the versions are referred as Release '99, Release 4 and Release 5 etc.

Release 99 (R99): A particular version of the UMTS standard produced by the 3GPP. Release 4, Release 5, etc. are the following versions. In context with 3GPP2 Specifications, the versions are referred as Release A, Release B and so on.

Security: The ability to prevent fraud and protect information availability, integrity and confidentiality.

Selection/Distribution Unit (SDU): Functional entity that performs macrodiversity combining/splitting. Origin is 3GPP2.

Service: Set of functions offered to a user by an organisation.

Services (of a mobile cellular system): The set of functions that the mobile cellular system can make available to the user.

Control: The exchange of information specifically concerned with the establishment, control and management of connections, in a telecommunications network (Source: ITU-T I.112).

Soft handover/handoff: Handover/handoff between cells/sectors in which a radio layer 1 connection is maintained with the old cells when the new connection is made.

Softer handover/handoff: Soft handover/handoff between multiple antennas originating from the same physical location, commonly multiple sectors belonging to the same base station.

Um: The Radio interface between BTS and the User Equipment. Origin is 3GPP2. The identical term used in 3GPP Specifications is **Uu**.

UMTS Terrestrial Radio Access Network (UTRAN): A conceptual term used in 3GPP Specifications for identifying that part of the network which consists of RNCs and Node Bs between Iu and Uu.

Unspecified QoS: The lowest class among QoS traffic classes. Or the default QoS delivered when the guaranteed QoS cannot be delivered.

Uplink: The direction of mobile device to core network. Origin is 3GPP. In 3GPP2, this is called the reverse link.

User: A logical identifiable entity, which uses mobile telecommunication services.

User Equipment (UE): A mobile device capable of utilizing a radio link for network access. Network access may include voice, multimedia, and/or data. UE is a 3GPP [14], the equivalent 3GPP2 term is Mobile Station (MS).

Uu: The Radio interface between UTRAN and the User Equipment. The identical term used in 3GPP2 is Um.

4 SCOPE OF THE ARCHITECTURE

At this time, the OpenRAN architecture is not designed to support mobile ad-hoc networks in which all communications is over radio and no wire-line network is involved. The architecture is intended to support all radio link protocols in which a mobile communication or computing device is connected through a radio link to a terrestrial radio access point on a wired network, with the wired network running the Internet Protocol. While the architecture was primarily developed for CDMA protocols, the architecture can be applied to other protocols by simply dropping those atomic functions (such as macrodiversity combining/splitting) that are CDMA specific. Radio protocols that require minimal wire-support will require only a fraction of the OpenRAN functions, e.g. AAA and handoff.

On the core network side, the OpenRAN architecture is designed to support all core networks independent of technology. The architecture contains interworking functional entities that allow an OpenRAN to interwork with an existing core network based on one of the existing control protocols. The OpenRAN can also connect to an all IP core, based on the MWIF core architecture [4] or another all-IP core.

5 ARCHITECTURAL PRINCIPLES

General MWIF architectural principles are described in [1]. The following architectural principles apply to the OpenRAN:

- The development and evolution of the OpenRAN architecture should follow all MWIF architecture principles as specified in MTR-001 [1].
- The OpenRAN architecture should integrate with the MWIF Layered Functional Architecture (MTR-003) [3] and MWIF Network Reference Architecture (NRA, MTR-004) [4].
- The OpenRAN architecture should be independent of the MWIF Core architecture, to allow it to evolve independently of the MWIF Core architecture.
- The OpenRAN architecture should be designed with high QoS capability, scalability, availability, security and cost reduction as design goals.
- The OpenRAN architecture should provide QoS support as part of MWIF end-to-end[3] QoS strategy.
- The OpenRAN architecture should allow internal RAN resources used for control, transport, and processing to be optimized.
- The OpenRAN architecture should support the necessary functions to ensure that the necessary level of security can be achieved.

6 REQUIREMENTS

The proposed architecture shall satisfy all the applicable architectural requirements for basic RAN functionality. In addition, new requirements are identified in this chapter. For background, see [6] [7][9][10][11].

6.1 Architectural Requirements

6.1.1 Wireless Access Technology Independent

The OpenRAN architecture shall at least support the current 2G and 3G radio technologies such as WCDMA, CDMA2000, EDGE, IS-95. Also wireless LAN.

6.1.2 Minimal Functionality

The Open IP RAN architectures and protocol set shall provide at least equivalent functionality to existing RAN architectures [10].

[3] end to end in this context means from terminal to the termination point of the call or session

6.1.3 IP Based Transport Network

The OpenRAN architecture shall transport bearer and control traffic based on IP technology. Detailed requirements of IP in the RAN as transport option are documented in MTR-006 [5]. Layer 1 and layer 2 can be any technology.

6.1.4 IETF Protocols

The OpenRAN architecture shall use IETF protocols whereever applicable.

6.1.5 Use of IPv6

In recognition that IPv6 will become the dominant protocol and that the MWIF Architecture should exclusively support IPv6, although the MWIF architecture must be capable of interworking with IPv4 networks and devices [2].

6.1.6 Separated Control and Bearer Function

The OpenRAN architecture shall be defined in terms of separate functions such that it is possible to separate transport/bearer from control [8] to the extent allowed by the radio protocols.

6.1.7 Distributed Control and Bearer Function

The OpenRAN architecture shall support distributed control and bearer function, in order to facilitate load balancing and reliability.

6.1.8 Distribution of Cell Dependent and UE Functions

The OpenRAN architecture shall support distribution of cell dependent and UE control and bearer functions.

6.1.9 QoS Support

- The OpenRAN Architecture shall be capable of simultaneously supporting multiple transport and radio QoS levels, including in handoff scenarios.
- The OpenRAN Architecture shall provide support such that radio resources can be managed to actualize application QoS in the RAN and over the air.
- The OpenRAN Architecture should be capable of supporting multiple levels of static QoS (negotiation of parameters before the session setup) as well as dynamic QoS (negotiation of parameters while the session is in progress).

6.1.10 Radio Resource Management

The OpenRAN architecture shall allow optimized use of different wireless access technologies that are supported.

6.1.11 Availability and Reliability

Platform, link and system (or sub-system) availability and reliability is driven by a combination of operator, subscriber and regulatory needs (e.g. emergency services). The OpenRAN architecture shall support the necessary functions to ensure that the necessary availability and reliability can be achieved.

6.1.12 Scalability

The OpenRAN architecture shall be able to support deployment within LAN, MAN, WAN environment. The architecture shall also support increase in capacity without architectural impact.

6.1.13 Operations, Administration, and Maintenance Support

The OpenRAN architecture shall use IETF-based standard network management protocols.

6.1.14 Core Support

The OpenRAN architecture shall interoperate with the MWIF core network architecture as defined in MTR-004 [4].

6.1.15 Authentication, Authorization, and Accounting Requirements

- Authentication, authorization, and accounting can handle multiple radio channel authentication protocols (IS-95, GSM-SIM, new).
- Authentication, authorization, and accounting can be present in the RAN or provided by core network functions.

6.2 Operator Requirements

The following operator requirements are mainly from MTR-002 [2].

6.2.1 Open Interface Support

The OpenRAN architecture shall support open interfaces between any network entities in the OpenRAN that may be implemented by operators/ISPs and manufacturers as separate systems, sub-systems, or network entities. IETF protocols shall be considered and adopted in these open interfaces when possible.

6.2.2 Interoperability with Legacy (2G/3G) Networks

- The OpenRAN architecture shall support interoperability between current 2G/3G Core network and the OpenRAN.
- The OpenRAN architecture shall support interoperability between current 2G/3G access networks and the OpenRAN.

6.2.3 Various Deployment Scenarios

The OpenRAN architecture shall support network deployment in public as well as in enterprise/corporate environments. While existing RAN deployments do not permit the connection of a RAN directly to the public Internet, this configuration may be desirable in the future for new business models, e.g. the wireless ISP model.

6.2.4 Scaleable Architecture

The OpenRAN architecture shall provide network operators the ability to expand specific RAN functional entities independently of other entities. In addition, this architecture shall allow network operators to gradually deploy network entities and expand their networks.

6.2.5 Security

The OpenRAN architecture shall provide functions to protect its network resources and traffic from unauthorized control access.

6.2.6 Plug and Play

"Plug and Play" refers to easy installation and configuration of a network entity, especially Node B/BTS or other Base Station/Access Point Functional Entity.

For example, the IP address and basic network information of each entity could be delivered automatically, e.g., through the use of DHCP (Dynamic Host Configuration Protocol).

Because it is considered that the number of such entities to ubiquitously support broadband radio service may increase tremendously and because the OpenRAN architecture is intended to introduce a distributed system architecture, installation and maintenance costs for a large number of servers and other entities may increase unless automatic configuration is available. "Plug and Play" brings many advantages, such as:

- Easy and reliable equipment installation without specific technical knowledge, reducing the labor cost for installation;
- Easy deployment of a distributed network system;
- Easy and hot (i.e. to keep network running) exchange of the network equipment when it is broken or version incremented.

"Plug and Play" may require introducing a configuration server functionality or may be realized by another technique. "Plug and Play" could be useful not only for IP configuration but also for radio, L2, and other aspects.

6.2.7 System Migration

The OpenRAN architecture shall demonstrate the ability to integrate with legacy RAN and core network infrastructure to allow a smooth migration. Migration issues include:

- Protection of existing investment on infrastructure;
- Ability for operators to migrate portions of their network functionality towards the new architecture at a pace that best fit their needs; etc.

6.3 Handoff Requirements

- Provide equivalent handoff mechanisms that equal or exceed current cellular performance, and work for both voice and data;
- Allow handoff between different radio access technologies on a single RAN for load balancing purposes (example: between GSM and WCDMA);
- Meets QoS requirements (e.g. low latency);
- Minimize transport data loss within the constraints of the medium;
- Support inter-RAN handoff by working together with core network mobility management.

7 FUNCTIONAL ENTITIES

7.1 Function Definitions

The following sections describe the atomic functions supported by the OpenRAN architecture.

7.1.1 Radio resource admission control

The purpose of the radio resource specific admission control is to admit or deny new users, new radio channels (for example due to handover) dependent on existing radio resource loading in co-ordination with the RAN admission control function. This atomic function should try to avoid overload situations and base its decisions on interference and resource measurements. Radio resource admission control concerns itself strictly with radio resources, and not with RAN resources, and it informs the RAN admission control co-ordination function should an overload situation occur.

7.1.2 Radio directed packet flow admission control

The purpose of radio directed packet flow admission control is to admit or deny a new radio directed packet flow. This requires co-ordination with radio resource admission control, and involves both radio and RAN resources. This co-ordination is handled by admission control co-ordination.

7.1.3 Radio resource congestion control

The task of radio resource congestion control is to monitor, detect and handle situations when radio resources are reaching a near overload or an overload situation with the already connected users. This means that the radio link has run out or will soon run out of capacity. The congestion control should then bring the system back to a stable state as seamlessly as possible.

7.1.4 Static common physical radio resource configuration and operation

This function configures the common physical radio channel resources, i.e. cells/cell sectors and common channels, and takes the resources into or out of operation. This is an OA&M function

7.1.5 Dynamic common physical radio resource configuration and operation

This function dynamically manages common physical channels upon cell traffic needs (within the limits set by O&M). It is necessary for common physical channels that are heavily used, for example, TDD in WCDMA. This function does no allocation or mapping of physical to logical resources, it sets up the hardware in the base station with the allocated resources.

7.1.6 Static common physical radio resource allocation and deallocation

This function manages the common physical radio channel allocation (resp. deallocation). The function defines limits on the radio parameters for the common radio channels (e.g. frequency, CDMA spreading codes, timeslots etc.) within which dynamic physical allocation and deallocation operates. It is an O&M function. This function does not actually configure these resources nor take them into/out of operation.

7.1.7 Dynamic common physical radio resource allocation and deallocation

This function dynamically manages the common physical radio channel allocation (resp. deallocation). The function defines, reserves and frees the radio parameters for the common radio channels (e.g. frequency, CDMA spreading code, timeslots etc.) within the limits defined by the static common physical allocation and deallocation. This function does not actually configure these resources nor takes them into/out of operation.

7.1.8 Common logical radio resource allocation and deallocation

This function manages the common logical radio channel allocation (resp. deallocation), including the mapping to physical channels. Examples of common logical radio resources are the broadcast control channel, paging control channel, common control channel, broadcast or quick paging channel etc. Preconfiguration is accomplished at BTS installation as an OA&M function.

7.1.9 Dedicated physical radio resource allocation and deallocation

This function manages the dedicated physical radio channel resources, specifically allocation and release, for a single user. This function may be activated during the call since e.g. the user service request may vary, or macrodiversity may be used. Examples of physical radio resources are Walsh codes, channel processors, etc. This function does not actually configure these resources nor take them into/out of service.

7.1.10 Dedicated logical radio resource allocation and deallocation

This function manages the dedicated logical radio channel allocation (resp. deallocation) according to the QoS needs for a radio bound IP flow of single user. This function may be activated during the call since e.g. the user service request may vary. An example of a dedicated logical radio resource is a dedicated radio channel.

7.1.11 Dedicated physical radio resource configuration and operation

This function configures the dedicated physical radio network resources, and takes these resources into or out of operation This function does no allocation or mapping of physical to logical resources, it sets up the hardware in the base station with the allocated resources.

7.1.12 System information broadcast

This function provides the UE with the radio access specific information needed for its operation within the network, for example: power, synchronization, and cell parameters. Other information, for example core network information, may also be provided.

7.1.13 Cell environment measurement collection

This function controls and collects the radio environment measurements on both dedicated and common channels within a cell, such as channel quality estimates, for purposes of, e.g., admission control and handoff. Actual measurements are performed by a radio L1 function, see Radio environment survey measurements.

7.1.14 RAN environment measurement collection

This function controls and collects channel quality estimates on both dedicated and common channels in the RAN for purposes of load balancing between cells. It depends on cell environment measurement collection to provide the individual cell measurements.

7.1.15 Dynamic channel data rate allocation co-ordination

This function co-ordinates the dynamic allocation of the data rate for a radio channel, and it is optional depending on whether the radio protocol supports it. It is For Further Study.

7.1.16 Downlink open loop power control

The downlink open loop power control sets the power of downlink channels.

7.1.17 Radio resource context management

This function is responsible for correlating a UE and allocated RAN resources into a context and managing the context. It does no resource allocation/deallocation on its own. As part of its operation, this function deals with setup and release of a control connection between the UE and the RAN. The functional entity in which this atomic function resides performs centralized management of the UE context.

7.1.18 Connection setup/release

This function is responsible for the control of radio bearer connection set-up and release in the RAN. This function manages radio bearer setup, maintenance, and release, and includes both radio and terrestrial (i.e. RAN) resources. It is the global manager for radio bearer connections.

7.1.19 Handover control

This function performs the mobility of the radio interface, based on information provided by the network load optimization control function and on radio measurements collected from the UE. The function is responsible for maintaining the required transport and radio QoS. Handovers may also be directed across different radio systems (e.g. UMTS, GSM).

7.1.20 Network load optimisation control

This function signals a request for handover for purposes of load-balancing, path optimization, and resource optimization. Relevant information shall be provided to the handover control function for that purpose.

7.1.21 UE measurement control

This function manages the measurements to be performed by the UE. It sends measurement requests and modifications to the UE and collects the measurement results. Besides the radio network measurements, information such as mobile location, etc. may also be collected.

7.1.22 UE alerting co-ordination

Depending on whether the UE currently has an active dedicated control channel or not, this function selects a channel and message type to use to alert the UE that incoming data is available. In 3GPP, this function decides whether to use a dedicated control channel or paging channel to deliver the paging message. In 3GPP2, this function decides whether to alert the UE via a dedicated control channel and its particular message, or the paging channel and the paging message. This function is the first point of contact between the core network and RAN for purposes of paging.

7.1.23 Multi-cell UE alerting co-ordination

This function determines in which cell paging should occur and activates the appropriate functions, according to whether the UE currently has a context active or not. This function also determines in which cells paging should occur.

7.1.24 Cell paging

This function executes paging via the paging channel in a cell upon command of the UE alerting co-ordination function.

7.1.25 UE dedicated alerting

The function alerts the UE about available incoming data via a dedicated control channel upon command of the UE alerting co-ordination function.

7.1.26 Radio directed packet flow QoS to radio QoS mapping

This function maps radio directed packet flow QoS into radio QoS. Radio directed packet flow QoS is application QoS on application IP packets in the RAN, radio QoS is QoS associated with the radio channels.

7.1.27 Radio QoS to transport QoS mapping

This function maps radio QoS into transport plane QoS. Radio QoS is QoS associated with the radio channels, transport plane QoS is IP QoS associated with IP transport where radio frames are carried as payload in IP packets.

7.1.28 Location management

This function handles the location update messages to/from the UE while the UE mobility is being tracked by the RAN. This does not include geo-location information. The granularity of the paging area, whether to have differently sized paging areas depending on service, whether to involve the core network, etc., are all items For Further Study.

7.1.29 Macrodiversity combining/splitting control

This function controls the combining/splitting of information streams to receive/transmit the same information through multiple channels from/to a single UE. This function does not control any other aspect of macrodiversity combining/splitting except the combining/splitting of legs.

7.1.30 Radio channel coding control

This function generates control information required by the channel coding/decoding execution functions. This may include channel coding scheme, code rate, etc.

7.1.31 Media access measurement control

This function collects information on radio media utilization for making a decision on whether the radio channel should be switched to a higher or lower capacity.

7.1.32 TDD Timing Advance control

This function is used in uplink to align the uplink radio signals from the UE to the RAN. Timing advance is based on uplink burst timing measurements, and on Timing Advance commands sent downlink to the UE.

7.1.33 Tracing

This function executes tracing of various events related to a UE and its activities.

7.1.34 Tracing Control

This function controls tracing of various events related to a UE and its activities, at the request of the core network. This is an O&M function.

7.1.35 Geo-position information generation

This function generates the geographic position measurements for the UE. This radio layer 1 function does not query the UE since it has no access to the radio protocol. The Geo-position collection and calculation function performs this.

7.1.36 Geo-position collection and calculation

This function collects geographic location data from the Geo-position information generation function or by querying the UE and calculates the geographic location.

7.1.37 Radio broadcast/multicast

This function supports radio broadcast/multicast at the cell level.

7.1.38 Radio Broadcast/multicast flow control

When processing units on the bearer plane become congested during broadcast/multicast, this function informs the data source about the congestion situation and takes means to resolve the congestion.

7.1.39 Radio Broadcast/multicast status information

This function supports return of broadcast/multicast status information to the sender.

7.1.40 Core network control protocol conversion function

This function covers control protocol conversion between RAN and core. One example is OpenRAN to 3GPP UTRAN RANAP conversion for 3GPP IuCS interface.

7.1.41 Core network bearer protocol conversion

This function covers bearer protocol conversion between RAN and core.

7.1.42 Core network control plane anchor attachment

This function provides routing of RAN control plane packets to a given point of attachment in the core network. In the absence of a core control interworking function, this function routes the control to the Access Gateway.

7.1.43 Core network bearer plane anchor attachment

This function provides routing of RAN bearer plane packets to a given point of attachment in the core network.

7.1.44 Admission authorization

This function admits IP flows into the RAN based on authorization of the UE or core flow. This function is optional and unnecessary if AAA is handled by the core network.

7.1.45 RAN address management

This function manages address assignment and network parameter information for entities within the RAN. If IPv6 multi-homing is used, the network elements acquire (or lose) additional addresses, interface and prefixes dynamically. This is an OA&M function.

7.1.46 Database management

This function manages databases of RAN information. Examples of such information are:

- Authentication, authorization, and accounting information;
- QoS policy;
- Radio parameters;
- Radio network topology information;
- Pilot mapping onto cell sector info database.

This function is For Further Study

7.1.47 Radio network operations and maintenance

This function provides operations and maintenance on the radio network. Some sub-functions are:

- Configuration management;
- Network change control;

- Fault management;
- Performance management.

This function is For Further Study.

7.1.48 Inter-RAN control protocol conversion

This function converts control protocol traffic between OpenRAN protocols and legacy RAN protocols of the same radio link technology. An example is conversion of OpenRAN control protocols to 3GPP R99 Iur protocols. If an inter-technology handoff occurs, either the bearer path must be moved or an inter-RAN bearer conversion function (see Section 7.1.69) may be applied.

7.1.49 Segmentation and reassembly

This function performs segmentation and reassembly of radio frames to/from packets across the radio channel.

7.1.50 Common delivery acknowledgement

This function performs acknowledgement of delivered packets and undelivered packets on common channels according to radio bearer QoS. Replies from specific UEs to traffic on a common channel are acknowledged through dedicated delivery acknowledgement.

7.1.51 Dedicated delivery acknowledgement

This function performs acknowledgement of delivered packets and undelivered packets on the dedicated channels according to radio bearer QoS.

7.1.52 Header compression

This function performs header compression over the radio link.

7.1.53 Common multiplexing/demultiplexing

This function performs multiplexing/demultiplexing of services and multiplexing of UEs on common radio channels. Replies from specific UEs to common channel traffic are demultiplexed through dedicated multiplexing.

7.1.54 Dedicated multiplexing/demultiplexing

This function performs multiplexing/demultiplexing of traffic streams on dedicated radio channels.

7.1.55 Macrodiversity combining/splitting

This function performs the combining/splitting of information streams to receive/transmit the same information through multiple channels from/to a single UE.

7.1.56 Radio channel encryption and decryption

This function is a pure computation function whereby the radio frames can be protected against a non-authorized third-party. Encryption and decryption may be based on the usage of a session-dependent key, derived through control and/or session dependent information. The data, including radio frame headers, travels to and from the UE over the air in encrypted form but once past the functional entity containing this atomic function, the data is in clear text form.

7.1.57 Uplink outer loop power preprocessing

This atomic function preprocesses uplink power measurements, including averaging, forwarded from Radio Layer 1.

7.1.58 Uplink outer loop power measurement

This atomic function performs power measurements for effecting uplink outer loop power control. The measurements are forwarded through the uplink outer loop power preprocessing function for use in making power control decisions.

7.1.59 Uplink outer loop power control

This atomic function makes the decision about power control and sends commands to the UE to effect power control.

7.1.60 Downlink outer loop power control co-ordination

This atomic function receives power control measurements from the UE, makes the decision about the need for downlink power control, and commands the downlink outer loop power control to perform power control.

7.1.61 Radio downlink outer loop power control

This atomic function directly operates on the radio layer 1 to effect radio power control.

7.1.62 Radio frame delivery measurement and accounting

This function measures the number of delivered and undelivered radio frames and sends that information back to the core network for accounting or QoS performance measurement purposes.

7.1.63 Initial random access detection

This function detects an initial access attempt from a mobile station and responds appropriately. The handling of the initial access may include procedures for a possible resolution of colliding attempts.

7.1.64 RAN admission control co-ordination

The purpose of the RAN admission control co-ordination function is to co-ordinate various distributed admission control functions and deliver a definitive answer to whether or not the new user or radio bearer can be admitted to the RAN. This function also negotiates service options with the mobile. RAN admission control co-ordination has the last say about whether the new user or radio bearer is admitted.

7.1.65 Radio environment survey measurements

This function performs actual measurements on radio channels (current and surrounding cells) and translates these measurements into radio channel quality estimates. Measurements may include:

- Received signal strengths (current and surrounding cells);
- Estimated bit error ratios, (current and surrounding cells);
- Estimation of propagation environments (e.g. high-speed, low-speed, satellite, etc.);
- Transmission range (e.g. through timing information);
- Doppler shift;
- Synchronisation status;

- Received interference level;
- Total DL transmission power per cell.

This is only a partial list of the measurements that might be performed. The actual list will depend on the radio link protocol.

7.1.66 Uplink inner loop power control

The Uplink inner loop power control function sets the power of the uplink dedicated physical channels. It receives the quality target from Uplink outer loop power controland quality estimates from Uplink outer loop power measurement. The power control commands are sent on the downlink dedicated physical control channel to the UE.

7.1.67 Radio channel coding

This function introduces redundancy into the source data flow, increasing its rate by adding information calculated from the source data, in order to allow the detection or correction of signal errors introduced by the transmission medium. The channel coding algorithm(s) used and the amount of redundancy introduced may be different for the different types of logical channels and different types of data. This function optionally also performs interleaving and softer handoff, if supported by the radio protocol.

7.1.68 Radio channel de-coding

This function tries to reconstruct the source information using the redundancy added by the channel coding function to detect or correct possible errors in the received data flow. The channel decoding function may also employ *a priori* error likelihood information generated by the demodulation function to increase the efficiency of the decoding operation. The channel decoding function is the complementary function to the channel coding function. This function optionally also performs interleaving and softer handoff, if supported by the radio protocol.

7.1.69 Inter-RAN bearer conversion

This function converts OpenRAN IP-based bearer traffic into legacy RAN traffic for internetworking with RANs of the same radio link technology, e.g between an OpenRAN running WCDMA and a 3GPP R99 ATM-based RAN. It is For Further Study.

7.1.70 System information broadcast control

This function manages the radio access specific information that is provided to the UE for its operation within the network. Common channel access information is included. Whether it involves a higher level entity in 3GPP2 is For Further Study.

7.1.71 System information broadcast configuration

This function configures system information for broadcast. It is an O&M function and is For Further Study.

7.1.72 Radio media access measurements

This function performs radio media utilization measurements for making a decision on whether the radio channel should be switched to a higher or lower capacity.

7.1.73 User Radio Gateway relocation control

This function decides when the User Radio Gateway relocation procedure should be performed and initiates the necessary actions..

7.1.74 User Radio Gateway relocation execution

This function is responsible for actually executing the relocation of all bearer plane functions. It is controlled by the User Radio Gateway relocation control function.

7.1.75 Mobile Control relocation control

This function decides when the Mobile Control relocation procedure should be performed and initiates the necessary actions.

7.1.76 Mobile Control relocation execution

This function is responsible for actually executing the relocation of all control plane functions. It is controlled by the Mobile Control relocation execution.

7.2 Functional Architecture

In this section, the functional entities composing the functional architecture are presented. The description of each functional entity contains a list of the atomic functions contained in the entity, and a list of the reference points for interconnecting entities. The reference points are labeled with the identifiers from Figure 1.

The list of atomic functions included in a functional entity describes the detailed function of that entity. The following list gives a high level description of what each functional entity is intended to do:

- UE Geo-location - Collect and calculate geo-position information on a UE.
- Cell Control - Functions involving cell-related radio control.
- Common Radio Resource Management - Collect information on radio channel quality and initiate action to optimize radio link utilization.
- Mobile Control - Functions involving dedicated UE radio control.
- Paging/Broadcast - Co-ordinate UE and cell paging and perform radio broadcast/multicast.
- Local Authentication, Authorization, and Accounting - Admission authorization, if not done by the core network.
- Core Network Control Interworking - Protocol conversion between OpenRAN control protocols to/from legacy core network protocols.
- RAN Control Interworking - Protocol conversion between OpenRAN control protocols to/from legacy RAN control protocols.
- Micromobility Anchor - Co-ordinate bearer traffic between core network macromobility and RAN micromobility.
- Cell Bearer Gateway - Perform functions involving bearer delivery for common channels, and radio/broadcast multicast.
- User Radio Gateway - Perform functions involving bearer delivery for dedicated channels.
- Core Network Bearer Interworking - Protocol conversion between OpenRAN bearer protocols to/from legacy core network bearer protocols.
- RAN Bearer Interworking - Protocol conversion between OpenRAN bearer protocols to/from legacy RAN bearer protocols.
- Radio L1 - Perform functions specific to Radio Layer 1, the physical layer.

7.2.1 Control Plane

The following table contains the functional entities, their atomic functions, and their interconnections for the OpenRAN control plane.

Functional Entity	Atomic Functions	Reference Points
UE Geo-location	• Geo-position collection and calculation	• Xr_4 - Mobile Control • Xr_5 - Cell Control[4] • Xr_{28} - Radio L1[4] • Xr_{23} - Access Gateway[5]
Cell Control	• Radio resource admission control • Radio resource congestion control • Dedicated physical radio resource allocation and deallocation • Common logical radio resource allocation and deallocation • Dynamic common physical radio resource allocation and deallocation • Dynamic common physical radio resource configuration and operation • System information broadcast control • Cell environment measurement collection • Cell paging • Downlink open loop power control	• Xr_5 - UE Geo-location[4] • Xr_8 - Common Radio Resource Management • Xr_{14} - Cell Bearer Gateway • Xr_9 - Mobile Control • Xr_{25} - Paging/Broadcast • Xr_{19} - Radio L1
Common Radio Resource Management	• RAN environment measurement collection • Network load optimisation	• Xr_6 - Mobile Control • Xr_8 - Cell Control

[4] Optional, depends on the radio protocol.

[5] If the core network is all-IP.

Mobile Control	• Dedicated logical radio resource allocation and deallocation • Dedicated physical radio resource configuration and operation • User Radio Gateway relocation control[6] • Core network control plane anchor attachment[7] • Dynamic channel data rate allocation co-ordination • Radio directed packet flow admission control • RAN admission control co-ordination • Radio resource context management • Tracing • Connection setup/release • UE measurement control • Uplink outer loop power control • Downlink outer loop power control co-ordination • Radio directed packet flow QoS to radio QoS mapping • Radio QoS to transport QoS mapping • Location management • Macrodiversity combining/splitting control • Radio channel coding	• Xr_4 - UE Geo-location • Xr_{24} - Paging/Broadcast • Xr_7 - Access Gateway[5] • Xr_6 - Common Radio Resource Management • Xr_9 - Cell Control • Xr_{10} - User Radio Gateway • Xr_7 - Core Network Control Interworking[8] • Xr_{11} - RAN Control Interworking[9] • Xr_2 - Local AAA[10] • Xr_{13} - Micromobility Anchor • Xr_3 - Mobile Control[11]

[6] This mapping is provisional, final mapping depends on micromobility solution and is For Further Study.

[7] Only if Core Network Signalling Interworking is not present.

[8] If the core network is a legacy network.

[9] Optional, depending on the interworking situation.

[10] Optional, and not needed if AAA is handled by the core.

[11] Necessary for Mobile Control relocation.

	control • Media access measurement control • TDD Timing Advance control • Radio frame delivery measurement and accounting • UE dedicated alerting • Mobile Control relocation control • Mobile Control relocation execution • Handover control	
Paging/Broadcast	• Radio Broadcast/multicast flow control • Radio Broadcast/multicast status information • Multi-cell UE alerting co-ordination • UE alerting co-ordination	• Xr_{24} - Mobile Control • Xr_{25} - Cell Control • Xr_{26} - Core Network Control Interworking[8] • Xr_{27} - Cell Bearer Gateway • Xr_{26} - Access Gateway[5]
Local Authentication, Authorization, and Accounting (AAA)[10]	• Admission authorization	• Xr_{2} - Mobile Control • Xr_{1} - Core Network Control Interworking[8] • Xr_{1} - Access Gateway[5]
Core Network Control Interworking[8] (CN Control IWF)	• Core network control protocol conversion function • Core network control plane anchor attachment	• Xr_{7} - Mobile Control • Xr_{26} - Paging/Broadcast • CN_{c} - Core Network Control • Xr_{1} - Local AAA[10] • Xr_{12} - Core Network Bearer Interworking[8]
RAN Control Interworking[9] (RAN Control IWF)	• Inter- RAN control protocol conversion	• Xr_{11} - Mobile Control • Xr_{15} - RAN Bearer Interworking[9] • RR_{c} - External RAN control.

7.2.2 Bearer Plane

The following table contains the functional entities, their atomic functions, and their interconnections for the OpenRAN bearer plane.

Functional Entity	Atomic Functions	Interconnections
Micromobility Anchor[12]	• Core network bearer plane anchor attachment[13]	• Xr_{22} - User Radio Gateway • Xr_{20} - Access Gateway[5] • Xr_{20} - Core Network Bearer Interworking[8] • Xr_{13} - Mobile Control
Cell Bearer Gateway	• Common delivery acknowledgement • Common multiplexing/demultiplexing • Radio broadcast/multicast	• Xr_{14} - Cell Control • Xr_{17} - User Radio Gateway • Xr_{16} - Radio L1 • Xr_{27} - Paging/Broadcast
User Radio Gateway[14]	• Segmentation and reassembly • Dedicated delivery acknowledgement • Radio channel encryption and decryption[15] • Header compression • Dedicated multiplexing/demultiplexing • Macrodiversity combining/splitting • Uplink outer loop power preprocessing • User Radio Gateway relocation execution • Radio media access measurements	• Xr_{17} - Cell Bearer Gateway • Xr_{27} - Mobile Control • Xr_{22} - Micromobility Anchor • Xr_{18} - Radio L1 • Xr_{21} - RAN Bearer Interworking[9]

[12] This functional entity is For Further Study.

[13] If not included in Core Network Interworking.

[14] Depending on the micromobility implementation, there may need to be an intra User Radio Gateway connection. This connection would be involved in moving the User Radio Gateway. Since the Micromobility Anchor is For Further Study, this connection has been left out of the chart.

[15] If the radio link technology does not support encryption

Core Network Bearer Interworking[8] (CN Bearer IWF)	• Core network bearer protocol conversion • Core network bearer plane anchor attachment	• Xr_{20} - Micromobility Anchor • CN_b - Core Network Bearer • Xr_{12} - Core Network Control Interworking[8]
RAN Bearer Interworking[9] (RAN Bearer IWF)	• Inter-RAN bearer conversion	• Xr_{21} - User Radio Gateway • RR_b - External RAN bearer • Xr_{15} - RAN Control Interworking[9]

7.2.3 Radio L1 Functional Entity

The Radio L1 functional entity spans both control and bearer planes. The following table contains the atomic functions and interconnections for the Radio L1 functional entity.

Functional Entity	Atomic Functions	Interconnections
Radio L1	• Geo-position information generation • System information broadcast • Radio environment survey measurements • Radio channel coding • Radio channel de-coding • Initial random access detection • Uplink outer loop power measurement • Radio downlink outer loop power control • Radio channel encryption and decryption[16] • Uplink inner loop power control[16]	• UR - The UE • Xr_{19} - Cell Control • Xr_{16} - Cell Bearer Gateway • Xr_{18} - User Radio Gateway • Xr_{28} - UE Geo-location[4]

7.2.4 OA&M Functions

A complete set of OA&M functions is For Further Study but the following have been identified initially:

[16] If supported by the radio link protocol

- Static common physical radio resource configuration and operation
- Static common physical radio resource allocation and deallocation
- System information broadcast configuration
- RAN address management
- Radio network operations and maintenance
- Database management
- Tracing Control

Interoperable OA&M is a crucial aspect of the OpenRAN and OA&M based on standardized, IETF network management protocols is For Further Study in Version 2.

7.3 Transport Plane

Although the atomic functions and functional entities associated with the transport plane play an important role in the OpenRAN, they are not included in the base architecture. The transport plane supports both the control and bearer planes. A traditional RAN architecture strictly separates functions provided by the radio network layer and the transport network layer (or transport plane). The OpenRAN does not require this strict separation; however, focusing on the radio network layer (or control plane) and the bearer plane is useful for purposes of decomposing the RAN into atomic functions, functional entities, and network elements. Later, when the consequences of this decomposition for disaggregation and distribution of RAN functions is well-understood, particular functions that are duplicated in the transport layer can be extracted and moved to the transport plane.

In this section, we present the atomic functions and functional entities associated with the transport plane. More detail on the IP transport and how it supports traditional RAN architectures can be found in [5].

7.3.1 Atomic Functions

7.3.1.1 Interior route information distribution

This function provides for the distribution of routing information among routers interior to the RAN.

7.3.1.2 Transport broadcast/multicast

This function supports all aspects of broadcast/multicast in the RAN transport plane, including multicast routing, multicast group allocation, etc.

7.3.1.3 Transport path reconfiguration

This function is responsible for reconfiguring the transport path after the execution of the Mobile Control and/or User Radio Gateway relocation. It is For Further Study whether this is simply a routing function (i.e. transport plane only) or whether it involves changing IP addresses of host functions.

7.3.1.4 UE address management and network parameter configuration

This function assigns a global home IPv6 address and other network parameter information to the UE, in the event that UE address management is not handled by the core network. An example of a case where it may already have a global address is if the UE has been assigned a permanent home address or if the UE address is assigned by the core network. This function is For Further Study depending on the address provisioning implementation.

7.3.2 Functional Entities

The following table contains the functional entities, their atomic functions and their interconnections for the OpenRAN transport plane.

Functional Entity	Atomic Functions	Interconnections
Interior Routing	• Interior route information distribution • Transport broadcast/multicast • Transport path reconfiguration[17] • UE address management and network parameter configuration	• Access Gateway

7.3.3 IPv4/IPv6 Interworking

If the OpenRAN is connected to an IPv4 core network, IPv4/IPv6 interworking is required. Since IP version interworking is a transport plane interoperability function with the core network and not really an OpenRAN function, it should be located in the border router for the respective core network. Chapter 10 discusses transport plane interworking through an Access Gateway to the MWIF core network.

7.3.4 Micromobility Anchor and the Transport Plane

Currently, the Micromobity Anchor is located on the bearer blane, but it is For Further Study whether the Micromobility Anchor is required and, if so, whether it is located in the bearer plane. If micromobility is completely handled by the transport plane, then the Micromobility Anchor can move to the transport plane.

8 FUNCTIONAL ARCHITECTURE

8.1 Introduction

The functional architecture containing functional entities is shown in Figure 1. In the figure, only the control and bearer planes are shown. The working group chose not to perform any aggregation of functional entities into network elements during phase 1 in order to keep the architecture as flexible as possible, and because future movement of atomic functions from the control plane to transport plane may cause some rearrangement.

[17] If transport path configuration after movement of a User Radio Gateway or Mobile Control involves routing changes only.

The figure shows the architecture for connections to both a legacy core network, via the Core Network Control/Bearer IWF, and to an MWIF core network, via the Access Gateway. This is for illustration purposes only. In reality, a single RAN only connects to a single core network, though it may connect to different core network subsystems (circuit-switched or packet-switched) and it may connect to a single MWIF core network through multiple Access Gateways.

The division between control and bearer traffic is maintained in the OpenRAN so far as possible. Some radio protocols allow control to be multiplexed onto dedicated channels, and for this purpose, reference points between the control and bearer plane are in the architecture between the Cell Control control plane functional entity and the Cell Bearer Gateway and User Radio Gateway bearer plane functional entities.

Some network elements are optional depending on the need to connect with a legacy core or legacy RAN, or if the function handled by the functional entity is handled in the core. If the Local AAA is lacking, Xr_1, Xr_2, and Xr_7 are merged into a single interface. If Mobile Control is required to become involved in paging a mobile in order to perform geo-location, Xr_{24} is not necessary. Finally, if no interworking with a legacy core network or RAN is required, none of the interworking interfaces are required.

There are several optional interfaces that depend on how the radio protocol handles particular functions, or on whether optional functional entities are included in the RAN. Xr_5 and Xr_{28} are both involved in conveying requests/responses for geo-location information to/from the UE, but, depending on the radio protocol, one or the other is required. Xr_{23} conveys geo-location requests/responses directly from/to the core network, and is optional depending on whether the UE Geo-location function itself is capable of requesting UE alerting through the Mobile Control function, or whether the core network must first send the geo-location requests through the Mobile Control function and have the Mobile Control function convey them to the UE Geo-location function after having alerted the UE. Xr_1 and Xr_2 are optional and are present if the AAA functional entity is present and absent if AAA is handled in the core. Xr_{13} is optional because the Micromobility Anchor is For Further Study.

The figure contains notations for specific reference points that could become open interfaces with protocols. The next section discuss the reference points in more detail. Note that in cases where particular network elements have been left For Further Study, in particular micromobility and security, additional atomic functions, functional entities, and reference points may be necessary.

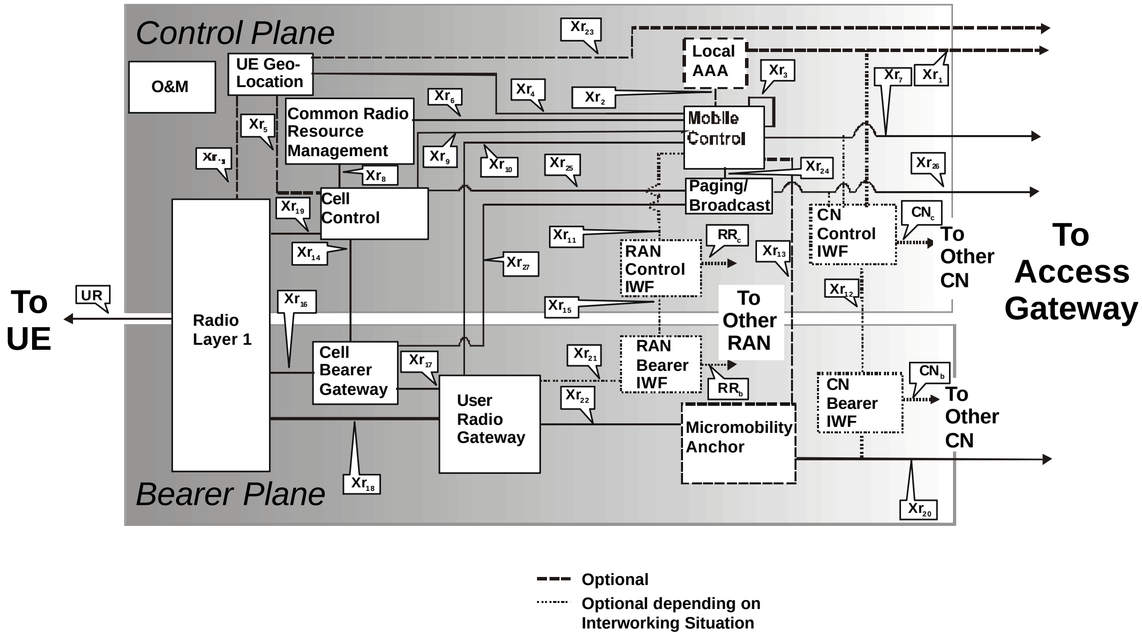


Figure 1 – OpenRAN Network Reference Architecture [18]

8.2 Reference Points

8.2.1 Xr_1 – Local AAA to Access Gateway

Local AAA is an optional function. This reference point carries inter-AAA server traffic between the Local AAA server network element in the RAN and an AAA server in the core. In the absence of Local AAA, this reference point is omitted and AAA messages with the core network are exchanged through Xr_7. Candidates for a protocol on this reference point are the IETF AAA protocols, in particular Diameter [15] and Radius [16].

8.2.2 Xr_2 – Local AAA to Mobile Control

The Local AAA is an optional function. If absent, Xr_2 is also absent. This reference point carries traffic involving RAN and UE AAA between the Mobile Control function, where it is recognized as AAA control traffic, and the Local AAA function (or CN Control IWF in the absence of Local AAA). If the reference point connects to the CN Control IWF, the AAA traffic is converted into a legacy protocol such as IOS 4.1 for 3GPP2 or RANAP for 3GPP R99 UTRAN. Candidates for a protocol on this reference point are the IETF AAA protocols, in particular EAP [17], Diameter [15], and Radius [16].

8.2.3 Xr_3 – Mobile Control to Mobile Control

This reference point connects two Mobile Controls in a single RAN. This reference point carries the following traffic:

- Messages to control and execute the transfer of Mobile Control for handling a particular UE,

[18] The Transport Plane is not shown in this figure. For a discussion of IP as transport see [5].

- Messages to control and execute the transfer of User Radio Gateway for handling a particular UE,
- Admission control traffic during admission of a new UE in order to load-balance among Mobile Controls.

During Mobile Control relocation, a User Radio Gateway may be transiently connected to two Mobile Controls, but only one connection exists between a User Radio Gateway and a Mobile Control after the relocation occurs. Xr_3 may carry traffic for a short period relayed from Xr_7 during Mobile Control relocation.

8.2.4 Xr_4 – UE Geo-location to Mobile Control

This interface carries commands from the Mobile Control function to the UE Geo -location function to perform geo -location determination. The UE geo -location function may use this reference point to exchange measurement commands and results with the UE.

8.2.5 Xr_5 – UE Geo-location to Cell Control

This reference point carries commands from the UE Geo-location function to the UE via the Cell Control to perform geo -location and returns the results to the UE Geo-location function. This reference point is optional depending on the radio protocol, and only necessary if the geo-location procedure requires interaction with the Cell Control in order to co-ordinate power suppression for accurate geo-location. If such co-ordination is not required, Xr_{29} is present instead. The exact nature of the protocol depends on the radio link protocol.

8.2.6 Xr_6 – Common Radio Resource Management to Mobile Control

This reference point carries commands from the Common Radio Resource Management to Mobile Control to invoke handover, in order to balance the load between cells. The CRRM uses measurements received from the Cell Control function to decide upon the need for load balancing.

8.2.7 Xr_7 – Mobile Control to Access Gateway

This reference point connects with the Access Gateway and carries QoS control traffic between the Access Gateway and the Mobile Control, and RAN/core control traffic related to setting up a radio directed packet flow. Other RAN/core control traffic involving AAA for admission control goes through different reference points, except if the Local AAA is absent. The reference point also carries RAN transparent signaling from the UE, geo-location positioning requests/results if no Xr_{24} reference point is present, tracing requests/results, radio frame delivery measurements for data volume requests/results, and forwards dropped frame accounting from the User Radio Gateway. Overload indications are handled as part of the QoS signaling. In the event that the OpenRAN connects with a core network requiring interworking, Xr_7 runs through the CN Control IWF instead of to the Access Gateway.

8.2.8 Xr_8 – Cell Control to Common Radio Resource Management

This reference point carries traffic involving commands from the Cell Control to measure the radio environment, and returns the results to the Cell Control.

8.2.9 Xr_9 – Cell Control to Mobile Control

This reference point carries radio control traffic related to a single UE. Particular functions are:

- Commands from the Mobile Control requesting the Cell Control to perform admission for a particular UE.

- Commands from the Cell Control informing the Mobile Control that admission is granted or denied. If admission is granted, these commands will include radio channel allocation information.
- Commands from the Mobile Control to release a UE's resources. These commands will include radio channel deallocation.
- Commands from the Cell Control to the Mobile Control notifying the Mobile Control of congestion conditions in the cell.
- Dedicated channel configuration and power control commands directed to the Radio Layer 1.

8.2.10 Xr_{10} –Mobile Control to User Radio Gateway

This reference point carries radio control traffic related to establishing, maintaining, and tearing down a bearer path for a UE. Traffic across this reference point consists of:

- Commands from the Mobile Control to establish and tear down a bearer channel,
- Commands from the Mobile Control to establish and tear down a soft handoff leg for a bearer channel,
- Commands from the Mobile Control to relocate the User Radio Gateway dedicated to a particular UE,
- Dedicated channel paging,
- Frame to packet mapping for dropped frame accounting,
- Media access measurement requests and replies,
- Changes in radio parameters affecting the User Radio Gateway, an example of which is the 3GPP2 long code mask,
- Uplink frame quality indications that act as input for uplink outer loop power control.

This reference point also carries all control traffic that is exchanged between the RAN and a particular UE. Examples of such traffic are RAN transparent core network/UE signaling, power control commands/measurements, handover measurements, context control, radio resource configuration, and geo-location measurement requests/results.

8.2.11 Xr_{11} – Mobile Control to RAN Control IWF

The RAN Control IWF is an optional function. If absent, Xr_{11} is absent. This reference point carries any OpenRAN radio control traffic that is needed when the OpenRAN is connected to a legacy RAN via a RAN Control IWF. The RAN Control IWF converts it into the legacy protocol. An example is a connection between an OpenRAN and a 3GPP R99 UTRAN, where the conversion to RNSAP is done.

8.2.12 Xr_{12} – CN Control IWF to CN Bearer IWF

Since both the CN Control IWF and CN Bearer IWF are optional, Xr_{12} is an optional reference point. The traffic on this reference point consists of commands to co-ordinate control and bearer traffic for a particular legacy CN reference point, and will depend on the CN reference point. This reference point is For Further Study.

8.2.13 Xr_{13} Mobile Control to Micromobility Anchor

The traffic on this reference point consists of commands from the Mobile Control to change the micromobility to macromobility mapping of the bearer packets. The functionality on this reference point is For Further Study depending on the function of the Micromobility Anchor.

8.2.14 Xr_{14} – Cell Control to Cell Bearer Gateway

Traffic on this reference point consists of control required for cell management but dedicated to a particular UE. Some particular functions are:

- Downlink open loop power control upon initial UE admission,
- Control traffic that needs to be multiplexed on the common channels,
- Common channel scheduling control.

In addition this reference point carries cell related control commands that are conveyed to the UE via system information broadcast.

8.2.15 Xr_{15} – RAN Control IWF to RAN Bearer IWF

Since both the RAN Control IWF and RAN Bearer IWF are optional, Xr_{15} is an optional reference point. If both network elements are absent, Xr_{15} is absent. The traffic on this reference point consists of control traffic to co-ordinate control and bearer for a particular legacy RAN interconnection, and depends on the legacy RAN protocol.

8.2.16 Xr_{16} – Cell Bearer Gateway to Radio Layer 1

Traffic on this reference point consists of radio frames for transmission to/from the common channels. This traffic is common bearer control traffic multiplexed onto the common bearer channels. The radio frame protocol dictates the exact format of the radio frames. The radio frames may be further processed for transport on the transport plane, e.g. through compression and multiplexing.

8.2.17 Xr_{17} – User Radio Gateway to Cell Bearer Gateway

Traffic on this reference point consists of radio frames for transmission to/from the common bearer channels, including multiplexed control and bearer traffic. Also, paging on dedicated channels is sent through this reference point. The radio frame protocol dictates the exact format of the radio frames. The radio frames may be further processed for transport on the transport plane, e.g. through compression and multiplexing.

8.2.18 Xr_{18} – User Radio Gateway to Radio Layer 1

Traffic on this reference point consists of radio frames for transmission to/from the dedicated bearer channels, including multiplexed control and bearer traffic. The radio link protocol dictates the exact format of the radio frames. The radio frames may be further processed for transport on the transport plane, e.g. through compression and multiplexing.

8.2.19 Xr_{19} – Cell Control to Radio Layer 1

This reference point carries signaling traffic for the control of the Radio Layer 1 functions. Some particular functions are:

- Downlink power control commands and measurement results,
- Radio resource configuration commands,
- Radio environment measurement requests.
- System information broadcast

8.2.20 Xr_{20} – Micromobility Anchor to Access Gateway

Traffic on this reference point is identical to that on Xr_{22}, with the exception that the address/tunnelling state of the packets may be different. Exactly how the co-ordination of micromobility and macromobility occurs is For Further Study. If the Micromobility Anchor is absent, this reference point extends to the User Radio Gateway.

8.2.21 Xr_{21} – User Radio Gateway to RAN Bearer IWF

The RAN Bearer IWF is an optional function. If absent, Xr_{21} is absent. Examples of traffic on this reference point are RTP packets [18] for multimedia traffic and application packets (for example HTTP [19]) for non-multimedia traffic. For Further Study is having the URG be responsible for assuring that packets to/from a UE in soft handoff into a legacy RAN are properly routed through the RAN Bearer IWF.

8.2.22 Xr_{22} – User Radio Gateway to Micromobility Anchor

Examples of traffic on this reference point are RTP packets [18] for multimedia traffic and application packets (for example HTTP [19]) for non-multimedia traffic.This traffic is ready for routing into the core network, with the exception that it might require some micromobility processing (address translation, detunnelling, etc.). The exact relationship between the User Radio Gateway and Micromobility Anchor is For Further Study depending on the micromobility solution. If the Micromobility Anchor is absent, this reference point is dropped.

8.2.23 Xr_{23} - UE Geo-location to Access Gateway

This reference point carries geo-location requests from the core network to the UE Geo-location, and the replies back to the core network. This traffic contains UE geo-location information in a standard IETF format[19]. This reference point is optional. For example, it is not required in 3GPP because the UE may need to be paged before geo-location information can be obtained.

8.2.24 Xr_{24} – Mobile Control to Paging and Broadcast

The traffic on this reference point consists of paging related messages used for UE dedicated alerting when the UE is in a connected state, since the UE alerting coordination function is located in the Paging and Broadcast network element.

8.2.25 Xr_{25} –Paging and Broadcast to Cell Control

This reference point carries commands from the Paging and Broadcast network element to alert a particular UE currently has no active context (i.e. cell paging),

8.2.26 Xr_{26} – Paging and Broadcast to Access Gateway

This reference points carries paging messages coming from the core network to the UE alerting coordination function in the Paging and Broadcast network element. Radio broadcast/multicast requests from the core network and radio broadcast/multicast status information reports to the core network are also carried by this reference point. In the event that the OpenRAN connects with a core network requiring interworking, Xr_{26} runs through the CN Control IWF instead of to the Access Gateway.

8.2.27 Xr_{27} – Paging and Broadcast to Cell Bearer Gateway

This reference point carries Cell Broadcast service information to the radio broadcast/multicast function responsible for broadcasting in a particular cell. In addition this reference point carries radio broadcast/multicast requests from the core network and radio

[19] The IETF is currently discussing a standardized geo-location protocol. There is no RFC published yet.

broadcast/multicast status information reports to the Core Network. The cell broadcast is traffic other than system broadcast.

8.2.28 Xr_{28} - UE Geo-location to Radio Layer 1

This reference point carries commands from the UE Geo-location function to the UE via the Radio Layer 1 to perform geo-location and returns the results to the UE Geo-location function. This reference point is optional depending on the radio protocol, and only necessary if the geo-location procedure does not require interaction with the Cell Control in order to co-ordinate power suppression for accurate geo-location. If such co-ordination is required, Xr_5 is present instead. The exact nature of the protocol depends on the radio link protocol.

8.2.29 CN_c – CN Control IWF to Other Core Network

The CN Control IWF is an optional function. The nature of the CN_c reference point is to connect OpenRAN control with the core network control for a legacy core network. For example, if the reference point to the core network is via a legacy 3GPP2 IOS4.1 gateway, then the protocol on CN_c is equivalent to the A1/A9/A11 control reference points. Depending on the transport protocols on both sides of the reference point, traffic on CN_c may require transport interworking as well.

8.2.30 CN_b – CN Bearer IWF to Other Core Network

The CN Bearer IWF is an optional function. The nature of the CN_b reference point is to connect the OpenRAN bearer path with the bearer for a legacy core network. For example, if the CN_b connects the OpenRAN bearer to an MSC in a legacy 3GPP2 core network, then CN_b is equivalent to the A2/A8/A10 voice and packet bearer reference points. Depending on the transport protocols on both sides of the reference point, traffic on CN_b may require transport interworking as well.

8.2.31 RR_c – RAN Control IWF to Other RAN

The RAN Control IWF is an optional network element. Control interworking between the OpenRAN and legacy RANs is only possible if the radio link protocol in both is the same. The nature of the RR_c reference point depends on the radio protocol and legacy RAN protocol with which the OpenRAN is connected. For example, if the radio protocol is WCDMA and the OpenRAN is connected with a legacy 3GPP R99 UTRAN, RR_c is equivalent to the Iur control plane reference point (RNSAP). Depending on the transport protocols on both sides of the reference point, traffic on RR_c may require transport interworking as well.

8.2.32 RR_b – RAN Bearer IWF to Other RAN

The RAN Bearer IWF is an optional network element. Bearer interworking between the OpenRAN and legacy RANs is only possible if the radio link protocol in both is the same. The nature of the RR_b reference point depends on the radio protocol and legacy RAN protocol with which the OpenRAN is connected. For example, if the radio protocol is WCDMA and the OpenRAN is connected to a legacy 3GPP R99 UTRAN, RR_b is equivalent to the Iur bearer plane reference point (DCH FP and several CCH FPs). Depending on the transport protocols on both sides of the reference point, traffic on RR_b may require transport interworking as well.

8.2.33 UR – Radio Layer 1 to UE

The traffic on this reference point depends on the radio link protocol, and will consist of radio frames in the radio protocol. These frames contain both control and bearer traffic.

9 CONCEPTUAL MODEL

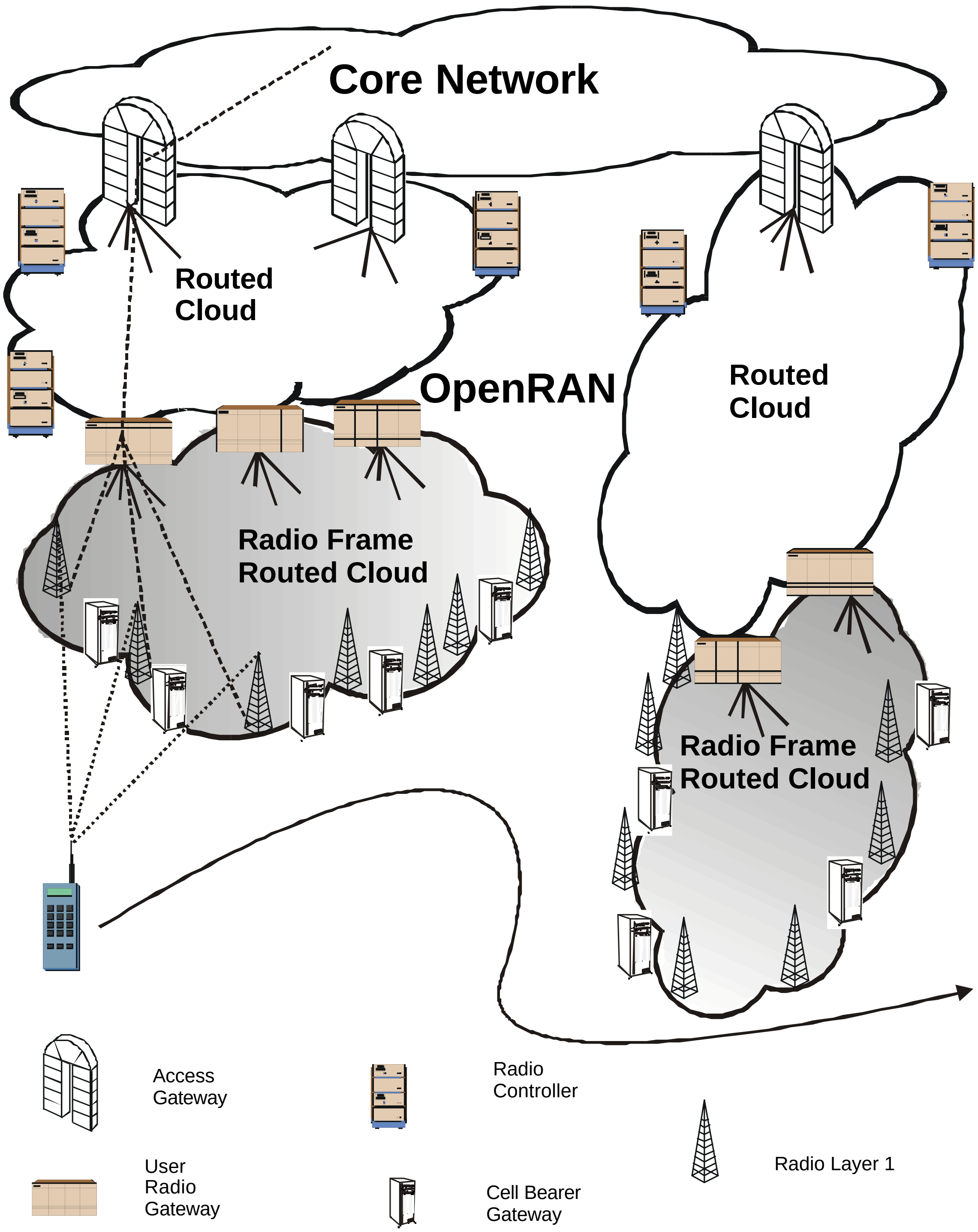


Figure 2– OpenRAN Conceptual Model

In this document, the RAN is defined as a collection of IP subnets under the same administrative domain that interface a set of radio access point to a wire-line backbone network via one or more Access Gateways. Figure 2 shows the dual nature of the OpenRAN. User IP packets are transported between the Access Gateway and the User Radio Gateways.

The packets on this part of the RAN network look exactly like the packets in the core network, with perhaps some additional tunnel headers depending on the micromobility implementation. On the lower part of the RAN network, transport plane IP packets carry radio frames between User Radio Gateways and the BTSs. Packets in this part of the network contain radio frames. IP is essentially acting as a medium for tunneling radio frame packets from the User Radio Gateway to the BTS. These two domains represent two logical networks, but can be mapped onto a single physical network. The Radio Controller contains the Mobile Control and Cell Control functional entities. These functional entities have been bundled in the figure, but could be separated in an actual implementation.

The architecture has been designed for maximum flexibility of implementation and deployment. The figure shows a fully distributed implementation, but modifications in the amount of distribution are possible. The following are some examples:

- Clustering the User Radio Gateway, the Cell Bearer Gateway, and all the control network elements (Mobile Control, Cell Control, Common RRM, etc.) with the Access Gateway is equivalent to a monolithic RNC/BSC and distributed Node Bs/BTSs.
- Clustering the User Radio Gateway, Cell Control, and Cell Bearer Gateway with the Radio Layer 1 resulting in a “smart” BTS/Node B.
- Clustering RAN Control IWF and RAN Bearer IWF into an InterRAN Gateway.
- Clustering the CN Control IWF and CN Bearer IWF for a RAN/Core Gateway.
- Clustering all signal plane network elements except for the Cell Control.

Note that the first bullet item above is compatible with a star topology and can be deployed where networking bandwidth is limited, while the second bullet item above is compatible with a mesh topology and can be deployed where more bandwidth is available. Other clusterings are possible, as are subclusterings within the larger clusterings.

The design allows all RAN operations to be confined within the RAN. This preserves the independence of the core network from the access network, an important scalability property. For example, relocating macrodiversity combining/splitting and segmentation/reassembly during an active session (SRNS relocation in 3GPP [12]) can be performed without involving the core, potentially simplifying and reducing the amount of time required for the operation. The relocation happens within the routed cloud between the Access Gateways and the User Radio Gateways. If the mobile moves between RANs, a hard (break before make) handoff through the core must occur.

10 INTEGRATION WITH MWIF CORE ARCHITECTURE

As with all access networks, the OpenRAN integrates with the MWIF core network through an Access Gateway. Besides providing simple packet forwarding between the RAN and the Core, the Access Gateway from the RAN side has the following functions:

- During establishing of end-to-end QoS, receives a QoS request either from the core network or from the UE, maps the request into a request for radio directed packet flow QoS, and forwards the request to the radio QoS mapping atomic function in the Mobile Control functional entity. This causes a request for application QoS to be mapped to a request for radio QoS.

- During packet forwarding, maps application QoS classifications on packets received from the core network into radio directed packet flow QoS classifications for the RAN, and vice versa in the RAN to Core direction.
- Admits IP flows to and from the core network based on QoS.
- Enforces QoS on IP flows, which may include policing, packet marking, priority queuing, packet forwarding and packet discarding; that is, it serves as the QoS Policy Enforcement point for control and bearer streams between the Access Network and core network.
- Tracks QoS usage on a per flow basis and forwards the accounting information to the AAA server. These functions are performed by the Local AAA network element, or the core AAA network element if there is no Local AAA network element in the RAN .
- May be involved in providing firewall service. The exact nature of security for the OpenRAN is For Further Study and depends on the security solution.
- Co-ordinates between the core network Mobility Manager, the RAN Micromobility Anchor, and Mobile Control during movement of the UE's point of attachment between one Access Network and another.
- Depending on core network support for UE dormancy, handles control involved in tracking cross-RAN dormant mode UEs and paging.

The exact details of the interaction between the Access Gateway, core, and access network with respect to QoS and mobility management depend on the QoS and micromobility mechanisms within the OpenRAN and are For Further Study.

Note that the core network Control and Bearer Interworking Functions are not required if the OpenRAN connects to the MWIF core because these functions are only concerned with converting between legacy control and bearer protocols and the OpenRAN IP based proctocols.

11 MAPPING TO 3G ARCHITECTURES

This chapter maps the OpenRAN architecture(s) to current 3G RAN architectures in 3GPP and 3GPP2. The intent is to provide 3GPP and 3GPP2 RAN architects with a guide to how the OpenRAN architecture might be realized through evolution of the existing RAN architectures.

11.1 Mapping the 3GPP architecture

11.1.1 UTRAN architecture basics

The UTRAN architecture is described in [14]. An example of this architecture in relation to the support of one UE is illustrated in Figure 3.

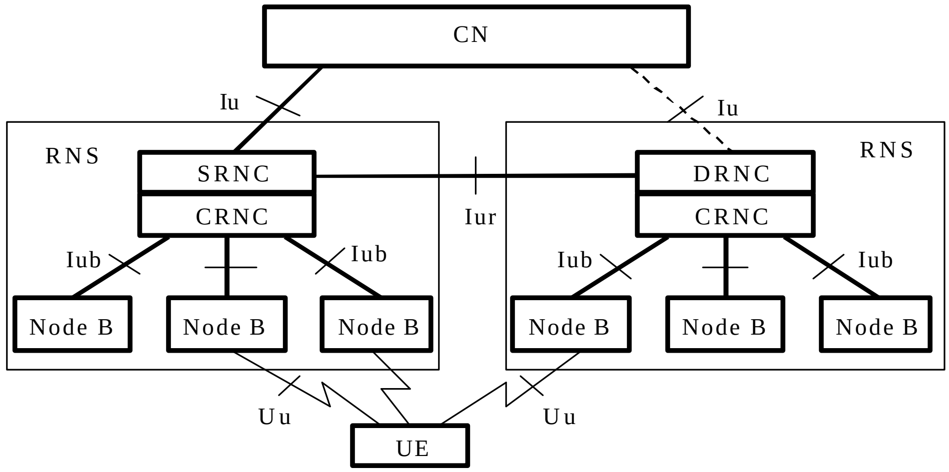


Figure 3 - UTRAN Architecture

The UTRAN consists of a set of Radio Network Subsystems (RNS) connected to the core network through the Iu interface. If the core network is split into separate domains for circuit and packet switched core networks, then there is one Iu interface (IuCS) to the circuit switched core network and one Iu interface (IuPS) to the packet switched core network for that RNS. In parallel there may be an Iu interface towards a Cell Broadcast Centre (IuBC) to support broadcasting of non-system information, like traffic jam, tariff changes, advertisements, etc.(not shown in the figure).

A RNS consists of the network entities Radio Network Controller (RNC) and one or more Node Bs. A Node B is connected to the RNC through the Iub interface. Inside the UTRAN, the RNCs in the RNSs can be interconnected together through the Iur interface.
The RNS is responsible for the resources of its set of radio cells and for handover decisions. During macrodiversity, a UE may be connected to a number of radio cells of different Node Bs and/or RNSs. With respect to a particular UE, any RNS can take on the role Serving RNS or Drift RNS. When required, Drift RNSs support the Serving RNS by providing radio resources, within radio cells connected to that Drift RNS.

The RNC encompasses almost all of the radio specific functions above the radio physical layer:

- The controlling part of each RNC (CRNC) is responsible for the control of resources allocated within Node Bs connected to that RNC and terminates the common channels. The CRNC handles RAN atomic functions that have a cell or a multiple cell related scope. Macrodiversity is optionally handled here.
- The Serving RNC (SRNC) handles the RAN specific control of a UE, terminates the radio layer 2 protocol and provides the macro diversity splitting/combining function relating to the connection paths over multiple DRNCs. It therefore handles atomic functions that have an UE related scope.
- The DRNC refers to the relaying function of the radio layer 2 between the Iur and Iub interfaces. The DRNC therefore represents a specific deployment of the CRNC in a macrodiversity situation.

A Node B can support one or more radio cells and terminates the physical layer of the radio interface. A Node B may support UEs based on FDD, TDD or dual-mode operation. It may include a combining/splitting function for “softer” handover between radio cells connected to that Node B.

Iu, Iur and Iub are both reference point and interface designations. Although IuCS, IuPS, IuBC, Iur and Iub are logically separated in a control and a bearer plane part (indicated by adding "-c" resp. "-u" suffixes in Figure 4 below), there does not exist a similar separation at the network element level.

11.1.2 Mapping the OpenRAN to the UTRAN architecture

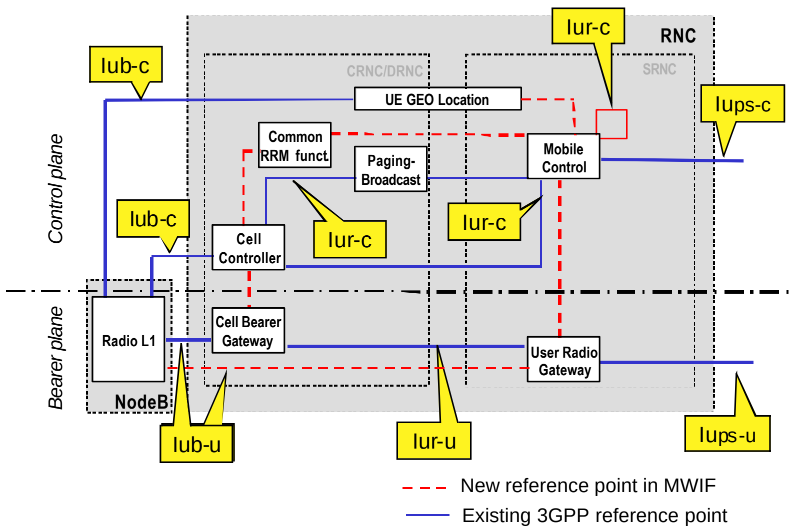


Figure 4 - OpenRAN mapped to the UTRAN Architecture

Figure 4 shows how the monolithic RNC network element with its logical SRNC and CRNC functions has been distributed in the OpenRAN over multiple network entities in order to allow for the physical separation of the control and the bearer plane and to improve the scalability.

The atomic functions with a cell or wider scope, i.e. the CRNC functions in 3GPP, are represented in the OpenRAN by Cell Control, Cell Bearer Gateway, Common RRM and Paging/Broadcast.

The Common RRM in 3GPP is limited in scope to the cells managed by a single CRNC. Due to the centralization and appropriate interfaces, in the OpenRAN this scope can be widened to the RAN level.

The atomic functions with a UE related scope, i.e. the SRNC functions in 3GPP, are represented in the OpenRAN by the Mobile Control function and the User Radio Gateway.

The geo-location functions in the 3GPP RNC are logically separated in CRNC and SRNC/SMLC (Serving Mobile Location Centre) functions. In the OpenRAN, because of the routed transport network, the SLMC can now directly address any NodeB allowing both geo-location functions to be centralized in a single functional entity.

Some network elements in the OpenRAN are not supported by the 3GPP RAN and have therefore been omitted from Figure 4. They relate to atomic functions that are handled in

3GPP by the core network (e.g. AAA, UE configuration). These functions are in the OpenRAN in order to allow a network operator to function as a wireless ISP without a service-based core, and are optional. Other functions are specific for a distributed architecture using IETF mechanisms (e.g. Micro Mobility Anchor). A final set of omitted functions relate to backward compatibility capabilities of the OpenRAN.

Some reference points of the OpenRAN can be mapped to 3GPP reference points and are annotated on Figure 4. 3GPP's "control plane" and "bearer plane" designations correspond with the "control plane" resp. "bearer plane" designations in the OpenRAN. Notice that this mapping refers only to a similarity of the functionality provided on the corresponding interfaces; it does not imply the complete re-use of these protocol stacks in the OpenRAN. Other reference points in the OpenRAN cannot be mapped because in 3GPP the corresponding interfaces only exist internal to the RNC.

11.2 Mapping to 3GPP2

11.2.1 General IOS Architecture

The 3GPP2/TSG-A cdma2000 Radio Access Network reference architecture is shown in Figure 5. This architecture is also known as the InterOperability Specification, or IOS, Version 4.1 architecture. In this architecture a base station (BS) consists of a base station controller (BSC) and one or more base station transceiver subsystems (BTSs).

The BSC performs the Mobile Control function plus the User Radio Gateway bearer functions. It contains the resources for setting up and maintaining traffic channels between the BTS and the core network. The BSC functions include call control logic and packet routing and switching functions and OA&M. These functions are required for interconnecting the BSC to the MSC, the BTSs that are part of the BS, other BSCs, and BTSs of neighboring BSs for purposes of soft handoff. The BSC also distributes necessary timing and frequency information within the BSC and provides billing information (air-time, number of packets/bytes, etc). Another major component of the BSC is the SDU function that is activated only in the source BS (see Figure 5). The SDU performs the following functions:

1. Traffic Handler: This function exchanges traffic bits with the associated vocoder or CDMA RLP function, or is directly connected to the A5 interface.
2. Control Layer 2: This function performs the radio layer 2 functionality of the air interface control protocol and is responsible for the reliable delivery of layer 3 control messages between the BS and the UE.
3. Multiplex Sublayer: This function multiplexes and demultiplexes user traffic and control traffic for the air interface.
4. Power Control: This function administrates the forward and reverse link power control in a CDMA system. This function and the channel element provide the power control function for the CDMA operation. As part of this function, it generates or utilizes relevant power control information that is exchanged over the air interface or with the channel element.
5. Frame Selection/Distribution: This function is responsible for selecting the "best" incoming air interface reverse link frame from the channel elements involved in the soft handoff. It also distributes forward air interface frames to all channel elements involved in a call.

6. Backhaul Frame Handler: This function demultiplexes the control information and the air interface reverse frame from the frame received over the backhaul network. It also multiplexes the control information and the air interface frames in the forward direction.
7. External Frame Handler: This function exchanges backhaul frames with channel elements which are remote from the Selector.
8. Intra-BS Frame Handler: This function exchanges backhaul frames with channel elements involved in intra-BS soft handoff.
9. Control: This function provides various radio resources control functions at the BSC level.

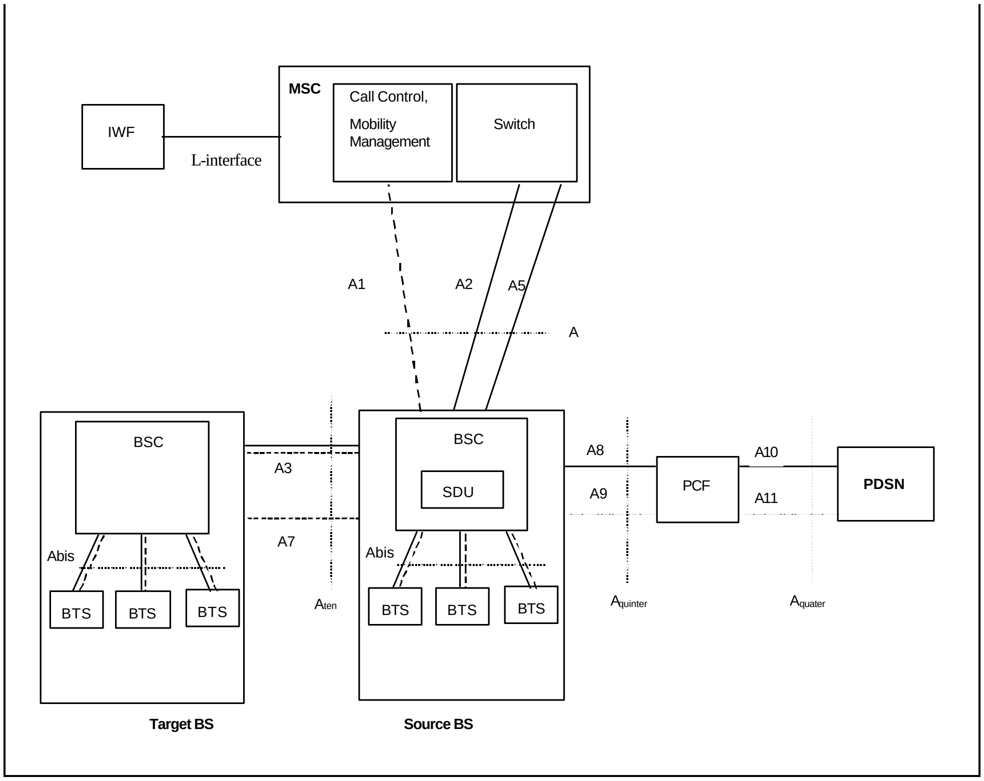


Figure 5. The 3GPP2 TSG-A IOSv4.1 Architecture

The logical network reference architecture in Figure 5 does not imply any particular physical implementation. Figure 5 shows the relationship among network components in support of mobile originations, mobile terminations, and direct BS-to-BS soft handoff operations.

An interface between the source BS and the target BS is defined that provides for inter-BS soft handoffs. Note that the source BS is in control of the call and remains the source BS (i.e., anchored) until it is removed from control of the call. The interface between source and target BSs specifically represents the demarcation point between these two base stations and coincides with the reference point Ater. This point establishes the technical interface and designates the test points and operational division of responsibility between the source BS and target BS. The source BS is connected to the target BS through the A3/A7 interface (during a soft handoff call) as shown in Figure 5.

The BTS performs all cell bearer and control functions plus the radio layer 1 functions required for the air interface protocol. The BSC-BTS (Abis) interface carries user traffic and network operation related information such as call control, radio link management and mobility management. Additionally, it performs necessary functions to support soft handoff connections, paging and access channel messaging, 'Keep Alive' operation for backhaul links and broadcast system information.

For packet domain support, two additional entities exist. User packets are routed from the Packet Control Function (PCF) to the Packet Data Serving Node (PDSN) and vice versa. The PCF-PDSN interface is defined to provide access for high-speed packet data services. It specifically represents the demarcation point between the PCF and the PDSN that coincides with the reference point Aquater. This point establishes the technical interface and designates the test points and operational division of responsibility between the PCF and the PDSN. The PCF-PDSN interface is labeled as the A10/A11 interface shown in Figure 5.

It is important to note that the functional split between the PCF and PDSN serves the purpose of making the RAN mobility (layer 2 mobility, for example, handoffs between cells) independent from the IP layer mobility (layer 3 mobility such as Mobile IP handoffs). In other words, in an IOS compliant system the Mobile IP handoff is transparent to the RAN and any UE movement within the RAN is not visible to the IP layer.

The functions of the PCF include:

- Interact with the PCF to receive packet data service profile of the UE such as QoS;
- Interact with PDSN to maintain PPP connection as part of dormant handoff;
- Maintain state of reachability for packet service between the radio network and the UE;
- Buffers packets arriving from the PDSN, when radio resources are not in place or are insufficient to support the flow from the PDSN.

The PDSN functions include:

- Establish maintain, and terminate link layer to the UE;
- Assign IP address for simple IP, the dynamic address may be chosen by the PDSN or AAA;
- As Mobile IP Foreign Agent, advertise as a foreign agent in the mobile network;
- Initiate the authentication, authorization and accounting for the mobile client packet data service to the AAA;
- Map NAI and Mobile Client IP address to the Mobile Identifier and unique identifier used to communicate with the PCF;
- Establish, maintain, and terminate secure tunnel to the Home Agent;
- Interacts with PCF to establish, maintain and terminate the layer 2 connection;
- Receives service parameters from AAA for mobile client;
- Record usage data, receive accounting information from the PCF, correlate to generate the accounting information, and relay the correlated information to the AAA;
- Routes packets to external packet data networks or to HA in the case of tunneling to the HA;

- Interact with the serving PCF and the target PCF to maintain PPP connection to the mobile client as part of the hard handoff or dormant handoff.

The PDSN may also interact with a previous PCF to obtain:

- Address of the Home Agent Function for the mobile client;
- Security information for authentication;
- QoS and packet service parameters for the mobile client.

11.2.2 Interface Reference Model

This architecture contains four reference points: A, A_{ter}, $A_{quinter}$ and A_{quater} of the 3GPP2 Network Reference Model [19]. These reference points are implemented by the protocols and interfaces as described in the IOSv4.1 standard [20], which are:

- The A reference point which is implemented by A1, A2 and A5 interfaces,
- The A_{ter} reference point which is implemented by A3 and A7 interfaces,
- The A_{qinter} reference point which is implemented by A8 and A9 interfaces and
- The A_{quater} reference point which is implemented by A10 and A11 interfaces.

The interfaces defined in this architecture are described below.

A1 The A1 interface carries control information between the Call Control (CC) and Mobility Management (MM) functions of the MSC and the call control component of the BS (BSC).

A2 The A2 interface carries 64/56 kbps PCM information (voice/data) or 64 kbps Unrestricted Digital Information (UDI, for ISDN) between the Switch component of the MSC and one of the following:

- The channel element component of the BS (in the case of an analog air interface),
- The Selection/Distribution Unit (SDU) function (in the case of a voice call over a digital air interface).

A3 The A3 interface carries coded user information (voice/data) and control information between the SDU function and the channel element component of the BS (BTS). 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: control and user traffic. The control 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 carries a full duplex stream of bytes between the Interworking Function (IWF) and the SDU function.

A7 The A7 interface carries control information between a source BS and a target BS.

A8 The A8 interface carries user traffic between the BS and the PCF.

A9 The A9 interface carries control information between the BS and the PCF.

A10 The A10 interface carries user traffic between the PCF and the PDSN.

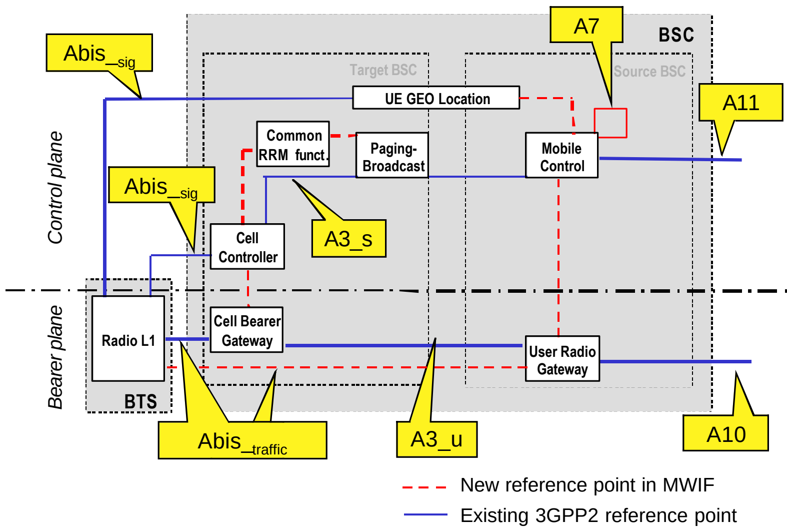
A11 The A11 interface carries control information between the PCF and the PDSN.

Abis-$_{traffic}$ The Abis-$_{traffic}$ interface carries user traffic including frame quality and power control information between the BSC and the BTS [21].

Abis-$_{control}$ The Abis-$_{control}$ interface carries control traffic between the BSC and the BTS [21].

11.2.3 Mapping to 3GPP2 IOS RAN Architecture

The figure below shows how the 3GPP2 IOSv4.1 interfaces could be mapped onto the Open-RAN architecture. Some of the reference points and their associated interfaces are not defined as open in the IOS model. Also some of these are new reference points and do not exist in the current IOS architecture. The IOS reference points that are not defined as open interfaces are implemented using vendors' proprietary solutions. The exact mapping of the IOS functional entities (BSC/SDU, BTS, PCF, PDSN) to those of the OpenRAN is For Further Study.



Open-RAN mapped to 3GPP2 IOSv4.1 (cdma2000 RAN) Architecture

The Open-RAN architecture can be realized using the IOS interfaces (with appropriate modifications) as described below.

11.2.3.1 Xr$_1$ – Local AAA to Access Gateway

This reference point does not exist in the current IOS model.

11.2.3.2 Xr$_2$ – Local AAA to Mobile Control

This reference point does not exist in the current IOS model.

11.2.3.3 Xr$_3$ – Mobile Control to Mobile Control

The reference point between two Mobile Controls (Ater) is defined to support inter-URG handoffs (soft handoff and access handoff) using the following interfaces:

- A3 control interface
- A7 control interface

11.2.3.4 Xr_4 – UE Geo-location to Mobile Control

This reference point is not currently specified as an open interface in the IOS model.

11.2.3.5 Xr_5 – UE Geo-location to Cell Control

This reference point is currently supported as part of the Abis control interface.

11.2.3.6 Xr_6 – Common Radio Resource Management to Mobile Control

This reference point does not exist in the current IOS model.

11.2.3.7 Xr_7 – Mobile Control to Access Gateway

This reference point is currently supported as part of the A1 control interface.

11.2.3.8 Xr_8 – Cell Control to Common Radio Resource Management

This reference point is currently supported as part of the Abis control interface.

11.2.3.9 Xr_9 – Cell Control to Mobile Control

This reference point is currently supported as part of the Abis control interface.

11.2.3.10 Xr_{10} – Mobile Control to User Radio Gateway

This reference point is not currently specified as an open interface.

11.2.3.11 Xr_{11} – Mobile Control to RAN Control IWF

This reference point does not exist in the current IOS model.

11.2.3.12 Xr_{12} – CN Control IWF to CN Bearer IWF

This reference point does not exist in the current IOS model.

11.2.3.13 Xr_{13} – Mobile Control to Micromobility Anchor

This reference point does not exist in the current IOS model.

11.2.3.14 Xr_{14} – Cell Control to Cell Bearer Gateway

This reference point is not currently specified as an open interface.

11.2.3.15 Xr_{15} – RAN Control IWF to RAN Bearer IWF

This reference point does not exist in the current IOS model.

11.2.3.16 Xr_{16} – Cell Bearer Gateway to Radio Layer 1

This reference point is not currently specified as an open interface.

11.2.3.17 Xr_{17} – User Radio Gateway to Cell Bearer Gateway

For mobile originations and terminations the user data in radio frames is exchanged between the User Radio Gateway and the Cell Bearer Gateway over the Abis bearer interface. For soft handoff scenarios, however, user radio frames are carried between the source URG and one or several target CBGs over the A3 bearer interface. The control traffic required for establishing transport connections between the source URG and the target CBGs are carried over the A3 control interface.

11.2.3.18 Xr_{18} – User Radio Gateway to Radio Layer 1

Same as Xr_{17}.

11.2.3.19 Xr_{19} – Cell Control to Radio Layer 1

This reference point is currently supported as part of the Abis control interface.

11.2.3.20 Xr_{20} – Micromobility Anchor to Access Gateway

This reference point does not exist in the IOS model.

11.2.3.21 Xr_{21} – User Radio Gateway to RAN Bearer IWF

This reference point does not exist in the IOS model.

11.2.3.22 Xr_{22} – User Radio Gateway to Micromobility Anchor

This reference point does not exist in the IOS model.

11.2.3.23 Xr_{23} - UE Geo-location to Access Gateway

This reference point does not exist in the IOS model.

11.2.3.24 Xr_{24} - Mobile Control to Paging and Broadcast

This reference point is not currently specified as an open interface.

11.2.3.25 Xr_{25} - Paging and Broadcast to Cell Control

This is currently supported as part of the Abis control interface.

11.2.3.26 Xr_{26} - Paging and Broadcast to Access Gateway

This reference point does not exist in the IOS model.

11.2.3.27 Xr_{27} - Paging and Broadcast to Cell Bearer Gateway

This reference point is part of the Abis bearer interface.

11.2.3.28 Xr_{28} - UE Geo-location to Radio Layer 1

This reference point does not exist in the IOS model.

11.2.3.29 CN_c – CN Control IWF to Other Core Network

This reference point does not exist in the IOS model.

11.2.3.30 CN_b – CN Bearer IWF to Other Core Network

This reference point is currently supported via the A10 interface.

11.2.3.31 RR_c – RAN Control IWF to Other RAN

This reference point does not exist in the IOS model.

11.2.3.32 RR_b – RAN Bearer IWF to Other RAN

This reference point does not exist in the IOS model.

11.2.3.33 UR – Radio Layer 1 to UE

This is the Um reference point of the 3GPP2 NRM. This interface is specified in the cdma2000 air-interface (IS-2000) standard.

12 FUTURE WORK

The working group considers Version 1 of this report to be suitable input for the 3G SDO discussions on rearchitecting existing RANs for WCDMA and cdma2000. The functional decomposition in Version 1 does not require breaking down the strict separation between transport and control layers, in particular the radio network layer, that is considered an important characteristic of existing RAN architectures. This should allow the 3G SDOs to apply the functional decomposition to their existing radio network layer protocols without having to change them substantially. The only changes that might be necessary involve adding protocol support where new reference points (and thus new interfaces) are defined and modifying the interaction between the radio network layer and transport layer in existing protocols where necessary to support IP as the transport protocol.

In Version 2, the working group plans to explore breaking down the strict separation between transport and control layers. The motivation for this work is to achieve efficiencies that are not possible when such a strict separation is maintained. For example, it may be possible to achieve an integrated approach to micromobility between different radio link protocols (e.g. GSM and WCDMA) by using IP routing and IP mobility to implement micromobility. The same considerations apply for other areas, such as QoS and security. This exercise will also lead to determining which interfaces should be open. The working group began discussions on these areas for Version 1, but postponed them when it became evident that the issues were not well understood and more time was required to develop a complete understanding. In Version 2, use of IP protocols for implementing micromobility, QoS, and security will be explored in detail. Version 2 will explore how the architecture can support non-CDMA radio link protocols. The current architecture focuses on CDMA, and the scope of the OpenRAN requirements encompasses other radio link protocols as well. Version 2 will also develop migration strategies for existing networks. Requirements tracebility will also be done in Version 2, so that the architecture can be validated against the requirements established for it. All For Further Study items from Version 1 are expected to be resolved in Version 2. The table at the end of this section contains a list of For Further Study items and the section in which the item was first introduced.

In Version 3, the working group intends to study the feasibility of defining a common RAN (or radio network layer) protocol that would allow support of all radio link protocols, and an OA&M protocol based on IP network management protocols. The goal is to replace the WCDMA UTRAN protocols, GSM MAP, the cdma2000 protocols, and ANSI-41 with a single set of protocols that would support the common radio link protocols and have room for future growth into high-speed data. At the time of this writing, there is no consensus in the working group about whether this goal is technically possible.

Section	For Further Study Item
Section 7.1.15	How dynamic channel data rate co-ordination is accomplished.
Section 7.1.28	The granularity of paging areas, whether to have differently sized paging areas depending on service, whether to involve the core network in location management/paging, etc.
Section 7.1.46	RAN database management and the atomic function.
Section 7.1.47	Radio network operations and maintenance and the atomic function.
Section 7.1.69	Inter-technology RAN bearer conversion atomic function.
Section 7.1.70	Whether System information broadcast control involves a higher level entity in 3GPP2.
Section 7.1.71	System information broadcast configuration atomic function.
Section 7.2.4	A complete set of OA&M functions and how to implement interoperable OA&M with standard IETF network management protocols.
Section 7.3.1.3	Transport path reconfiguration atomic function in Transport Plane.
Section 7.3.1.4	Address provisioning and the role of the UE address management and network parameter configuration atomic function.
Section 7.3.4	The Micromobility Anchor functional entity, whether it is needed and

	if so, whether it should be in the Transport Plane.
Chapter 7	The atomic functions for Radio L1 may not be complete. A possible need was identified during the review period for one or several additional atomic functions in Radio L1 involved in actually performing physical radio resource configuration in the BTS. This needs to be examined during Phase 2.
Section 8.2.12	The Xr_{12} interface between CN Control IWF and CN Bearer IWF.
Section 8.2.13	The Xr_{13} interface between the Mobile Control and the Micromobility Anchor.
Section 8.2.20	The co-ordination between micromobility and macromobility.
Section 8.2.21	Having the User Radio Gateway be responsible for assuring that packets to/from a UE in soft handover into a legacy RAN are properly routed through the RAN Bearer IWF.
Section 8.2.22	Relationship between the User Radio Gateway and Micromobility Anchor.
Chapter 10	Whether and how the Access Gateway plays the role of a firewall for the RAN.
Chapter 10	The exact details of the interaction between the Access Gateway, Core, and Access Network with respect to QoS and mobility management depend on the QoS and micromobility mechanisms within the OpenRAN.
Section 11.2.3	Exact mapping of IOS functional entities to those of OpenRAN.

A. STYLE LIST

Abbreviation	used for abbreviations (chapter 3)
Document title	reserved for document title on front page
editor's note	used for editor's notes (in red italics)
Figure caption	for figure captions – underneath figure
Figure	for figures
First page header	header style used on first page only
Footer	footer to include date, MWIF CONFIDENTIAL and page number
Footnote reference	used for footnotes
Footnote text	
Header	header to include MWIF technical report reference number
Heading 1 – Heading 9	no more than four levels of header recommended
Hyperlink	
List 2	free format list - second level
List bullet 2	bulleted list – second level
List bullet	bulleted list - first level
List continue 2	list continuation paragraph – second level
List continue	list continuation paragraph – first level

List numbered 2	numbered list – second level
List numbered	numbered list – first level
List	free format list - first level
MWIF	reserved for MWIF name on front page
Normal	style for standard paragraphs
Notice	reserved for IPR notice on front page
Page number	
Reference	used for references (chapter 2)
Table caption	for table captions – underneath table
Table of Figures	
TOC base, TOC1 – TOC9	Table of contents use only

DOCUMENT HISTORY

Date	Version	Comment
29 September, 2000	V0.0.0 Draft	Document template proposal
6 October, 2000	V0.0.0 Draft	Strawman proposal on scope of the document, architectural principles and architectural requirements
11 October, 2000	V0.0.0 Draft	Updated strawman proposal of architectural principles and requirements based on review comments received on the OpenRAN task force meeting.
26 October, 2000	V0.0.0 Draft	Updated the following sections based on comments received from the last OpenRAN task force meeting in Berlin: - Motivations (Sec. 1.1) - Objectives (Sec. 1.2) - Architectural Principles (Sec.7) - Requirements (Sec.8)
23 December, 2000	V0.1.0 Draft	Updated the document based on review comments received from the OpenRAN Task Force lockdown session in Palo Alto. The editing work is not complete yet.
2 February, 2001	V0.1.1 Draft	Updated the document based on review comments and contributions received from the OpenRAN Task Force meeting last month in Sydney. The editing work is not complete yet. A more updated version will be provided before the next conference call scheduled on Feb. 9, 2001.
16 February 2001	V0.2.0	Cleaned up formatting problems, integrated comments from Sydney meeting, added NRA diagram, added descriptions of the interconnections in the functional architecture. Decisions from conference call 2/16 as well as missing text not added yet.
23 February 2001	V0.2.2 R01	Added decisions from the conference call 2/23
26 February 2001	V0.2.2 R02	Redraw Fig. 1 so that it matches Fig. 2, add missing connections, clear up overlapping connections
28 February 2001 2 March 2001	V0.2.2 R03 V0.2.3	Added text in this table explaining updated copies of V0.2.2 Added interface numbers to Fig. 2, added text to Section 9.2 describing interfaces, added text to Chapter 11 describing the interface between the MWIF core and OpenRAN.

9 March 2001	V0.2.4	Added decisions from conference call 3/2 and 3/9. Reformatted functional entity descriptions in Chapter 6 so that they are in tabular form, to avoid Word messing up the formatting when the document is saved.
16 March 2001	V0.2.5	Added section on the architectural procedure and chapter on mapping to 3GPP2 architecture. Added decisions from conference call 3/16.
26 March 2001	V0.3.0 Revision 0	Editorial changes. Consolidated transport plane architecture discussion into a single section, removed further references to transport plane. Disaggregate Radio Control Server, add interfaces a according to Alcatel comments for 3/23 teleconference. Added resolved issues. Removed Fig. 1 because Fig. 1 and 2 were exactly the same with removal of transport plane and removal of Radio Control Server. Fig. 1 does not yet reflect Radio Control Server removal.
	Revision 1	Fixed Fig. 1 and 4 to reflect removal of Radio Control Server, added sections in Chapter 8 to describe new interfaces introduced into NRA by moving CN Interworking functions into a parallel, gateway position.
6 April 2001	V0.3.1	Comments from Seoul meeting. This is a release candidate for V1.0.0
12 June 2001	V1.0.0	Release of V1.0.0 incorporating TC comments.
27 July 2001	V1.0.0	Approved by membership
4 Sept. 2001	V1.0.0	Ratified by Board of Directors